Precision molding
Low Tg glass simplifies mass production

Imaging light and color
Display evaluation with cameras

3D structuring in the nanometer range
A new generation of laser lithography equipment

Long wavelength DFB lasers
DFB lasers exceeding 3 µm for industrial applications
High-speed video analysis for motorsport
3D evaluation of high-speed videos is well known, for example, in safety analysis and from motion analysis in sports. But high-speed recordings can also provide valuable information in motorsport, particularly motorcycle racing.
As usual, in this issue of Laser+Photonics: Made in Germany, Austria & Switzerland you will find a selection of the best Laser+Photonik articles published in 2011 – but in English. Some of these articles are freely available in the archive in our new web portal (www.laser-photonik.de) where we also feature industry highlights and products (largely) from the European region. Supplementary to these previous articles you will find some brand new contributions. All of the articles originate from companies and institutions based within the German-speaking regions of Europe – Germany, Austria and Switzerland. The raison d’être of the magazine is, in fact, to provide those outside of these regions with a glimpse of the industry within.

Laser+Photonik celebrated its 10th anniversary in 2011, and a number of (other) heavy weights of the photonics scene had something to celebrate too: Jenoptik observed its 20th anniversary, the Laser Zentrum Hannover looked back on 25 years of industrial R&D (p. 56) and Newport’s Spectra Physics celebrated 50 years since its founding. Incidentally, this edition features a genuinely interesting interview with the Heads of the two Jenoptik divisions Lasers & Material Processing and Optical Systems, the joint activities of these division forming the central core of Jenoptik’s commitment to the photonics industry. You can read about Jenoptik’s strategy and the Heads’ observations on the market starting on p. 52.

But 2011 has been an interesting year for many other reasons too. Company reports for turnover and profit have returned to levels that would almost suggest that the recent financial crisis had never occurred. Confidence in the market returned with avengence in 2011, as indicated, for example, by Carl Zeiss achieving over 4 billion Euros turnover for the very first time. Which is just as well, as the next economic situation for Europe may be lurking just around the corner.

Gregory Flinn, Editor-in-Chief
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For a long time, microoptics have been an indispensable component of the system design for shaping the beam of high power semiconductor lasers – whether in the form of fast and slow axis optics for collimation or symmetrization of the laser beam, or in the form of beam transformation optics for efficient fiber coupling. For many innovative applications – from display production in electrical engineering, to the interaction of laser radiation with the skin in medical technology, through to the use of special beam profiles in sensor and measurement technology – a significant improvement in the homogeneity of the laser beam is a critical requirement when using semiconductor lasers. Likewise, for the next generation of laser diode types, appropriate collimation optics need to be developed and be manufacturable on a large scale.

**Microcylinder lens arrays**

There are several different methods for the homogenization of laser radiation. For example, homogenization of a specified beam profile, for example a Gaussian beam, can be achieved using specially shaped aspheres. The disadvantage of this solution is the high sensitivity of the homogenization result in terms of fluctuations in the initial beam profile and the assembly accuracy. Another method for homogenization of laser radiation is the use of waveguides or optical fibers. However, this method requires a sophisticated assembly process and sufficient installation space.

Homogenization using microcylinder lens arrays is a considerably more elegant and compact solution. In this case, the incident laser beam is separated into partial beams by one or more microlens arrays. These partial beams are then overlaid in the homogenization plane by the downstream optics. Depending on the arrangement and geometry of the microlenses, this enables homogeneous illuminated lines, rectangles or squares to be generated. The major advantage of this solution lies in the huge scope for adjustment to account for the initial beam profile, as well as the extremely compact design.

**Microlens arrays**

ALTHOUGH MICROOPTICS can now be found in many applications, microlens arrays made of highly refractive optical glass occupy a rather special position. Because of their technical properties, they are important for a variety of new high power laser applications.
Only the highest quality

The crucial requirements for the fault-free performance of the microcylinder lens array are sufficient high damage threshold, high contour accuracy, and the minimum possible dead zone between the lens segments. The damage threshold is determined by the glass itself and the surface coating. Typical limit values for the optical intensity are around 150 kW/cm², which is met by both quartz glass and highly refractive optical glass. In terms of contour accuracy, it is not just the shape of the individual lens segments that is crucial, but particularly the repeat accuracy and the pitch accuracy (the spacing and positioning of the lens segments relative to one another). To guarantee fault-free imaging, the required accuracies fall into the sub-micrometer range. The dead zone describes the area immediately between the lens segments and, because of technical production limitations, cannot typically be described deterministically. The larger the dead zone, the higher the radiation losses and so the variations from the desired homogeneity. The exact manufacturing method has a crucial influence on the size of the dead zone, although modern techniques can achieve values as low as around ±40 to 50 μm.

The latest generation of XP microcylinder lens arrays from Ingeneric is tailor-made for the tasks outlined above. The X-Treme Precision arrays provide fault-free imaging and optimum light output. This is guaranteed by the extremely high component quality and minimization of the dead zones between the lens elements (in this case less than 20 μm). Following optical analysis of the microcylinder lens array using a stereo microscope and plane parallel plate, this property is recognizable through the extremely thin line width (Figure 1, right). Because...
of the excellent contour accuracy, the arrays also have an extremely constant focal position. To illustrate the quality difference, Figure 1 compares an optimum cylinder lens array and an array with deficiencies in terms of the focal position. All arrays are produced from highly reflective and highly transparent optical glass to ensure reliable operation with high laser powers. Focal lengths of 2.2 to 7.3 mm and pitch sizes of 0.2 to 1.0 mm are available as standard. In addition, customer-specific designs can be produced, as well as lens arrays exhibiting a large height profile relative to the spacing of the lens segments.

Arrays with rotationally symmetrical aperture

While crossed cylinder lens arrays generate a rectangular flat top profile, the output beam profile when using arrays with a rotationally symmetrical aperture is circular. The general conditions with regard to the design and production requirements for the arrays are comparable with those for a cylindrical structure. However, as well as being able to homogenize laser beams, this array structure is of particular interest for beam shaping of VCSELs and LEDs. Arranging VCSELs in a row enables optical powers ranging from several 100 W and up into the kilowatt range to be achieved. The advantage over edge emitting diodes is the cost effectiveness of VCSELs, as they can be completely processed at wafer level all the way along the production chain and are very durable in use. The design freedom of the VCSEL arrays therefore results in tough requirements for the lens arrays, which are used for collimation of the laser light. As well as varying the distance between the VCSELs, the shape of the emitting region can also vary from circular. In terms of the appropriate optics, there may thus be a future demand for micro-freeform optics arranged as high performance arrays.

When it comes to the design, the advantage of Ingeneric arrays (Figure 2) lies in the use of highly reflective optical glass. For example, complex designs with tough demands on the apertures can be translated into structures suitable for manufacture. Typical apertures for manufactured lens arrays range from 0.5 to 3.0 mm, while focal lengths scale from 0.7 mm for extremely short focal length requirements on up to 25.0 mm. The standard pitch is between 0.2 and 3.0 mm. To ensure a high fill ratio for hexagonal arrangements, the selected pitch between the lenses can be smaller than the aperture, in which case the lenses literally overlap.

Monolithic microprism arrays

For diverting, expanding or rearranging laser beams, prismatic microoptics with a refractive effect are commonly used with high power diodes. If, as in the case of edge emitting diode laser bars, several emitters have to be diverted at different but discrete angles, high precision arrangement of the prisms is absolutely essential. The positioning and orientation within six degrees of freedom makes such demands in terms of the precision of the individual prisms and the assembly technology that cost-effective production in compliance with the required tolerances is not possible.

Ingeneric has thus developed a production method that enables micro prism arrays to be manufactured as a monolithic component (Figure 3). This eliminates the assembly process and therefore removes a significant source of errors in terms of variation in the beam diversion, the optical damage threshold and the long-term stability of the component. As illustrated in Figure 3, despite their monolithic characteristics, the micro prism arrays feature sharp-edged transitions from one prism element to another and small dead zones. The rounding in the corners is typically less than 20 µm and therefore allows loss-free beam diversion with an appropriate beam path design. The relative angle accuracy from one prism segment to the next is 0.05° in all rotational degrees of freedom, while the dimensional accuracy is ±10 µm. The typical value for the width of the segment (400 µm) can be adapted for both smaller and larger dimensions according to the selected beam source, optical design and application. As with the arrays described above, this component is based on highly reflective, highly transparent optical glass, to ensure suitability for high optical power densities.

Summary

Refractive glass microarrays open up a wide range of applications for high power lasers. The developments outlined partly demonstrate significant improvements in the current state of the art and allow new optical solutions based on totally new production methods.

Dr. Volker Sinhoff is the managing partner of Ingeneric and is responsible for marketing & sales. Dr. Stefan Hambücker is a managing partner and responsible for production of optical components. Dr. Olaf Rübenach is also a managing partner and is responsible for process development. Christian Wessling is the head of research & development for optical systems and products.
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Precision molding is the most modern method for mass production of complex lens shapes. In fact, it even enables high surface quality directly following the hot forming process. Nevertheless, the unique properties of the glass materials used in this field also need to be taken into account, and Schott has therefore developed special glass types that best meet the manufacturing requirements. In addition, the company is constantly expanding its product range in this area.

Classic grinding and polishing

Traditional manufacturing consists of a multi-stage process in which a raw glass block is formed into a lens blank using cutting and grinding processes. These lens blanks are then polished (depending on the requirements) using either a typical CNC-controlled polishing method or a modern magnetorheological finishing for aspherical surfaces. Using hot pressed lens blanks is one way to simplify mass production. During the hot pressing process, blocks of the initial glass with a predefined volume are pressed into a so-called preform. The preform corresponds to the desired final outline to within a few millimeters, and the desired final shape and quality is achieved using traditional processes.

Using the pressing process saves CNC processing time, and thus makes lens manufacturing more economical, although the ideal solution would be for the glass to be brought into its final shape directly using a hot forming process. In any case, the optical surface still needs to meet the requirements for shape, roughness and maximum number of allowed defects to the highest extent possible, and precision blank pressing is indeed able to meet these requirements.

Precision molding of complex geometries

Precision molding is now the method of choice when it comes to cost-effective mass production of optical components with complex geometries. Typical applications include aspherical lenses for cell phones, projectors and compact cameras (Figure 1), lens arrays for LED lighting (Figure 2), but also micro-optical components such as diffractive optical elements and nanostructures. These all require a preform with high surface quality.

Appropriate preforms include spherical lenses, polished rods, polished disks or precision gobs created directly from the glass melt. One thing that all preforms have in common is that they can be manufactured very cost-effectively and are made of a special glass well suited for the precision molding process. They can be used to manufacture aspherical lenses of variable sizes and geometries (Figure 3), for instance.

Manufacturing of optical components with a diameter of less than 40 mm has now proven to be most economical. Typical surface radii for aspherical geometries are then between 0.8 and 250 mm. Maximum...
precision can be achieved if extreme aspect ratios between the
thickness of the edge and center are avoided. On plane surface
sections, small deviations can either be tolerated or polished
out later. Surfaces with a slight radius are more stable and can
therefore be molded more precisely.

**Molding without sticking**

Precision molding applies principles from the manufacture of
polymer optics to that of glass, although this isn’t actually a
simple task because, unlike polymers, glass is an inorganic
material with strong atomic bonds. This means that high tem-
peratures are often necessary for molding. In addition, each
glass has its own characteristic viscosity depending on the
temperature.

During traditional hot pressing, glass is pressed in a low vis-
cosity range at high temperatures of between 750 and 1500°C.
To prevent the glass from adhering to the mold, separating
agents or steep temperature gradients must be used between
the glass and the mold. This alters the surface texture and the
shape of the pressed optic, however, therefore reworking is
necessary in order to achieve high accuracy.

By contrast, precision molding is performed at lower tempera-
tures of between 500 and 900°C with significantly higher
viscosities. In order to reproduce the desired shape accurately
and achieve high surface quality, the pressing mold itself must
be optically polished. It is nearly always impossible to use a
separator in such cases because this would have a negative
effect on the molding results. The high glass viscosity prevents
the optic from adhering to the mold anyway.

**Giving glass its shape**

The accuracy of the mold determines the precision of the
pressed optic. When creating the mold, the designer must also
take proper account of the thermal properties of the glass, such
as the shrinkage of the optic after the hot molding process. Be-
cause the mold design is a significant cost factor in the blank
pressing process, it is important to make sure the mold can be
used for as long as possible.

The molds are usually produced from tungsten carbide or sili-
con carbide. These can contain a binder such as cobalt in the
structure, although these chemical elements could diffuse into
the glass and lead to discoloration on the surface. For this rea-
son, the molds are given different coatings normally based on
precious metals (Pt, Au, Ir, Rh) or carbon. These prevent the
glass from reacting with or adhering to the mold material.

The cleaning processes used with glass preforms must be
strictly controlled so that they do not result in soluble compo-
nents of the glass structure being drawn out of the surface, as
this could adversely influence the surface quality that can be
achieved after pressing. It is also important to avoid potential
vaporization processes of substances from the glass surface at
the high temperatures used during pressing, as these can con-
densate on the surface of the mold and shorten its service life.

**Controlling quality**

The design of an optical system defines the requirements for
the material, shape and surface quality of its components. With
precision molding, the accuracy of the pressed optic is deter-
mined by the quality of the mold and by monitoring the tem-
perature closely over time. The number of macroscopic defects
on the surface and their roughness depend on how much time
the pressing process consumed and how much pressure was
applied, but also on the initial
surface quality of both the
mold and the preform.

The quality of the optical glass
used is also critical, which
means that the initial material
should be free from bubbles
and inclusions and should have
a reproducibly high homoge-
neity. On the other hand,
both the molds and the mold-
ing machine would have to
meet high demands with re-
spect to their temperature
stability if glass types with a
high transformation tempera-
ture (high $T_g$) were to be used
in precision molding. For this
reason, Schott has developed
a range of special glass types

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2 The use of an optimized precision molding process enables aspheres with a very high refractive
index to be manufactured in the form of arrays or strips

3 Schott’s low $T_g$ glass for precision molding allows for efficient production of tiny optical components such as aspheres
that can be processed at much lower temperatures (under 650°C). These so-called low T_g glasses allow for established presses and mold materials to be used. The range of materials already includes glasses at a variety of positions in the Abbe diagram (Figure 4). This enables numerous optical designs to be realized using molded components.

### Controlling the index drop

The special feature of Schott’s blank pressing glass is that it is manufactured in the highest reproducible quality and to minimal tolerances. This makes it easier to process in a precision molding operation. However, while for normal optical glass, it is the glass manufacturer who is in complete control of the process and thus determines the refractive index and dispersion in the form of the Abbe number, the optics manufacturer is the one who controls the temperature progression and thus the final optical values of the component with precision molding.

Whereas the glass manufacturer controls the cooling rate to lie between 1 and 10°C per hour with normal optical glass, after the precision molding process, the glass will cool off at high rates of several 100 to several thousand degrees Celsius per hour to room temperature. This fixes the geometry and reduces the process time, however the refractive index of the glass drops significantly compared to the initial value. This so-called index drop depends on the process and the geometry of the component.

Thanks to a precisely controlled melt process, Schott can ensure excellent reproducible quality of its glass, therefore the index drop remains a predictable parameter if the optics manufacturer uses the same process parameters. The index drop is included in the data sheets with respect to a reference cooling rate and must be taken into consideration in the optical design. In case a specific index drop is required for a particular application, the glass manufacturer can take this into account with a specially prepared glass melt.

### Summary

Schott is constantly expanding its wide range of arsenic and lead-free low T_g glasses, distributed across the entire Abbe diagram. Modern glass development methods allow Schott to meet the requirements that apply to processing and optical quality and continuously expand its product range, with nine new low T_g glass types introduced only recently.

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– Precision polymer replication (compression and injection molding, polymer-on-glass processing)
– Custom finishing (trimming, printing)
– Product enhancement processes (AR-structures / coatings, aluminum and hard coating)
– Subassembly processes

Our Products

– Fresnel lenses
– Fresnel cylinder lenses
– Fresnel prisms and beam splitters
– Micro-lens arrays
– Hybrid optics such as Silicone-on-Glass (SOG) lens parquets for CPV applications

LAYERTEC, established in 1990 as a spin off from the Friedrich-Schiller-Universität Jena, produces high quality optical components for laser applications in the wavelength range from the VUV (157nm) to the NIR (≈4µm).

The company combines a precision optics facility and a variety of coating techniques (magnetron sputtering, thermal and e-beam evaporation).

The precision optics facility of LAYERTEC produces plane and spherically curved mirror substrates, lenses and prisms of fused silica, optical glasses like BK7 and some crystalline materials, e.g. calcium fluoride. Fused silica and calcium fluoride can be offered with rms-roughnesses as low as 0.15nm.

Components for the UV are coated by evaporation techniques. Coatings for the VIS and NIR are mostly produced by magnetron sputtering. This special coating process yields amorphous layers with a very high packing density resulting in lowest straylight losses and a high thermal and climatical stability of the optical parameters. Furthermore, the coatings are optimized for high laser damage thresholds. LAYERTEC has developed magnetron sputtering for optical coatings from a laboratory technique to a very efficient industrial process.

The main products of LAYERTEC are

· High – power - coatings for the NIR (e.g. for Nd:YAG-, Ho:YAG- and Er:YAG-lasers)
· Femtosecond laser mirrors with exactly determined phase properties (low GDD or negative GDD and R>99.9%)
· Steep edge filters, e.g. HR 1030nm >99.9% + R(980nm)<1% with high laser damage thresholds
· Low loss laser mirrors (R>99.99 in the VIS and NIR)
· Coatings on laser- and nonlinear optical crystals
· Metallic mirrors and coatings (Au, Ag, Al, Cr)
· Coatings for all excimer laser wavelengths including 157nm

Besides the development of efficient coating plants LAYERTEC has preserved its capabilities for flexible production and the development of prototypes and OEM components.
FISBA OPTIK AG
FISBA OPTIK is a world leader in optical systems, instruments and components. At FISBA we develop and produce high-grade solutions in the field of micro- and macro-optics. From simple lenses to complex optical components and systems, the optical solutions created by FISBA are perfectly tailored to the specific customer needs.

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FISBA unites all required disciplines and expert knowledge under one roof. Lens designers and engineers, backed by specialists in physics and coating technology, develop, analyze and optimize optical systems and components for the entire spectral range from UV to NIR — integrated and sustainable.

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FISBA employs and develops leading technologies to provide outstanding results for every production stage, from prototypes to complex optics in large-scale production. Uncompromising quality control vouches for flawless products that render incoming goods inspection superfluous, saving valuable time and increasing process stability.

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Product Portfolio
Advanced Optical Components
• Precision molded lenses
• Fast axis collimation lenses (FACs)
• FISBA Beam Twister™
• Aspheres

Optical Systems
• Lens systems
• Objectives
• Laser Modules
• Laser Optics
• Collimators
• Illumination

Optical Microsystems

Application Fields
• Biophotonics
• Bildverarbeitung und Sensorik
• Industrielle Fertigung
• Sicherheit und Verteidigung
• Weltraum und Astronomie
MOELLER-WEDEL OPTICAL GmbH, a subsidiary of MÖLLER-WEDEL GmbH, concentrates on high-precision optical test equipment for industry and science.

**Products**

The different lines of electronic autocollimators ELCOMAT cover the most common measurement tasks in industry and science: ELCOMAT HR for ultra-precision measurement and calibration tasks with an accuracy up to 0.01 arcsec, ELCOMAT 3000 for extremely precise alignment and angular measurements with an accuracy up to 0.1 arcsec and a measurement range of 2000 arcsec, ELCOMAT vario product line as well as of ELCOMAT direct product line for precise angular measurement and adjustment with an accuracy between 3 arcsec and 0.3 arcsec. Moreover, ELCOMAT direct series enables the user to evaluate multiple autocollimation images and thus to measure wedges, prism angles etc. directly.

The measuring combination for lenses and optical systems MELOS 530 provides fast and reliable measurement of most relevant optical parameter, i.e. focal lengths, back focal lengths, radii of curvature. The low cost VI-vario interferometer line can be used to measure plane and spherical optics such as mirrors, prisms, cubes or lenses. The Goniometer II allows the accurate measurement of prism angles with an accuracy of 0.6 arcsec, the GONIOMETER-SPECTROMETER VIS enables the measurement of refractive index in the visual range with an accuracy of 10⁻⁵.

The new GONIOMAT M is a unique user-friendly semiautomatic portable goniometer that is able to measure angles of prisms, polygons and wedges with an accuracy of up to 1.5 arcsec. Well known visual collimators, autocollimators, testing telescopes, diopter telescopes and alignment systems complete the extensive range of products.
DOCTER OPTICS – Turning Ideas Into Components

Docter Optics has earned international recognition as an OEM partner of the optical technology sector and a leading supplier to the automobile industry. Headquartered in Germany’s “Optical Valley” with presences in China, Japan and the USA, the company offers customers services along the entire added-value chain. The company’s list of first-class references from the areas of automotive, illumination optics, concentrating photovoltaics, biometrics, security and medical applications testify to a track record of exceptional customer- and market-driven performance.

Quality plus Efficiency: Precision Glass Components

The Precision Glass Components division produces optical components such as light pipes (concentrators) for advanced Concentrated Photovoltaics (CPV) systems in large runs using a process that makes it possible to mold the glass as soon as it leaves the furnace. The Precision Fast-Molding process developed by Docter Optics permits production of precision glass components, e.g. free-form-lenses, lens-arrays/integrator plates, prisms, light pipes and mirrors for high-end medical and analytical equipment or illumination/LED applications. The Precision Glass Components-value chain encompasses:
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- Mass production
- Ready molding
- Design freedom
- Cost effective solutions
- Optical Glass Doctan SG 2

A Single-Source Supplier: Optical Systems

The bundled competencies of the four Docter Optics business units represent unique synergistic potential, which makes Docter Optics an industry leader in the development and production of custom-tailored optical, optomechanic and optoelectronic subassemblies:
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- Optical and Optomechanical design
- Assembling, prototyping and series production
- Development of customer-specific testing methods, procurement and logistic models

Top-Tier Services: Express Glass Services

The Express Glass Services unit ships semi-finished products of optical glass to customers worldwide and manufactures prototypes, samples and one-of-a-kind parts and can deliver pre-production and limited quantities with extremely short lead times. An extensive inventory of special glass qualities allows Express Glass Services to react to customer needs quickly and efficiently.

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Docter Optics is the market leader in the area of projection lenses of optical glass for automotive headlights. Automated production processes and use of DOC3D® for double-sided precision-molded projection lenses give Docter Optics a competitive advantage that permits quick reaction times and precise compliance with customer quality specifications. Customers can avail themselves of a complete array of services:
- Aspheric lenses, free-form shapes and lens arrays for projection headlights
- Development, design and prototyping of new lens shapes
- Adjustment of photometric characteristics of lenses for different light sources (Halogen, HID, LED) and regional standards (ECE, SAE)
- Textures and coatings

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Fiber optics update

Product catalogue 2012. In their product catalogue 2012 Fiber Optics – Light switching, Light transportation, Light distribution Leoni Fiber Optics presents the first multimode splitters produced by means of ion exchange in glass. In addition to the extensive update, the chapters Fiber optic cables, Optical components, POF/PCF, Laser probes (medical devices) include a wide range of new products as well as a short overview of fiber optical assemblies for harsh environments, such as in industrial applications and in the energy sector. New products in the sections LargeCore, Singlemode, Fiber bundles, Tubes and loose tubes and Accessories are clearly laid out. The catalogue is available for download in the service area on the website as well as in print upon request via contact form.

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FDN glass fiber closures for FTTH sector. With their FDN closure, Ficonet systems is launching an FRBU for up to 144 fibers with heat shrink splice protection, and whose capacity doubles to 288 fibers with crimp splice protection, a solution widely used in Germany. For custom projects, the closure can be adapted to specific requirements and fiber capacities (up to 576 fibers) on request. Up to 61 ports are available for cable feeds, of which 52 are cable inlets for cables or injectors up to 9.5 mm. These apertures have different sizes, making them suitable for a huge variety of cable diameters. Uncut multi-fiber loose tube cables can also be inserted and embedded. Cablelok fittings are used to seal the cables – these are rubber sleeves that are sealed by feeding in the cable opposite the body of the closure. This system has been tested up to a water column depth of 8 m. The FDN closure can be fitted with various splice trays containing heat shrink or crimp splice protection or fiber splitters. If required, the closure can be supplied completely pre-assembled to customer specifications. When using injectors, this allows fibers from the splice tray or from an external location to be injected into the splice tray at distances of several hundred meters.

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Machine vision systems are in higher demand than ever before. By means of special cameras and computers, industrial production systems are taught how to ›see‹, in other words, to inspect and make decisions accordingly. As a result, production processes can be designed to be safer and more efficient. The applications are numerous and range from completeness monitoring, to surface inspection, identification and robot guidance, to classic measuring technology.

Machine vision systems have never really been a true alternative and were in every sense inferior to the human eye when it came to accurate color assessment. Despite the fact that visual perception plays a far greater role for people than other modes of perception, correct color reproduction has hitherto played a lesser role within the context of automated quality control.

Color control in printing technology
To ensure print quality, today's modern printing machines are often already equipped with machine vision systems. These can be used to ensure the complete automated imaging of all print elements and avoid possible errors, such as streaking. Thus, the use of inline inspection systems to capture the spectral properties of inks, for example, opens up new opportunities for automated machine control and ensures the improved reproduction of the required colors. Color used to be checked manually after the test sheets were printed out. Using separate color measuring equipment, the operator compared the target values and actual values and made any necessary recalibrations. This was a time-consuming process, which typically required several iterations. It is also worth bearing in mind that visual color assessment is strongly dependent on lighting conditions and that the color perception of the human observer is restricted to three sensors (red, green, and blue). The risk of an erroneous color perception is extremely great under these conditions.

Extrasensory color recognition

12-CHANNEL SPECTRAL CAMERA. Chromasens presents a spectral inline color measuring system that uses twelve filters to allow the spectral reconstruction of the ink spectrum with a precision far greater than that of the human eye. This opens up entirely new applications for machine vision and quality control.
The best alternative therefore is to automate color measurements. However, the spectral resolution of industrial cameras was, until recently, also based on three sensors (also red, green, and blue). This led to considerable limitations in the color display and color measurement.

With the introduction of sensors in which the spectral sensitivity can be defined and reproduced much more precisely, it is now possible to manufacture multi-channel, spectrally selective sensors. These are much better able to identify the spectral resolution and detect the slightest deviation from the color scheme of the original.

**Physical simulation of reality**

As a rule, spectral photometers, which detect the reflectivity of a color sample using a high spectral resolution, are used for a sufficiently accurate spectral description of a color. The resolution of the spectrometer used largely depends on the task at hand. For colorimetric tasks, systems with a spectral resolution (nominal distance between the measurement sampling points) between 1 and 10 nm are used.

If you consider, for example, a visually relevant spectral range of 380 to 730 nm or often also from 400 to 750 nm, at least 36 sampling points (at distances of 10 nm) are needed to describe the spectral distribution of one color. The complete evaluation of large-format objects using spectral measuring systems can only be achieved with significant effort.

One technological approach is to use changeable or tunable filters, which are mounted in front of the camera. In this specific example, a filter system with 36 (or even more) filters would be used, which captures and measures 36 images each with one color channel. Even using modern trilinear line scan cameras, twelve cameras would be required, in theory, to capture the 36 sampling points, which would result in a data transfer rate that is twelve times faster.

For this reason, Chromasens has developed a spectral inline color measuring system using four trilinear RGB sensors (Figure 1). The trilinear line scan sensors have – integrated on one semiconductor chip – three red, green, or blue sensitive lines. The three sensor lines work simultaneously and determine three color values for each point in the image. The object point of a sample reaches the red sensor line first, for example, then the green sensor line and finally the blue one. This time lag is balanced out within the camera. For every point in the sample image scanned, true color information is obtained with all three color channels.

The color measuring system uses twelve filters for a spectral reconstruction of the ink spectrum with a color distance accuracy (see sidebar) of $\Delta E < 1$. The geometric resolution of this camera is 300 $\mu$m/pixel, and the minimum detection area is $3 \times 3$ mm$^2$ (Figure 2).

**Spectral reconstruction as underlying approach**

The spectral approximation that is based on a non-linear spectral reconstruction method is the basis for the technological approach. This method enables an iterative approximation by contributing general-prior knowledge from the printing process (Figure 3). This prior knowledge is general knowledge of the underlying properties of the inks used, such as the gradient and smoothness of the colors or the modality of the spectral gradient. The method has been successfully tested using standard trilinear Chromasens line scan cameras and an LED light source on numerous color samples from different ink manufacturers.

For the spectral camera system used here, the spectral homogeneity and smoothness of the spectrum is an important measure. This is why warm tone LEDs are used, which have an extremely smooth spectrum and do not have a highly pronounced blue peak. Although the behavior of the light source is also important for the color rendering index (CRI), this CRI value, which describes the color reproduction for the human eye, is irrelevant in this case since a spectral measurement is made that bears no resemblance to the eye’s sensitivity.

**The challenge of LED spectral homogeneity**

The light source, which also causes the greatest uncertainties, is a key part of the measuring system. It is subject to spectral changes caused by the temperature at the LED and
The method is based on an iterative approach and has the advantage that underlying properties of the object to be measured can be applied numerically within the iteration processes.

The impressed current. In addition, the light source ages and thereby changes its emission spectrum. Chromasens has taken the following counter measures:

- The current is kept constant – the LEDs therefore age at the same rate.
- The LEDs are mounted on a cooling element to dissipate the heat and homogenize heat distribution.
- The light emitted is bundled via a channel-shaped ellipsoid mirror and thus focuses on one line. A large number of LEDs in the LED line contribute to the intensity at one specific location of the illuminated sample. As a result, the different spectra of the LEDs are mixed thoroughly.
- A spectral measurement of the LED illumination is taken at each location in the line before installation. This is the most time-consuming part. Over the service life of the LED, the spectrum is constantly measured at one specific location and included in the spectral reconstruction.

It must be emphasized here that the system does not need to be calibrated. The LED line can be replaced without recalibrating the camera. However, the module-specific spectral data of the new LED line must be incorporated in the spectral reconstruction.

The particular advantage of this approach is that the filters used and their spectral characteristics can, to a large extent, be freely selected. The functionality of the solution is not reduced to the use of particularly narrow band filters. Thanks to the flexibility of the reconstruction algorithms, this method can correct differences in the spectral detection caused by the different angles of incidence of the light on the sensor and the color filter. Thus, the accuracy of the spectral estimation is no longer subject to any immediate dependency on the sampling location. The ‚truePIXA-6C‘ technology, developed by Chromasens together with the Constance University of Applied Sciences and the Chemnitz University of Technology, is now ready for the market and for use. It enables multi-channel image acquisition within the RGB and infrared area (360 to 950 nm). The enhanced versions ‚truePIXA-9C‘ and ‚truePIXA-12C‘ can be used for measurement applications in the area of spectral reconstructions of the originals. Once calibrated in the factory, the spectral properties of the camera system are extremely stable and do not require any further readjustments. For implementation on the customer side, only the spectral properties of the light source used need to be captured. This is usually done via a white balance measurement.

**Spectral camera opens up new applications**

While it may take some time for the commercial use of spectral image acquisition to become more widespread, this method can be used anywhere today where camera systems and measuring systems are needed for high precision image acquisition and color measurement.

A good example is print quality control, where the use of inline inspection systems to capture the spectral properties of inks unlocks new opportunities for automated machine control. Other possible applications are to be found in material sorting and classic production technology. Besides these ‚traditional‘ machine vision segments, the targeted use of spectral cameras opens up a wide range of new applications. In the field of safety engineering, for example, official documents, such as passports, can be checked for authenticity or products of unknown origin can be checked for plagiarism. The product engineers also envisage many useful applications in medical technology, such as in minimally invasive surgery or remote diagnoses in the field of teledentistry. In both these areas, images without chromatic aberrations – for example, for assessing changes to the surface of the skin – are just as important as optimizing the image contrast.

**Summary**

The spectral acquisition of objects and the spectral reconstruction of colors pave the way for new fields of applications. Whereas the most precise spectral measurement of colors and hence correct color reproduction – within the context of automated quality control – has hitherto played a lesser role, this will change with the new technological approaches. Twelve-channel spectral cameras are for the first time capable of detecting the most minute color differences with a precision that is far beyond the capability of the human eye. This opens up entirely new applications for machine vision.

**Markus Schnitzlein** is the Managing Director of Chromasens. Based in Constance, Germany, the company develops and produces image acquisition and image processing systems. The company’s expertise includes both system and components development.

**References**

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Light and color measurement through imaging

THE NUMBER OF DISPLAY ELEMENTS that we encounter in our daily lives is constantly increasing, from simple indicator LEDs through to high resolution graphic displays. At present, quality assurance is the dominant application for camera-based measurement systems for light and color in this area. With all the advantages and the constant stream of new applications for this now well-established technology, there are also situations where other measurement methods are indispensable.

ERIC SCHWABEDISSEN

When used correctly, light and color make an important contribution to our well being and it is well known that luminous color consistency is viewed as a key element of value. It is no wonder that, with the development and production of the various self-illuminating devices, huge focus is placed on correct brightness and color. The automotive industry can be seen as particularly demanding on this issue, where multifunction displays need to deliver high contrast and good legibility, even under adverse conditions. No matter whether they are brightly or dimly illuminated, they must not convey an impression of low quality, and all backlight switches must exhibit the same color and brightness. We even expect the inside of a modern refrigerator to be uniformly illuminated, preferably in a defined, cold white color.

Luminance and color measurement cameras have established themselves in these and other applications that require brightness, color and the homogeneity or gradient of these to be determined. Each pixel of a camera’s CCD chip can deliver brightness and color values, such as luminance [cd/m²], luminous intensity [cd], illuminance [lux], color coordinates and other values derived from these, such as color temperature [K], dominant wavelength [nm] and color purity. For each pixel, all of these measurement points are obtained within seconds and can be combined to give a two-dimensional image map that can then be analyzed further.

Figure 1 shows an example evaluation of a temperature display in the instrument cluster of a vehicle. The luminance is shown as a measure of the brightness. A false-color scale (left) provides an overview of the absolute luminance values and their spatial distribution. A quasi-3D representation (top right), in which the vertical axis shows the luminance, enables complex luminance distributions to be identified at a glance. Even the evolution of luminance along an axis – in this case along the temperature indicator (bottom right) – can be represented graphically.
Needless to say, these and many other evaluation methods represent a major simplification compared to spatially selective measurement methods, and have helped camera-based systems to become widespread in research departments, in quality assurance and in manufacturing.

**Imaging photometry and colorimetry**

Photometry involves evaluation of the energy or power of light using what is known as the $V(\lambda)$ curve (Figure 2) that describes the sensitivity of the human eye in the wavelength range from 360 to 830 nm. It is used, for example, to calculate the photometric luminance value [cd/m²] from the radiance [W/m² sr]. Thus, if we want to measure luminance with a camera system, the object to be studied is reproduced on a CCD image sensor using a high quality lens followed by a $V(\lambda)$ filter. The signals of the individual pixels of the image sensor then only have to be adjusted on a PC according to a previously determined calibration.

Colorimetry, the quantitative description of color, is very similar. CIE tristimulus colorimetry is the most widely-used system for color determination and is based on the assumption that every color is a combination of the three primary colors red, green and blue. The tristimulus system was established by the CIE (International Lighting Commission) in 1931. The tristimulus values $X$, $Y$, and $Z$ are obtained by integrating the spectral radiation distribution $S(\lambda)$ over the three eye sensitivity curves $x(\lambda)$, $y(\lambda)$ and $z(\lambda)$ (Figure 2) in the wavelength range 360 to 830 nm. The tristimulus values $X$, $Y$, and $Z$ are then used to calculate the widely used color coordinates $x$, $y$, and $z$.

If color coordinates and values derived from them, such as the color temperature, are to be determined using a camera system, at least three filters are required to simulate the tristimulus functions $x(\lambda)$, $y(\lambda)$ and $z(\lambda)$. As $y(\lambda)$ corresponds to $V(\lambda)$, photometric measurements are also possible. However, the $x(\lambda)$ function is normally captured using two separate filters, one filter for the blue component and one for red, which results in a significant improvement in accuracy compared to conventional color measurement equipment with just three filters.

Figure 2 shows the variations of actual spectral response functions from the ideal CIE curves. These variations are relatively significant on the wings of the curves. Particularly with blue, red and white LEDs, this results in major variations in the photometric value determined and the measured dominant wavelength [1, 2]. Figure 3 illustrates this using an error in the dominant wavelength of different colored LEDs determined using a typical color measurement camera.

If samples with the same spectral radiation are investigated repeatedly, for example in quality assurance, the user can correct for this undesirable effect by adjusting the calibration in the relevant wavelength range. This requires high precision measurement of the absolute value for...
a specimen using a spectrometer. This kind of adjustment always applies to a particular spectrum and can lead to severe measurement errors on specimens with different spectral characteristics.

With all the advantages of light and color measurement through imaging, it is important to always be aware that filter-based systems can have significant measurement variations for narrow-band light sources such as LEDs. In such cases, the use of a spectrometer, for example with a telescopic optical system, is often preferred, as these systems allow a purely mathematical evaluation of the spectrum with the precisely defined CIE functions. However, the disadvantages of a spatially selective, non-image-based measurement have to be accepted.

**Determination of luminous intensity distribution curves**

The determination of luminous intensity distribution curves is an interesting application for camera-based light measurement. Most light sources radiate their light into the surroundings in a non-uniform way. Therefore, to completely characterize a light source, the luminous intensity emitted in all spatial directions must be recorded. Conventionally, this is done using a variety of individual illuminance measurements, which are used to scan the entire solid angle range to be studied. The photometric law of distance allows conversion into the corresponding luminous intensity values. However, as the photometric law of distance is only applicable for a point source, a minimum measurement distance corresponding to ten times the largest luminaire dimension must be used.

So-called goniometers allow all spatial directions to be scanned by rotation of the light source and/or a detector, for which photometers or spectrometers can be used as detectors. Most goniometers are, however, mechanically somewhat sophisticated and correspondingly expensive, and the measurements can be very time consuming. In many cases, such as in quality assurance, corresponding measurement times of up to half an hour are simply not feasible. Cost can also be a prohibiting...
factor. If we are only interested in a limited solid angle range of up to ±65° and we can accept a measurement variation of up to five percent compared to goniometric measurements (as is the case for many LEDs and other directional light sources, for example), then the setup shown in Figure 4 represents a usable alternative.

The LED mounted on a slide on the optical bench is located on the optical axis of the camera positioned on the right. A transmission screen placed between them is illuminated by the LED and recorded by the camera. Taking into account the transmission of the screen, the camera calibration and the distances between the LED and the screen and the screen and the camera, the software calculates the luminous intensity distribution in a solid angle range of ±65° about the mechanical axis of the LED.

Figure 5 shows the evaluation of this kind of measurement for an LED with a false-color scale of the luminous intensity distribution in polar coordinates (left) and four luminous intensity distribution curves for a 45° interval pattern. In most cases, this kind of measurement takes less than a second. If, in addition to the luminous intensity distribution, the distribution of values such as color coordinates, color temperature, dominant wavelength or color saturation are to be investigated, the measurement time increases to just a few seconds to allow for the automatic filter change required.

**Summary**

Because of the short measurement times and the wide range of computer-based evaluation options, camera-based measurement systems are outstandingly well suited for investigating light and color and their homogeneity. If maximum measurement accuracy is required, then a spatially selective but time consuming measurement is recommended, using a system made up of a spectrometer and appropriate input optics. Determination of luminous intensity distribution curves is an application of camera-based systems that is still relatively rare. With sufficient accuracy for many situations, it allows cost-effective, easy and very fast characterization of the spatial radiation properties of various light sources.

**References**


Eric Schwabedissen is a physics graduate and is currently Sales Engineer for Instrument Systems, a leading supplier of complete light metrology solutions.
Scanning Fizeau interferometry

DETERMINISTIC CORRECTION OF PRECISION ASPHERES.

Optical systems, such as photographic lenses, projectors, cameras, binoculars and laser systems are made up of a variety of individual optical elements. In addition to the standard planar and spherical optical components, such as prisms, filters and lenses, these also increasingly include aspherical lenses.

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The advantage of aspheres lies in their greater design flexibility and the possibility of achieving identical or even better imaging qualities with fewer optical components (Figure 1). This enables lighter and more compact complete systems to be designed and makes them easier to produce, all resulting in considerable cost savings.

Local surface correction for high precision surfaces

The quality of optical surfaces is typically expressed as the variation of the actual shape from the specified shape, for example using the PV (peak to valley) value. These are measured by interferometric comparison with a reference surface that matches the exact intended shape. To achieve surface qualities better than \( \lambda/10 \) (with wavelength \( \lambda \) being typically 633 nm), the measured result is used to determine local correction. Relevant technologies include ion beam figuring, fluid jet polishing and magnetorheological finishing (MRF).

This correction process places high demands on the measurement technology as every measuring error or data artifact has a negative influence on the result and, in the worst case, leads to errors being incorporated into the surface. Of course, they are then no longer identified as errors by the measurement system used.

Suppression of coherent artifacts

Interferometers that are able to suppress measurement artifacts have been proven to be appropriate metrology systems for this kind of correction method, also because they provide a high lateral resolution and feature a very low system noise. This approach is already widespread for planar and spherical surfaces, although aspheres still present a major challenge as there are no suitable surfaces that can act as an interferometric reference surface. Current measurement methods therefore use standard interferometers with spherical or planar reference optics and generate the measurement wavefront by using a computer generated hologram or a null optic. Nevertheless, a wavefront accuracy of \( \lambda/10 \) is difficult to achieve with these optics, and the manufacturing process taking several weeks is a barrier to rapid product launches.

Another more flexible method is to measure smaller sub-apertures and then combine the overlapping individual results to give an overall measurement (stitching). The disadvantages when using a large number of sub-apertures are extremely long measurement times and problems in detecting long period surface errors caused by the measurement principle.

The sub-apertures are selected in such a way that the high fringe resolution of the interferometer in the current field of view can be utilized to perform a measurement. For milder aspheres, measurements can also be made directly against a reference sphere.

Fizeau common path measurement principle

The crucial advantage of the Fizeau
interferometers used is their so-called ›common path‹ construction. The interferometric beam splitter and the reference surface are combined in a single component at the output aperture, which means that if there is a perfect match between the reference surface and the measurement surface, the path of both wavefronts in the interferometer is identical and no ›retrace‹ errors occur. This match is achieved by nulling fringes during alignment of the measurement object. The key requirement is that the surface to be measured must have exactly the same shape as the reference surface. However, when measuring a complete asphere or when using sub-apertures, this is obviously not possible.

It is thus necessary to use calibration methods to correct for errors, but even still, with increasing aspherical variation from the ›best fit‹ sphere, the measurement uncertainty increases.

Scanning Fizeau interferometry
To assist in manufacturing rotationally symmetric precision aspheres, Zygo has developed a measurement method that avoids or minimizes these sources of errors through the approach used. Scanning Fizeau interferometry is based exclusively on interferometric length measurement (Figure 2) [1]. The method utilizes the fact that, in principle, a rotationally symmetrical asphere is nothing other than a surface made up of a large number of circular rings (zones) with different radii. Each individual circular ring can be measured against a spherical reference surface in the common path approach. Starting at the outer edge of the lens, each zone is successively measured and used to determine the surface coordinates of the asphere. The number of zones required essentially depends on the aspherical variation and determines the total measurement time (typically between five and ten minutes).

The starting point for every measurement process is the specific asphere formula, which is entered into the software along with the required test diameter. This determines the measurability of the lens based on mechanical and optical conditions, and thus determines the measurement sequence. A crucial advantage of the method is direct measurement in the object coordinates of the asphere to be tested, so there is no need for a conversion between the detector and object coordinates. This means that image field distortion and magnification of the instrument’s optical system have no influence on the measurement accuracy.

In contrast to alternative measurement methods, as discussed above, precise measurement of the vertex radius of the asphere (R₀) is possible, as is the determination of coma error in the specimen.
The VeriFire Asphere measurement instrument based on this method uses a Fizeau interferometer with a 1000x1000 pixel camera and uses a special light source to suppress coherent artifacts (Figure 3). A laser interferometer is also used for monitoring the position of the z-axis. The device enables rotationally symmetric aspheres to be measured with up to 800 µm deviation from the best fit spherical surface. The maximum difference between the lens and the design is specified as 10 µm. Lenses between around 1 and 130 mm diameter can be tested.

The VeriFire Asphere can also measure standard plano and spherical surfaces and determine the radius of curvature of spherical lenses with unmatched precision. Comparing the measured results for a parabolic mirror that can be measured using both the classic null configuration against an additional reference sphere and using the method described shows an outstanding degree of match. The difference in the rms values for the two measurements is 2.0 nm, and for the PV values 2.3 nm.

**Ion beam precision processing of an asphere**

In the production of aspherical components with extremely tough demands in terms of dimensional accuracy and surface roughness, increasing use is being made of ion-beam finishing for error correction, such as asphericon’s own ION Finish technique. This totally new method enables peak to valley error to be corrected with high time efficiency and allows maximum dimensional accuracy to be achieved. Unlike current leading technology, asphericon’s ION finish can be used for non-contact processing of a huge range of shapes and materials. The basic requirement for this kind of local correction is a laminar measurement of the surface with sufficient accuracy, such as that guaranteed by the VeriFire Asphere. In terms of the equipment, a new concept based on two independent vacuum locks is used for ion-beam correction. The substrates, with a diameter of up to 300 mm, are clamped on to specially developed holders and upon which they are subsequently measured (in order to prevent positioning errors). The clamped substrate is then loaded into one of the two lock systems and, when a sufficient vacuum has been reached, is fed into the process chamber for processing with a dwell time controlled ion beam. Using the two independently working vacuum locks guarantees continuous processing, thus increasing flexibility and simultaneously reducing process costs considerably.

In contrast to spherical surfaces, aspherical surfaces are processed using smaller mechanical tools. A direct consequence is that short period deviations from the intended shape occur together with long period error components. To reduce processing costs, short and long period errors are separated and processed in turn – that is, the long period errors are significantly larger in absolute terms and can be processed using larger tools.

Figure 4 shows the before and after results of the correction on an aspherical lens with high frequency polishing errors. Using a specially produced aperture, the existing polishing errors can be corrected down to a PV value of 50 nm and an rms of 7 nm (Table A).

**Summary**

The measurement method outlined is a good example of how consistent avoidance of error sources can minimize measurement uncertainty. Particularly well suited for rotationally sym-
metric aspheres, the method allows high-speed, artifact-free measurement for the first time. Because the phase information over the entire measurement process is known, no stitching of separate measurements with the corresponding artifacts and inaccuracies is required. Each individual measurement is carried out in-line using the Fizeau common path approach. Calibration of the measurement instrument is also not necessary, as only relative changes of length are measured interferometrically. Local correction methods such as ION-Finish precision correction can be used successfully.

Torsten Glaschke is a Product Manager at ZygoLOT, the European subsidiary of Zygo Corp. (USA). He is responsible for sales and applications for the Zygo Fizeau interferometer. Sven R. Kiontke is the founder and Technical Director of asphericon. His responsibilities include asphere production and R&D.

Aspherical lens before and after ION Finish processing
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JENOPTIK I Optical Systems

Integrating Opto-electronic Technologies

Through its Optical Systems division, the Jenoptik Group delivers world class precision optics and systems designed and manufactured to the highest quality standards. Besides offering customized systems, modules and assemblies, the Optical Systems division is a development and production partner for optical, microoptical and coated optical components - made of optical glasses, IR materials as well as polymers.

It possesses outstanding expertise in the development and manufacture of optics and microoptics for beam shaping used in the semiconductor industry and laser material processing. The product portfolio also includes optical and opto-electronic systems and components for applications in defense & security, health care & life science, digital imaging, machine vision as well as lighting.

Our Key Markets are:
- Semiconductor & flat panel display equipment
- Laser material processing
- Defense & security technology
- Medical technology
- Digital imaging
- Automotive

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MAZeT GmbH – Electronic Design & Manufacturing Services

MAZeT GmbH is an electronics design & manufacturing services provider, which is specialized in the market segment of medical electronics, automation technology and industrial electronics with customized, embedded computing solutions and mixed signal ASIC/FPGA design services. MAZeT provides its own products and solutions for applications of spectral and color sensor technology. MAZeT is certified according to ISO 9001:2008.

The business concept of MAZeT GmbH has the goal of providing comprehensive service from the product idea of the customer to the delivery of customized electronics and their maintenance during the complete product life cycle.

MAZeT GmbH has an experienced engineering staff for developing FPGAs with substantial requirements for data throughput (e.g., image processing), embedded computing modules (Power PC, Intel) for medical equipment and measuring equipment used outdoors, as well as mixed signal ASICs for processing sensor signals in industrial electronics. Developing firmware and customized application software round out the scope of services offered by MAZeT GmbH.

The development and production of electronics for medical equipment is becoming increasingly important in the market orientation of MAZeT GmbH. MAZeT is regularly and increasingly required to depict partial processes conforming to the DIN EN ISO 13485 standard in projects for medical equipment. There are currently activities for checking the on-going process and the introduction of risk management according to DIN EN ISO 14971. The goal of the activities is to obtain the DIN ISO 13485 in 2012 certificate.

FRAMOS has been active in the area of industrial image processing for the last 30 years and as an innovative partner provides a broad range of high-quality components and services. Along with offering image components such as sensors, companion chips, camera modules, cameras and accessories, we provide a real variety of development support services for camera manufacturers and users.

FRAMOS Imaging Components
Sells our partner companies’ image processing components and systems across the globe.

In our component portfolio, we focus on the areas of machine vision, medical, traffic and security and provide you with every possible component, from sensors to the GigE interface, tailored to your needs.

FRAMOS Engineering Services
You have an idea for a camera or an image processing system? Your prototype needs to be developed? Or you’re not happy because the design is finished but it didn’t turn out as you had hoped? We will support you throughout the whole value chain of your image processing system. We consider the whole surrounding architecture (optics, lighting, mechanics, server infrastructure, data editing etc.).

FRAMOS Solutions
FRAMOS Solutions works in linking our expertise for system integrators to camera users. Specialist engineers will support you in implementing your ideas and projects, comprehensively and competently. If you want to use an image processing system, we will help you to select the best possible combination of all components such as cameras, lenses and lighting, as well as the right software.
Solutions from Optics Balzers

Optics Balzers is the leading European competence center for optical coatings and components, and worldwide the preferred and independent partner for the photonics industry. The company possesses a broad and in-depth know-how in optical thin-film coating processes, complemented by sophisticated patterning, glass bonding and sealing, and further processing capabilities necessary for producing optical thin-film coated components up to optical subassemblies. Highly experienced and skilled development and engineering teams closely collaborate with customers to develop innovative solutions meeting their specific requirements and design robust processes to manufacture the customer specific components. The combination of these capabilities and skills places Optics Balzers at the forefront of markets in the photonics industry such as Sensors & Imaging, Biophotonics, Space & Defence, Lighting & Projection and Industrial Applications.

With over 65 years of experience in optical coating technology, Optics Balzers possesses profound knowledge in optical component manufacturing. Customers benefit from state-of-the-art vacuum-deposition technologies, various adapted patterning, bonding and glass processing technologies operated in modern facilities with clean room environments.

Examples of Optical Coatings & Components
- Anti-reflection coatings
- Matched ITO coatings
- Opaque chrome coatings
- Bandpass filters
- NIR filters
- Notch filters
- UV filters
- Filter Arrays
- Filter-on-chip

Sealing Technologies
- Gelot™ solderable coatings
- B-stage Epoxy

Patterning
- Photolithography
- Laser Ablation
- Masked coatings

With its acquisition of mso jena Mikroschicht-optik GmbH in Jena, Germany, Optics Balzers is expanding its competencies and manufacturing technologies into a unique portfolio, generating added value for customers. Optics Balzers’ continuous innovation, quality improvements, additions of expertise and production sites in Liechtenstein and the EU, will continue to support customers’ novel product development efforts with Optics Balzers as a trusted, reliable, and innovative partner.
Made to measure

Customized spectrometers. Brand new compact subsystems extend tec5’s range of premium UV/VIS/NIR spectroscopy products. The spectrometer modules are customized with electronic boards and other components and supplied as ready to use solutions. The measurement results can be transferred to a host computer via Ethernet or USB as spectral data or directly evaluated by the internal microcontroller (embedded processing). The individually tailored design, range of functions and external interfaces ensure reliable and time-saving integration of the units, fully assembled and tested to customer specifications. If servicing is needed, the subsystem can be exchanged quickly and easily. Production, spare parts storage and logistics are provided by tec5 as customer services.

www.tec5.com

USB stick ...

... spectrometer. RGB Lasersysteme’s ›Qstick‹ represents the ultimate in spectrometer miniaturization: a complete spectrometer in a small USB stick design, offering a resolution of 1.0 nm across the full visible spectrum. It includes the advanced spectroscopy software ›Waves‹ that offers sophisticated algorithms for data acquisition and evaluation and provides these features through a clear and simple user interface. The Qstick is an ideal instrument for scientific field measurements and light analysis.

www.rgb-laser.com

Layer analysis

THz-TDS analysis software. Menlo Systems is introducing ›TeraLyz‹, a new terahertz data evaluation software developed by LyTera, enabling advanced data analysis and THz time-domain spectroscopy (TDS) experiments. Menlo presents TeraLyz as a first-of-its-kind solution for the extraction of sample thickness, enabling the investigation of sub-100 µm samples without the need for a differential measuring setup. At the same time, complex THz material parameters of a wide variety of substances can be determined. As an option, the TeraLyz software is also able to analyze multilayer systems in a standard THz-TDS setup, thus opening up the door for a whole new range of experiments. Menlo Systems’ experience in fs-laser based THz-TDS laboratory systems in conjunction with LyTera’s background in the THz field offer a sound platform for customer specific applications.

www.menlosystems.com
LED inspection

... with five channels. Micro-Epsilon offers their new colorControl MFA-5i for the inspection of LEDs, starting with a basic version that offers five measuring channels. This simplifies the inspection of LEDs for function, contrast and luminosity. The MFA-5i is very compact and can verify up to five LEDs simultaneously. The measuring system can be extended in a modular fashion by adding extra MFA-E modules in batches of five channels. The light from the target object is transmitted to the inspection system via a flexible, 2 mm diameter, plastic optical fiber and is therefore evaluated dynamically using a color sensor for color and intensity. The color value, which is evaluated within just a few milliseconds, is output as RGB-, HIS or CIE values and then transmitted via USB or RS232 interface at a rate of between 9600 and 115200 baud to a higher level inspection or evaluation system for further processing. In order to ensure a wide measurement range for intensity (illumination), the sensitivity of the sensor can be adjusted by using two different modes (High Sensitivity Mode and Low Sensitivity Mode) to eleven settings. Due to these settings, it is possible to identify LED colors up to ± 4 nm. A test software to install the MFA-5 system is included in the scope of delivery.

www.micro-epsilon.de

Randomness at high bit rates

Quantum random number generator. At Photonics West, PicoQuant will unveil their photonic quantum random number generator PQRNG 150, which they claim to be the fastest system of its kind commercially available today. The PQRNG provides turn-key usability, a high bit rate of up to 150 Mbits/s, delivered over USB, with long term statistical data quality. This high speed was achieved by exploiting the most recent photon timing instrumentation and state-of-the-art data processing in hardware.

www.piqoquant.com

Compact, precise

Laser surface velocimeter. The new compact LSV-2000 laser surface velocimeter from Polytec can detect the direction of movement and provide precise measurements when stationary, allowing production processes to be fully optimized. Measurement field depths and speed ranges are independent of the measurement distance. This extends the range of possible applications, particularly where short distances are involved, such as variations in material thickness or pipe diameter. Due to its compactness, the LSV-2000 is suitable for installation in tight spaces, such as in thickness micrometers for rolling mills. For applications in harsh and hot environments, a stable protective enclosure with water cooling is available, while optional air purge units ensure the laser has a clear view in dusty surroundings. Laser Surface Velocimeters allow users to reliably reduce waste in processes by reliably and accurately measuring lengths. The speed is measured directly on the material without contact, thus reflecting the actual material speed without slipage problems. This enables the implementation of reliable control processes, such as mass flow control.

www.velocimeter.de
Spectroscopy, marking or medical engineering – lasers are used everywhere in laboratories or machines. All over the world, customers from quantum optics to the automotive industry rely on Owis’ comprehensive experience with optical systems and positioners. They appreciate the precision and high quality of ›made in Germany‹. Development, production and assembly are all located at Owis’ headquarters in Staufen, Germany.

Proven design

The Owis systems SYS 40, SYS 65 and SYS 90 – proven over more than three decades – enable beam handling on defined beam heights of 40, 65 and 105 mm, respectively. Since 2010, the miniature beam handling system SYS 25 – with a beam height of just 25 mm – complements the product portfolio, being introduced as a reaction to the market trend of transmitting light over even smaller and smaller dimensions.

The assembly of a set-up or the alignment of a light beam in an industrial machine is greatly simplified when using a beam handling system. Optical components are fixed on slides and positioned on guide rails, meaning that existing set-ups can easily be expanded. All components that belong together are machined so precisely that optical components reach the standard beam height without further adjustment, saving time and effort. The Owis combination of rail and slide has been often imitated, but only the original dovetail and clamping technique guarantees highest stability.

Beam redirection

The use of laser light or other light beams for more than one experiment is becoming increasingly important. Flip mirror holders are optical mounts that are used to transmit light to different assemblies or experiments. These flip at a 45° angle into the beam – either manually operated or motor controlled – and the light can thus be deflected by 90°, redirecting to a different area (Figure 1). Simply flipping the mirror back out of the beam allows it to pass unheeded back on the original path.

In industry today, many manufacturing or measurement systems have to multitask, be multifunctional. Working in different modes, an engraving system might have to both mark and then verify the beam path and the engraving, for example. To enable this multifunctionality, laser light can be redirected with flip mirror holders to one or another machine area.

Beam redirection, even upside down

NEW FLIP MIRROR HOLDERS from Owis are available to suit all of their current beam handling systems, and have been optimized in their design to enable even more applications than before.
The requirements are similar in set-ups for research at institutes. A laser beam has to be used for one experiment – for example for atomic spectroscopy – whereas another team works on the spectroscopy of molecules. But both teams might need the same laser (perhaps at different times), but do not want to have to completely readjust the beam path every time they switch usage. Using flip mirror holders, the light can be used in parallel for both experiments or individually as desired.

Flip mirror holders

In order to comply with all these different requirements, Owis exclusively markets flip mirror holders – the KSH and KSHM series – in four different sizes. A new development is the variable deflections now also available for use with the Owis miniature beam handling system SYS 25.

If required, motorized flip mirror holders enable beam deflection in enclosed machines or inaccessible areas. The Owis NG-E02, a control unit with TTL input, is the appropriate additional component needed to actuate the KSHM (Figure 2). The holders have now been revised according to customer requirements, so that they can be used in all positions – horizontally, vertically and even upside down. The flip mirror holders can thus also be implemented in the four-sided system profiles of the SYS 40 or SYS 65 series, so that beam redirection in all three dimensions is possible.

The holders are designed in a way that they can be used in their respective Owis system. At the same time, they have a thread for M4 (KSH 25 and KSHM 25) or M6 to permit their mounting on pins. To integrate the flip mirror holders in the corresponding system – and despite the small amount of space available – Owis has developed slides for the KSH(M) of the systems SYS 25, SYS 40 and SYS 65 to be screwed with the base plate of the flip mirror holders. For the largest flip mirror holders (KSH 90 and KSHM 90), there is an adapter plate available to reach the system height of the SYS 90.

Not only mirrors with diameters ranging from 12.5 up to 50.8 mm (2") – depending on the version – but also transmitting optics, for example beam-splitter plates, can now be mounted in all sizes due to an opening. Thus, the flip mirror holders are more flexible and can be used for two assemblies or experiments at the same time. The repeatability of the flip mechanism is less than 100 µrad. To fine adjust the deflection, the optic can be set in φ, ϕ and z so that the beam is aligned in an optimal way.

Comprehensive protection against reflections and diffused light is provided by a special, high quality black anodized coating. Depending on the application, other coatings (for example, nickel plating) are available as an option. And applications in a vacuum chamber environment are equally well served by Owis’ appropriate vacuum KSHM flip mirror holders.

Summary

The manual (KSH) and the motorized versions (KSHM) of the flip mirror holders can be used in research assemblies as well as in industrial systems. They give the user the opportunity to always align the beam in the area where it is really needed.
A new generation of laser lithography equipment

3D STRUCTURING. Laser lithography is already a key technology in many areas. However, the conventional methods to date are already reaching their limits, both in research and in industrial applications. A brand new technique now allows very complex three-dimensional micro- and nanostructures to be produced in photosensitive materials for the first time.

Following six years of intensive work at the Karlsruhe Research Center’s Institute for Nanotechnology and the University of Karlsruhe’s Institute of Applied Physics, Nanoscribe GmbH was founded at the end of 2007. In addition to innovative 3D laser lithography equipment, the dedicated young entrepreneurs offer their customers services ranging from sample design and production through to material implementation, for example with silicon. Support comes from the leading optics concern Carl Zeiss, Zeiss having shown great interest in the start-up firm’s potential and emphasizing this by providing both technical and financial support.

Lithographic detail via laser
The innovative 3D lithography technique that Nanoscribe has brought to market (Figure 1) permits almost any three-dimensional micro- and nanostructures to be created fully automatically, such as might be required in tomorrow’s optical technologies. In principle comparable to the internal engraving of glass, this new lithography method is straightforward to comprehend and is already suitable for a wide range of commercially available photoresists. Strong focusing of ultrashort laser pulses precisely exposes photosensitive material located directly at the focus via a non-linear optical process. Just like a pen that is moved in three dimensions, the laser beam can draw any desired path in the material. Line widths of several micrometers down to 150 nm can be achieved, and a total volume of up to 300x300x80 µm³ can be accessed, depending on the selected microscope lens and the scanner configuration. As an option, the system can be adapted for larger, fully automatic structuring volumes or line widths. A reproducibility of better than 5 nm can be realized.

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Precise positioning of objects in the laser beam

During the lithography process, the laser and focus remain in a fixed position, while the object or sample is moved along a predetermined three-dimensional path. While this approach enables extremely high quality results to be obtained (Figure 2), it does place considerable demands on the controller, as it is not sufficient to simply move precisely to specific positions. Highly accurate path control is required and the intensity of the laser must be accurately controlled to account for any acceleration or deceleration of the positioning system as well as providing additional functionality so that line widths can be modulated or even interrupted completely (for dotted lines, for example).

To address the critical need for a precision motion system, Nano-scribe turned to Physik Instrumente (PI). One of PI’s positioning products now forms a key component of the lithography system. The piezo adjuster (see side bar) can be easily attached.

NEW

DFB lasers up to 3500 nm
www.nanoplus.com/3500nm
to the conventional microscope xy scanner tables used for the precision adjustment and operates with displacements of up to 300 µm on all linear axes (x, y and z). The repeat accuracy is in the nanometer range.

New perspectives in 3D
This technology opens up new perspectives in a wide range of applications. A typical application can be found in the manufacture of three-dimensional frameworks for cell biology (Figure 3). Ultimately, life happens in three dimensions – in stem cell research, for example, it is widely recognized that as well as an appropriate chemical environment, the physical environment has a significant influence on the differentiation of cells. Thanks to the new Nanoscribe technology, physical parameters such as the geometry and rigidity of the three-dimensional artificial extra-cellular matrix can now be selectively studied in terms of its influence.

User-friendly software
Using the technology is both easy and practical. The required structures can be designed and imported using any CAD software that supports the DXF format or, alternatively using Nanoscribe’s proprietary script language GWL, which has been specifically designed for the requirements of 3D structuring. A true all-rounder, the method is not only suitable for three-dimensional structuring, but can also be used for today’s 2D or 2.5D structuring tasks – although with considerably higher resolution than when using conventional equipment.

Summary
This new laser lithography technique is also opening up a range of applications in production of microoptic components and photonic crystals. Photonic crystals can selectively control the propagation of light and, in the future, will be used in lasers, optical filters, waveguides, polarizers, beam splitters, couplers and sensors. In addition, the 3D lithography equipment is ideal for rapid prototyping and small-scale production of micro and nanofluidic systems.

Steffen Arnold is the head of Marketing & Products at Physik Instrumente (PI). Martin Hermatschweiler is Managing Director of Nanoscribe.

INFO

Parallel kinematic multiaxis system
Precision adjustment of objects and samples produced using laser lithography is performed using a piezo nanopositioning system from Physik Instrumente (PI) (photo). The parallel kinematic multiaxis construction makes a major contribution to the excellent positioning accuracy: The driving force in the nanopositioning systems comes from pre-stressed, very long lifetime, high performance piezo actuators, which are integrated into a zero friction parallel kinematic guidance system with FEM optimized solid flexures. All piezo actuators thus act on a central platform, enabling identical dynamic behavior to be achieved for all axes. This is particularly advantageous for 3D lithography, as the process more or less allows any type of structure to be realized. A slower axis, which is not a problem in a line scan for example, would have a detrimental effect here. Sensors monitor all the controlled movement axes simultaneously – this parallel measurement actively prevents axis crosstalk and guidance errors, thus benefiting path accuracy and repeatability. Path control is performed by a digital controller in a PCI board design. Like the nanopositioning system itself, it is part of the PI product range and it is tailored to work with the company’s multi-axis parallel kinematic piezo nanopositioning systems.
Profound Knowledge in a Flexible Multi-Media System:
Since 1928 Hanser Publishers have established themselves as competent providers of information. Hanser Publishers do not only offer you 19 technical magazines and almost 3,400 technical and textbooks in the fields of computer, engineering, and management & business but also specific portals and practical seminars for a successful career. Read more at www.hanser.de
The Company

Leistungselektronik JENA GmbH (LEJ) was formed in 1991 as a spin-off of the research center of Carl Zeiss Jena GmbH. More than 25 years of continuous research and product development in the field of ballasts for gas discharge lamps and complete light sources are the basis of LEJ as a technology company. LEJ supplies a wide range of standard products, plus custom modifications for sophisticated industrial application and use in research and development.

The products

- High-stability ballasts, lamp housings, ignition modules and compact light sources, glass fiber link, if needed, based on mercury, xenon and mixed gas lamps in the output range of 50 W to 2000 W.
- Electronic ballasts and luminaires for high-power light sources using metal halide, sodium vapor or other comparable of 150 W to 2500 W output.
- Xenon flashers for industrial use in different versions, coupling in optical fibers, flash energy and frequency adjustable, up to 10 Ws or 100 Hz.
- Lighting modules based on high-power LEDs in different configurations
- Electronic ballasts, processor-controlled, programmable, for UV high power radiation sources for DC or AC, output range from 500 W to 2000 W
- Custom modifications of all standard products, tungsten halogen and deuterium lamp supplies

Applications

The products find application in: precision mechanical/optical industries, industrial image processing, analytical products, projection, environmental simulation/solar simulation, UV disinfection

mechOnics ag

- Competence in micropositioning –

mechOnics ag, a German company founded in 2003, is specialized in development, production and sales of systems for micro- and nanopositioning applications. These systems are driven by a new developed, innovative piezo inertial drive, which combines high resolution in the nm-range with large travels up to 50 mm. Together with piezo controllers with very low power consumption this permits main voltage free applications in laboratories and out of doors. In telecommunication, semiconductor industry, laser- and bio-technology, sensors and space industry multiple customers profit of the high competence of mechOnics.

Range of standard products

- Linear stages up to 50 mm travel
- Ultra compact xyz-stages (travel ≤ 10 mm)
- Monomode coupler (travel ≤ 2 mm)
- Ultra low temperature stages (≤ 300 mK)
- Ultra high vacuum stages (≤ 10^-10 Torr)
- Mirror mounts for transm. optics (tilt ± 3 deg.)
- Linear measuring systems (resolution < 50 nm)
- Handheld battery driven controller
- USB-controller (open or closed loop)

Customized products

- Positioners for ultra low temperature applications
- Low temperature microscopes
- Slits for electronic microscopy
- Filter slider for space applications
- Positioners for UHV applications
Satisloh – The Company

The Satisloh Group is one of the leading manufacturers when it comes to complete solutions for ophthalmic and precision optics manufacturing and reliable high-tech equipment.

Optical manufacturing requires optimally balanced processing components: machinery for grinding, polishing, centering, measuring, finishing and coating. Experience in process engineering is a prerequisite to be able to specify appropriate tools, consumables, software and technical services. Satisloh provides proven complete solutions for optical manufacturing which perfectly fit together.

Innovation is the biggest challenge for Satisloh. No other company in the optical industry offers their customers the same number and quality of innovations. Satisloh derives its R&D projects from market intelligence, dialogue with customers and valuable business partners. Engaged employees are working continuously on the development and improvement of high quality system solutions to support customers in their work.

Divisions:
- Ophthalmic - equipment and solutions for spectacle lens production
- Precision Optics - equipment and solutions for manufacturing of optical and non-optical components

Precision Optics

The Satisloh GmbH located in Wetzlar, Germany, whose roots stretch back to 1922, is the biggest production site of the complete group and furthermore competence center and top location of the business unit Precision Optics.

Applications

Satisloh equipment is designed for processing hard and brittle materials with a clear focus on optical applications. Typical materials are glass, crystals, ceramics, semiconductors (IR-materials) and hard metal. The main process steps, consisting of grinding, polishing, centering and coating, can easily be combined with additional production steps such as edging, chamfering, sawing and drilling, facilitating the manufacturing of very complex components. Dimensions from below 1 mm to typically 500 mm diameter and a wide range of geometries are covered, for instance:
- Convex/concave spheres and aspheres
- Domes
- Cylindrical surfaces
- Plano optics like prism and filters
- Free-form, multi-focal and off-axis optics

Processing Solutions

Machines for:
- Generating
- Polishing
- Centering
- Coating

Software Solutions

Customer Services
- Tool Service
- Consulting Service
- Technical Service

Consumables & Tools
Solutions for light measurement
Instrument Systems, founded in 1986, is a leading manufacturer for light measurement solutions. The portfolio includes array and scanning spectroradiometers, and imaging photometers and colorimeters. Headquarters are located in Munich and the global customer base is supported by a worldwide network of representatives.

Core competencies
LED measurement
Instrument Systems continues to set the benchmark in LED metrology. Whether testing single LEDs (standard or high-power), LED modules, or OLEDs - the company engineers turnkey solutions ranging from high-speed production testing to high-performance spectroradiometers (e.g. CAS 140 CT series) for R&D and QC. The instruments provide accurate and reliable results as per CIE recommendations for all relevant parameters like luminous intensity, luminous flux, chromaticity coordinates and color rendering index.

Display measurement
Instrument Systems offers a wide range of refined and proven systems for testing displays. The LumiCam 1300 and LumiCam 4000 imaging photometers and colorimeters with GigE interface determine luminance, chromaticity, color temperature and dominant wavelength in a fast and accurate way. The high-resolution LumiCam 4000 captures and evaluates around 11 million pixels simultaneously in a single measurement.

Spectroradiometry and photometry
Scanning spectrometers based on single or double monochromators are used for precise determination of radiant power, radiant intensity and irradiance. The SPECTRO 320 series covers a spectral range from 190 to 5000 nm and meets the highest requirements for wavelength accuracy, signal dynamic range and low stray light.
Swiss, but at home all over the world.
At WZW we have been producing high-end optics and precision optical components for customers all over the world for more than 40 years. Based in Balgach, Switzerland, our innovative company is a market leader in the engineering and manufacture of high-end optics and opto-mechanical assemblies. Our aim is to strengthen our position even further, so it is vital that we act as a full-service provider to our customers. We place the most rigorous demands on our employees in every way, from product design, product development and quality assurance procedures to prototyping and series production. This ensures first-rate products, and to help us sustain this level of quality we draw on our highly qualified staff and cutting-edge technology. In 2009 WZWOPTICAG invested in wafer dicing technology to dice prism bars. This has created many opportunities within the medical industry, where the requirement is for very small prisms with sharp edges and no edge chips. The Tilting Spindle capability is designed to provide both perpendicular cuts and 8° angular cuts needed to suppress back-reflection in optic components.

Capabilities for High – End Optics

TECHNOLOGY
- MRF – Magnetorheological Finishing
  - Flatness Lambda 60
  - Angle correction < 0.1” arc sec
- Wafer dicing with tilting spindle capability
- Sub Angstrom Polishing < 1 Angstrom
- 150m² optical and opto-mechanical assembly clean rooms

CAPABILITIES
- Surface roughness < 1 Angstrom
- Sizes of substrates 0.3 – 450 mm
- Angle tolerances ± 0.4” arc seconds
- Thickness Tolerance ± 0.0002mm

METROLOGY
- Zygo New View 6300 (Å)
- Scattered light inspection
- Autocollimator (resolution ± 1”)
- Interferometer (Zygo, Fisba, Kugler)
- Centration

PRODUCTS
- Complexe cemented sub assemblies
- Development of OEM opto-mechanical and electronic assemblies
- UV optics
- In and ex cavity optics
- Laser crystals
- Plano Optics
- Collimation systems
- Optical windows
- Free form polishing in cavities and turbular surfaces Mil 20 – 10

SERVICES
- R&D Services
- Optical design (Oslo, Zemax)
- Mechanical design (3D CAD- solid edge)
- Spectrometry MTF measurement equipment
- Environmental testing in house (~40º up to 180º)

Our diversity and unity brings creativity to our relationships within our company and to our customers. We are also fortunate to be based in one of the most beautiful regions in the world, the Rhine Valley in Switzerland. Our Balgach facility covers 3,000 square meters and offers excellent working conditions including a clean room environment and the latest technical equipment.
Cost-effective racers

Line scan cameras. Basler has just introduced the first models of their new compact and cost-effective line scan camera family ›racer‹. The cameras are available with either a Gigabit Ethernet or a CameraLink interface. They use the latest line scan sensors based on highly sensitive CMOS technology and reach line rates of up to 48 kHz via Gigabit Ethernet and up to 80 kHz with the CameraLink interface. The first models offer 2k and 4k resolutions, cameras with 8k and 12k will follow in the course of 2012. This new series is designed to cover the whole spectrum of standard line scan cameras, making it easier for users from many different markets and application areas to choose suitable cameras for their needs. The CameraLink models are equipped with Power over Camera Link (PoCL) support so that data and power are transported over the same cable, reducing both overall costs for accessories and system complexity. The compact cameras with an industrial housing (w x h, 56 x 62 mm²) are ideally suited for multi-camera designs, especially in applications where many line scan cameras are installed side-by-side.

Improved fluorescence imaging

sCMOS camera. Hamamatsu Photonics Germany introduces their new ›Orca-Flash4.0‹ 4 MP sCMOS camera, engineered around a new second-generation sCMOS detector. The camera promises high sensitivity, high resolution and a fast readout, with a significantly improved signal-to-noise for low-level, fast fluorescence imaging. This enables the camera to cover a wide range of imaging needs, including super resolution microscopy, TIRF microscopy, live cell GFP, high-speed calcium ion imaging, FRET, real-time confocal microscopy and many more. The Orca-Flash4.0 has quantum efficiency values of over 70 percent at 600 nm and 50 percent at 750 nm and has only 1.3 electrons of read noise (at 100 full-resolution frames per second) with considerable high speed acquisition at full resolution. This combination of high quantum efficiency and low noise, in the absence of EM-CCD multiplicative noise, makes the camera ideally suited for demanding microscopy applications.

FILTROP AG – Your Supply-Chain!
Fully customizable

USB camera platform. Framos presents the new ›Visiosens VFU‹ camera series, a highly flexible and customizable imaging platform with more than 140 camera variants per image sensor and a uniform software interface for all models. The series is available with USB 2.0 as well as the latest USB 3.0 interface enabling up to 5 Gbit/s. The platform consists of a growing number of image sensors (CMOS and CCD sensors with resolutions from 0.3 to 10 MP), a variety of output interfaces, complementary assembly concepts, mounts (C-, CS- or M12-mount), filters, and, optionally, an LED lighting ring integrated in the housing and connected to the 8-pin I/O port. For all variants, the user and system interface is built on a unified, future-proof, cross-platform software development kit based on the latest ›.NET‹ technology. The robust camera housing was specifically designed for industrial systems as well as for microscopy. It offers multiple mounting options on each side and the front face which are all symmetrical to the optical axis of the sensor.

www.framos.de

Illumination

... for machine vision. The ›intraLED 3‹ LED light source from Volpi promises a service life of 50,000 h and a light intensity of more than 500 lm (measured on a 1 m light guide with an active diameter of 13.5 mm). As the follow-up model to the ›intraLED 2020+‹, it has been specially designed for machine vision applications, providing a 30 percent increase in power and a typical color temperature of 6000 K. It is actuated either manually, using the integrated RS-232 interface (USB optional) or using the Multiport with digital and analog input. Its power consumption is 24 VDC with a maximum of 55 W. The compact enclosure makes it easy to use in small spaces, while the threaded bars (M4) on four sides ensure trouble-free system integration. The ›intraLED 5‹, based on the same design platform as the ›intraLED 3‹ and delivering more than 700 lm.

www.volpi.ch

High flexibility

Board level camera series. Baumer has designed their new MXG board level camera series specifically to meet the growing demand for miniaturization and higher flexibility. The separate sensor board measures only 28 x 28 mm² and is connected to the system circuit board via flexprint, allowing the cameras to be individually integrated even into small, cramped spaces. The series comprises four monochrome and four color cameras with resolutions ranging from VGA up to 4 MP, featuring CCD sensors, as well as a 4 MP CMOS sensor from Cmosis. The first model available offers VGA resolution and a 140 fps transfer capability. While Trigger Delay simplifies synchronization between the application and the camera, the sequencer makes it much easier to capture image series with changing acquisition parameters. Both Packet Delay and Transmission Delay modes are available to support reliable data transfer in multi-camera operation. Storable user sets and the GigE standard interface with Power over Ethernet help simplify camera integration.

www.baumer.com/cameras
3D evaluation of high-speed videos is well known, for example in safety analysis and from motion analysis in sports. But high-speed recordings can also provide valuable information in motorsport, particularly motorcycle racing. Extremely short exposure times and high frame rates on modern high-speed cameras not only deliver impressive sequences of images in super slow motion, they also allow objective analysis based on measured values on the vehicle and the chassis components.

3D analysis with camera

3D points on a motorcycle can be quickly and easily identified with a stereo image high-speed camera system. Camera speeds of 2000 frames per second (fps) allow detailed chassis analysis in extreme situations. Lean angle, speed and acceleration can also be directly linked to wheel revolutions, spring rates and even the rider’s posture on the bike. 3D analysis is frequently capable of identifying unexpected movement that would be very difficult, perhaps impossible, to detect using sensors. Flex of the entire chassis can even be compared with the original design.

With up to 200 horsepower and a weight below 200 kg, so-called superbikes can accelerate from 0 to 100 km/h in less than 3 s and have a top speed of up to 300 km/h. An increasing number of private riders are thus using their sports motorcycle not only on the road, but also for training on a racetrack. With rebound and compression damping as well as spring preload on the forks and on the rear strut, the motorcycle can be tailored to the rider’s weight and the track in order to achieve high cornering speeds, maximum acceleration and short braking distances.

While driver safety training is primarily concerned with preventing accidents
on the road by safe emergency braking and hazard
avoidance, when it comes to riding on a racetrack,
a fast lap is the top priority. Both areas benefit from
the rider’s ability to optimally slow down the bike.

Measurement strategy
A small number of measurement markers attached
to the bike at clearly visible points allow a complete
analysis of the interaction between the individual
chassis components.
On a racetrack, one typically accelerates on the
straights and brakes as late and as hard as possible
just before entering a corner. Figure 1 shows
the braking at the end of the back straights at the
Oschersleben Motopark (Germany), from speeds
well over 200 km/h down to around 120 km/h.
The recording enables the exact braking point and the maxi-
mum deceleration to be determined as well as the spring
travel on the forks and the position of the rear of the bike to be
measured. The remaining spring travel on the front wheel can
also be measured and must remain in control without bottom-
ning out. The high resolution of a high-speed camera together
with high sensitivity and low noise enables the initial response
of the motorbike, which is critical for a short braking distance.
The build-up of braking rate can also be measured.
Maximum deceleration allows late braking points and there-
fore longer acceleration periods. For example, imagine two
riders, A and B, both of whom are at a speed of 200 km/h at
the braking point and which needs to be reduced to 100 km/h
at the end of braking. Rider A requires 0.3 s for maximum
braking to be achieved, rider B just 0.1 s. This means that
rider B can start braking 10 m later, thus gaining a crucial lead
at the entrance to the corner.
In the acceleration phase at the exit from the corner, as can be
seen in Figure 2, the performance of the rear end is crucial.
Here, a 3D analysis allows the lean and acceleration to be
determined, in conjunction with an analysis of the suspension
and damping on the rear of the bike.

Fiber Optics for Industrial, Medical
and Communications Applications

Innovative Solutions
SFP+ SR, LR 10km, LR 20km, ER 40km & CWDM
XFP SR / LR / ER & ZR DWDM / 120km
Customised Labelling, EEPROM, Packaging etc.
Robust ESD and Thermal Solutions
Crystals, Oscillators, TCXO, VCTCXO & VCXO

Specialty Photonics
Fibers, Cables and Assemblies
Specialty Single Mode, HCS, PYROCOAT®
Metalized, Carbon Coated, Tight Bend Radius
Crimp and Cleave Fiber Termination Kits
ISO 9001 and ISO 13485 certified

MSA Transceiver Products
SFP LC Duplex & Bi-Di, DDM, opt. F-3000 Connector
SFF 2x5 LC Duplex & SC Bi-Di
1x9 SC (Shielding Optional), ST, SC & SC Bi-Di
−40 °C to 85 °C / 120km GbE & 200km FE
XFP, SFP Cages and Connectors
Applications away from the racetrack

The same technology can also help participants in driver safety training to learn about emergency braking. Unlike in a car, the braking distance on a motorbike depends hugely on the individual abilities of the rider. Training and practice on a closed track are essential for achieving maximum deceleration when braking. The reason for this is that the front wheel in particular should not lock, as this almost inevitably leads to a crash. However, fear of crashing due to a locked front wheel often hinders the rider from rapidly reaching full braking potential, which is essential in achieving the shortest possible braking distance. Table A illustrates the relationship between three different times a rider requires to reach maximum braking and the resulting braking distances for full braking, both from 50 km/h and from 100 km/h (a linearly increasing deceleration of 0 to 10 m/s² is assumed). From 50 km/h the braking distance is extended by up to 5 m, from 100 km/h by up to 10 m. Even more revealing are the speeds $V_e$ with which the ‘slower’ riders are still moving after 10.7 or 40.8 m (at which points the ‘fast’ reacting rider is already at a standstill).

3D analysis with a single camera

A 3D video analysis system such as the SOLVing3D.titan system is made up of a low-noise, high-speed camera system (the pco.dimax in this case) and a stereo mirror attachment (Figure 3). The high resolution sensor on the pco.dimax has 2016x2016 pixels and the stereo mirror attachment used in the SOLVing3D.titan system has a fixed stereo basis of 300 mm and slightly convergent acquisition axes. The two stereo images are normally mapped to the central area of the sensor (2016x1008) and thus resulting in two image sequences during the recording – each with 1008x1008 pixels and slightly different angles of view. The system provides an exceptional image quality and resolution of the 3D stereo film, in color and at a frame rate of 2128 fps.

The system is calibrated in the same way as a normal stereo camera system. After appropriate conversion, two time-synchronous image sequences from the virtual stereo camera are obtained, which can be evaluated in 3D. This kind of system is very compact, robust and comparatively easy to use. A disadvantage of the titan system compared to a stereo measurement system with two cameras is the reduced flexibility in the choice of location due to the fixed geometry of the mirror attachment. The advantages are the very robust operation and the elimination of synchronization errors and differently exposed stereo sequences.

When analyzing the recordings, the accompanying software provides comprehensive functions for calculating and display-

<table>
<thead>
<tr>
<th>Time [s]</th>
<th>$V_e$ [km/h]</th>
<th>Braking distance [m]</th>
<th>$V_e$ [km/h]</th>
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<tr>
<td>0.3</td>
<td>50</td>
<td>10.7</td>
<td>0</td>
</tr>
<tr>
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<td>50</td>
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<td>100</td>
<td>40.8</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>100</td>
<td>44.0</td>
<td>31</td>
</tr>
<tr>
<td>1.0</td>
<td>100</td>
<td>50.6</td>
<td>52</td>
</tr>
</tbody>
</table>

Table A: Braking distances (full braking) for different rider reaction times, specified for 50 and 100 km/h. Also shown are the final speeds of riders with slower reactions, measured at the end of the braking distance of the rider with the fastest reaction time.

2 Accelerating out of a corner

3 Accelerating out of a corner

3 The SOLVing3D.titan 3D video analysis system
ing the measured results (Figure 4). This enables analysis of parameters such as position, speed, acceleration, orientation and trajectory progressions to be determined quickly. The software supports evaluation with menu-based evaluation processes. The software can also be used to geometrically correct the image sequences so that they can be viewed stereoscopically. The resulting 3D impression often makes it easier to interpret the measured values. For close-up applications the SOLVing3D.titan system achieves accuracies of 0.3 mm.

A further advantage of the measurement system over the individual measurement sensors mentioned above (which would have to be attached to the motorbike along with the corresponding data capture equipment), is that only low-cost point markers have to be attached to the bike or to the rider. Only one set of measurement equipment is required and can thus be used directly for multiple bikes. This enables comparative analyses between different riders and bikes to be carried out. This makes the system ideal for analysis within small groups – including driver safety training.

Summary
Using high-speed 3D video analysis in driver safety and race-track training provides valuable information to improve motorbike and rider behavior. This kind of measurement system can also be used for other applications such as crash testing, motion analysis in various branches of sport and much more.

Dr. Gerhard Holst is the head of the science and research department at PCO. Dr. Bernd-Michael Wolf is Executive Director at SOLVing3D.
Jenoptik was restructured four years ago, what were the reasons for this change?

Dirk Rothweiler: It was certainly the right step to take! The new logical grouping of Jenoptik, with its portfolios of products and technologies, better aligned our activities with customers and markets. The restructuring was actually not all that easy, but the changes have long since been implemented successfully. From today’s perspective, the restructuring was very much justified, as is demonstrated by the Group’s continuous positive development in recent years.

Thomas Fehn: As an integrated optoelectronics company, it is paramount to our strategy to bundle the technologies and value chains of the sections more tightly, to exploit synergies within and between divisions and to be able to offer our customers integrated solutions. We have already seen that our customers very much appreciate this integrated approach. Today, Jenoptik’s Optical Systems division is more a provider of optical and optoelectronic systems, whilst the Lasers & Material Processing division is a full service provider of the entire value chain of laser technology and laser processing systems. In the field of lasers and optics, we often cooperate closely on common projects – our ability to offer complete solutions, a consistent orientation towards customer requirements and market realities, as well as intensive dialog with our customers, all enable us to better understand customer demands and specifications, much more so than competitors who are only able to deliver part of a solution. The customer is ultimately offered a ›one stop shop‹ solution – from the laser sources to the imaging optics, and, should he be interested, up to complete laser processing systems.

The divisions Lasers & Material Processing (LM) and Optical Systems (OS) appear together under Lasers & Optical Systems. How are the two organized together?

TF: Our divisions effectively cover the complete field of photonics. This capability then applies elsewhere within the entire Jenoptik as well. All the important optical technologies (that is, lasers and optics) and laser materials processing are in-house – in other words, the entire value chain.

In the Laser Business Unit within the Lasers & Materials Processing division, for instance, we offer high power lasers of all types relevant for processing of materials, from direct diodes, via traditional DPSS, to fiber and disk lasers – gas lasers being the one exception that is not part of our portfolio. And in the Laser Processing Systems Business Unit, we offer process-optimized machines and systems – based on robot, portal and scanner approaches – for materials processing applications.

DR: The Optical Systems division has three business units – classical optics, microoptics and optoelectronic systems. We cover all types of classical optical components, such as lenses, filters and optics with aspherical or freeform surfaces, and all of these in high precision and with coatings supplied by one of the best coating laboratories in the world. We also provide integration of individual components into modules and even entire systems. We additionally have in-house expertise for the manufacture of diffractive, refractive and hybrid microoptics and we deploy microstructuring techniques to achieve highly complex beam shaping and guiding characteristics. Last but not least, our optoelectronic systems integrate these components with electronics, providing both hardware and software. We make use of our breadth in technology for the development and manufacture of customized optical systems and solutions,
integrating a range of technologies such as optics, microoptics and optoelectronics. As a result of this system capability, we rank as one of the very few leading suppliers worldwide.

**What is the expected turnover of this segment, and how will Jenoptik develop photonics into the future?**

**DR:** Together we generate around 40 percent of Jenoptik’s total turnover – this amounted to 189 million Euros in 2010, which, by the way, represents a very rapid recovery from the recent worldwide financial crisis. Without doubt, the change in our Group structure – notably undertaken before the 2009/2010 financial and economic crisis – did greatly benefit our recovery, so that we emerged more rapidly and smoothly than some of our competitors.

**TF:** Barring the recent crisis, photonics actually boasts a rather comfortable long-term development, averaging growth rates of seven to eight percent. Certain areas are highly susceptible to distinct cycles, so we see some differences, obviously, but the market for high power diode lasers, for instance, is growing disproportionately fast. In general, we are fairly optimistic about the future, simply because our activities are focused mainly in this and other typical high performance markets. And we always strive to achieve growth rates clearly above market average anyway.

**DR:** The market for semiconductor and flat panel display equipment has boomed enormously over the past two years, but is starting to normalize again at present. This market and others have always been cyclical, so we take this into account and implement it internally by adopting a flexible structure.

**TF:** We mentioned the joint systems development earlier – in particular for more complex tasks, this type of solution is enjoying increasing demand, so this is then another reason why our business activities promise above average opportunities for growth.

**Jenoptik includes companies located in Germany, the United States and Asia. Where is the development of technologies and products centered? What is the future development of the Group in this respect?**

**Jenoptik is a member of Photonics21. How important is the interaction via Photonics21?**

**DR:** The former CEO of Jenoptik, Alexander von Witzleben, was Photonics21’s first president, so Jenoptik actually played a significant role in its founding. Photonics21 is an important platform for photonic technologies in Europe, it undertakes important interdisciplinary activities and has achieved a position of considerable significance in the European technology landscape. This significance is mirrored by the recent joint commitment of the European Commission and industry.
Design, optimized beam quality and high power up to 8 W for [JenLas D2] femtosecond laser technology, boasting compact There are also presentations of medical systems based on the OEMs and for complete turnkey systems.

TF: discussing our road-map for fiber laser development, both for power diode lasers as well as disk and fiber lasers. We will also be reporting on our novel high power fiber laser and discussing our road-map for fiber laser development, both for OEMs and for complete turnkey systems.

There are also presentations of medical systems based on the [JenLas D2] femtosecond laser technology, boasting compact design, optimized beam quality and high power up to 8 W for ophthalmology and also for applications in the Show & Entertainment sector.

DR: In the Optical Systems division we are introducing, for instance, the new high power [JENA] f-Theta fused silica lenses for laser material processing developed for laser powers in the multi-kW range. In general, we are not focusing on standard products, as we are a strongly customer-oriented OEM partner and our customers are often market leaders in their fields. We will thus demonstrate our solution capabilities and our technology platform, effectively a one-stop-shop for high precision optical solutions – from optical components all the way up to integrated optoelectronic solutions, including software and image processing.

Leading trade fairs such as Photonics West or Laser World of Photonics, where we jointly exhibit our entire range of technologies and competency in the field of photonics, remain an important sector platform to us. But we are also keen to exhibit at application-specific technical trade fairs, with the opportunity of convincing customers from specific industries, markets or regions of our services.

To what extent does Jenoptik support and run programs for training and development of (junior) staff?

TF: We consider this a very important topic, as a highly knowledge and experience-dependent industry such as ours relies heavily on the know-how of its staff. Sustained staff development and education programs for young employees are therefore very important with regard to the further qualification of our already well-trained workforce. Company-specific training is indispensable in this respect.

At the same time, we are also in close cooperation with Schott and Carl Zeiss, in that we share a joint training center located in Jena. And we also have specialist internal programs for further education, such as the junior management program [J 2LP] (Junior to Leadership Program) for targeted development and promotion of young Jenoptik staff with leadership potential.

DR: We also cooperate closely with network partners – institutes, universities and polytechnics as well as the local Thuringian industry. We actively support joint projects, and even altruistic investments such as the [Abbe School of Photonics], a university-run training program offered in English by distinguished lecturers and focusing on optics and photonics.

We have, of course, also earned a good reputation for ourselves – Jenoptik is positioned 59th in the top 100 employer rankings in the field of natural sciences. That said, and even though Jenoptik is a strong and attractive company, attracting highly qualified professional staff still remains a challenge.

Could you please elaborate on medium-term future developments in the divisions: which product and/or technological developments are on the agenda?

DR: Ever smaller chip structures are increasingly in demand for smart phones, tablet computers et cetera. Ongoing development of ever higher performing optical and microoptical systems for lithography and inspection in the semiconductor industry will thus remain a powerful driver into the future. We also apply this same know-how in solutions for flat panel display and laser processing applications. The trend in all of these fields is towards more durable and higher performance optics and optical systems, frequently including micro-optics as well.
We additionally see a future in budding optoelectronic markets such as LED lighting or in the automotive field, for which we already provide integrated solutions. Regardless of the industry segment, we are always closely aligned to the demands of our customers, so it remains important to us that future developments are tackled in partnership with the same.

TF: In the Lasers & Material Processing division, we try to illustrate planned laser technology development in road-maps. This incidentally highlights part of our market strategy, namely the transition of business acquisition from ‘push’ to ‘pull’. Automotive ranks as the top market sector – that is, plastics, metals and hybrid materials must all be processed. Processing systems need lasers to achieve this, in particular high power fiber and diode direct lasers systems coupled to 200 to 600 µm fibers. We also envision great potential in the medical field (aesthetics/treatments), in certain areas of Defense & Security and also in photovoltaics. We are furthermore targeting a greater market share in more complex laser processing systems, which can in turn only be realised through adequate investment in R&D.

Dr. Rothwell and Dr. Fehn, thank you very much for your time.

DR & TF: Thank you!

The interview will also appear online on our portal soon, both in English and in German.

JENOPTIK’S 20 YEAR SUCCESS STORY

1990 to 1993
The Trust Agency takes over the state-held VEB Carl Zeiss Jena in 1990. In 1991, the Jena parent company splits to form Carl Zeiss Jena GmbH and Jenoptik GmbH.

1994 to 1995
To develop an operational business, Jenoptik sets up joint enterprises and acquires companies with established distribution channels and a global presence, such as Meissner-Wurst GmbH + Co. (later M+W Zander) in 1994.

1996 to 1997

1998 to 2002

2003 to 2006
Following the sale of M+W Zander GmbH in May 2006, Jenoptik focuses on the core business of lasers, optics, sensor systems and mechatronics. The acquisition in 2006 of industrial metrology company Etamic S.A. complements this enterprise.

2007 to 2008

2009 to 2011
Jenoptik increases its global presence, for instance in China, Korea and Israel and opens a new laser application center in South Korea. Towards the end of 2010, Jenoptik sells its aerospace business to EADS Astrium. In June 2011, Jenoptik celebrates its 20th anniversary.
GREGORY FLINN

The Laser Zentrum Hannover (LZH), the influential German institute that develops laser applications across a wide range of interdisciplinary topics, celebrates its 25th birthday this year. The institute was founded in June of 1986, under the auspices of the Lower Saxony Ministry for Economics, Technology and Transport, and with the goal of developing the then still relatively untapped laser applications technology.

Roots dating back to 1985

The founding of the LZH has its roots back in 1985, when the then Economic Minister of Lower Saxony heard an impressive talk given by a Prof. Welling from the University of Hannover. Even though Lower Saxony was, at the time, still largely an agricultural center, the adoption of high technology as a future building block to the local economic area was given high priority. Thus, in an effort to support small and medium-sized companies in their development and adoption of new laser technologies, the LZH was founded under the leadership of Professors Welling, Tönshoff and Haferkamp, all of the University of Hannover. The mix of experts in quantum optics, production technology and materials science, respectively, proved to be a fortunate one.

Role of the LZH

Since first founded, the role of the LZH was and indeed continues to be clearly defined. These include the (for an institute at least) typical roles of promoting R&D, providing consulting to companies with the aim of marrying the needs of industry with the available innovations, and in providing the community with an adequately skilled technical workforce. There were, however, deeper ties to the needs of the region, for

1 The Professors Haferkamp, Welling and Tönshoff founded the LZH 1986 with the support of the Ministry of Economics of Lower Saxony
example in supporting the local automotive and aerospace industries, in providing a firm basis for the growth of the then still young optical technology industry, and in nurturing an environment favourable to spin-offs.

**Grassroots research for industrial innovation**
As most of the LZH’s projects have their roots in applied industrial research, the resulting economic benefits are evident through the establishment of 18 spin-off companies since 1986, with a total of 500 employees. Many of these were founded as a direct result of the pursuit of projects in a variety of high-tech fields – lightweight construction in automotive, rail and aerospace applications, environmental sensing, diagnostic and therapeutic medical technology, and in the development of highly innovative laser and optical systems, either industry-capable or for R&D. The majority of these spin-offs have been created in the past decade, and include for example the femtosecond laser micromachining company Micreon (in 2003), solid-state laser specialist neoLASE (in 2007) and H2B Photonics (in 2005), the latter a developer of a laser glass cutting process, that has since been acquired by Rofin. But although laser manufacturing is an obvious area of expertise at LZH, it is by no means the only one. Other recent spin-offs include Rowiak, developer of a femtosecond laser platform with medical and pharmaceutical applications, and in July 2010, the laser-produced nanoparticle manufacturer Particular began operations.

**Status quo**
The LZH is currently involved in more than 100 R&D projects, spanning eight speciality areas – even for a fully fledged university this would be worthy record!
Roughly 80 to 90 percent of these projects are Germany centric, with a further 5 percent exhibiting a European focus and the rest being primarily US-based. Many still cater to and are destined to benefit the region of Lower Saxony – the LZH has not forgotten its grassroots!

Over the years, the LZH has naturally amassed a truly phenomenal collection of lasers and laser systems – for companies seeking an answer to a laser-based ›proof-of-concept‹, the LZH thus personifies the proverbial ›one stop shop‹. Flagship activities include the construction of a 200 W, frequency-stable, narrow linewidth laser (Figure 2) for gravitation wave detection using high precision interferometry. This laser must exhibit extreme stability (in ›24/7‹ operation) to allow detection of the faint gravitational wave signals expected, and was thus constructed to exacting standards.

Trends for the future

While LZH remains closely involved in various scientific applications, laser-based production remains its core area. Goals in this respect include the establishment of new laser processes in mainstream industry, for example for upscaling of existing processes, in the functionalization of surfaces, and in achieving greater efficiency and thus realizing maximum manufacturing potential. To a greater or lesser extent, this may or may not be achieved with new high power ultrafast laser systems – certainly the LZH is both watching and partaking in their development.

Another focus is on establishing laser-based production technology for composite or carbon-fiber reinforced plastic (CFRP) materials – seen by many as the lightweight materials of the future that will eventually supplant metals in a wide range of applications. One of those applications is expected to be transportation, where composites are set for near-term use in lightweight automotive and aerospace designs, although their widespread implementation in the automotive sector is probably still some way off.

Beyond that, LZH is looking at global challenges to inspire its next wave of applications – including those facing the energy, security and life sciences sectors. Examples include laser structuring of thin-film CIGS solar cells, laser welding of glass tubes used in solar thermal collectors, and microstructuring of new types of biomedical components (Figure 3).

LZH is also part of a research alliance at the ›Lower Saxony Centre for Biomedical Engineering and Implant Research‹ in Hannover, which was awarded 27 million Euro from the German Federal Ministry of Education and Research in July 2010 towards a new research complex in Hannover’s medical park. The federal state of Lower Saxony is expected to fund the remainder of the 53.8 million Euro project, which is expected to be completed in 2013.

Summary

Essentially, the main focus of the LZH has long remained a synergy of the evolution of laser sources in their application to R&D and to process development and refinement. However, many of the tools needed for applied innovation and manufacturing development are not available in lasers ›off the shelf‹, and thus one of the LZH’s major strengths is the ready availability of a unique set of (sometimes individually developed) laser systems. What has changed is the breadth and depth of the LZH’s interaction with and contributions to industry – and this has only been beneficial for all.
Manufacturer – Distributor – Partner

LASER COMPONENTS specializes in the development, production and sales of components and services for laser technology and optoelectronics and offers one of the largest product portfolios worldwide. The focus of the company is clearly the manufacture of customer-specific products. More than 120 employees worldwide produce and distribute components.

Our in-house manufacturing capabilities play an important role in our product portfolio which comprises avalanche photodiodes and pulsed laser diodes for rangefinding, laser diode modules and optical measurement technology, and the assembly of fibers for e.g. medical applications.

One of the most important production lines at LASER COMPONENTS is our optical coatings. High damage thresholds and short delivery times as well as the ability to customize are the traits of our optics. Our high quality standard, our flexibility, and our fast response time have made LASER COMPONENTS a trusted name among coating manufacturers.

Expanding this reputation, we added manufacturing capabilities for optical substrates in 2008. Our customers can now enjoy the benefits of prototypes being delivered within a very short time.

Since 2010 we also manufacture photon counting modules with the lowest dark count rate and highest quantum efficiency available on the market.

**Fields of activity**
- Laser optics
- Fiber optics
- Laser diodes
- Detectors (UV-IR)
- Measurement technology
- Laser accessories

**Range of services**
- Development, production and distribution of optical and optoelectronic components
- Calibration center for laser power meters

**Research & development activities**
- Thin layers
- Pulsed laser diodes and Si avalanche photodiodes for rangefinding applications
- Photon Counting
- Fiber assemblies for medical applications
Optical technologies made in Germany

The German Pavilion at Photonics West 2012 showcases the latest products from German photonic firms and institutions.

For the photonics and laser industry worldwide, the kick-off event of the year is the SPIE Photonics West, held from January 24 to 26, 2012 at the Moscone Center in San Francisco, California, USA. North America’s largest exhibition of companies in the photonics sector is organized by the International Society for Optics and Photonics (SPIE) and features about 1150 exhibitors. In 2011, over 19 000 visitors from around the world explored the latest innovations in light-driven research and technology.

With 52 companies and research institutes, the German Pavilion provides an insight into the innovative strength and diversity of the photonics industry in Germany. The German exhibitors will present their innovations in a brochure titled ›Product – news & innovation Optical technologies‹, which will be exclusively produced for the Photonics West show. This brochure can also be requested at Spectaris or OptecNet as a pdf-file free of charge.

The German Pavilion at Photonics West 2011

The third most important target market for German producers. German exports to the US equaled 417 million Euros in 2010, an almost 50 percent increase compared to 2009 and fully compensating the 11 percent loss in 2009. German imports of US photonic products in 2010 grew 105 percent compared to 2009 and amounted to 564 million Euros. The US ranks after Japan as the second most important country of origin for lasers, LEDs and optical components and accounts for 22 percent of all German imports of these products.

The German Pavilion at Photonics West 2012 was initiated by OptecNet Deutschland, the Association of the German Competence Networks, and Spectaris, the German Industry Association for Optical, Medical and Mechatronical Technologies, and is supported by the German Federal Ministry of Economics and Technology. Since its inception in 2005, the ›German Evening‹ (entry by invitation only) has been an annual event at Photonics West, and will this year again provide the exclusive opportunity for networking with colleagues and industry specialists from around the world. This event is highly anticipated by the German exhibitors and one of the highlights of the fair. It is officially hosted by the German Consulate in San Francisco, supported by several industry sponsors and the two associations.

A selection of German exhibitors will also present their innovations in a brochure titled ›Product – news & innovation Optical technologies‹, which will be exclusively produced for the Photonics West show. This brochure can also be requested at Spectaris or OptecNet as a pdf-file free of charge.

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IMM Photonics
inno spec
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JCMwave
Laser Optics Berlin
Laser Zentrum Hannover
LEG Thüringen
Leica Microsystems
LightTrans VirtualLab UG
Luphos
Moulded Optics
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neoLASe
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Paul Pleiger Maschinenfabrik
Photon Energy
PicoLAS
Primes
RGB Lasersysteme
S & R Optic
Schmidt & Bender
TEC Microsystems
TEM Messtechnik
THM Technische Hochschule Mittelhessen
Topag Lasertechnik
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TSB Innovationsagentur Berlin
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The Fiber Optics business unit of LEONI Group is one of the leading suppliers of optical fiber technology for special applications in a host of industrial sectors as well as in science and medicine. LEONI offers a unique product portfolio at every stage in the value chain: from the perform and the fibers drawn from it to fiber-optic-cables and cable assemblies fitted with in-house design components. We operate seven production sites throughout Germany.

Learn about product families:

**FiberConnect® Light Guide Cable Solutions**

We offer you cables with optical fibers made from glass (singlemode and multimode), plastic optical fibers (POF), plastic cladded fibers (PCF) and large-core fibers (silica/silica). All fiber types are also available in a radiation-resistant version. We manufacture different cable designs from central core cables to breakout cables with all buffered fiber types and specific inner and outer jacketing materials, customised according to your needs. We use all fiber types to produce hybrid cables with optical fibers and electrical conductors.

**FiberTech® Special Optical Fiber Technologies**

We manufacture multimode and singlemode fibers and fiber bundles with different numerical apertures, coatings and claddings. We specialise in special fibers and special coatings. Our company has four optical fiber drawing towers as well as corresponding screeners and extruders. All fibers can be assembled to the customer’s specific needs for high-performance laser cables or, for example, spectroscopic applications. We manufacture medical fibers for laser energy transmission and also offer series production of surgical, ophthalmological, urological, dental and endovascular laser probes with biocompatible material.

**FiberSwitch® Light Switching for Optical Systems**

Our fiber optical switches are based on a patented micromechanical/micro-optical design. This guarantees excellent properties, considerable flexibility and maximum long-term stability for many applications. The switches are available for wide wavelength ranges from the visible to the infrared and for a wide variety of fiber types. Our switches are designed for applications with the highest requirements in the telecommunications area, in measurement and testing and in the biomedical area. Examples of these complex applications include spectroscopy, laser scan microscopy, multi-channel optical performance monitoring, fiber Bragg sensors, testing of fiber optical cables and environmental trace analysis.

**FiberSplit® Light Distribution for Optical Systems**

Based on optical chip technology, the FiberSplit® product portfolio includes standard components such as 1xN or 2xN splitters as well as customised modules or systems with integrated complex functionality for fiber optical singlemode and multimode systems. Fiber-Split® products guarantee expandability with wide optical bandwidth and maximum bit rates thanks to extremely low PDL/PMD. Our products meet TELCORDIA standards and have been failure-free in the field for the past 16 years. We also produce customer-specific chips, components and modules, for example optical waveguide structures for wavelength ranges between 600 and 1700 nm with various waveguide properties and functions including optical chips and fiber arrays.

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Get to know our product families:

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**FiberSwitch® Light Switching for Optical Systems**

**FiberSplit® Light Distribution for Optical Systems**

www.leoni-fiber-optics.com
RAYLASE AG – TOTAL CONTROL OF YOUR LASER BEAM

As a global market leader RAYLASE develops and manufactures galvanometer-scanner based components and subsystems for laser beam deflection, modulation and control. Since its foundation in April 1999, RAYLASE has been facing the challenges in this field and supplying the market with innovative, high performance and quality scan solutions. DIN EN ISO 9001:2008 standard certified RAYLASE offers customized solutions for the increasing requirements of laser technology in many industries such as automotive, electronics, packaging, textiles, security and solar. In these industries laser technology is used for diverse applications like cutting, marking, perforating and welding of plastics, metal, glass, textiles and other materials.

In addition to reliable 2-axis laser beam deflection units and 3-axis laser beam subsystems, RAYLASE offers customers the right combination of application software and control electronics.

With our subsidiary in Shenzhen, customers can benefit from our services in mainland China and Asia region. In addition to our footprint in Asia we recently opened a RAYLASE Certified Service and Repair Center in Sao Paulo, (Brazil) in 2010; this activity underlines our focus on the BRIC states (Brazil, Russia, India, China). Our new center in Brazil acts as an important hub for South America. Further we have a RCSC in St. Petersburg together with our partner Laser Technology Centre. These RCSCs are able to maintain and repair all RAYLASE products supplied to each relevant country. International sales are handled by a worldwide network offering you global know-how and local expertise.

SCHOTT AG, Advanced Optics
Your Partner for Excellence in Optics

SCHOTT Advanced Optics, as part of the international SCHOTT group, is a valuable partner for its customers in developing products and customized solutions for applications in optics, lithography, astronomy, opto-electronics, life sciences, and research. With a global network of engineering, production and sales, Advanced Optics offers a portfolio of excellent products: more than 100 optical glasses, special materials, such as active laser glass, IR-materials and sapphire, ultra-thin glass, high-precision optical components, wafers, and optical filters. With more than 125 years of experience in optics, Advanced Optics masters the value chain: from customized glass development to high-precision optical product finishing and metrology always reflecting market’ and customer’s needs.

Optical Materials: Optical Glass, Active Laser Glass, IR-Materials, ZERODUR®, Sapphire, Radiation Shielding, B 270®, AF 32®, D 263®…..

Optical Components: Prisms, Lenses, Wafers & Substrates, Optical Filter Glass [Color Glass & Interference Filters]…..

Competences: Processing [Polishing, CNC-Machining…..], Glass Development, Melting, Up- and Down-Draw Processes, Coating, Metrology…..
ARGES develops and manufactures laser scanning systems for the deflection and positioning of laser beams for complex applications in a diverse range of end user markets. Besides producing a highly versatile range of standard scanning systems, the portfolio of services offered by ARGES also includes the development of tailored customer- and application-specific solutions, and complete OEM laser subsystems. Our customers predominately are manufacturers of turn-key solutions for industries such as semiconductor, electronics, automotive, solar/photovoltaic as well as the medical technology and the research and development sector. We are involved both in micro and macro laser processing.

With the in-house developed "InScript®" Software, and the universal design of the ARGES System Controller (ASC), ARGES provides highly integrated scanning solutions. The ASC is the central device in a scanning system and combines control and synchronization of lasers and beam delivery systems in real-time. The InScript® Software allows interactive configuration and remote monitoring via a network connection. Device drivers integrate the operation with the execution of user-defined jobs.

Definite answers to your ideas

Our research and development team has a great deal of expertise in the development of laser-based manufacturing processes and machines, and in solving complex and challenging problems. Our services offered ranges from individualized technology advice, pilot studies and application tests, laser-suitable design, hardware and software customizations right through to prototypes and series production. To reach best possible “product-process-fitting” we operate very flexibly in the areas of hardware and software development, e.g. optical design, mechanical design, electronic interface adaption, opto-mechanical special solutions, project-specific software, device drivers, integration of third-party components and external machines. Our application laboratories which are equipped with a wide range of laser beam sources and beam deflection systems as well as a wide variety of mechanical handling systems provide the ideal environment for the development of new technologies. Our in-house Materials Sciences Laboratory supports the process development and, as an important element in our trial-accompanying quality assurance process, acts as a test and qualification center for our laser material processing solutions. From iterative internal development cycles of this kind and given our high-end laboratory environment we are able to develop suitable and reliable process solutions. Our aim is to respond flexibly to a wide variety of requirements, implement complex tasks in a timely manner, reduce innovation timeframes for our customers, and put them in a leading position through innovative and revolutionary technologies.

Visit us at the:

Photonics West 2012
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Booth #2137
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LASYS 2012
12 – 14 June 2012
Booth #4B47
Stuttgart, Germany

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Phone +49 (0)9431 7984-0
Fax +49 (0)9431 7984-300

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www.ARGES.de
USB 3.0 series

Compact and robust cameras. IDS has just introduced its first USB 3.0 camera series, the uEye CP. It offers a bandwidth of 400 MB/s via USB 3.0. The ultra-compact (29 x 29 x 29 mm³) camera in a magnesium casing weighs less than 45 g and is very robust. It offers trigger and flash as well as two General Purpose I/O, which can also be changed into a serial interface (RS232). Hence, peripheral devices can easily be triggered or controlled. With its lockable Micro USB connector and the available fittings, the camera is ideally suited even for rough environments. Initially, this series is available with three different sensors with resolutions ranging from VGA to 5 Megapixel and offering monochrome and color variants. Power is supplied via the USB bus, hence an extra power cable is obsolete.

High power LED

... for machine vision. Zett Optics has designed its new LED high-power cold light source, the ZLED CLS 9000 MV, specifically for machine vision applications. The compact fiber light source in a sturdy metal enclosure produces light similar to daylight and a luminous flux of up to 900 lm at the fiber output. Fibers with an active fiber cross-section of up to 13 mm and a standard Volpi/Schölly connector and the available fittings, the camera is ideally suited even for rough
Small, powerful, nearly indestructible

Industrial cameras. A range of ECO series cameras from SVS Vistek are now available in a watertight and exceptionally durable design called ‘BlackLine’ version. The enclosure has IP67 protection and is totally HF and moisture proof. The C-mount lens connection is sealed and a lens barrel compatible with most compact lenses provides additional protection against environmental influences. The M12 connector from Phoenix Contact complies with the requirements for protection class IP67 and allows rapid and cost-effective cabling. Three inputs, three outputs (two with high current LED driver) and an RS 232 Ethernet interface are provided. The supply voltage is industry compliant at up to 24 V DC ±20 percent. A variety of different trigger modes enable almost any conceivable system configuration. The new ‘Logic Trigger’ allows multiple inputs on the camera to be linked using logic functions, for example rotary encoders and light barriers. Two LED lighting systems can now be controlled directly. The ECO sequence shutter and LED control functions provide exposure combinations that allow almost any test specimen to be optimally analyzed. Ten sensor resolutions from VGA to 5 MP will be available in monochrome or color design, making the ECO BlackLine ideal for use in automation and in the transport and medical sectors.

www.svs-vistek.com

CoaxPress interface

High speed camera. Optronis has presented its first 4 MP camera with a CoaxPress interface, claiming it to be the world’s first 4 MP CoaxPress high speed camera. The ‘CL4000CXP’ allows up to 500 fps to be transferred to a PC in real time. The CoaxPress interface’s serial transmission concept enables data to be transferred at a gross clock frequency of up to 6.25 Gbit/s via a single coaxial cable, or using multiple 75 W coaxial cables if the transmission capacity is upscaled. The CoaxPress interface’s serial transmission concept enables data to be transferred at a gross clock frequency of up to 6.25 Gbit/s via a single coaxial cable, or using multiple 75 W coaxial cables if the transmission capacity is upscaled. The CoaxPress interface’s serial transmission concept enables data to be transferred at a gross clock frequency of up to 6.25 Gbit/s via a single coaxial cable, or using multiple 75 W coaxial cables if the transmission capacity is upscaled.

www.optronis.com

COS4-corrected

Laser for machine vision. Laser 2000 offers a COS4-corrected laser, which helps avoid the vignetting that occurs in laser systems with cylinder lenses, particularly with a larger field of view. The special optical grinding compensates for overexposure in the center of the image, which can be as much as 40 percent with a 90° laser, and ensures that only approximately 25 percent of the output is visible at the ends of the lines. This compensation for the COS4 effect enables the lasers to generate lines of maximum homogeneity and projections with the greatest possible uniformity in their intensity.

www.laser2000.de
More precise beam deflection

NEW HIGH-PRECISION SCAN HEADS. With the increasing use of high brightness lasers on the one hand and the increasing complexity of production processes on the other, end-users require increasingly higher precision with regard to processing optics and beam positioning.

Peter von Jan
Markus Axtner

High brightness lasers often enable higher processing speeds that simply cannot be matched with standard movement systems. Galvanometer scanner systems that have been used successfully for many years, in particular in the marking sector, offer here the only alternative to the traditional multi-axial systems. It is, however, inherent to the operating principle of a scanner that even the smallest angle deviation of the scanner motors can have a dramatic impact on the position of the laser focus in the processing plane, in particular because relatively large processing distances can be used.

A new high-precision scanner generation is thus required that continuously shows the same stable performance under all operating conditions (deflection speed, duty cycle) in the long-term, and that additionally offers higher maximum performance and greater dynamic range for these operating conditions compared with previous generations. The new Superscan-II by Raylase fulfills all of these requirements perfectly.

New Superscan-II

The new scan head (pictured above) is a compact unit qualified for high demand applications with regard to precision and long-term stability. At apertures of 10, 15, 20 und 30 mm,

<table>
<thead>
<tr>
<th>Laser</th>
<th>Nd:YAG</th>
<th>Nd: YAG doubled</th>
<th>Nd: YAG tripled</th>
<th>Broadband</th>
<th>Diode lasers</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>1064</td>
<td>532</td>
<td>355</td>
<td>400-1064</td>
<td>800-980</td>
<td>10600</td>
</tr>
<tr>
<td>Coating</td>
<td>dielectric</td>
<td>dielectric</td>
<td>dielectric</td>
<td>silver IP</td>
<td>dielectric</td>
<td>dielectric</td>
</tr>
<tr>
<td>Min. reflection @ wavelength (nm)</td>
<td>99.5% @ 1064</td>
<td>99.5% @ 633</td>
<td>99.0% @ 355</td>
<td>97.0% @ 400-1064</td>
<td>99.0% @ 808-980</td>
<td>99.9% @ 10600</td>
</tr>
<tr>
<td>Flatness - 633 nm</td>
<td>λ/4</td>
<td>λ/4</td>
<td>λ/4</td>
<td>λ/4</td>
<td>λ/4</td>
<td>λ/4</td>
</tr>
<tr>
<td>Max. laser power, cw (W/cm²)</td>
<td>500</td>
<td>500</td>
<td>100</td>
<td>70</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Max. laser power, 100 ns pulse width (MW/cm²)</td>
<td>100</td>
<td>100 (10 ns)</td>
<td>20 (10 ns)</td>
<td>N/A</td>
<td>N/A</td>
<td>400</td>
</tr>
<tr>
<td>Scratch &amp; dig</td>
<td>40/20</td>
<td>40/20</td>
<td>40/20</td>
<td>40/20</td>
<td>40/20</td>
<td>40/20</td>
</tr>
</tbody>
</table>

A Mirror specifications for the Superscan-II
Numerous different mirror types are available (Table A) for use with Nd:YAG ($\omega$, $2\omega$, $3\omega$), with diode lasers (800 to 980 nm) and with CO$_2$ lasers. Typical applications for the Superscan-II are marking, engraving, ablation, drilling, cutting, welding, structuring, trimming and rapid tooling/prototyping. Due to its high deflection speed and high positioning accuracy, it is particularly well suited for processing on the fly.

**Mechanical structure**
The required precision can only be achieved through adoption of a new mechanical construction, which simultaneously provides high assembly accuracy of the components and even distribution and efficient dissipation of the heat produced (largely) by the driver electronics. The classical construction with dowelled location plates as case and component support (Figure 1, left) is not conducive to attaining the required positioning precision nor the required thermal performance, so a new construction approach was chosen for the Superscan-II. The new approach (Figure 1, right) comprises two precisely milled shells of aluminium, ensuring both high physical stability and at the same time efficient thermal flow by means of convection and heat conduction. The supports for the galvanometric heads are precisely milled into the shells so that later adjustment is no longer required and thus greatly simplifying subsequent placing of the scanning system.

**Cooling concept**
Despite the aforementioned optimized construction of the case and the component supports in relation to the issue of heat dissipation, highly uneven warming of the scan head (due to heat migrating from the driver electronics) cannot be entirely avoided when only implementing passive cooling approaches, as for example revealed in FEM calculations (Figure 2, left). Without active cooling, the overall temperature increase of the scan head compared with room temperature ($23^\circ$C) is already at approximately $17^\circ$C under normal load, while at the warmest point (on the housing cover directly above the power electronics) it is closer to $23^\circ$C.

The Superscan-II is therefore optionally equipped with an active water cooling control system (Superscan-II-LD), with which the heat of the galvo motors given up to the housing is better dissipated and which clearly results in a much improved thermal management. The main generators of heat are however the driver electronics, which naturally do not possess a direct thermal bridge to the housing for dissipation of excess heat. As convection cooling is not sufficient, the heat dissipation has to be increased by means of additional measures, and the introduction of the LD scan head marks a new approach to efficient heat transport in scanning systems. Implementing this...
cooling approach in the FEM calculations (Figure 2, right) now reveals temperature increases of only approximately 4 to 8°C in the left lower corner of the scan head.

The efficient, active cooling of the Superscan-II-LD allows problem-free continuous operation without overheating of the driver stages, even at elevated temperatures of up to 40°C for the surroundings. In order to achieve the specified precision and long-term drift of <200 µrad (per axis) over 24 hours, however, then it is necessary to maintain water temperature and room temperature to \( \Delta T \leq \pm 1°C \).

**Auto-calibration**

Despite an almost perfect cooling concept, drift effects arise that – depending on the current operating modes – can still have a negative impact on the accuracy of the positioning. To cater to even this type of situation, the actively calibrated Superscan-II-AC is available. With this system, the standard measurement process used for all drift measurements has been integrated into the laser head. The internal calibration functions by checking the position of the light from an LED passing through a pin hole mounted onto one of the axes – in combination with an appropriate sensor, the precise actual value of deflection can be compared with the intended value and can be adjusted accordingly. The calibration is carried out automatically on demand – that is, the end-user can carry out auto-calibrations depending on the application and knowledge of the specific operating mode, and can thus realign the process with regard to accuracy within just a few seconds. Using this approach, long-term drift can be reduced to <50 µrad with the auto-calibration scan head system. The appropriate calibration software has been developed by Raylase and is, if required, readily integrated in the DLL of the SPICE card (Raylase’s standard control card for laser systems and deflection units).

**Optimized mirror technique**

Further improvements in the performance data of the Superscan-II have been realized through the utilization of an optimized mirror construction. Weight, moment of inertia and stiffness naturally determine the maximum achievable values for speed, acceleration and accuracy. The challenge in any design is therefore the achievement of maximum stiffness and optimal moment of inertia for the lowest possible weight via the appropriate choice of form and materials for a specific mirror size (as defined by the aperture). Extensive FEM calculations and detailed tests have been used to optimize the new construction, using coated beryllium as the base material. Clear weight saving results directly from the choice of the material and the optimized form, in particular as the mirror and its mount are made a single piece. The increases in performance thus achieved are impressive – initial measurements show an increase in the maximum final speed of the mirror of approximately 30 per cent. This final speed is furthermore achieved within a shorter timeframe than when using silicon carbide mirrors or standard beryllium mirrors. This gain in speed can be utilized in two ways, depending on requirements – either to improve the dynamic of a standard range of movement or via the use of a scan head with a larger aperture/deflection while retaining previous dynamic performance, whereby the latter may also bring improvements in the focus performance and with the scannable field.

**Summary**

A new, innovative construction concept has been developed and implemented by Raylase in the new Superscan-II. Compared with previous approaches, the new shell-like construction offers relatively straightforward and precise mounting and clear thermal management improvements. Even with continuous operation, overheating of the driver stages can be confidently avoided via an optionally available water cooling system. A further option is an internal auto-calibration function, also ensuring high positioning accuracy even under frequently changing operating modes. Due to the modular structure with optional system enhancements, then choice of the ideal system for any one particular application is made all the easier.

Peter von Jan is CEO of Raylase and has more than 15 years of management experience in laser technology. Markus Axtner moved to Raylase in 2006 and headed the Department of Mechanics and Optics before moving to Alphaform GmbH later in 2011.
For laser machining with long travel

Air bearing granite gantry. Steinmeyer - Feinmess Dresden has developed a new air bearing granite system with a large travel range and high payload capability, especially designed for laser machining of thin film solar panels. The same concept can also be used for other highly dynamic and precise applications requiring long travels. The basis for the system is a solid stable granite structure. For the x-axis with 1600 mm travel, preloaded air bearings are used to achieve flatness of travel <1 µm over 100 mm. Moreover, the air bearings eliminate any wear despite very high cycling typical in industrial applications. The y-axis is a cost-optimized and industry-tested standard linear stage model PMT320-1150-EDLM with 1150 mm travel. Using Tecnotion servolinear motors on both axes, acceleration of up to 5 Gs as well as speeds exceeding 120 m/min are possible. The integrated linear encoders enable a position resolution of 0.1 µm. For the vertical movement of the laser, a standard ball screw driven stage is used.

www.feinmess.de

3D scan head

... for micro machining and high-speed applications. With the Anteater, Arges is introducing a very small, compact and watercooled 3D scan head for micro-processing. The scan head with apertures ranging from 8.5 to 21 mm has an extremely reliable and dynamical focus translator. A specially designed focusing system allows a rapid change of focal plane, thus enabling high application speeds. The 21 mm aperture, for example, is ideal for focusing on applications with minimum spot sizes, the 8.5 mm aperture is optimized for high-speed applications, e.g. on-the-fly-processing of moving objects of up to 200 m/min with processing speeds of up to 32 m/s. The slim construction of the Anteater allows the overlapping scan field operation of several scanning units. Depending on the system requirements (e.g. small spot size or large processing field), the scan head is versatile and can be equipped with different types of f-theta lenses. It is available with all commercially available wavelengths. As an option, the Anteater can be equipped with a cross-jet in order to reduce contamination of the optics and guaranteeing high process stability. A vision system can be mounted, too.

www.arges.de

Parallel soldering raises throughput

Selective laser soldering system. ›NanoRapid‹ from nanosystec is a high-speed selective laser soldering system that combines ultra-precise hardware with a powerful software package and is suited for high volume production. To compensate for the limitations of laser soldering – the time required for each soldering point – NanoRapid is able to solder several solder points simultaneously and thus increase the throughput proportionally. The optical assembly is able to generate several individual laser beams, each of which can be tailored to the task’s requirements. The geometrical form can be fit to the shape of the solder point and the power distribution among the individual beams takes the specifics into account. Due to the modular architecture of the system, the functional groups can be chosen and combined according to specific requirements. NanoRapid is designed for integration in production lines.

www.nanosystec.net
A prerequisite for thermal laser material processing is direct interaction between the focused laser radiation and the copper surface. This then requires part of the radiation to be absorbed at the copper surface. As Figure 1 shows, however, for a polished copper surface at room temperature, less than five percent of the laser radiation is absorbed (at 1 µm wavelength).

Despite this problem, there are a range of measures that can be taken to allow copper to be welded successfully and efficiently, particularly with solid-state or fiber lasers. The first of these measures is coating the surface with more absorbent materials, such as nickel or chromium. Mechanical preparation of the surface, for example roughening or painting, also increases the absorption. However, both of these measures have a negative impact on production costs, as they require additional fabrication steps. Chemical impurities can also influence absorption behavior and thus make it more difficult to achieve a reproducible welding process.

As can be seen from the absorption curve, shorter wavelengths would be an advantage. Diode lasers (0.8 to 1 µm, IR) or a frequency-doubled Nd:YAG laser (532 nm, green), for example, can deliver these wavelengths, although neither of these lasers has yet reached the stage where copper welding would be industrially viable.

Heating at the point of incidence of the laser radiation is faster or slower depending on the level of absorption, and the risk of overheating and splatter formation becomes unpredictable. The problem of poor reproducibility is even more pronounced for spot welding than for seam welding. Each individual laser pulse strikes the cold copper material and thus experiences different initial conditions. However, because the absorption depends not only on the wavelength and the surface characteristics, but also on the material temperature (absorption improves significantly at increased temperatures) and the intensity of the laser radiation, there is additional scope for improving the welding process.

Overlaying two wavelengths

The poor reproducibility of copper welding can be significantly improved by overlaying a laser pulse with a wavelength of 532 nm on to a laser pulse with a wavelength of 1 µm. If the two laser beams are focused using the same chromatically compensated
lens, this has the general result of causing the copper surface to heat up from the center to the edge of the weld spot due to the better absorption of the green wavelength, thus raising the temperature of the copper and, therefore, raising the absorption of both wavelengths.

With increased absorptivity, variations in the surface characteristics have a less significant impact. For example, if a laser beam is made up of 15 percent green and 85 percent IR and the different initial absorptions of the two wavelengths are taken into account, approximately the same quantities of energy from the green and IR radiation will be absorbed (at room temperature). **Figure 2** shows pure IR welding (2.5 MW/cm²), pure green welding (1.1 MW/cm²) and welding with both wavelengths on a 300 µm thick copper strip. The focal spot diameter is approximately 200 µm for both wavelengths. In the case of the pure IR pulse, no fusing of the copper surface is observed, while with a pure green pulse, some fusing can be seen. Overlaying the two pulses results in a significant enlargement of the weld pool.

**Process details**

Choosing an appropriate IR pulse shape allows the relative green component or the conversion efficiency to be adjusted. **Figure 3** shows a typical IR pulse shape and the resulting green conversion. The laser pulse can be split into three phases, which are described in more detail below.

At the beginning of the laser pulse (0.5 to 1 ms), the pulse intensity is deliberately set as high as possible to ensure that the highest possible proportion of the IR radiation is frequency doubled. The combination of IR and green radiation heats the copper surface until the absorption is sufficiently high for IR and the copper surface begins to melt. Typical values for the pulse power during the melting phase are between 0.5 and 5 kW, depending on the thickness of the copper strips used.

As soon as the copper begins to melt, the pulse power is sharply reduced. Although this means that very little green is then converted, the absorption of IR is high enough in the melting phase. From this point onwards, the welding is continued with IR only (negligible green component). The duration of the welding phase is determined by the extent and depth of the weld spot.
Efficiency considerations

In a further investigation, the melting threshold intensities of pure IR, pure green and a mixture of both types of radiation were determined and compared. Table A summarizes the measured melting threshold intensities. Although the melting intensity for pure green radiation is the lowest, the upconversion represents a significant limitation on process efficiency.

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Melting threshold intensity [MW/cm²]</th>
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<tbody>
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<td>IR</td>
<td>10</td>
</tr>
<tr>
<td>Green</td>
<td>2</td>
</tr>
<tr>
<td>IR (88 %), Green (12 %)</td>
<td>4.6</td>
</tr>
</tbody>
</table>

However, if a mixture is used instead of pure IR radiation, the melting threshold is practically halved – this for identical laser efficiency, and thus representing an effective increase in process efficiency.

Comparison with pure IR welding

Figure 4 shows a comparison between pure IR welding and welding with IR and green laser light. The pulse duration was 1 ms and no pulse shaping was used (rectangular pulses). The weld spots in the upper half of the figure were made using IR pulses with a 0.8 kW pulse power, while the weld spots in the lower half were created with 0.8 kW IR and 0.08 kW green. As expected, the reproducibility of the pure IR welding is very poor, significant fluctuations in diameter and even missing weld spots can be observed. The reproducibility of the welds with IR and green light is however considerably better – no defects can be identified. The insert in Figure 4 shows a series of weld spots created using the pulse form described in Figure 3. The weld spots achieved using this method look practically identical. A more precise analysis reveals that the variation in the weld spot diameter is well below ten percent. This figure meets the strict specifications of medical applications, for example.

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</tbody>
</table>

However, if a mixture is used instead of pure IR radiation, the melting threshold is practically halved – this for identical laser efficiency, and thus representing an effective increase in process efficiency.

Industrial implementation

As shown in Figure 5, the upconversion module has been developed as an add-on component for a standard Rofin-Lasag welding laser (SLS2200 series). Unlike with other industrial green laser concepts, this solution uses only one laser source, which naturally has a positive impact on the investment costs of the system. Both wavelengths are transported onto the copper surface using optical fibers and a special processing head.

More strategies for improving reproducibility

Another strategy for spot welding is to use special ring optics to create a small weld ring, typically with a diameter of 0.5 to 2 mm, with one single laser pulse. In this case, the heat flows radially both inwards and outwards, creating a more advantageous temperature and stress distribution. This strategy has proved extremely useful, particularly for welding of thin copper strips (<100 µm thick). Unwanted penetration caused by excessive intensities in the center of the beam can be completely eliminated by selecting appropriate parameters. Studies have shown that for copper it is possible to monitor and control the heat conduction welding process during the laser pulse. This involves continuously measuring the reflection of the laser radiation and the temperature of the surface. At the beginning of the pulse, a calibrated reflection measurement determines the absorption below the melting threshold. The pulse power for the actual welding is selected according to the amount of absorption. As the absorption of copper increases erratically as soon as the melting phase is reached, from this point onwards the surface temperature can be monitored and kept constant by regulating the supply of laser beam energy, thus preventing overheating and the associated tendency to splattering.

Summary

This article describes methods that enable the reproducibility of laser welding of copper materials to be significantly improved. The combination of IR and green light using intelligent pulse shaping not only results in improved reproducibility of the welds, it also brings about a considerable increase in process efficiency.

Dr. Christoph Rüttiman is the Head of Research and Development at Rofin-Lasag. One of his main tasks is the development and industrial implementation of new laser sources and process strategies. Dr. Ulrich Dürr has more than 30 years’ experience in the development of solid-state lasers and their applications and, for several years, worked as the Head of Development and Applications at Rofin-Lasag.
GWU-Lasertechnik: The Experts in Tunable Laser Systems and Non-linear Optics

GWU-Lasertechnik Vertriebsges. mbH was founded in 1988 as a sales and service organisation for lasers and laser accessories. Starting as an agent for the predecessor of Fujian Castech Crystals, Inc. GWU-Lasertechnik started to develop products around crystals from these world-leading specialists for BBO and LBO. First results were demonstrated at Laser show 1989 in Munich where GWU introduced the first commercial BBO-OPO worldwide pumped by the third harmonic of a q-switched pulsed Nd:YAG laser at 355 nm. Since then the OPO technology has been permanently improved by GWU. Now they are offering the fourth generation of BBO-OPOs suited for a variety of applications including spectroscopy, environmental analysis, process control in the chemical and pharmaceutical industry, and lidar systems. The product line of OPOs is completed by useful accessories like a wavemeter that fully integrates into the OPO installation and software thus allowing fully automated wavelength calibration, and frequency converters to cover the UV range efficiently down to about 205 nm. GWU also integrate Nd:YAG laser heads and OPOs/harmonic generators on a common platform or completely sealed housings some of which have been successfully used outdoor and in harsh environments. These systems have no need for extra optical tables and are easily movable. The pulsed OPO product line is completed by versions pumped at 532 nm or 1064 nm. Non-linear materials used in these systems include BBO or KTP thus allowing to cover the spectral range between 205 nm and >4000 nm. Customised solutions are developed and offered as well. GWU’s OPOs are available in a variety of configurations among which you find broadband and midband systems as well as a version with a smooth round beam profile and symmetric low divergence beam characteristics. Unique feature of all these BBO-OPOs is the low pump thresh-

old in combination with the most conservative pump scheme on the market ensuring highest reliability and lifetime of the optical components inside.

Besides these nsec OPOs GWU develop and manufacture OPOs and harmonic generators for pumping by commercial lasers in the psec and fsec regime such as Spectra-Physics Tsunami lasers.

Recently GWU started to distribute products from Ultrafast Systems manufacturer of time-resolved spectrometry solutions covering the time-range from femtoseconds to milliseconds.

The wide spectrum of laser crystals and non-linear crystals offered by GWU includes BBO, LBO, KTP, KD*P, Nd:YVO4, Nd:YAG among many others manufactured by their partner Castech. Periodically-poled crystals such as MgO:PPLN manufactured by HC Photonics, available as bulk or waveguide with a variety of grating-structures (single, multiple, fan-out chirped,…) are of increasing interest especially due to their high conversion efficiency for continuous wave and low power applications. This portfolio of optical components is complemented by prisms, wave-plates, polarizing optics and standard items.

GWU’s product family also includes fiber lasers and ASE products of the leading manufacturer in this field – NP Photonics. These products include ultra-narrowband fiber lasers with powers from 10 mW to several Watts. Major features are ultra-low noise and extremely high mechanical stability (air-borne, harsh environments). GWU-Lasertechnik support and distribute diode pumped q-switched lasers and laser systems – combined with frequency converters (e.g. 213nm system commercially available) or tunable products (OPG, OPO) from Xiton Photonics.

Due to their superior service and competence GWU have generated a broad base of satisfied customers in the industry and in scientific research facilities worldwide.
The new force in the world of high-precision positioning technology

miCos GmbH was founded in Eschbach near Freiburg, Germany in 1990. As PI miCos, it now belongs to the company group of PI (Physik Instrumente), located in Karlsruhe, Germany. With currently more than 50 employees, the Breisgau company develops, produces and markets innovative systems and components for high-precision positioning applications throughout the world. A main focus is on optical measurement technology in research and industry. For this purpose, PI miCos offers customized system solutions with multiple axes in addition to a comprehensive standard program. Wide-ranging application know-how guarantees the implementation of technically demanding solutions. Flexible positioning systems for ultra-high vacuum applications with parallel-kinematics and six degrees of freedom are an example of this, as are systems with linear motors and air cushion bearings.

The company

NUMERIK JENA draws from over 30 years of experience in the development, manufacture and sale of position encoders. The roots of production metrology and its associated technology for the manufacture of precision scales go back to Carl Zeiss and Ernst Abbe. In following this great tradition, the goal of all our activities is continuous innovation and the improvement of our products. We orient ourselves to the demands of the international market to which we can react flexibly thanks to the modular character of our encoders.

The products

NUMERIK JENA offers positioning sensors with a wide variety of options according to the demands of the application.

- high resolution for the precise dynamics of the actuator
- high accuracy for accurate and repeatable positioning
- low short-range errors for constant and smooth motion
- low profile requirement for ease of implementation and to allow simple integration with existing mechanics
- low mass for high acceleration
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- customer friendly mounting tolerances for low assembling costs
- high insensitivity against contamination for high reliability

Applications

- suppliers and users of linear and rotary actuators
- production equipment of semiconductor industry
- linear, rotary and planar direct drives
- torque motors
- coordinate measuring equipment
- medical technology
Omicon-Laserage Laserprodukte GmbH
Flexible Lasers and LED Light Sources for Industry and Science

Omicon, located in Rodgau in the Rhein-Main area, develops and produces state-of-the-art diode lasers and DPSS lasers for the industry. Founded in 1989, Omicon is a well established company which has succeeded in positioning itself as a market leader in the area of laser diode systems and laser applications within a relatively short time-span. At first Omicon focused its production on opto-mechanics, laser optics and fibre couplers. In 1997 the company began, with increasing success, developing and producing lasers in-house. Since then, the team has continuously grown and meanwhile launches countless innovations and new products every year. Examples are the successful LDM-Series and the lasers of the FK-LA-Series which were developed for high-end laser applications such as Computer to Plate (CtP), DVD mastering, wafer inspection, microscopy and reprography. Continuing to develop products in order to remain a step ahead of current standards is an integral part of Omicon’s philosophy. One secret behind the success is the modular principle Omicon uses for construction. This is to great advantage for the customer since it allows an easy integration of both LDM- and FK-LA series lasers in existing and new machines, so that adjustments in accordance with customer’s wishes can be made at any given point in time. Further important developments were the PhoxX® compact high-performance laser in 2008, LuxX® compact CW diode lasers and SOLE® laser light engines in 2009 as well as the LightHUB® beam combiners in 2010. With these developments Omicon is one of the leading manufacturers for demanding applications in biotechnology, microscopy, microlithography and many more.

Innovative Products

LuxX® Compact CW Diode Lasers

With the LuxX® diode laser series, Omicon is showing the way forward in the 375–830nm wavelength range. The LuxX® series offers many unbeatable advantages when compared with conventional argon gas and DPSS lasers. As a result of the fast, direct analogue power modulation of greater than 1.5MHz, and a full ON/OFF shutter function of greater than 150kHz, opto-acoustic modulation is no longer needed. Compact construction and flexible input signalling allows the lasers to be integrated simply into existing or future machine designs. One significant feature of the LuxX® diode laser is its all integrate intelligent laser electronics with RS-232 and USB 2.0 interfaces that permit easy interaction with the application. The ultra compact footprint of only 4 x 4 x 10 cm makes these lasers the most compact in the market. Furthermore, by using innovative Omicon optics, astigmatism is corrected so that the beam has a diameter of around 1 mm and the focus is absolutely circular. The lasers are available in 20 different wavelengths between 375 and 830nm with single-mode optical output powers up to 150mW.

Multi Wavelength Solutions

The SOLE® laser light engines and LightHUB® compact beam combiners represent a new era of Omicon products. Especially designed to meet today’s needs in biotech and microscop-ic applications, they combine up to 6 wavelengths of diode and DPSS lasers. The SOLE® light engines are compact laser sources with up to six lasers, coupled in up to two single mode fibers. The SOLE® systems offer fast analogue and digital modulation for each laser line and fast switching between the individual wavelengths. The LightHUB® compact beam combiners are able to steadily combine the laser beams of up to six diode or DPSS lasers into a co-linear beam, which can then be used in free-space or fiber coupled applications. Whereas the SOLE® laser light engines mainly address end-users, the LightHUB® compact beam combiners are very attractive for OEM integration. For both products, the customer can choose from over 25 different wavelengths in the range of 375 to 830nm. Various power levels of up to 200mW per laser line are available.

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Tradeshows 2012:
Photonics West, San Francisco
January 24th – 26th
Optatec 2012, Frankfurt
May 22nd – 25th

When deciding on the implementation of a laser process into industrial production, process quality and investment costs have to be taken into account. For micromachining in particular, it is important to manufacture products with highest quality. Each process and material has to be evaluated to find the best solution, which often leads to a compromise between available laser sources and process quality. Nanosecond laser sources are available with pulse durations from around 7 ns up to several hundred nanoseconds. If the process requires higher quality results, modelocked ultrashort pulsed (ultrafast) lasers are an increasingly attractive option. However, corresponding laser systems have been complex and came with a large footprint, and are thus not easy to integrate into existing and future production system designs.

Until recently, laser sources in the sub-nanosecond regime have been somewhat neglected in terms of materials processing applications. A closer look reveals the existence of a pulse duration gap as large as two orders of magnitude between modern ultrafast and traditional nanosecond lasers.

InnoLight is bridging this gap with a series of new industrial laser sources designed to serve exactly this pulse duration regime (gap). The laser sources can be adapted to fulfill customer requirements and can produce pulse durations between 300 ps and 10 ns. InnoLight’s goal in developing this type of laser source is to provide a compact and robust system that addresses the current needs of integrators and machine builders, in particular where high quality process results with low thermal effects (made possible by the shorter pulse duration) are required.

Short pulses – cost effective and intelligent

The ›Helios‹ laser is based on a micro-module DPSS laser and impresses with a compact and simple design. The ability to deliver actively Q-switched pulses with pulse durations down to 300 ps in a compact industrial package is currently without equal on the market. The laser cavity design is based on a classical approach as shown in Figure 1. Fiber-coupled laser diodes deliver the pump power for Nd-doped laser crystals, and only Pockels cells can achieve the rapid switching times required to deal with the short pulse build-up times present in short cavities with high gain. While the...
general approach is straightforward, one has to implement innovative technology to push the potential of the existing range of components to the absolute limits. InnoLight has thus strived to make an art out of optimizing the design of the cavity, the laser crystals and the electro-optic crystals, all without sacrificing the reliability demanded by industry.

**Higher processing quality**

Even just a quick microscope view of the process results on various materials shows increased processing quality when compared to the results from industrial nanosecond lasers. While for nanosecond systems, thermal heating of the area immediately surrounding the process zone is a primary limitation on processing quality, for ultrafast laser systems a different (temperature) interaction model governs the process and results in less heat sacrifice to the surrounding material.

A detailed comparison on crystalline silicon shows substantial differences in processing quality when using a 2 ns system in comparison to a 500 ps laser system. In Figure 2a, higher processing quality with less melt and debris is observed. In both cases, material ablation was performed with high pulse overlap, in which case heat accumulation is obvious and leads to different process qualities.

**Applications**

In particular for thermal sensitive materials, such as semiconductors and thin films in electronics and photovoltaics, the pulse duration has a significant influence on the process result, with corresponding functionality of the processed sample. Thanks to adequate ablation ratios per pulse, the Helios picosecond laser shows excellent results, especially for surface-near laser processing, as shown in Figure 3 for Si$_x$N$_y$ on crystalline silicon and for a copper thin film on polyamide foil. It is obvious that the ablation ratio is closer to the ultrafast laser systems than to nanosecond lasers. A detailed view of the ablation ratio shows for crystalline silicon that a single pulse ablation depth depends on the wavelength, lies between 150 and 300 nm for a laser fluency of around 5 J/cm$^2$ and is thus comparable to common layer thicknesses.

The Helios laser can be delivered in different power configurations for different applications. The 532 nm version is available with 0.9, 1.5 and 3.0 W. As demonstrated for the ablation of thin film copper, where just 4 µJ show good results, even the lowest power system is already adequate. A similar pulse energy is required to ablate the silicon nitride layer on a crystalline solar cell with negligible melting and damage.

**Integration**

The Helios DPSS lasers with micro-module resonator concept have reached the next evolutionary step for compact laser sources. Due to the compact design, the lasers can be easily integrated into existing process system technology, regardless of applications in micromachining, medical technology and metrology in general. Already proven by industrial customers, the Helios is available in a common housing at all three important harmonics (1064, 532 and 355 nm).

**Summary**

Examples of the laser sources described here are already successfully deployed in industry today. In terms of materials processing, the process regime accessed by pulse lengths of a few 100 ps is still largely an unknown quantity, but promises to present a very real opportunity for process optimization. For even more demanding applications, InnoLight is developing the next generation of actively Q-switched picosecond laser sources, with output powers in the 20 W regime on the one hand, and with shorter pulse durations around 100 ps on the other.

Dr.-Ing. Oliver Haupt is responsible for Sales and Marketing of InnoLight’s sub-ns industrial lasers systems. Dr. Stefan Spiekermann and Dr. Ingo Freitag are Managing Directors of InnoLight. The company is based in Hannover, Germany.
The near infrared (NIR) wavelength range up to 3 µm comprises many absorption features of gases of great relevance for industrial applications, such as water and carbon dioxide, for example. Employing tunable diode laser spectroscopy (TDLS) has proven to be a powerful concept for very fast and highly sensitive detection of gas species in this wavelength range. TDLS exploits the fact that characteristic rotational and vibrational excitation features are unique for each gas species, and, when utilizing a monomode laser, these features can be scanned very selectively.

Highly sensitive detection of hydrocarbons is especially interesting for industrial and automotive applications. Very strong characteristic absorptions (related to fundamental molecular transitions) of most hydrocarbons are located in the longer wavelength mid-infrared (MIR) range around 3.0 to 3.6 µm. They often exceed corresponding NIR absorption strengths by more than an order of magnitude (Figure 1) and thus permit TDLS with much higher sensitivity. This type of approach to hydrocarbon detection has so far been impeded by the lack of commercially available industrial-grade monomode laser sources in the wavelength range beyond 3 µm. For an uncomplicated and inexpensive use, suitable lasers ideally operate in continuous wave (cw) mode at room temperature. Within the scope of the European project SensHy...
suitable monomode lasers have been developed by nanoplus, demonstrating previously unattained performance. They enable a new level of qualitative monitoring techniques using TDLS up to a wavelength of 3.4 µm, for example for hydrocarbon detection.

**DFB laser production technology**

nanoplus is an internationally leading supplier of high quality laser sources for gas sensing applications in the visible, NIR and MIR wavelength ranges [1]. The newly developed lasers presented here are produced using the company’s proprietary technology base to fabricate monomode, distributed feedback (DFB) diode lasers. Semiconductor laser material for emission >3 µm is used for DFB fabrication based on lateral metal gratings. The grating structures, with dimensions around 150 nm, are defined next to the sidewalls of etched ridge waveguide structures using highly accurate e-beam lithography. The structures are then patterned by metal evaporation, resulting in DFB laser devices as shown in Figure 2a. This patented, cost-effective approach has been well-established at nanoplus for more than ten years. It shows a high DFB yield and eliminates the need for epitaxial overgrowth in the production of the laser layers. An impairment of laser performance due to the insertion of patterning-induced defects near the active region is therefore avoided. Taking increased internal losses in high wavelength diode laser structures into consideration, the processing route is customized for high performance. Therefore the laser ridge waveguides are surrounded by a gold layer of high thermal conductivity (Figure 2b) for improved heat removal and equipped with a highly reflective backside gold coating for increased output efficiency. DFB devices can be exactly matched to their designated application in TDLS sensing and are subsequently mounted onto TO-headers with internal temperature controllers (see inset of Figure 3). Hermetical sealing of those headers in a dry nitrogen atmosphere yields application-ready, packaged DFB laser devices protected from humidity or the hazard of mechanical destruction.
Performance of DFB lasers

The DFB lasers described here operate in the wavelength range up to 3.4 µm. Their applicability to high quality hydrocarbon sensing is guaranteed by outstanding spectral properties. As an example, a laser device for detection of methane or propane at 3.37 µm is illustrated in Figure 3, showing a spectrum of the DFB laser operating in cw mode at a chip temperature of 10°C under a forward current of 125 mA. The emission is clearly monomode. Side-mode suppression ratios are typically better than 40 dB – an excellent value for high selectivity gas sensing. A plot depicting the temperature and current tunability of the monomode emission wavelength of the DFB lasers is shown in Figure 4. The overall tuning range is generally around 9 nm. Depending on the desired application, the emission wavelength can be set by adjusting the corresponding Peltier-controlled chip temperature, exhibiting temperature tuning of around 0.28 nm/K. Very fast current tuning of the emission wavelength in a TDLS application can then be performed with a typical tuning coefficient on the order of 0.025 nm/mA. Wavelength ranges of around 2 nm can be sampled in this manner.

These long wavelength DFB lasers are capable of cw operation up to temperatures around 20°C. Figure 5 shows typical L-I characteristics of a laser for selected chip temperatures. At an operating temperature of 10°C the laser output power exceeds 1.5 mW, enabling high sensitivity detection in TDLS applications. Higher power options are currently under development at nanoplus, as well as even larger wavelength coverage.

Summary

DFB lasers for TDLS applications in the wavelength range exceeding 3 µm are now commercially available. nanoplus has developed corresponding devices with industrial-grade performance up to wavelengths of 3.4 µm. Spectral and electro-optical characteristics of the lasers qualify them for high sensitivity and high selectivity spectroscopic applications. Their promising potential has already been demonstrated within the activities of the SensHy project, for example, in detecting acetylene impurities in ethylene and polyethylene manufacturing processes at a wavelength of 3.06 µm [2].

References


Lars Nähle is a PhD student at the University of Würzburg, working for nanoplus. Within his PhD work he developed DFB lasers with wavelengths larger than 3 µm for gas sensing applications. Dr. Lars Hildebrandt is Director of Sales at nanoplus. He received his PhD in physics in 2004 working on tunable external cavity diode lasers.
APE – Angewandte Physik & Elektronik GmbH is a premier manufacturer of non-linear instruments for the generation of ultrafast laser pulses with widely tuneable wavelengths as well as their measurement and management.

APE was founded in 1992 in Berlin, Germany. APE’s high-tech devices can be found in almost all renowned institutes and universities, the main field of operation being basic research in physics, chemistry, biology and medical science.

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Our main product lines include Ultrafast Pulse Diagnostics, Pulse Management, Wavelength Conversion and Acousto-optics. As part of a line of wavelength conversion we provide synchronously pumped OPO and solutions of harmonic generation. Technology leading pulse diagnostic devices are for instance highly flexible autocorrelators or diagnostics for phase resolved measurements. Pulse Management solutions such as pulse compressors, cavity dumpers and pulse pickers are a well established part of our product portfolio.

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For challenging atom optics applications

Narrow-band diode laser with 3 W. Topica’s TA pro laser system is now available with output powers up to 3 W. The narrow-band tunable continuous wave laser features a linewidth (5 µs) of only 100 kHz and a mode-hop-free tuning range of up to 50 GHz. The system is available for wavelengths ranging from 645 to 1083 nm. The master-oscillator of the MOPA system is a DDL pro laser in patented design. A tapered amplifier subsequently amplifies the signal of the master-oscillator to high output powers, while maintaining its spectral properties. A sophisticated laser design with flexure joints, specially developed mirror mounts and a solid laser head formed from a single metal block contribute to the laser’s extreme robustness. The electronics of the TA pro is set up for further power increases in the future with low noise TA chip currents up to 5 A. The TA pro is ideally suited for challenging atom optics applications. With its narrow linewidth, the system is an ideal cooling laser for BECs and ultracold Fermi gases. It is furthermore perfectly suited for optical dipole traps as well as optical lattices due to its high output power.

Laser lines

...for 2D/3D quality testing. Schäffer + Kirchhoff presents beam sources for structured illumination in 2D and 3D production and quality assurance, including a newly developed 514 nm laser diode. The laser diode systems used feature a full metal enclosure for industrial use, integrated control and power electronics and an interface for external modulation and power regulation. Developed for use in laser line generators, the systems provide a constant line width and homogeneous intensity distribution. Micro or macro line generator versions allow adaptation to specific measurement tasks. The laser line generators deliver an output of up to 500 mW at 640 nm.

Versatile platform

Laser diode module. Frankfurt Laser Company (FLC) presents the Askion cw laser diode module HQML3 as ideally suited for applications in medical diagnostic, biotechnology, flow-cytometry, microscope spectroscopy, bio-fluorescence and well as for general R&D. The HQML3 is a flexible platform enabling the use of almost all available laser diodes in the near-UV to the NIR spectral range and DPSS lasers for 532 nm. Wavelength, beam profile and output power can be tailored to the specific application, offering maximum flexibility. The available wavelengths are 408, 445, 473, 488, 515, 532, 638, 660 and 685 nm, with an option to add filters for spectral clean-up. Powers of up to 300 mW can be adjusted manually. The module can also be operated in different modes to provide power stability or constant current. It offers polarisation better than 1:100 over the entire dynamic range. Configuration is effected through the RS232 port, which also informs on the unit’s status. The power unit (4.5 to 15 V, maximum 2.5 A) is integrated into the unit. With a footprint of 100 x 40 x 40 mm³, the module can easily be integrated into any device.

www.frilaserco.com
Near perfect beam

Blue solid state disk laser. In cooperation with partners Xiton Photonics and the Institute for Medical Laser Technologies of Ulm University, Germany, Z-Laser has developed a blue 457 nm emitting laser module with a beam quality of $M^2 = 1.0$ and an optical power of >500 mW. Thanks to a new efficient pumping concept for the solid state disk, the 'Z-Blue beam' could be packaged in a compact housing. An 880 nm emitting laser bar pumps the disk inside a newly developed optical resonance system. The module can be equipped with air cooling or with water cooling. Due to its robust construction and cost-effective cooling system, the laser is suitable for use in industrial environments as well as in the medical sector.

www.z-laser.com

Homogenized and conduction-cooled

Line source at 600 W, 880 nm. Dilas is now delivering a new conduction-cooled, multi-bar, line-source module with a homogeneous top hat optical beam profile in the slow axis and diffraction limited profile in the fast axis. This module is capable of 600 W power output at 880 nm ±5 nm. It offers a 97.5 percent (+2.5 percent) homogenized intensity profile in the slow axis. The line dimensions are 10.5 mm x 325 µm (nominal). Customized focus geometries can be offered as well. Designed for materials processing applications, these homogenized, multi-bar modules are ideal for solar, plastics welding, semiconductor processing and thermal annealing. They are available with optional features to include a power monitor and user exchangeable protection window.

www.dilas.com

Opportune window

Medical laser with replaceable window. Limo Lissotschenko Mikrooptik have fitted their compact L-Mount type fiber-coupled diode laser modules with an additional replaceable window. This helps save time and money when fibers have to be replaced, as is often the case in medical applications. The laser in a compact and hermetically sealed housing outputs 30 to 60 W at 808 to 980 nm. The beam is directed to its target by a fiber connection with razor-thin fibers (diameter: 200 and 400 µm) through a glass window. In the newly designed housing, an additional replaceable window is fitted right behind the fiber connection. It protects the actual fixed window from the effects of fiber destruction and can be replaced quickly.

www.limo.de

Suitable for MOPA

Tapered amplifier. The GaAs-based tapered amplifier TA-0915-1500 from m2k-laser has an operating range of 905 to 925 nm and is suitable for MOPA (master oscillator power amplifier) setups up to 1500 mW. Both rear and front facets have an anti-reflection coating of less than 0.01 percent to avoid laser action of the amplifier chip itself. The module offers a beam propagation value $M^2<1.6$ and a sidemode suppression of more than 40 dB. Possible applications for MOPA setups with tapered amplifiers are optical cooling, optical traps or high resolution absorption or Raman spectroscopy. The device can be mounted on a C-mount or optionally on a DHP inset or a DHP frame for better handling. The module can be ordered with selected beam quality parameters $M^2$ and is also available for external cavity configurations.

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Ultrafast laser with 400 W power

SETTING STANDARDS WITH INNOSLAB. Founded in 2001 as a spin-off from Fraunhofer ILT, EdgeWave has successfully developed their ›Innoslab‹ laser technology. With their robust and efficient construction, they have proved to be effective as conventional pulsed high power lasers.

Innoslab technology
The key requirements in the design of high power lasers for industrial use are beam quality, stability and efficiency. The latter is currently achieved largely through the use of laser diodes for pumping the laser system, a technology also utilized by fiber and thin disk lasers.

Stability and robustness have long been a major issue for ultrafast lasers. The advent of the Innoslab technology (Figure 1) brought a laser design that solved these stability problems. The compact multi-pass arrangement provides excellent stability and efficiency, while the exceptionally low thermal lens effects are very important for laser output in the high power range. This first high power laser offering 400 W with 800 µJ pulse energy in the picosecond range.

Keming Du

Since Lasys 2010, it has been clear that ultrashort pulse (ultrafast) lasers are set to conquer the world of industrial applications. Major companies such as Trumpf and Rofin offered complete solutions based on picosecond lasers for the first time. But whereas the focus at that time was still on an average power of up to 20 or 50 W, much more powerful systems are now available. A new generation of ultrafast lasers offers several hundred watts, thus opening up applications in the printing industry and in solar cell production, among others. The laser systems behind these figures are based on the ›Innoslab‹ technology, as marketed by EdgeWave in Würselen. EdgeWave celebrated its 10th birthday in 2011, having been spun-off from the Fraunhofer Institute for Laser Technology (ILT) in Aachen in 2001. Back then, the focus was already on Innoslab technology, an innovative idea for the design of diode-pumped pulsed high power lasers. By 2002, EdgeWave had launched its first air-cooled Innoslab laser with a power of 20 W, by 2006 systems with an average power of 200 W had been developed, and 2011 saw the launch of the first high power laser offering 400 W with 800 µJ pulse energy in the picosecond range.

**Figure 1** Schematic design of the hybrid resonator on an end-pumped Q-switched Innoslab laser
makes the Innoslab systems exceptionally well suited for industrial applications in the pulsed high power regime, delivering very short pulses and excellent beam quality, even at high average power. A further advantage is the flexibility of the system in terms of the beam profile. Minor changes to the design enable circles or rectangles with a different intensity distribution to be created (Figure 2).

The Innoslab concept allows complete laser oscillators to be constructed that have proven to be effective both for high powers and in oscillator/amplifier configurations. The new QX series reaches a specified power of 400 W (Figure 3). A similar design featuring two coupled-amplifier stages achieved the current record of over 1 kW average power in an ultrashort pulse laser developed at the Fraunhofer ILT [1].

Even though the technology has been developed for industrial applications, the Innoslab technology still holds various general records for pulsed laser technology. As a result, the concept earned the coveted ›Innovation Award Laser Technology 2010‹ (with the Q-switched Innoslab laser) at the AKL ’10 laser congress.

Applications
Picosecond laser pulses allow so-called ›cold‹ ablation, which means that there is little to no thermal influence on adjacent areas. The material is evaporated so quickly that no heat affected zone (HAZ) is produced. One application of high power ultrashort lasers can be found in the manufacture of high-quality embossing cylinders for printing (title picture, left), where processing of large areas with a high throughput is required, while retaining maximum precision and a high aspect ratio. The almost cold evaporation of materials using ultrafast lasers with a high beam quality and several 10 µJ of pulse energy cuts away a tiny but well defined slice with a diameter of 10 µm and a depth of 100 nm per pulse. Combining these slices generates the embossing structures on the outer sleeve of cylinder. Because of the tiny volume of the ablated slices, a level of high lateral and depth resolution can be achieved that would be impossible with a more thermal process.

Production-capable processing of embossing cylinders requires high pulse repetition rates and high average powers. The lasers from the new QX series deliver 400 W with 10 ps laser pulses and a pulse repetition rate of up to 20 MHz, all in a very compact housing. This qualifies them as OEM systems for micro-processing with a high throughput and high precision.

Another application for Innoslab lasers can be found in tool manufacture (title picture, right). Here, precise ablation without significant deposits of melted material is crucial. Compared to ablation with conventional Q-switched solid state lasers, the lasers from the PX or QX series with ps pulse duration evaporate the target with no melted material, at high precision and free of recast. Point by point and layer by layer ablation can thus be used to produce high precision tools.

Summary
Stable ultrafast lasers with the robust Innoslab design are conquering the materials processing market. Systems from EdgeWave with more than 400 W average power and up to 1 mJ of pulse energy [3] are opening up a previously unattainable power range and thus creating new applications or significantly increasing the throughput in established processes.

References

Dr. rer. nat. Keming Du is founder and Managing Director of EdgeWave.
Lasers provide numerous advantages over other light sources. For example, the low divergence allows precise control of very high optical power, thus making lasers particularly attractive for projection systems. Laser projection systems have both a broader color spectrum and the advantage that the image is "focus-free." However, lasers do have the inherent problem of speckle. On rough optical surfaces, local interferences occur that manifest themselves as a grainy pattern of spots. This effect causes noise in projected images and reduces the resolution of measurement systems.

Previous solutions
There are various methods of tackling the problem of speckle. Rotating diffusers destroy the temporal and spatial coherence of the laser and smear the speckle pattern. However, the requisite mechanics behind this principle limit miniaturization and are susceptible to faults due to the constant friction. A similar effect can be achieved by oscillating mirrors back and forth in the micrometer range, with the caveats that this reflective method is not particularly compact, is dependent on polarization and is normally less effective. Alternatively, laser light can be passed through a vibrating glass fiber, although the practical implementation of this solution in small projectors is understandably not straightforward.

A mechanically stable and compact solution can be realized using broadband lasers. However, one of the most important arguments in favor of lasers, namely the high specific brightness, is lost. Another method would be to vibrate the object or the screen, but again, in most applications this is not feasible.

Reducing laser speckle

NEW ACTUATOR TECHNOLOGY. Several methods are available for reducing laser speckle, although none of them is as compact and cost effective as this solution – electroactive polymers oscillate a diffuser, permitting dimensions down to 6x9x1 mm³. Optotune has set its sights on the picoprojector market.

MARK BLUM

1 LSR-3000 with integrated electronics
**Electroactive polymers**

The ›Laser Speckle Reducer‹ (LSR) (Figure 1) from Optotune functions in a similar way to a rotating diffuser, but is many times more compact and economical. The principle is simple – a diffuser is mounted on an elastic membrane and moved back and forth using electroactive polymers (Figure 2). With the correct electrode geometry and appropriate actuation, planar circular oscillation of the diffuser can be generated, with lateral deflections of 100 to 500 µm at frequencies of 300 to 800 Hz, depending on the size.

The secret behind the solution is actuators made of electroactive polymers (EAPs, also known as artificial muscles). Flexible electrically conductive surfaces are attached to the top and bottom of a thin elastomer film. When a voltage is applied between the two electrodes, these are charged according to the principle of a plate capacitor, attract one another and thus squeeze the elastic film. Given that the volume remains constant, the electrodes expand laterally, theoretically by up to 40 percent, and thus move the diffuser.

**Small, effective and economical**

The major advantage of this technology is the extremely compact design. While a generously proportioned design for a 10 mm wide diffuser has a total size of 22x22x1 mm³, just 6x9x1 mm³ is possible for a diffuser size of 2x4 mm², for example. Compared to one-dimensional rotation, the two-dimensional circular movement method is also more effective, as a larger area of the diffuser surface can be utilized. Other advantages of the LSR are directly attributable to the basic EAP technology – there are no mechanics so it is completely silent, it has a long operating life-time and it can be used over a wide temperature range. The power consumption is also extremely low.

The maximum speckle reduction (Figure 3) that can be achieved depends on the entire optical system. Significant reduction can be expected at high frequencies and through the use of larger oscillation amplitudes, high resolution diffuser patterns and long observer integration times. As with all methods based on diffusers, an increase in the divergence of the laser beam must be tolerated, this increase being all the more significant with very fine diffuser structures. The optical design may then need to incorporate additional optics to collimate the laser.

The electronics requirements also need to be considered. Although actuation of the LSR is simple and requires little power, electrical voltages of up to 300 V are often necessary to achieve the desired amplitude of oscillation. As a result, battery operated devices must include voltage conversion electronics, although this only takes up around 40 mm² of PCB space.

**The breakthrough?**

The small size and the excellent cost potential are attracting the attention of those who develop laser-based picoprojector systems. Volumes of several millions are predicted if the projectors can be made to fit into a cell phone and (critically) deliver good image quality. At the moment, LED and laser-based systems are in a head-to-head race – Optotune’s LSR at least resolves the problem of laser speckle for the latter.

Lasers are also on the advance in larger projectors, particularly in the cinema sector, where high optical power and maximum image quality are required. In addition to image projection systems, the LSR is also used in laser-based measurement systems and in optical microscopy, where the precision of measurements is limited by speckle noise. Another application can be found in special lighting, for example for surveillance cameras, night vision equipment and biometric identification systems. NIR lasers are used to illuminate distant objects or specific geometries. In general, all the developers of such systems are happy that they can finally access a compact solution for speckle reduction.

**Summary**

The principle of electroactive polymers has been around for several decades, but so far the technology has hardly been exploited commercially. With the development of the LSR, Optotune has succeeded in utilizing the advantages of this actuator technology in a specialized optical component that is set to open up a range of new applications.

Mark Blum is Sales Director and one of the founders of Optotune.
Active cabinet window

Protection for 820 to 1100 nm. Due to the constantly increasing laser power and beam quality of modern disk and fiber lasers, laser safety standards can no longer be met using conventional filter materials. To ensure that direct visual process monitoring is still possible, Laservision has developed a safety concept for laser cabinet windows, which offers the required protection even for high-power lasers. The new patented active cabinet window integrates the electronics into the safety circuit of the laser system. If a laser beam hits the plastic screen and too much power is coupled into the sensor in the window frame, the laser switches off before dangerous radiation can leak through the screen. At the same time, the system is totally insensitive to scattered radiation and process light. The system is CE certified as category T1 in accordance with the currently valid mechanical engineering regulation. In combination with an active cabinet barrier system, a complete certifiable solution for industrial high power systems is available in the wavelength range between 820 to 1100 nm.

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Voltage amplifier

... for piezo actuators. piezosystem jena has engineered the iNV 120- and iNV 120/1 CLE series of single channel amplifiers for highly dynamic control of actuators in sub-nanometer positioning. The series provides a constant output current of 120 mA, ensuring that even high capacity piezo actuators can be dynamically controlled. Jump times are in the microsecond range, while settling times are low. Residual signal noise is < 0.3 mV RMS at 500 Hz. The compact table-top system in a sturdy metal enclosure is available in two versions: The NV 120/1 is designed for actuators without an integrated measurement system, while the NV 120/1 CLE is for actuators with an integrated measurement system or for capacitive sensors. The automatic sensor identification (ASI) function on the NV 120/1 CLE allows actuators with an identical construction to be used with the same amplifier, eliminating the need to repeat calibration. A manual control as well as an analog and various digital interfaces are available.

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