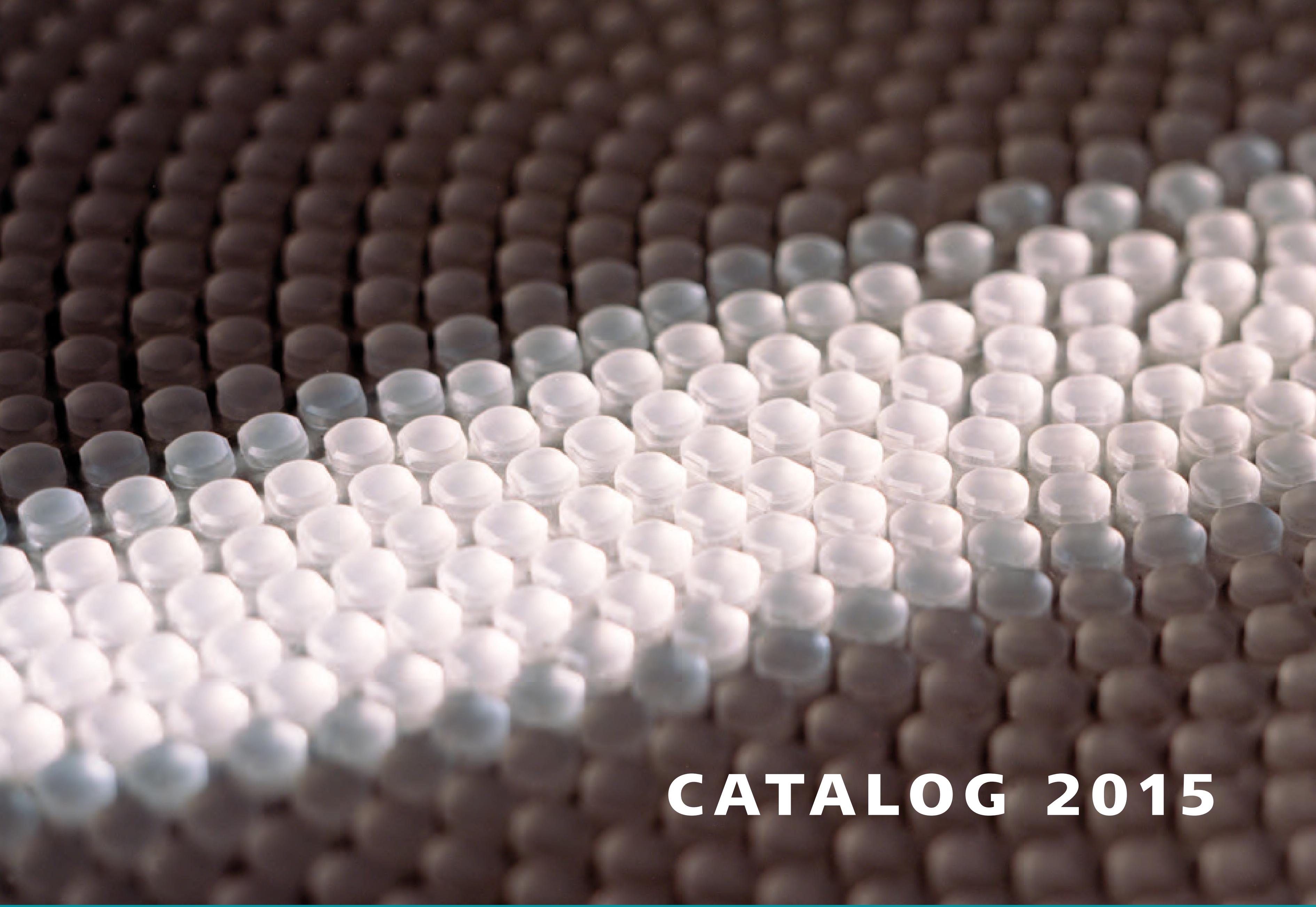

CATALOG 2015

LAYERTEC®
OPTICAL COATINGS · OPTICS

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ABOUT LAYERTEC

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

Since the beginning in the early 1990's, LAYERTEC has worked for universities and research institutes worldwide and many important developments in laser technology of the past years have been supported by LAYERTEC products.

Our company combines a precision optics facility and a variety of coating techniques (magnetron and ion-beam sputtering, thermal evaporation, ion assisted e-beam evaporation) which enables LAYERTEC to control the quality of the optical components over the whole production process from grinding, polishing and cleaning of the substrates to the final coating process.

Today, a staff of more than 150 employees are working in the precision optics facility and coating laboratories of LAYERTEC. More than 30 coating machines are available to cover the wavelength range from the VUV to the NIR using sputtered and evaporated coatings made of fluorides and oxides, metallic and metal-dielectric coatings.

LAYERTEC offers the full spectrum of design and manufacturing for a high flexibility to customize optical components for special applications with an optimum of coating performance and cost efficiency. The variety in size and technology of our coating equipment allows a high-volume fabrication of serial products as well as a flexible prototype manufacturing for R&D groups in the industry and for research institutes.

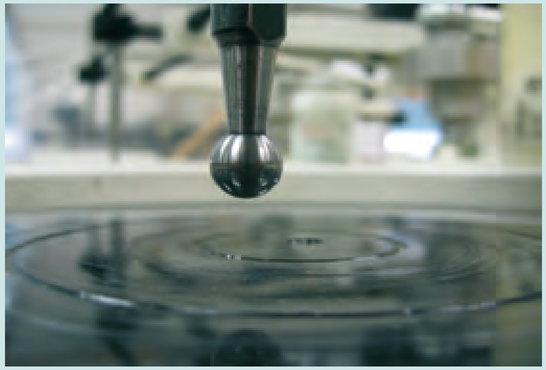
This catalog gives an overview about our production program and shows some highlights which represent innovative solutions of outstanding quality and which are intended to point out the capabilities of LAYERTEC for further developments.

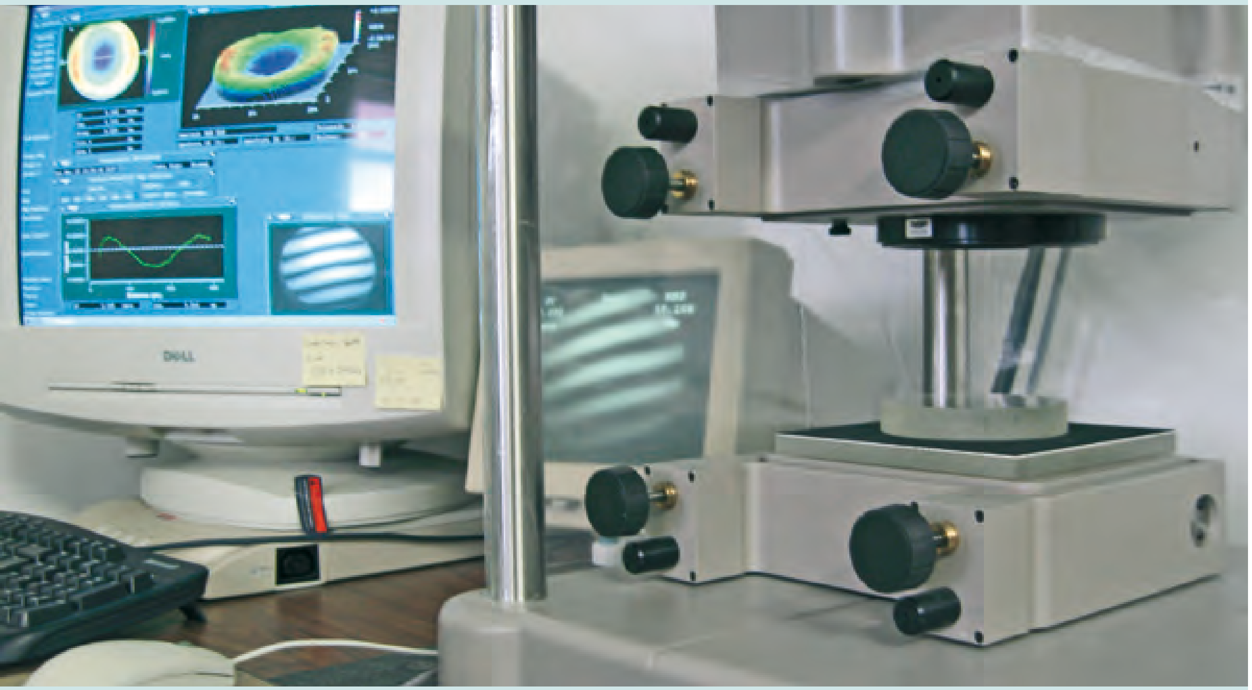
Please do not hesitate to contact LAYERTEC for an offer or for a discussion of your special problem even if your type of laser or your special field of interest is not explicitly mentioned in this catalog.

PRECISION OPTICS

The precision optics facility of LAYERTEC produces **mirror substrates, etalons**, retarders, lenses and prisms of fused silica, optical glasses like BK7® and SF10® and some crystalline materials, e.g. calcium fluoride.

The polishing of fused silica and YAG has been optimized over the recent years. We are able to offer fused silica substrates with a surface **rms-roughness of 0.12 nm**.





LAYERTEC produces precision optics in a wide range of sizes. Typical diameters for the laser optics are between 6.35 mm and 100 mm, but sizes down to 2 mm for a serial production of the smallest laser devices as well as **diameters up to 500 mm** for uncommon projects of high-energy lasers or astronomical telescopes are possible.

High quality substrates for laser mirrors are characterized by:

- Geometry and shape (diameter, thickness, wedge and radius of curvature)
- Surface roughness
- Surface form tolerance
- Surface defects

LAYERTEC offers substrates which are optimized for all of these parameters. The specifications of premium quality fused silica substrates with diameters up to 50mm are:

- Surface rms-roughness lower than 0.12 nm
- Surface form tolerance of λ / 30 (633 nm)
- Defect density as low as 5 / 1 x 0.010 (ISO 10110)

These parameters are not limited to a standard geometry but can also be achieved on substrates with uncommon sizes, shapes or radii of curvature. LAYERTEC substrates meet the demands for the production of components for Cavity Ring-Down Spectroscopy and EUV mirrors.

SPUTTERING

PRINCIPLE

In general, the term "sputtering" stands for the extraction of particles (atoms, ions or molecules) from a solid by ion bombardment. Ions are accelerated towards a target and collide with the target atoms. The original ions as well as recoiled particles, move through the material, collide with other atoms and so on. Most of the ions and recoiled atoms remain within the material, but a certain fraction of the recoiled atoms is scattered towards the surface by this multiple collision process. These particles leave the target and may then move to the substrates and build up a thin film.

PROPERTIES OF SPUTTERED COATINGS

Because of the high kinetic energy (~10 eV), i.e. high mobility, of the film forming particles, sputtered layers exhibit

- An amorphous microstructure
- A high packing density (which is close to that of bulk materials)

No external heating is necessary to produce oxide layers with minimum absorbance.

These structural characteristics result in very advantageous optical properties such as:

- Low losses due to scattered light
- High stability of the optical parameters under various environmental conditions due to the blocking of water diffusion
- High laser-induced damage thresholds
- High mechanical stability

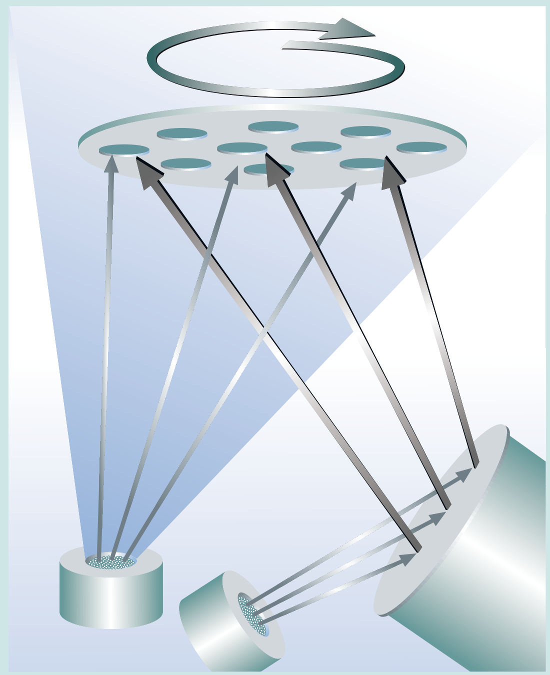
MAGNETRON SPUTTERING

Ions are delivered by a gas discharge which burns in front of the target. It may be excited either by a direct voltage (DC-sputtering) or by an alternating voltage (RF-sputtering). In the case of DC-sputtering the target is a disk of a high purity metal (e.g. titanium). For RF-sputtering, dielectric compounds (e.g. titanium dioxide) can also be used as targets. Adding a reactive gas to the gas discharge (e.g. oxygen) results in the formation of the corresponding compounds (e.g. oxides).

Developments at LAYERTEC have taken magnetron sputtering from a laboratory technique to a very efficient industrial process, which yields coatings with outstanding properties especially in the VIS and NIR spectral range. The largest magnetron sputtering machine can coat substrates up to a diameter of 500 mm.

ION BEAM SPUTTERING (IBS)

This technique uses a separate ion source to generate the ions. To avoid contaminations, RF-sources are used in modern IBS machines. The reactive gas (oxygen) is in most cases also provided by an ion source. This results in a better reactivity of the particles and in more compact layers.

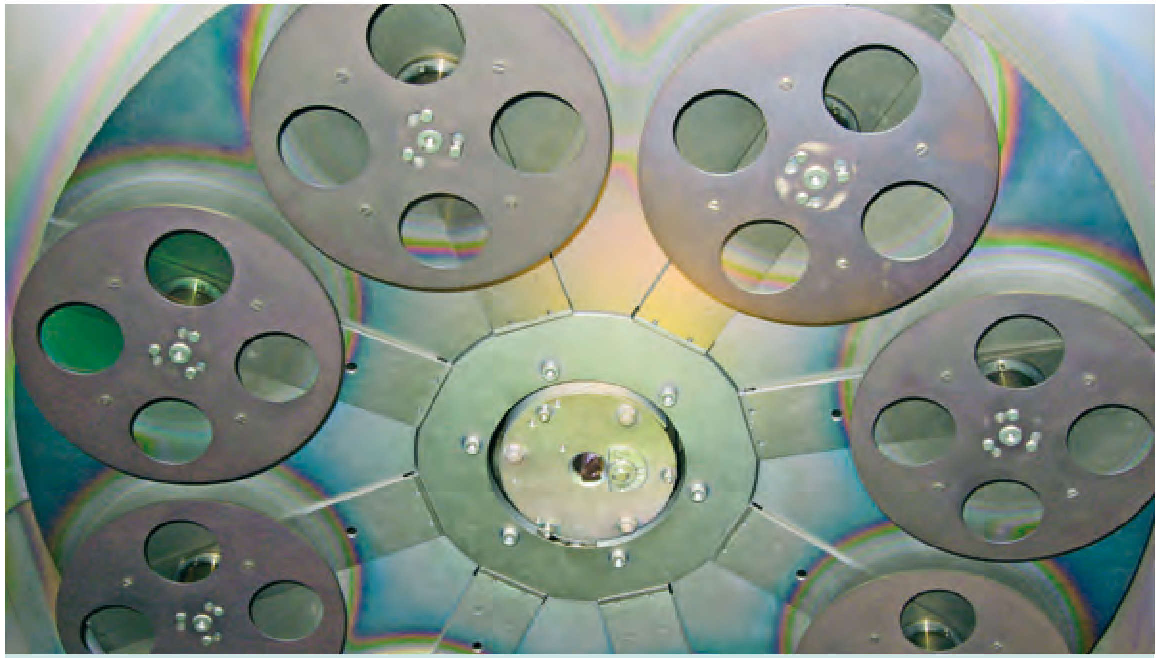


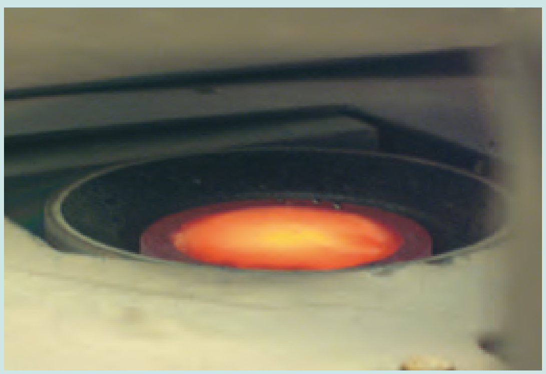
The main difference between magnetron sputtering and ion beam sputtering is that ion generation, target and substrates are completely separated in the IBS process while they are very close to each other in the magnetron sputter process.

THERMAL AND E-BEAM EVAPORATION

PRINCIPLE

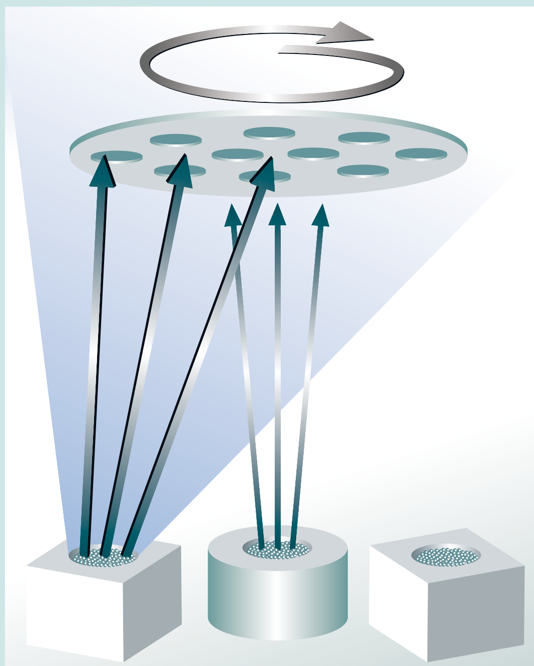
Thermal and electron beam evaporation are the most common techniques for the production of optical coatings. LAYERTEC uses these techniques mainly for UV-coatings. The evaporation sources are mounted on the bottom of the evaporation chamber. They contain the coating material which is heated by an electron gun (e-beam evaporation) or by resistive heating (thermal evaporation). The method of heating depends on the material properties (e.g. the melting point) and the optical specifications.
The substrates are mounted on a rotating substrate holder on top of the evaporation chamber. Rotation of the substrates is necessary to ensure coating uniformity. The substrates must be heated to a temperature of 150 – 400° C, depending on the substrate and coating materials. This provides low absorption losses and good adhesion of the coating to the substrates. Ion guns are used to get more compact layers.





LAYERTEC is equipped with several evaporation machines covering the whole bandwidth of the above mentioned techniques from simple thermal evaporation to ion assisted deposition (IAD) using the APSpro® ion source.

APSpro® is a trademark of LEYBOLD OPTICS GmbH



PROPERTIES OF EVAPORATION COATINGS

The energy of the film forming particles is very low (~ 1 eV). That is why the mobility of the particles must be enhanced by heating the substrates.
The packing density of standard evaporated coatings is relatively low and the layers often contain micro crystallites. This results in relatively high stray light losses (some tenth of a percent to some percent, depending on the wavelength). Moreover, atmospheric water vapor can diffuse in and out of the coating depending on temperature and humidity and resulting in a shift of the reflectance bands by ~1.5 % of the wavelength.

Shift-free, i.e. dense, evaporated coatings can be produced by IAD using the APSpro® ion source which provides very high ion current densities.

Nevertheless, evaporated coatings have also high laser damage thresholds and low absorption. They are widely used in lasers and other optical devices.

MEASUREMENT TOOLS FOR PRECISION OPTICS

SURFACE FORM MEASUREMENT

The precision optics facility of LAYERTEC is equipped with laser interferometers and special interferometer setups for plane, spherical and parabolic surfaces. LAYERTEC uses for aspheric surfaces tactile and contactless metrology systems. In general, the form tolerance of spherical and plane optics with diameters up to Ø ≤ 100 mm can be measured with an accuracy of λ / 10 (633 nm). However, in many cases, a higher accuracy up to λ / 30 is possible. Measurement protocols can be provided on request.

Optotech OWI 150 HP interferometer system

LARGE APERTURE INTERFEROMETRY

Especially for laser optics with large dimensions, LAYERTEC uses a high performance Fizeau interferometer and a Twyman-Green interferometer within the following measurement ranges:

- Plane surfaces: Ø ≤ 300 mm with an accuracy up to λ / 50 (633 nm) and Ø ≤ 600 mm better than λ / 10
- Spherical surfaces: Ø ≤ 600 mm with an accuracy better than λ / 10 (633 nm)
- Parabolic surfaces: Ø ≤ 300 mm full aperture measurement with an accuracy up to λ / 10 (633 nm)

ADE Phaseshift MiniFIZ 300 large aperture interferometer

Interferometry of large surfaces

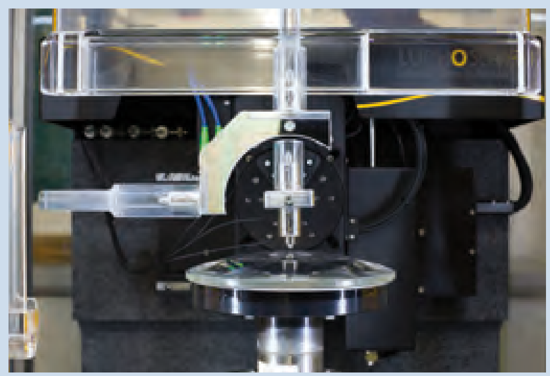
CONTACTLESS METROLOGY

The metrology measurement system LuphoScan, developed by Luphos GmbH, allows an ultra-high precision measurement of distance and surface form. The unique system combines many advantages of other distance measurement systems without their disadvantages of a necessary contact, a small working distance or a tiny working range. This technology allows the determination of the topology of different objects down to the nanometer range.

High reflective polished objects as mirrors or metal coated substrates can be measured as well as transparent objects providing only weak reflectivity (glass lenses, substrates).

Due to its absolute measurement range, it is possible to determine the height of structures of up to 1 mm height on polished objects with a precision of ± 5 nm.

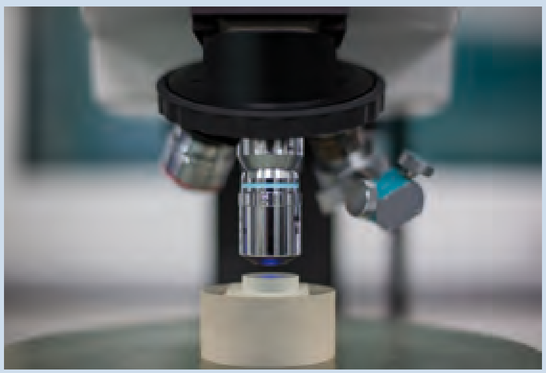
Especially topological errors of aspheric surfaces can be exactly determined and used for a correction of the form parameters during the polishing process.

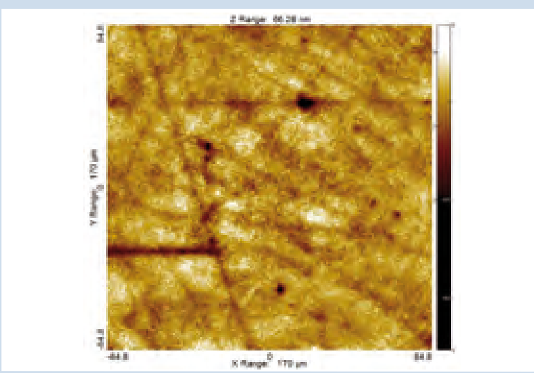


LuphoScan metrology system

OPTICAL PROFILOMETRY

A 3D optical surface profiler based on a white light interferometer is used to visualize the surface form and roughness of our substrates. The profiler is furthermore applied for the characterization of surface defects and other structures in the range of sizes from 0.5 µm up to 100 µm.

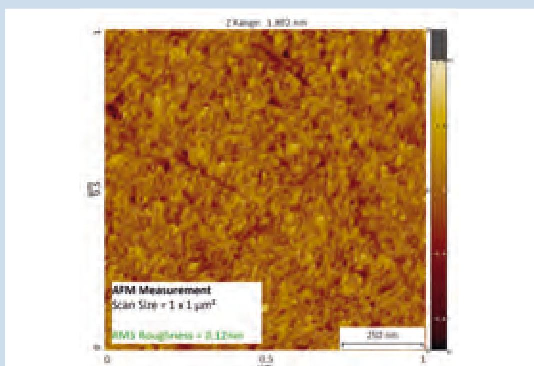

Optical profiler Sensofar


Surface defects visualized by the optical profiler

SCANNING PROBE MICROSCOPY

LAYERTEC is equipped with a scanning probe microscope (atomic force microscope, AFM) to control the special polishing processes for surface roughness values below Sq ≤ 0.5 nm as well as to provide inspection protocols on request.


DI Nanoscope 3100 AFM



AFM scan of an optical surface

SURFACE PROFILER

The Talysurf PGI 1240 is a tactile surface profile measuring tool used to characterize strongly curved surfaces. A small tip is in contact with the surface and moves along a line while its displacement is measured.

The measurement principle is independent from surface topology or optical properties such as coatings or thin contaminations, which often prevent direct interferometry. The vertical accuracy depends on the gradient of the surface and can reach values of 200 nm, which corresponds to ~ $\lambda / 2$ (633 nm).

LAYERTEC uses this tool for measurements of small to mid-size non spherical surfaces up to a diameter of 200 mm.


Taylor Hobson Talysurf PGI 1240 Asphere

MEASUREMENT TOOLS FOR COATINGS

Quality control is most important for production as well as for research and development. The standard inspection routines at LAYERTEC include interferometric measurements of the substrates and spectrophotometric measurements of the coated optics in the wavelength range between 120 nm and 20 µm.

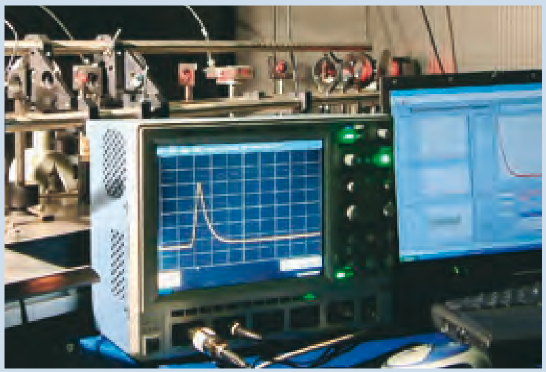
SPECTROPHOTOMETER

Standard spectrophotometric measurements in the wavelength range $\lambda = 120$ nm – 20 µm are carried out with UV-VIS-NIR spectrophotometers, VUV- and FTIR-spectrophotometers.

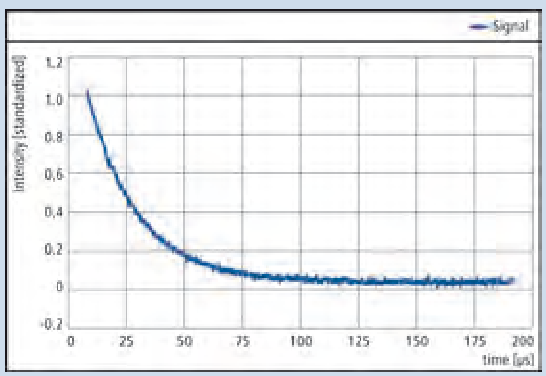
Spectrophotometer Perkin Elmer Lambda 950

CAVITY RING-DOWN (CRD)

High reflectivity and transmission values in the range of R, T = 99.5 % … 99.9999 % are determined by Cavity Ring-Down time measurements. This method has a high accuracy and is an absolute measurement procedure. LAYERTEC employs various CRD setups to cover the whole spectral range from 220 to 1800 nm without any gaps.



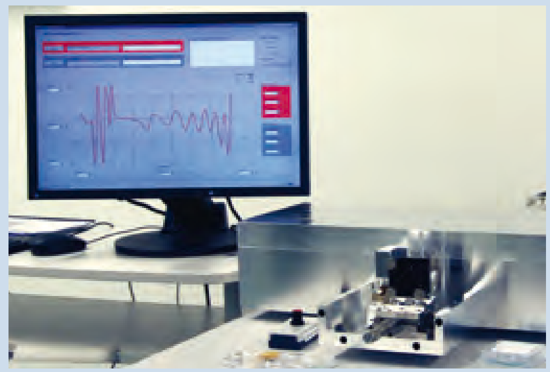
CRD measurement setup



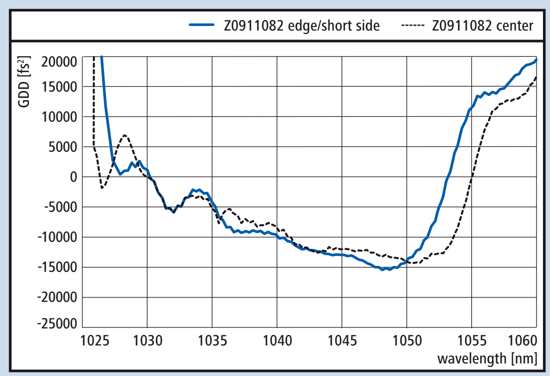
Exemplary mono-exponential CRD-curve of a highly reflecting mirror pair for 450 nm with R = 99,995 % measured using a resonator length L = 228 mm

GROUP DELAY (GD) & GROUP DELAY DISPERSION (GDD)

Besides transmittance and reflectance, LAYERTEC is able to measure the phase properties of mirrors in the wavelength range between 250 nm and 1700 nm with several white light interferometers. These setups can be used for the characterization of broadband femtosecond laser mirrors with positive or negative GDD as well as for measuring the GDD of GTI mirrors down to -10000 fs² in a narrow spectral range.



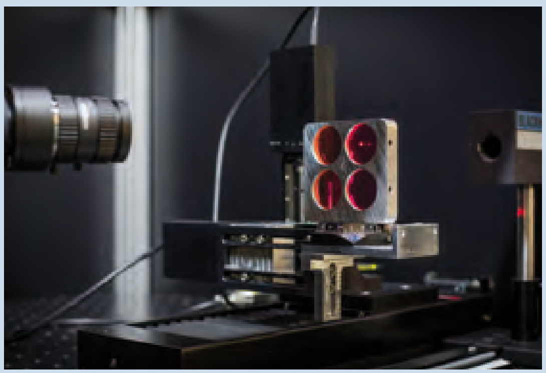
GDD measurement setup



GDD spectra of GTI mirrors, see also pages 96, 97

LASER INDUCED DAMAGE THRESHOLD (LIDT)

LIDT measurements according to ISO standards and to our own procedures can be carried out (see pages 37, 38) with a new measurement setup at LAYERTEC. The following wavelengths are available: 266 nm, 355 nm, 532 nm and 1064 nm. The pulse duration is 4 … 10 ns. Measurements with other LIDT test conditions are carried out in cooperation with the Laser Zentrum Hannover (LZH) for example.

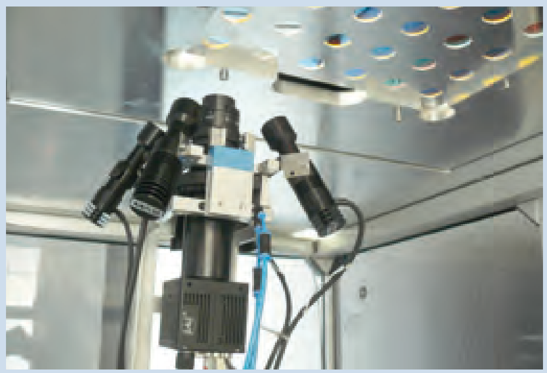


LIDT measurement setup for pulsed laser sources

LIDT beamline

DEFECT ANALYSIS

LAYERTEC is equipped with a measurement system according to ISO 10110-7 which enables us to detect, count and analyze defects on optical surfaces.



Defect inspection system for optical components

Automatic handling unit

ABSORPTION & SCATTERING LOSSES

The measurement of absorption and scattering losses of optical thin films and bulk materials are also available in cooperation with the Leibniz- Institute of Photonic Technology Jena e.V. (IPHT) and the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) Jena.

Intra-Cavity Heating Measurement Setup
Absorption losses in optical coatings lead to the heating of the coating and the substrate. At an average laser power of several kilowatts (cw) and higher, even low absorption losses in the range of some parts per million cause significant heating of the optical component. LAYERTEC has built a heating measurement setup for the purpose of quality assurance and technology development on high-power optical components for the wavelength 1030 nm.

Absorption measurement using a high power cw laser