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www.highlightoptics.com

LAYERTEC®
OPTICAL COATINGS · OPTICS

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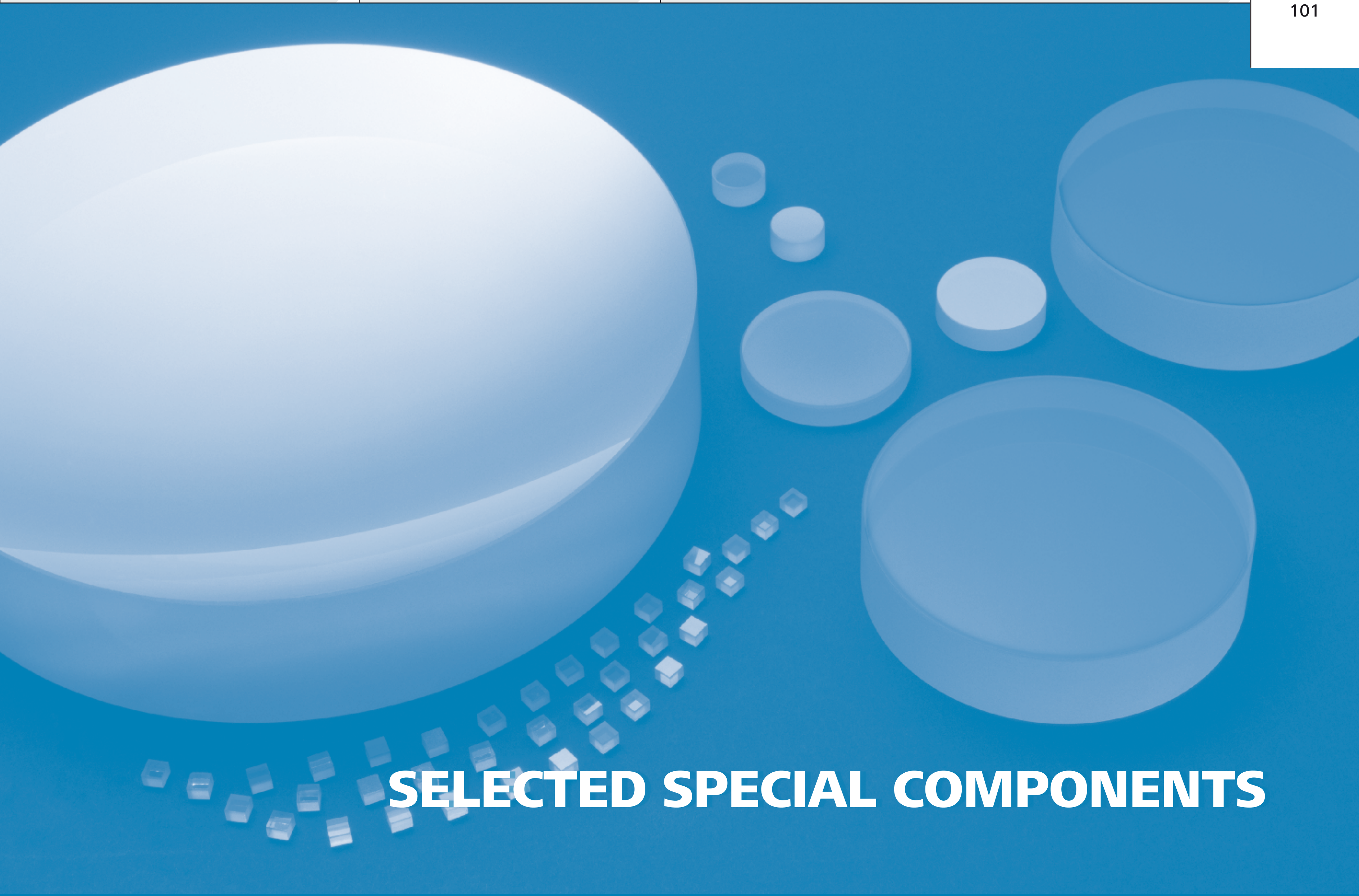


SELECTED SPECIAL COMPONENTS

LAYERTEC®
OPTICAL COATINGS · OPTICS

COMPONENTS FOR OPTICAL PARAMETRIC OSCILLATORS (OPO)

CAVITY MIRRORS FOR AOI = 0°

Mirrors for OPOs are optimized for separation of the pump laser, signal and idler wavelengths. This application requires a broad reflectance band for the signal wavelength and a wide range of high transmittance for the idler and pump wavelengths. Moreover, most of the optics show smooth group delay (GD) and group delay dispersion (GDD) spectra. Thus, wide tuning ranges for the signal and the idler wavelengths can be achieved. This enables the operation of OPOs with fs-pulses. Broadband output couplers are also available. Center wavelength and tuning range can be adjusted according to customer specifications.

All OPO coatings are produced by magnetron sputtering. This process guarantees that the optical parameters are environmentally stable, because the coatings are dense, free of water and adhere strongly to the substrate in spite of the extreme coating thickness of 20 – 30 µm. This makes sputtered OPO coatings ideal for application in harsh environments.

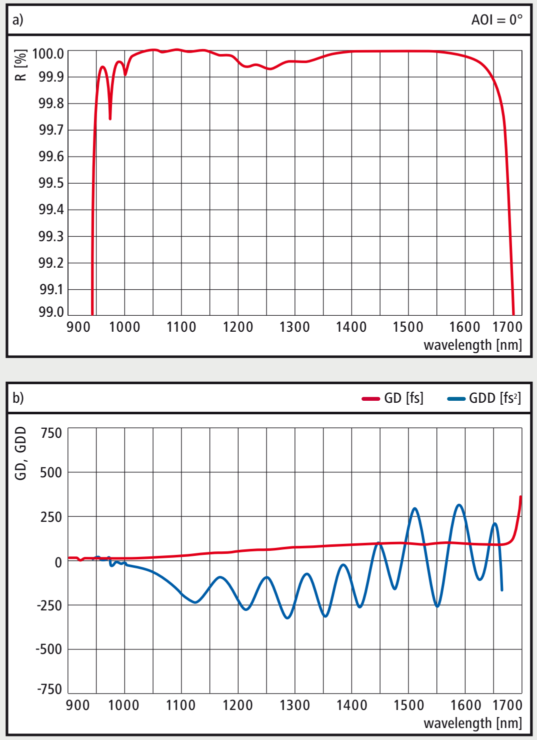


Figure 1: Reflectance, GD and GDD spectra of a broadband HR mirror for the signal wavelength:
HR (0°, 1000 – 1600 nm) > 99.9 %
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

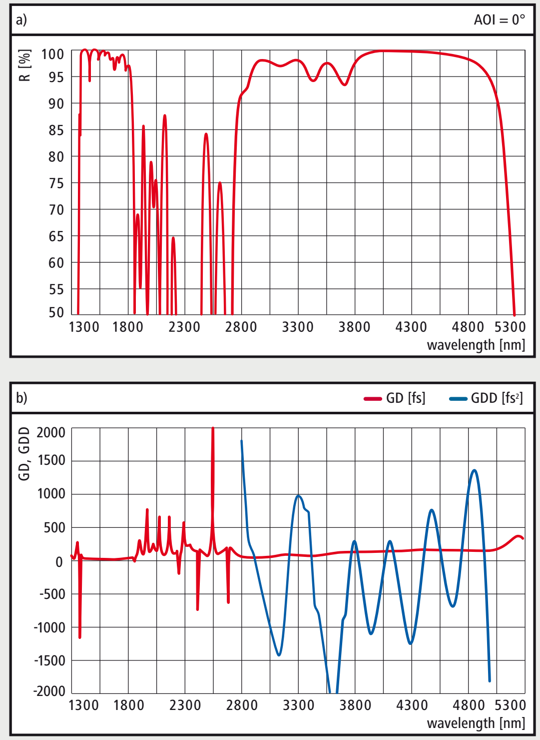
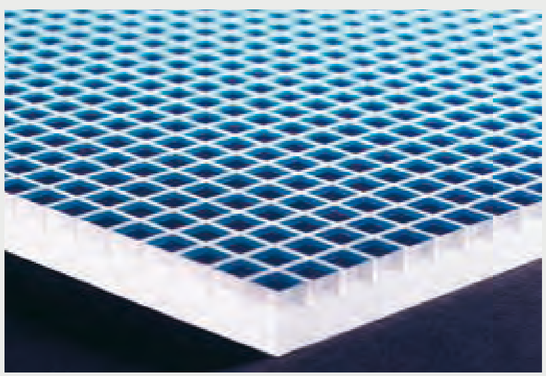


Figure 2: Reflectance, GD and GDD spectra of a dual HR mirror for the signal and idler wavelengths:
HR (0°, 1400 – 1800 nm) > 96 %
+ HR (0°, 2900 – 4900 nm) > 93 %
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength



This dual wavelength mirror posseses smooth GD spectra for signal and idler, but only the broadband mirror for the idler is GDD optimized.

PUMP MIRRORS AND SEPARATORS AOI = 0°

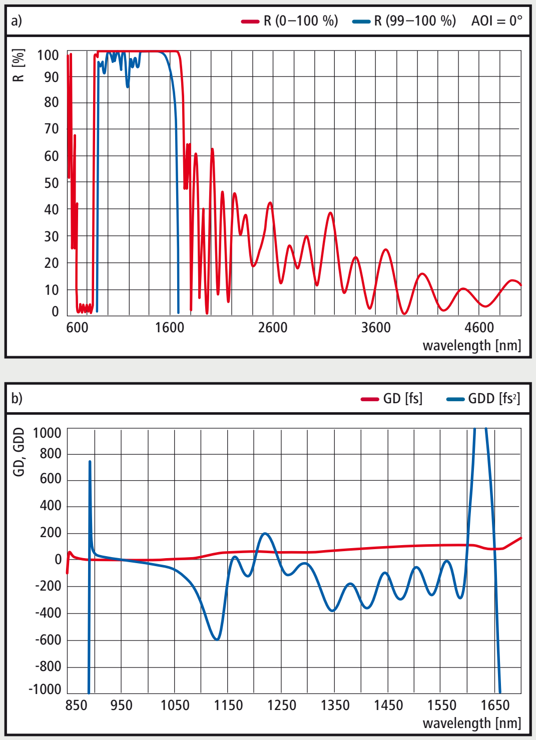


Figure 3: Reflectance, GD and GDD spectra of an OPO pump mirror
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

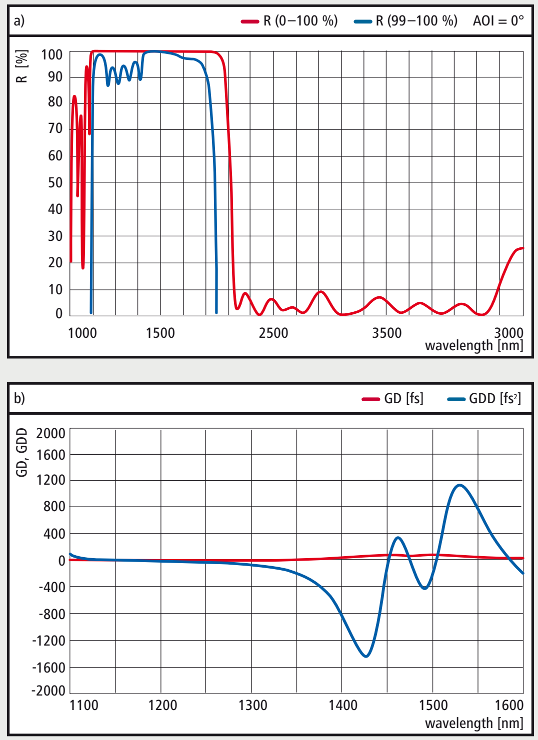


Figure 4: Reflectance, GD and GDD spectra of a separator for the signal and idler wavelengths
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

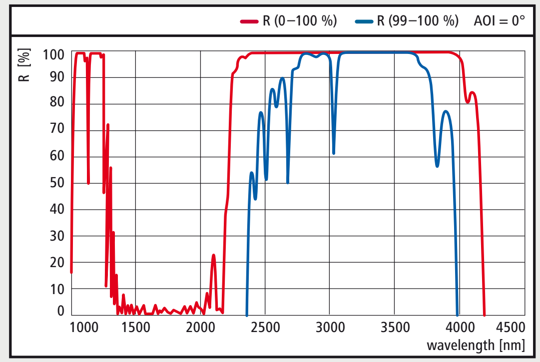


Figure 5: Reflectance spectrum of a broadband mirror for the NIR:
HR (0°, 2300 – 4000 nm) > 99 %

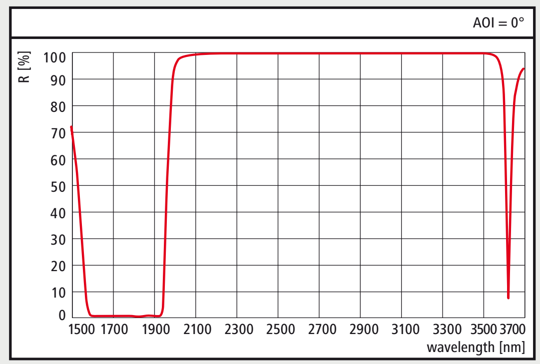


Figure 6: Reflectance spectrum of a separator for the signal and idler wavelengths:
HR (0°, 2050 – 3500 nm) > 99 %
+ R (0°, 1600 – 1930 nm) < 5 %

This type of mirror separates the pump and signal wavelengths while suppressing the idler wavelength:
R (0°, 700 – 850 nm) < 10 %
+ HR (0°, 900 – 1600 nm) > 99.8 %
+ R (0°, 1800 – 5000 nm) < 60 %.

- Edge filters separating signal and idler wavelengths can be used as broadband outcoupling mirrors for the idler:
  HR (0°, 1100 – 1600 nm) > 99.8 %
  + R (0°, 1730 – 2900 nm) < 10 %.
- These filters can also be provided with a band of high reflectance or high transmittance for the pump wavelengths or for the second harmonic of the signal wavelengths.
- LAYERTEC recommends undoped YAG or sapphire as substrate material if high transmittance for the idler wavelengths is required.
  (see also page 21 for transmittance curves)

COMPONENTS FOR OPTICAL PARAMETRIC OSCILLATORS (OPO)

OUTPUT COUPLERS FOR AOI = 0°

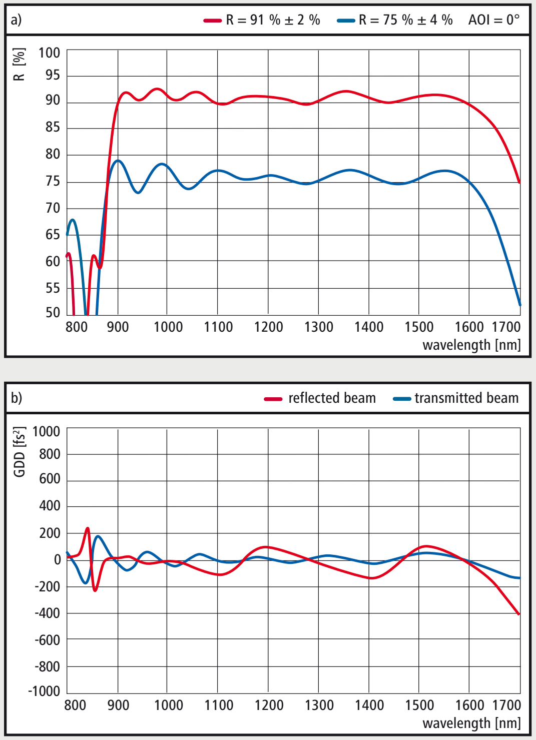


Figure 1: Reflectance and GDD spectra of different broadband output couplers for the signal wavelength range.
a) Reflectance vs. wavelength
b) GDD vs. wavelength
Please note the smooth GDD spectra. The GDD spectra shown are calculated for the 75 % output coupler, but the spectra for other reflectance values are very similar.

The reflectance of output couplers and beam splitters can be adjusted according to customer specifications.

BEAM SPLITTERS FOR AOI = 45°

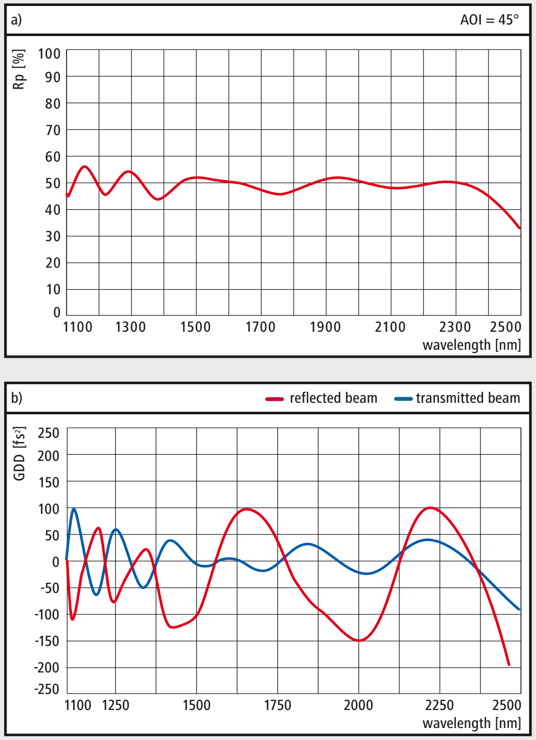


Figure 2: Reflectance and GDD spectra of a broadband beam splitter for p-polarized signal and idler radiation:
Rp (45°, 1100 – 2400 nm) = 50 % ± 5 %
a) Reflectance vs. wavelength
b) GDD vs. wavelength

SPECIAL OUTPUT COUPLERS FOR AOI = 0°

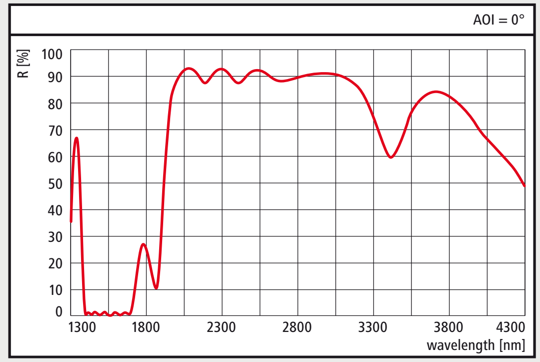


Figure 3: Reflectance spectrum of a special output coupler:
R (0°, 1400 – 1700 nm) < 3 %
+ PR (0°, 2000 – 3150 nm) = 90 ± 3 %

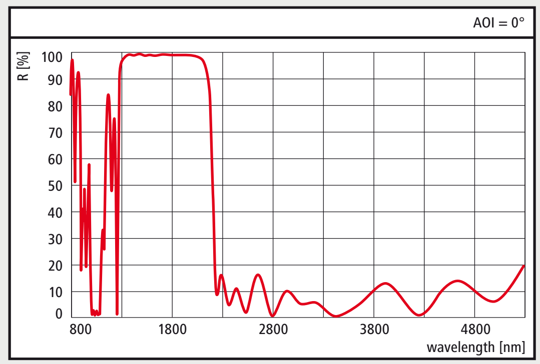


Figure 4: Reflectance spectrum of a special output coupler:
R (0°, 1000 – 1100 nm) < 3 %
+ PR (0°, 1350 – 2000 nm) = 98 % ± 0.5 %
+ R (0°, 2200 – 5000 nm) < 20 %

The output couplers for the signal wavelengths (fig. 3) can suppress the idler and vice versa (fig. 4). These output couplers may also have a pump window.

TURNING MIRRORS AND SEPARATORS FOR AOI = 45°

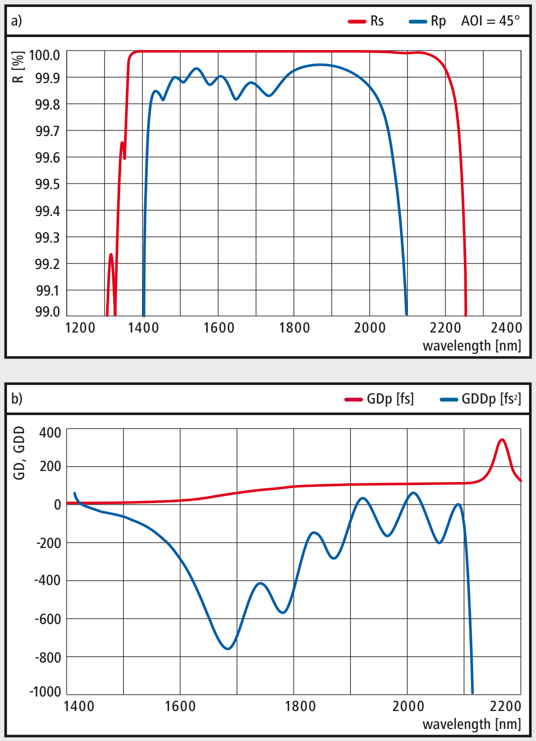


Figure 5: Reflectance, GD and GDD spectra of a turning mirror HRp (45°, 1450 – 2000 nm) > 99.8 %
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

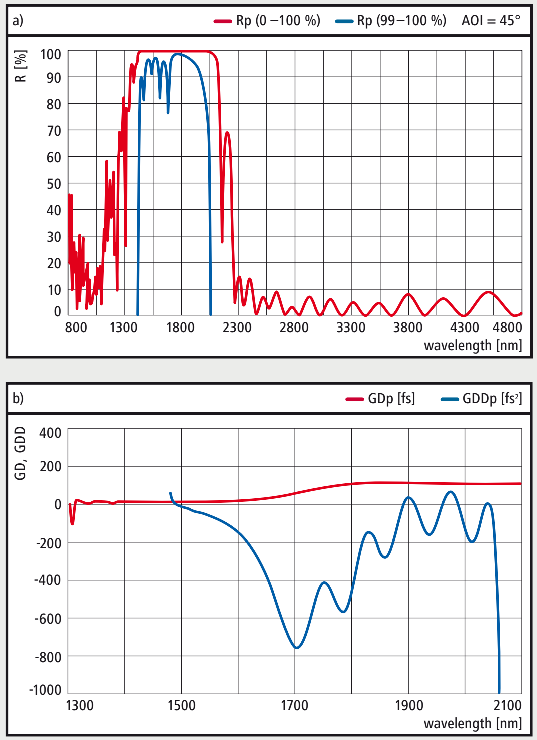


Figure 6: Reflectance, GD and GDD spectra of a separator for signal and idler
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

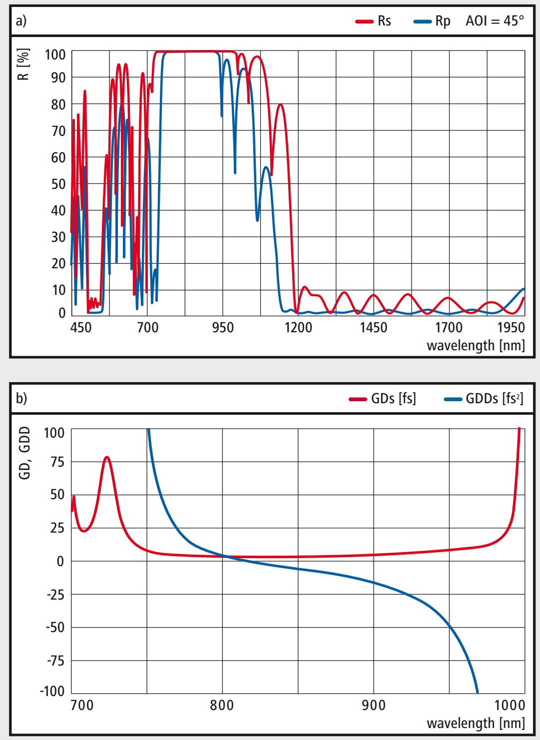


Figure 7: Reflectance, GD and GDD spectra of a separator for the signal and idler with high transmittance for the pump radiation
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

Turning mirrors and separators for pump, signal and idler are key components of OPOs. The spectral position of the reflectance and transmittance bands can be adjusted according to customer specifications. Please note that GD and GDD can only be optimized for s- or p-polarization while the reflectance is usually very high for both polarizations.

A broad reflectance band for the signal is combined with a broad transmittance band for the idler:
HRp (45°, 1450 – 2000 nm) > 99.8 %
+ Rp (45°, 2350 – 4000 nm) < 10 %.

This separator can be used to couple the pump radiation into the resonator:
HRs (45°, 770 – 930 nm) > 99.8 %
+ Rp (45°, 510 – 550 nm) < 1 %
+ Rp (45°, 1160 – 1900 nm) < 10 %.

COMPONENTS FOR OPTICAL PARAMETRIC OSCILLATORS (OPO)

ULTRA BROADBAND COMPONENTS FOR AOI = 45°

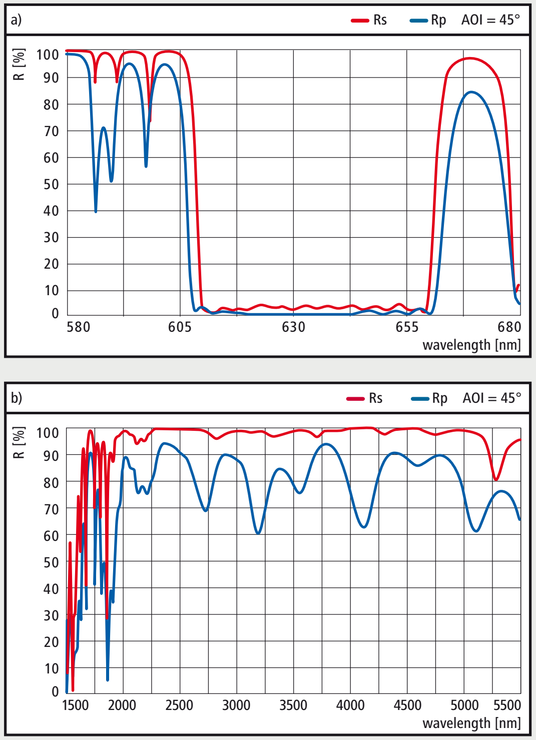


Figure 1: Reflectance spectrum of an ultra broadband beam combiner
HRs (45°, 2000 – 5000 nm) > 98 %
+ Rp (45°, 633 nm) < 2 %

This beam combiner can be used to couple an alignment laser into the beam line. Please note the very low reflectance at 620 – 650 nm.

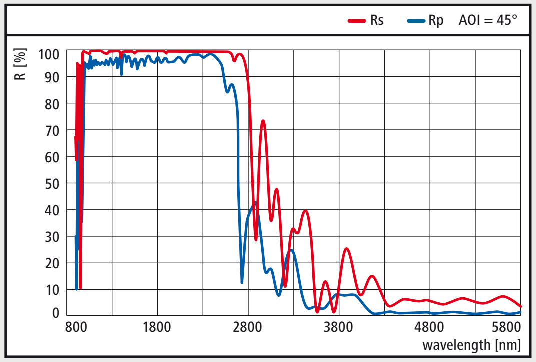


Figure 2: Reflectance spectrum of an ultra broadband separator for signal and idler wavelengths
HRu (45°, 1000 – 2500 nm) > 98 %
+ Ru (45°, 4400 – 5000 nm) < 5 %

EDGE FILTERS FOR AOI = 45°

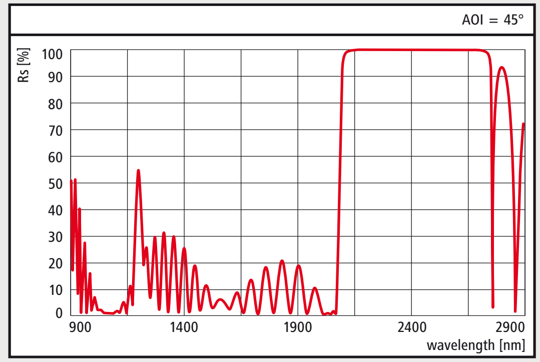


Figure 3: Reflectance spectrum of an edge filter for the idler and signal wavelength range with high transmittance for the pump wavelength:
HRs (45°, 2150 – 2700 nm) > 99.9 %
+ Rs (45°, 2000 – 2070 nm) < 10 % + Rs (45°, 1064 nm) < 1 %

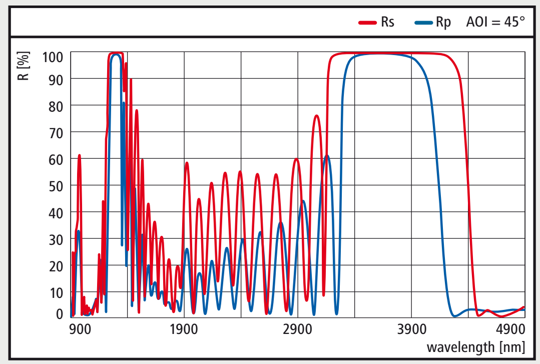


Figure 4: Reflectance spectrum of a broadband edge filter for the idler wavelength range with high transmittance for the pump wavelength:
HRs (45°, 3300 – 4200 nm) > 99.9 %
+ Rs (45°, 4500 – 4900 nm) < 6 % + Rs,p (45°, 1064 nm) < 5 %

SPECIAL MIRRORS AOI = 0°

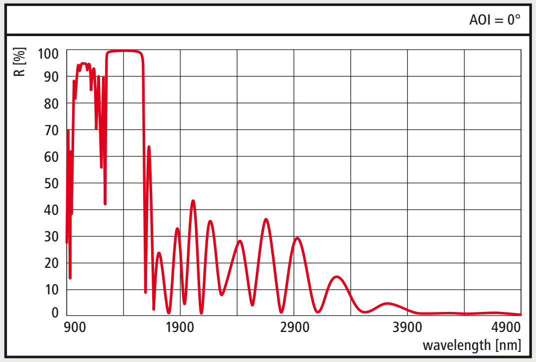


Figure 5: Reflectance spectrum of a special pump mirror:
PR (0°, 1064 nm) = 94 % ± 2 %
+ HR (0°, 1360 – 1460 nm) > 99.9 %
+ R (0°, 4000 – 4900 nm) < 3 %

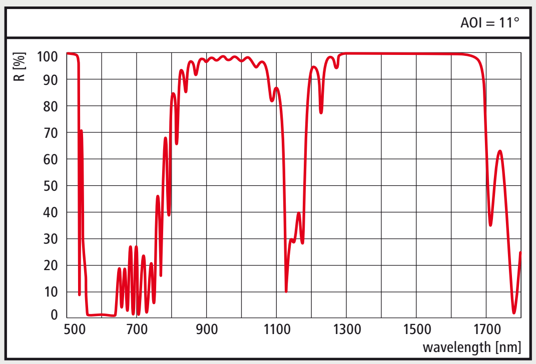


Figure 6: Reflectance spectrum of a special mirror:
R (11°, 565 – 620 nm) < 1 %
+ PR (11°, 900 – 1000 nm) = 98 % ± 0.5 %
+ HR (11°, 1280 – 1600 nm) > 99.9 %

COATINGS ON NONLINEAR OPTICAL CRYSTALS AOI = 0°

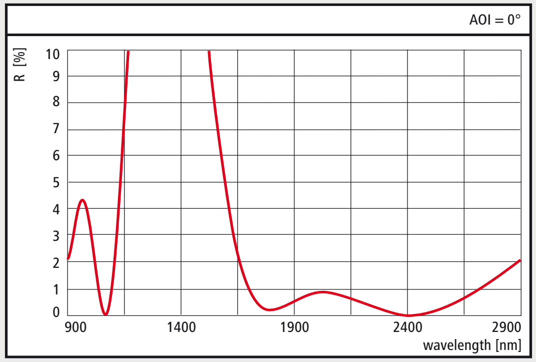


Figure 7: Reflectance spectrum of an AR coating on lithium niobate:
R (0°, 1064 nm) < 0.5 % + R (0°, 1750 – 2750 nm) < 1 %

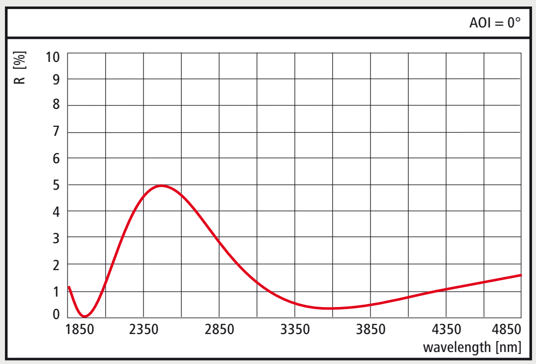


Figure 8: Reflectance spectrum of an AR coating on lithium niobate:
R (0°, 1910 – 2030 nm) < 0.5 %
+ R (0°, 3200 – 4200 nm) < 1 %

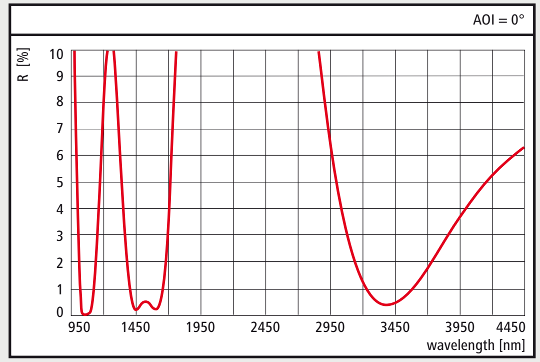


Figure 9: Reflectance spectrum of an AR coating on lithium niobate:
R (0°, 1064 nm) < 0.5 % + R (0°, 1420 – 1640 nm) < 0.5 %
+ R (0°, 3150 – 3700 nm) < 2 %

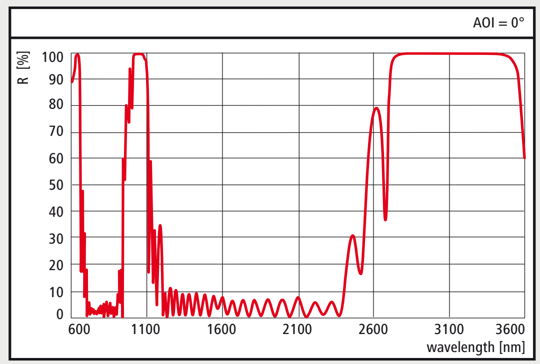


Figure 10: Reflectance spectrum of a double reflector with two regions of high transmittance on lithium niobate
HR (0°, 1010 – 1075 + 2750 – 3450 nm) > 99.8 %
+ R (0°, 700 – 900 + 1200 – 2400 nm) < 10 %

All coatings according to customer specifications.

BROADBAND AND SCANNING MIRRORS

LAYERTEC produces broadband and scanning mirrors according to customer specifications. Full dielectric and metal-dielectric coating designs are available. In the following, examples designed for broad wavelength regions or extremely large ranges of incidence angles are presented.

Broadband mirrors are widely used to reflect light from lasers that emit in a broad wavelength range like for example Ti:Sapphire lasers, dye lasers, or a combination of different diode lasers.
Special mirrors are also available to cover the whole visible spectrum, the near ultraviolet and considerable parts of the near infrared spectral regions. LAYERTEC recommends such mirrors as universal turning mirrors for nearly all types of laser diodes.

Broadband mirrors for the NIR range are especially useful for reflecting idler wavelengths of optical parametric oscillators or for special fs-applications. In combination with fused silica as a substrate material, a large blocking range from 2300 – 6000 nm can be achieved. Other NIR materials such as sapphire and YAG are possible alternatives. These materials can be used for high power applications to improve the cooling of the optics by the thermal conductivity of the substrate. This may be necessary if the absorption of water (around 2.8 µm) or of the coating material itself leads to an increase in temperature.

BROADBAND MIRRORS

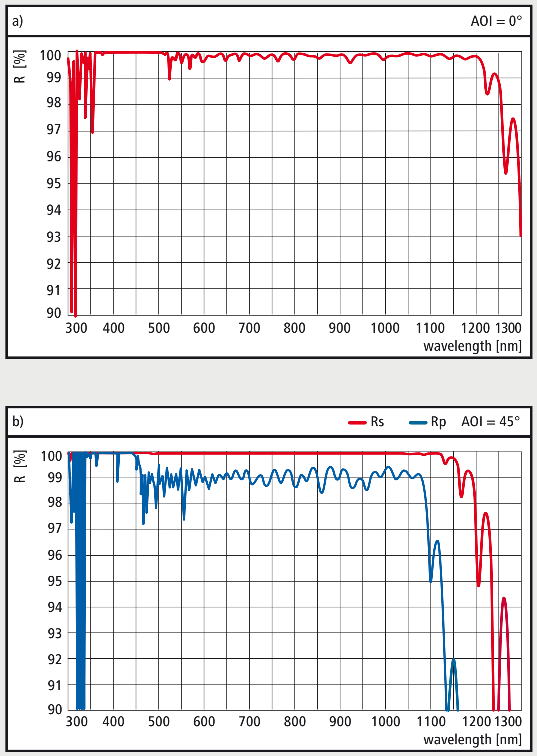


Figure 1: Reflectance spectra of an ultra broadband mirror for the NUV, VIS and NIR
a) R (0°, 360 – 1200 nm) > 99 %
b) Rs (45°, 350 – 1150 nm) > 99 %
+ Rp (45°, 350 – 1050 nm) > 97 %

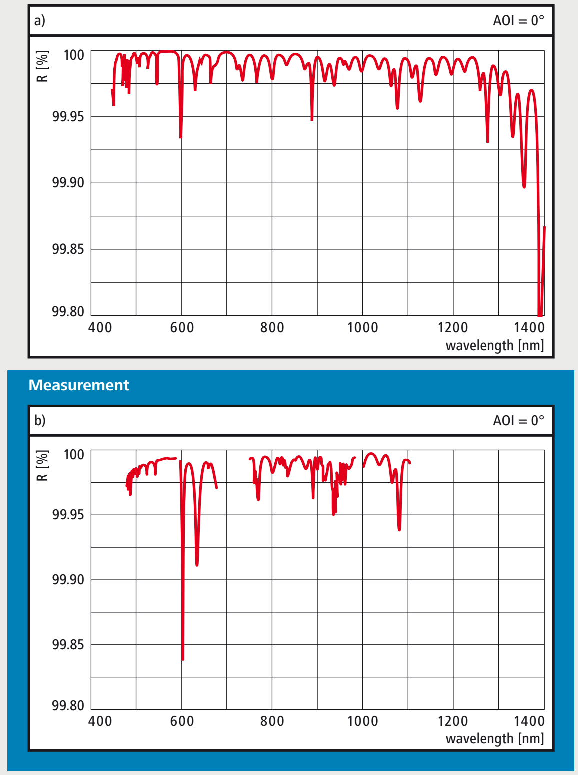


Figure 2: Reflectance spectra of a broadband mirror
HR (0°, 400 – 1400 nm) > 99.9 %
a) Calculated design
b) Broadband CRD measurement

Please note the good agreement between calculation and measurement. The CRD measurements are limited by the water absorption in the 750 – 780 nm and 1200 – 1400 nm regions. For these regions, measurements in vacuum are required.

400 – 1800 nm

SCANNING MIRRORS

LAYERTEC offers scanning mirrors for high power laser applications and for special demands with respect to wavelength and AOI range. Scanning mirrors are optimized for high reflectance for one wavelength or a certain wavelength region at a wide range of angles of incidence. LAYERTEC coating technology provides industrial solutions for light-weight scanning mirrors and special mirrors with uncommon sizes up to 600 mm for research with cw and pulsed high power lasers.

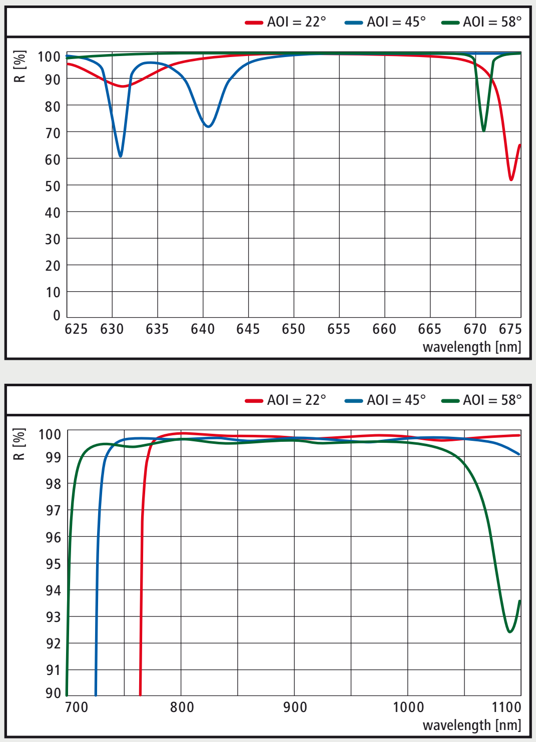


Figure 3: Reflectance spectra of a silver based scanning mirror with enhanced wavelength range for laser diodes in the NIR:
HRu (22° – 58°, 800 – 1000 nm) > 99 %
+ Ru (22° – 58°, 630 – 670 nm) > 50 %

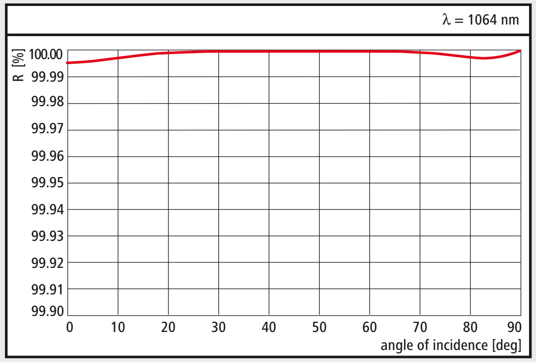
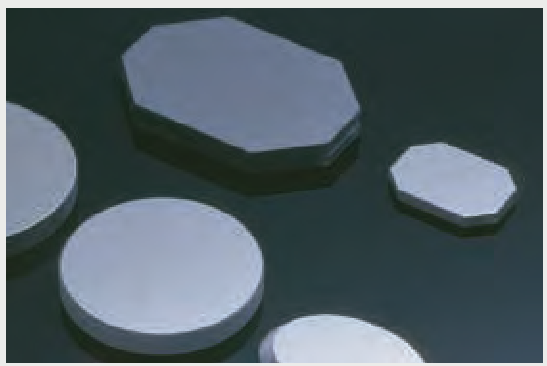


Figure 4: Reflectance vs. AOI of a wide angle scanning mirror for polarized Nd:YAG laser radiation:
HRs (0° – 90°, 1064 nm) > 99.9 %

These mirrors are ideal as scanning mirrors for s-polarized light or to facilitate the production of optical gratings.



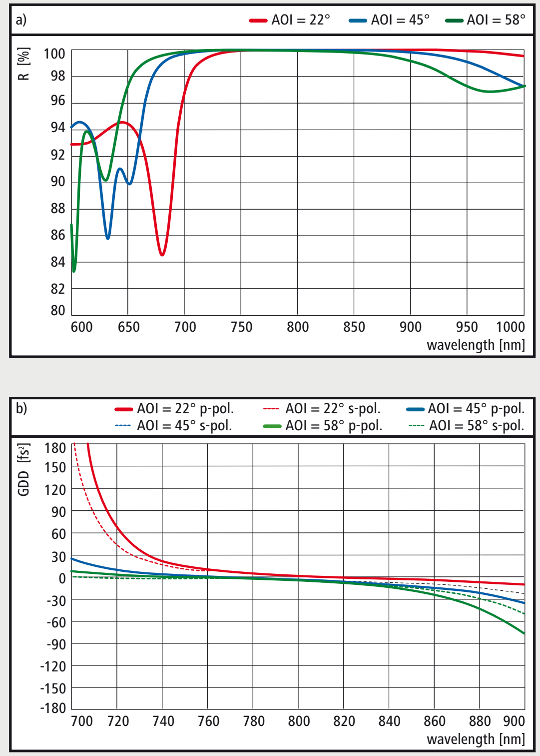


Figure 5: Reflectance and GDD spectra of a scanning mirror for femtosecond laser pulses from a Ti:Sapphire laser:
HRu (22° – 58°, 750 – 850 nm) > 99.5 %,
|GDD-Ru (22° - 58°, 750 - 850 nm)| < 20 fs^2
a) Reflectance vs. wavelength
b) GDD vs. wavelength

The broad low-GDD wavelength range of these mirrors makes it possible to use them in femtosecond laser applications.
For more information or more examples on broadband and scanning mirrors please see pages 50 – 53 (optics for Ti:Sapphire and diode lasers), pages 74 and following (femtosecond laser optics) and, especially for scanning mirrors, page 120 – 121 (silver mirrors).

FILTERS FOR LASER APPLICATIONS

ANGLE ADJUSTMENT OF NARROW BAND FILTERS

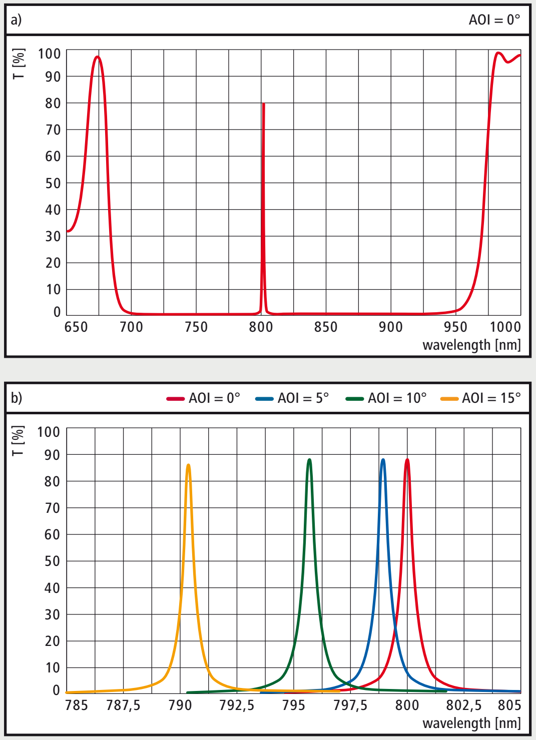


Figure 1: Transmittance spectra of a narrow band filter for ≈ 800 nm
a) Transmittance vs. wavelength, spectral overview
b) Transmittance vs. wavelength at AOI = 0°, 5°, 10° and 15°

- Narrow band filters with FWHM of 1 nm and maximum transmittance of T > 80 %.
- An FWHM of 50 pm with maximum transmittance of T = 50 % has been demonstrated.
- Blocking: T < 0.1 %, block band: ≈ 200 nm in the Ti:Sapphire range.
- These filters are useful to select one wavelength from the spectrum of the Ti:Sapphire laser.

VARIABLE FILTERS FOR LASER APPLICATIONS

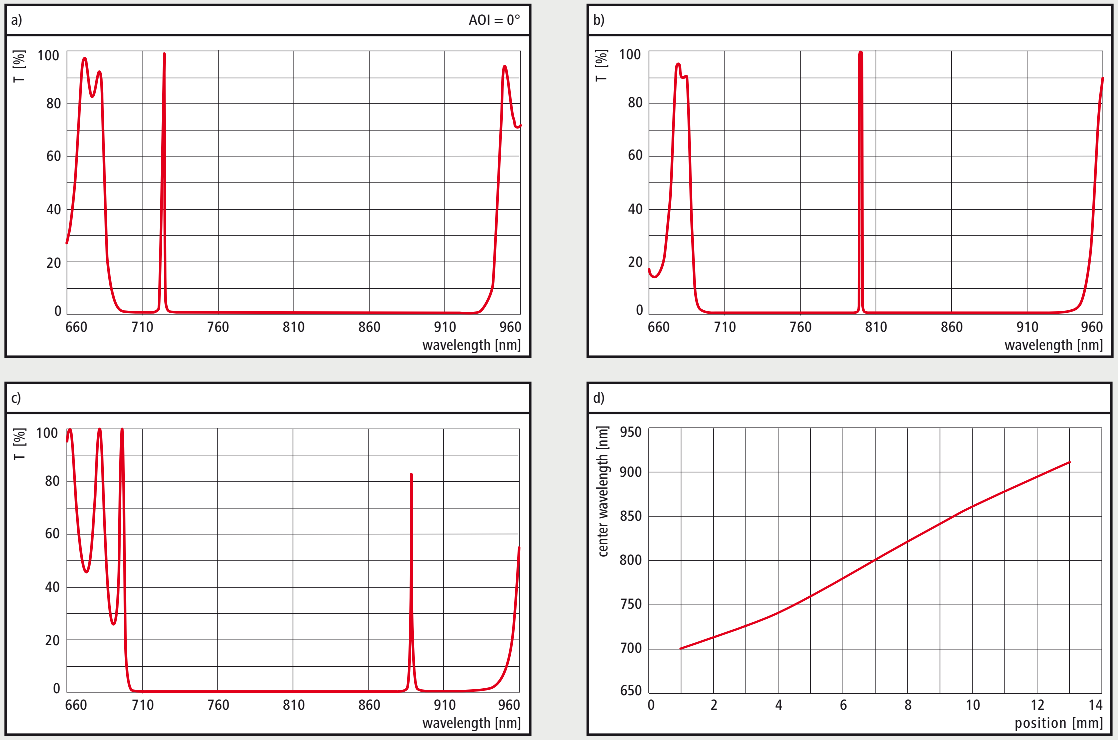


Figure 2: Transmittance spectra of a laterally variable filter for the wavelength range of the Ti:Sapphire laser taken
a) on the short wavelength side
b) in the center
c) on the long wavelength side of the filter
d) Center wavelength vs. position on the filter

Special features:

- Linear variation of the filter wavelength with respect to the lateral position on the filter.
- Similar designs for the VIS range (400 – 700 nm) and for the NIR range (up to 1800 nm).
- Blocking: T < 0.1 %; block band: ≈ 200 nm in the Ti:Sapphire range.
- Maximum transmittance: 90 %; FWHM: 1 nm.
- Shape: rectangular; size: 10 – 20 mm long, 5 – 10 mm wide.
- Spectral tolerance ± 1 % of center wavelength. The spectral position of the transmittance band may vary by ± 1 % between coating runs while the bandwidth remains unchanged. The spectral performance of the filter can be optimized by tilting the filter. Tilting results in a shift of the transmittance band towards shorter wavelengths. Thus, the spectral position of a filter, with the transmittance band at longer wavelengths than required, can be tuned to its best performance by angle adjustment.
- If angle adjustment is possible, the specifications for the filter can be less stringent which increases output and reduces price.

260 – 2500 nm

STEEP EDGE FILTERS

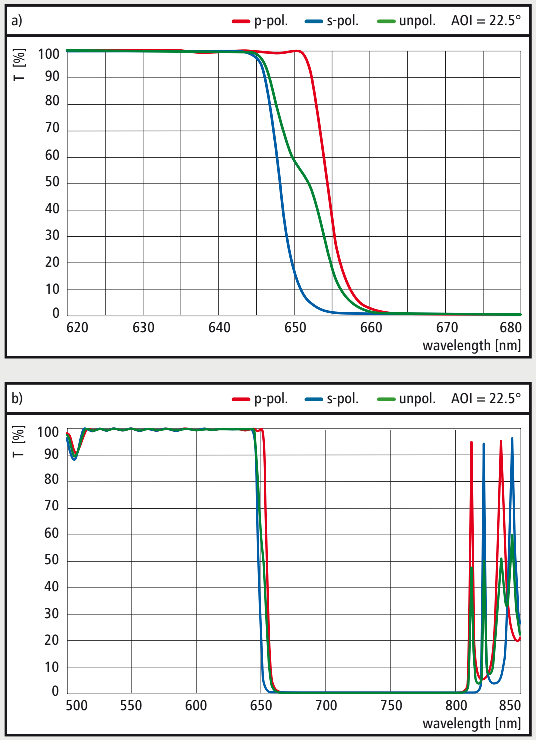


Figure 3: Transmittance spectra of a steep edge short-wavelength pass filter for use as a combiner for laser diodes at 635 nm and 670 nm
HRu (22.5°, 670 nm) > 99.9 %
+ Ru (22.5°, 635 nm) < 2 %, back side AR coated)
a) Section around the edge of the blocking band
b) Spectral overview

For more information on **combiners for diode lasers** see page 53.
For steep edge filters used as **pump mirrors** for solid-state lasers based on Yb-doped materials (e.g. Yb:YAG, Yb:KGW, Yb-doped fibers) see page 54.

NARROW BAND REFLECTANCE FILTERS

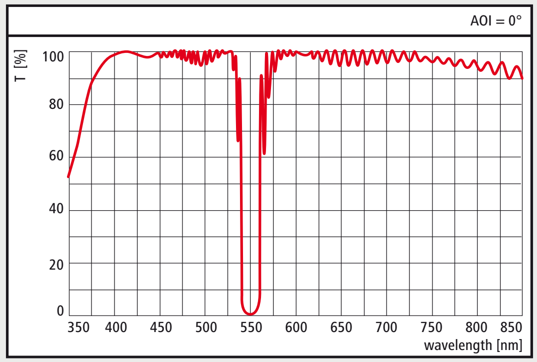


Figure 4: Transmittance spectrum of a narrowband reflectance filter for 550 nm

Filters of this type are ideal for the blocking of a single laser line while preserving a high and relatively constant transmittance over the whole visible range.

Special features:

- Spectral width of the reflectance band: 3 % (e.g. T < 1 % from 543 – 559 nm).
- T < 0.1 % at the center wavelength.
- T > 90 % throughout the visible spectral range.
- Filters for laser applications require excellent spectral quality and high damage thresholds.
- Spectral position of cut-on/cut-off wavelengths or reflectance bands according to customer specification.
- Sizes and shapes:
  Edge filters can be produced on round or rectangular substrates up to diameters of 38.1 mm (1.5 inch). The production of miniature size filters (e.g. 3 x 3 mm^2) is possible. Narrow band reflectance filters are limited to diameters of 25.4 mm (1 inch).
- Optical parameters are environmentally stable.

DUAL WAVELENGTH FILTER WITH BROAD BLOCKING RANGE

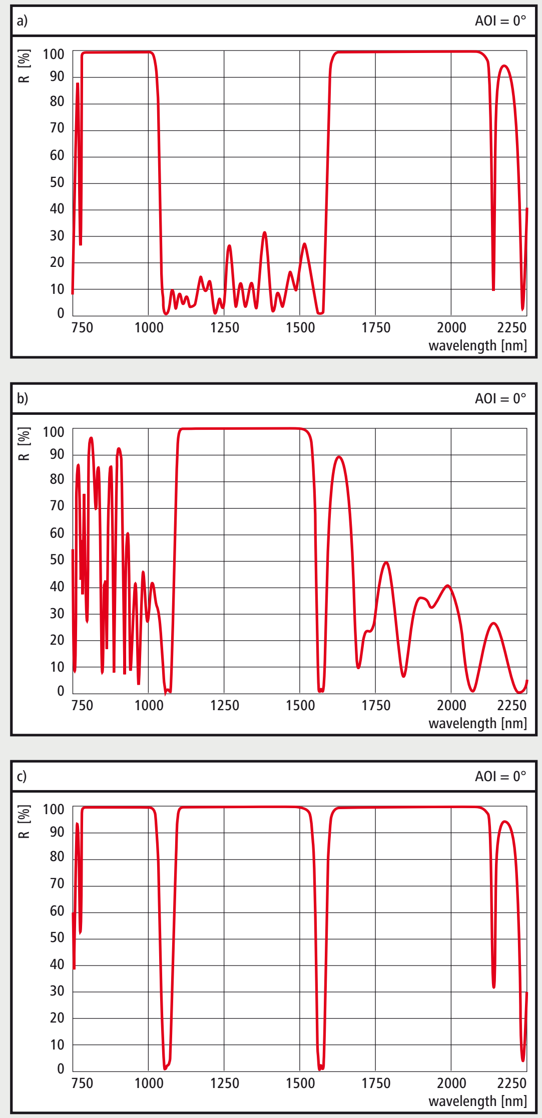


Figure 5: Reflectance spectra of a dual wavelength filter for 1064 nm and 1570 nm with a broadband blocking range from the UV to 2100 nm:
a) Front side coating
b) Back side coating
c) Sum
Double side coating reduces the mechanical stress. Blocking in the UV/VIS is done by a color glass.

THIN FILM POLARIZERS

TECHNICAL TERMS

In order to answer frequently asked questions and to help LAYERTEC customers to specify thin film polarizers, definitions of the most important technical terms are given here.
Light is a transversal wave; the vector of the electric field oscillates perpendicular with respect to the propagation direction of the light. Natural light (from the sun or from a lamp) is mostly "unpolarized". This means that the oscillation planes of the electric field vectors of the single light waves are randomly distributed, but always transversal with respect to the direction of propagation. In contrast, the term "linearly polarized light" signifies that there is only one plane of oscillation.
There are different optics which can polarize light. An example of this would be crystal polarizers which split light into an unpolarized "ordinary beam" and a polarized "extraordinary beam" or thin film polarizers.

To explain the meaning of the terms "s-polarization" and "p-polarization", first a reference plane must be determined (see fig.1). This plane is spanned by the incident beam and by the surface normal of the mirror (or polarizer). "**S-polarized light**" is the part of the light which oscillates perpendicularly to this reference plane ("**s**" comes from the German word "senkrecht" = perpendicular). "**P-polarized light**" is the part which oscillates **p**arallel to the reference plane. Light waves with a plane of oscillation inclined to these directions can be described as having a p-polarized and an s-polarized part.
The upper part of fig. 1 shows the reflectance of an uncoated glass surface vs. AOI for s- and p-polarized light. The reflectance for s-polarized light increases with rising angle of incidence. In contrast, the reflectance of p-polarized light decreases until reaching R = 0 at the "Brewster angle", then increases for angles of incidence beyond the Brewster angle. In principle, the same is true for dielectric mirrors. Thin film polarizers separate the s-polarized component of the light from the p-polarized component using the effect that s-polarized light posseses a higher reflectance and broader reflection band than p-polarized light. There always is a wavelength range, where Rs is close to 100 % while Rp is close to zero. Special coating designs are used to make this wavelength range as broad as possible and to maximize the polarization ratio Tp/Ts. Very high values of Tp (> 99.5 %) can be measured very precisely using a special Cavity Ring-Down setup. The TFP is inserted into a cavity thus introducing additional losses equal to 100%-Tp. Utilizing this method, the most beneficial AOI for each TFP can be determined.
Thin film polarizers (TFPs) are key components in a wide variety of applications, e.g. in regenerative amplifiers. LAYERTEC produces thin film polarizers on plane substrates (dimensions according to customer specifications) for wavelengths between 260 nm and 2500 nm. All TFPs are optimized for high laser-induced damage thresholds. Although there are no certified measurements available, LAYERTEC has learned from several customers that the LIDT of a TFP is approximately one third of the LIDT of a highly reflecting mirror for the same wavelength coated using the same technology.

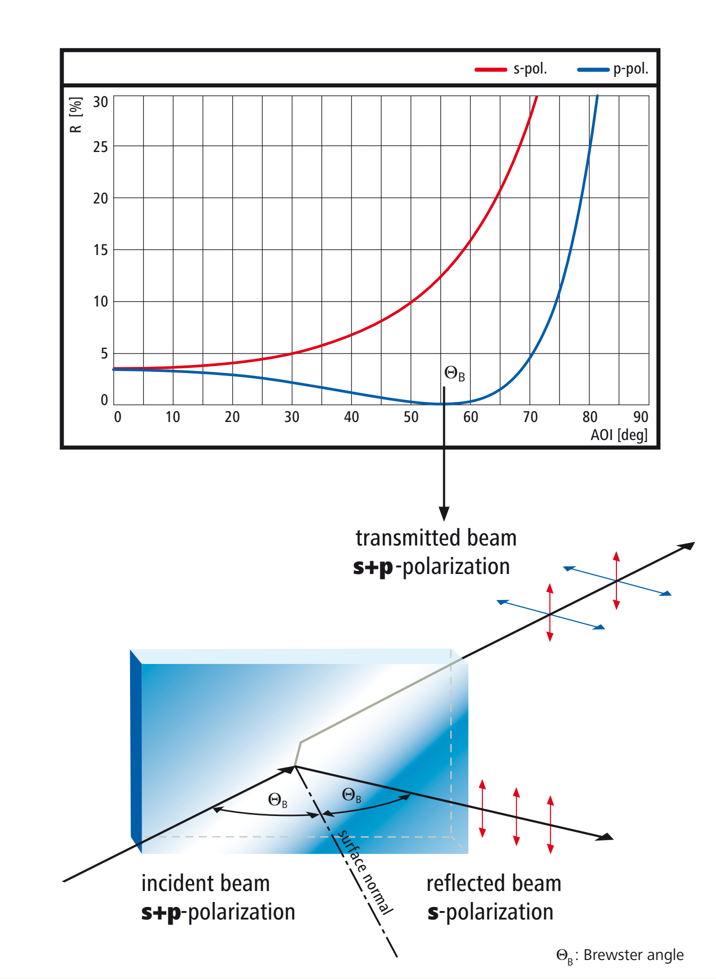


Figure 1: Explanation of the terms "s-polarized light" and "p-polarized light" and reflectance of an uncoated glass surface vs. angle of incidence for s- and p-polarized light

STANDARD THIN FILM POLARIZERS

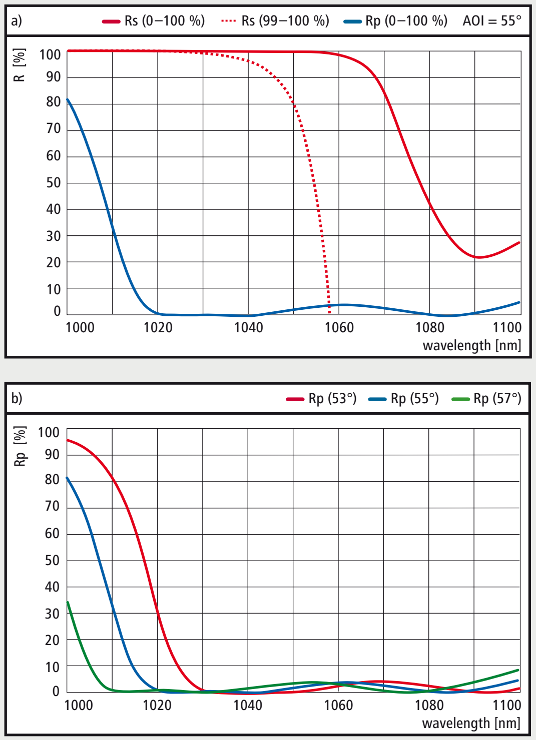
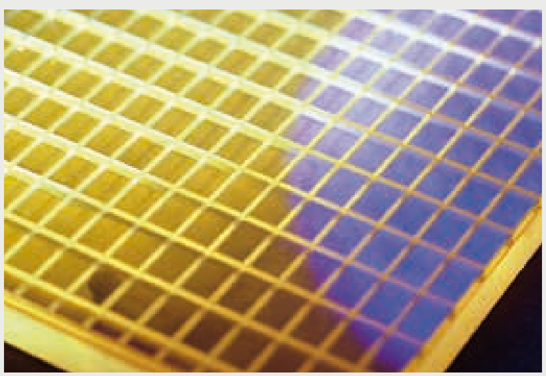


Figure 2: a) Reflectance spectra of a standard TFP for 1030 nm at AOI = 55° (Brewster angle) for s- and p-polarized light
b) Reflectance spectra of the same TFP design for AOI = 53°, 55° and 57° for p-polarized light (angle adjustment decreases Rp at 1030 nm from 0.25 % to < 0.1 % thus giving the option to optimize the polarization ratio)

- TFPs can be produced for AOI > 40°. Please note that thin film polarizers working at the Brewster angle exhibit a considerably broader bandwidth and a higher Tp / Ts ratio than those working at AOI = 45°.
- Typical polarization ratios Tp / Ts: standard: > 500 (AOI = 45° or 55°).
- An extended wavelength range with a limited polarization ratio can be obtained by choosing AOI beyond the Brewster angle.
- Special designs with a polarization ratio of Tp / Ts up to 10000 are possible.
- High laser-induced damage thresholds (useful for intracavity applications).
- It is beneficial to design the laser in a way that the polarizers can be tilted by ± 2° to adjust the polarizer to its best performance.
- The standard design can be used for wavelengths between 260 nm and 2500 nm.



SPECIAL THIN FILM POLARIZERS

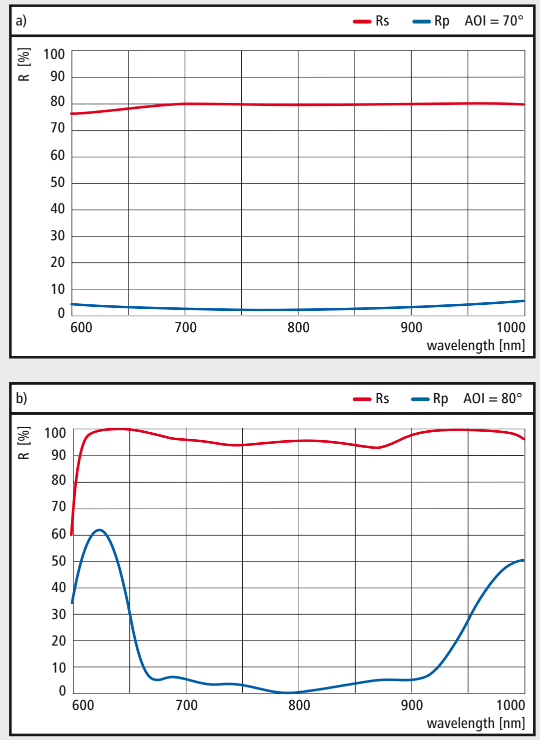


Figure 3: Broadband TFPs for the wavelength range of the Ti:Sapphire laser with different bandwidths and different polarization ratios, working at AOI = 70° and AOI = 80°
a) Rp and Rs vs. wavelength, TFP designed for AOI = 70°
b) Rp and Rs vs. wavelength, TFP designed for AOI = 80°

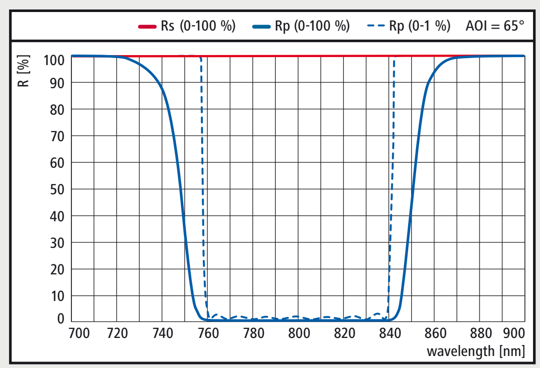


Figure 4: Broadband TFP for the 800 nm region

This special design provides an extremely broad polarizing wavelength range (≈ 10 % of the center wavelength) with Tp / Ts = 300 … 1000.

LOW LOSS OPTICAL COMPONENTS

HR MIRRORS

- **R > 99.99 %** in the VIS and NIR spectral range
- **R > 99.999 %** was demonstrated at several wavelengths between 1000 – 1600 nm.
- Mirrors with defined transmittance (e.g. T = 0.002 %).
- For Cavity Ring-Down time spectroscopy, it is favorable to adjust the transmittance to the value of the scattering and absorption losses (T = S + A), see fig.1.
- All mirrors for CRD experiments are delivered with back side AR coating. Wedged substrates on request.
- Plane and spherically curved fused silica substrates).
- Premium polish, rms-roughness: ≤ 1.5 Å (see page 15).
- Surface quality: 5 / 1 x 0.010 (ISO 10110) for Ø 25 mm.
- Coating technique: magnetron sputtering, ion beam sputtering.
- Optical parameters are stable against changes in temperature and humidity.
- Attractive prices for small and medium numbers of substrates per coating run.
- Very high reflectance values for complex coating designs, e.g. GTI laser mirrors with R > 99.95 %. (see pages 96 – 97)
- Vacuum packaging or packaging under nitrogen cover gas in dust free boxes.

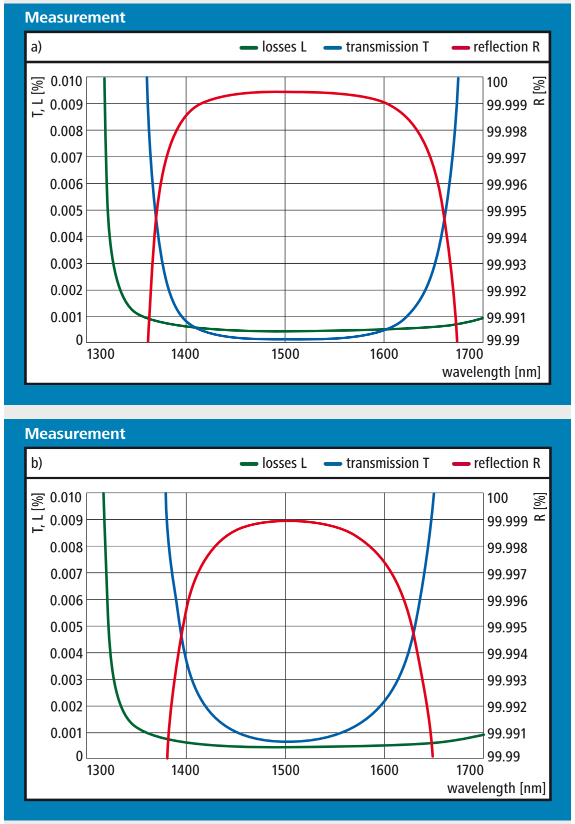


Figure 1: Reflectance, transmittance and loss spectra of low loss mirrors for 1550 nm
a) Optimized for highest reflectance (transmittance ~ 0)
b) Designed for T ≈ S + A

Please note that the reflectance of the mirrors in fig.1a and 1b is nearly the same. However, the extremely low transmittance of the mirror in figure 1a makes CRD measurements very difficult.

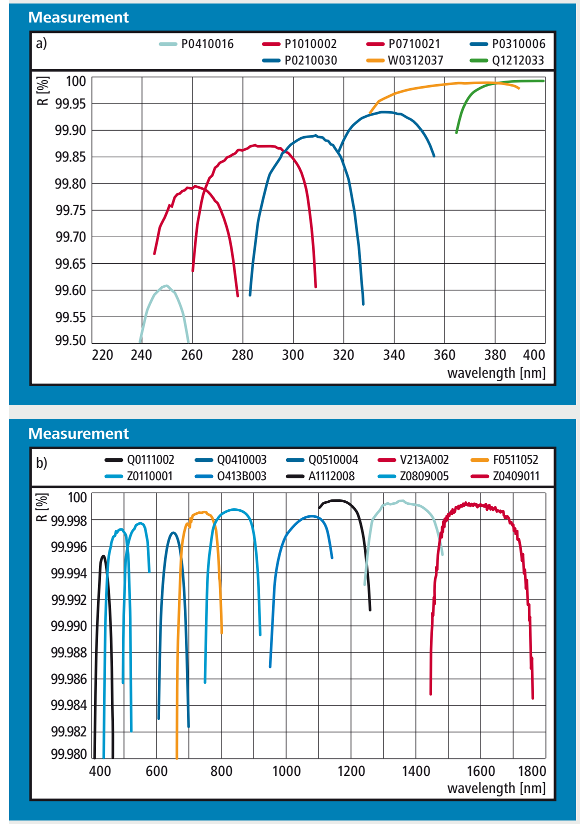


Figure 2: a) Reflectance spectra of a variety of low loss mirrors for the UV
b) Reflectance spectra of a variety of low loss mirrors for the VIS-NIR spectral range
All measurements were performed at the CRD setup which is described on pages 33 – 35. Please note that these mirrors are specially designed for relatively high transmittance.

340 – 3000 nm

DIRECT MEASUREMENTS OF OPTICAL LOSSES

Type of losses	VIS	NIR
Scattering	Typical: 20 – 30 ppm Measured: 15 ppm @ 633 nm*, 20 – 30 ppm @ 532 nm**	< 10 ppm
Absorption	10 – 20 ppm***	< 10 ppm***
Total	< 50 ppm	< 20 ppm

* Measurement performed at Jenoptik L.O.S. GmbH, Jena
** Measurement performed at Fraunhofer Institute IOF Jena
*** Measurement performed at Leibniz-Institute of Photonic Technology (IPHT) e.V. Jena

CAVITY RING-DOWN TIME MEASUREMENTS AND REFERENCE DATA

Wavelength	R_{max} [%]	T [%]	Loss [ppm] L = 1 - R - T	Measured at
248 nm	99.87	0.00024	1300	LAYERTEC GmbH
266 nm	99.941	0.0031	560	LAYERTEC GmbH
355 nm	99.988	0.0004	116	LAYERTEC GmbH
400 nm	99.9954	—	—	LAYERTEC GmbH
550 nm	99.9977	0.00039	19	LAYERTEC GmbH
633 nm	99.992	0.006	20	Westsächsische Technische Hochschule Zwickau, Germany
660 nm	99.992	0.006	20	Universität Heidelberg, Germany
798 nm	99.995	0.003	10	LAYERTEC GmbH
840 nm	99.9988	0.0002	10	LAYERTEC GmbH
1030 nm	99.9980	0.0012	8	LAYERTEC GmbH
1150 nm	99.9994	0.00035	2.5	LAYERTEC GmbH
1392 nm	99.9985	0.0007	8	TIGER OPTICS, USA (R measurement) LAYERTEC GmbH (T measurement)
1550 nm	99.999	0.0002	8	IPHT Jena, Germany
2350 nm	99.995	0.002	30	University of Grenoble, France
3250 nm	99.928	0.012	600	University of Grenoble, France
4000 nm	99.9	—	—	Universität Bielefeld, Germany

Table 1: Reflectance and transmittance values of LAYERTEC low loss mirrors; Reflectance measured by Cavity Ring-Down spectroscopy, AOI = 0°

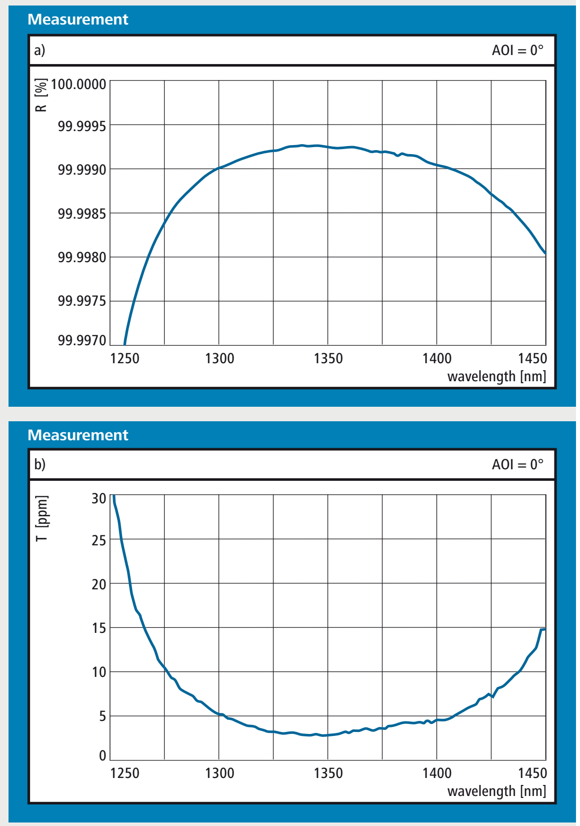


Figure 3: Measured reflectance and transmittance spectrum of a low loss mirror for the wavelength range 1250 – 1450 nm
a) Reflectance vs. wavelength
b) Transmittance vs. wavelength

COATINGS ON CRYSTAL OPTICS

Laser applications using crystal optics have reached a high standard in industry and research. Optical coatings on crystals are an essential part of modern laser designs. They cover a wide range from single wavelength AR coatings on laser and nonlinear optical crystals up to complex multilayer coatings providing several high-reflectance and high-transmittance wavelength ranges and thus, replacing external laser mirrors.

LAYERTEC has a lot of experience in coating laser crystals. LAYERTEC coatings are used in industrial high power Q-switched and cw lasers of several laser manufacturers. The quality of coatings on crystals depends on the coating technique as well as on the surface quality of the crystal. All coatings are produced using sputtering techniques which guarantee very low scattering losses and high environmental stability of the optical parameters.

The rapid progress in crystal growth techniques resulted in a wide variety of new crystals for laser applications, e.g. laser crystals like tungstanates and vanadates or nonlinear optical crystals like RTP. Each crystal type requires optimized polishing procedures and coating techniques. The coating design is determined by the optical properties of the crystal. However, the thermal expansion coefficients and the surface quality after storage and transport influence the coating quality as well. Especially, hygroscopic crystals like LBO or BBO require special pretreatments to achieve high damage thresholds and long lifetime for the coatings. Thus, coatings on new crystals always require experimental investigations to find the best coating procedures. Different dimensions and uncommon sizes and shapes are possible using the special LAYERTEC coating technology.

The following table gives an overview about the crystals which have already been coated at LAYERTEC and the types of layer systems which have been applied successfully.

EXAMPLES OF AVAILABLE COATINGS ON CRYSTALS

Crystal Type	AR/BBAR	Single HR optional with HT	Double HR/BBHR optional with HT
α-SiO_2 (Quartz)	x	x	x
BBO	x	-	-
BiBO	x	x	
$CaCO_3$	x		
CTA	x		
Nd:$GdVO_4$	x	x	x
Nd:GGG	x	x	
Nd:Cr:GSGG	x	x	
KTA	x	x	
KTP	x	x	x
Yb:KGW, Yb:KYW	x	x	x
LBO	x	-	-
$LiNbO_3$	x	x	
LMA	x		
Nd:LSB	x	x	x
RDP	x		
Ruby	x	x	x
Ti:Sapphire	x	x	x
Spinell	x	x	x
Cr:YAG	x	x	x
Er:YAG	x	x	x
Ho:YAG	x	x	x
Nd:YAG, Yb:YAG	x	x	x
Nd:YALO (YAP)	x		
YLF	x		
Nd:YVO_4	x	x	x
ZGP	x		
ZnSe	x	x	

x established coating process
- not possible due to technical reasons
empty box not requested yet

Detailed measurement reports are available for each batch. Do not hesitate to contact LAYERTEC for a discussion or a quotation regarding your special coating project.

340 – 3000 nm

COATINGS ON DOPED LASER CRYSTALS

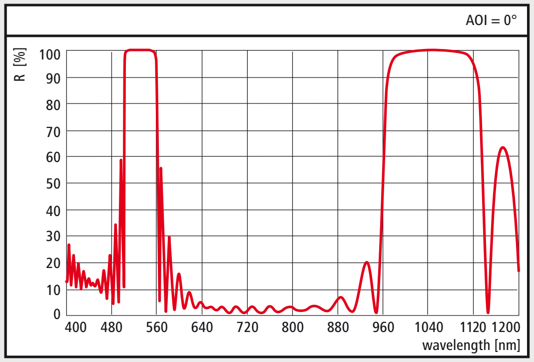


Figure 1: Reflectance spectrum of a dual HR mirror with a HT region for pumping with a laser diode (on Nd:YAG):
HR (0°, 532 nm + 1064 nm) > 99.9 % + R (0°, 808 nm) < 5 %

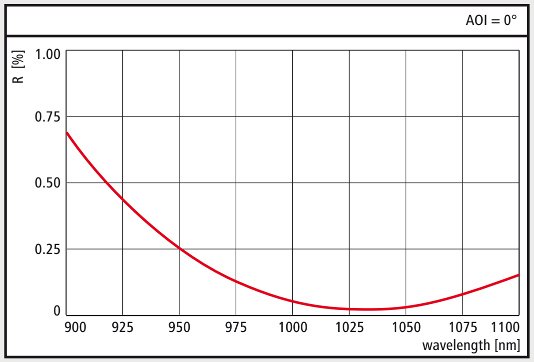


Figure 2: Reflectance spectrum of an AR coating for an Yb:KYW crystal:
AR (0°, 1030 nm) < 0.2 % + AR (0° - 30°, 980 nm) < 0.2 %.
Please note the large acceptance angle for the pump radiation

Sputtered coatings on laser rods, discs and slabs with:

- High laser-induced damage thresholds for critical industrial applications of Q-switched and cw lasers.
- Low residual reflectance.
- Broadband and multiple wavelength AR coatings.
- Complex HR and HR / HT-coatings for compact laser designs, e.g.
  HR (0°, 532 nm + 1064 nm) > 99.9 %
  + R (0°, 808 nm) < 5 %,
  on Nd:YVO_4 for diode-pumped and frequency-doubled "green" lasers).

COATINGS ON NONLINEAR OPTICAL CRYSTALS

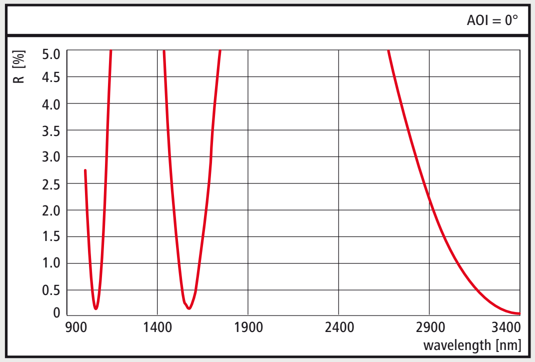


Figure 3: Reflectance spectrum of a triple wavelength AR coating on KTP:
AR (0°, 1064 nm + 1575 nm + 3400 nm) < 0.5 %

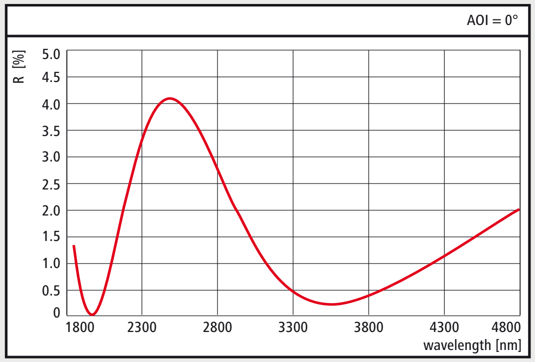


Figure 4: Reflectance spectrum of an AR coating for PPSLT:
AR (0°, 2000 nm) < 0.2 % + AR (0°, 3400 – 4400 nm) < 1.5 %

- Coating of crystals with variable or special sizes and shapes.
- Coating of the full aperture of small crystals.

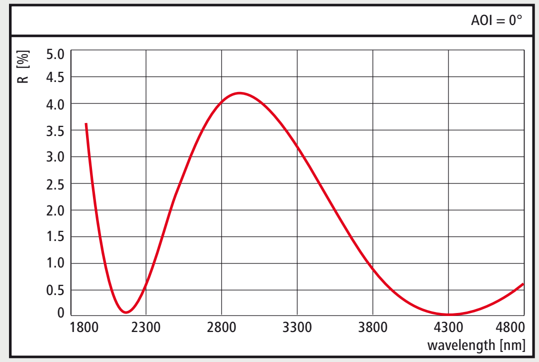


Figure 5: Reflectance spectrum of a dual wavelength AR coating on ZGP:
AR (0°, 2050 nm) < 1 % + AR (0°, 4300 nm) < 0.2 %

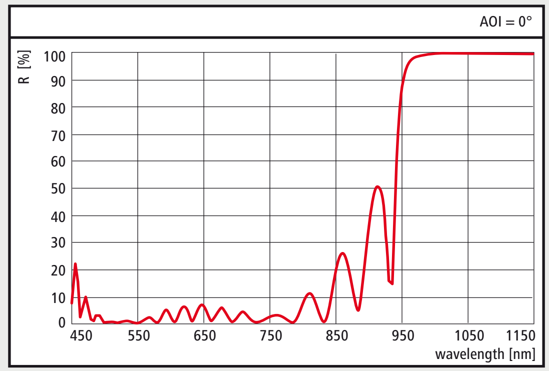


Figure 6: Reflectance spectrum of a dichroic mirror on KTP:
R (0°, 532 nm) < 1 % + HR (0°, 1064 nm) > 99.95 %

- Broadband and multiple wavelength AR coatings.
- Complex HR and HR / HT-coatings for compact laser designs, e.g.
  HR (0°, 1064 nm) > 99.9 % + R (0°, 532 nm) < 5 %, on KTP for frequency-doubled Nd:YAG or Nd:YVO_4 lasers.
- Coating for crystals with variable or special sizes and shapes.
- Coating of the full aperture for small crystals.

CLEANING OF OPTICAL SURFACES

1

Prerequisites:

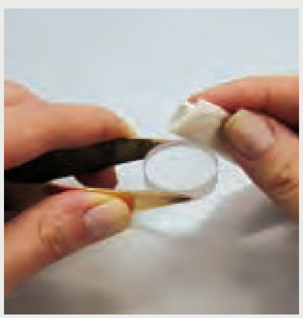
- An air blower
- Optical cleaning tissue (e.g. Whatman®)
- Nonslip tweezers (e.g. with cork)
- Spectroscopy grade acetone*


2

Pre-cleaning:

- Clean hands with soap or use clean gloves (latex, nitrile)
- Blow off dust from all sides of the sample (2)
- Moisten tissue with acetone (3)
- Remove coarse dirt from the edge and the chamfer (4)


3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* Compared to alcohol acetone is the better solvent as it significantly reduces the formation of streaks


5

Preparation of the cleaning tissue:

- Fold a new tissue along the long side several times (5, 6)
- Fold across until you have a round edge (7)
- Grab the tissue as shown in (8)


6

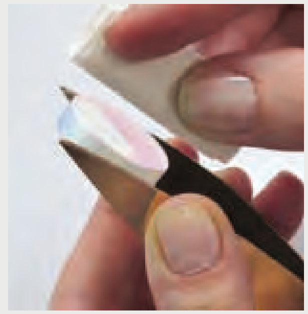

7


8


9

Cleaning of the optical surface:

- Moisten the tissue with acetone (9)
- A wet tissue will result in streaks
- Hold the sample with tweezers (10)
- Slide the curved tissue from one edge of the sample to the other **once** (10 … 12)
- The tissue may be turned inside out and used again once
- Repeat steps 9 … 12 with a new tissue until the sample is clean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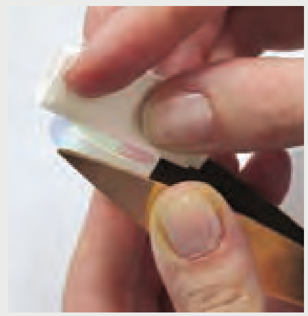
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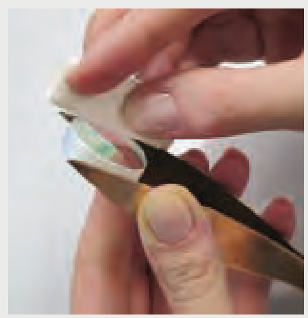

12

HINTS

13

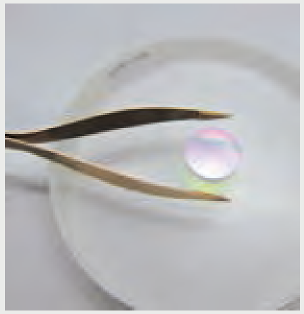
Small samples:

- Put sample onto a concave polished glass support to pick it up easily (13)
- Use special tweezers

14

Fingerprints on sputtered coatings (14):

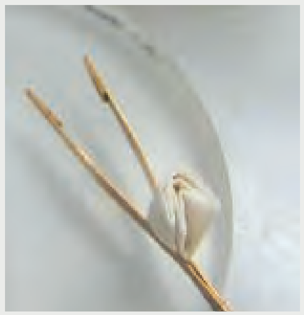
- Moisten the surface by breathing upon it
- Slide (acetone) moistened tissue over the surface as long as the water film is visible
- Exception: Never do this with hygroscopic materials (CaF_2 …)



15

Storage:

- It works best to store the samples on a polished curved glass support (15)
- Clean the support like an optical surface before use

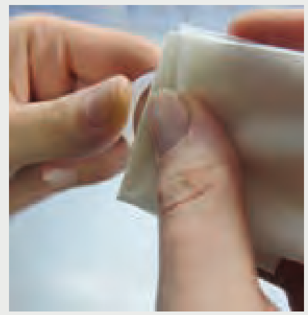


16

Holding the tissue:

- Use the tweezers to hold the moistened tissue (16)

17



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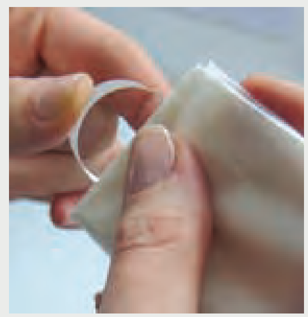

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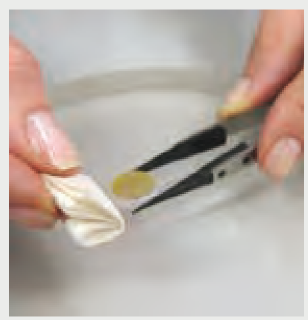
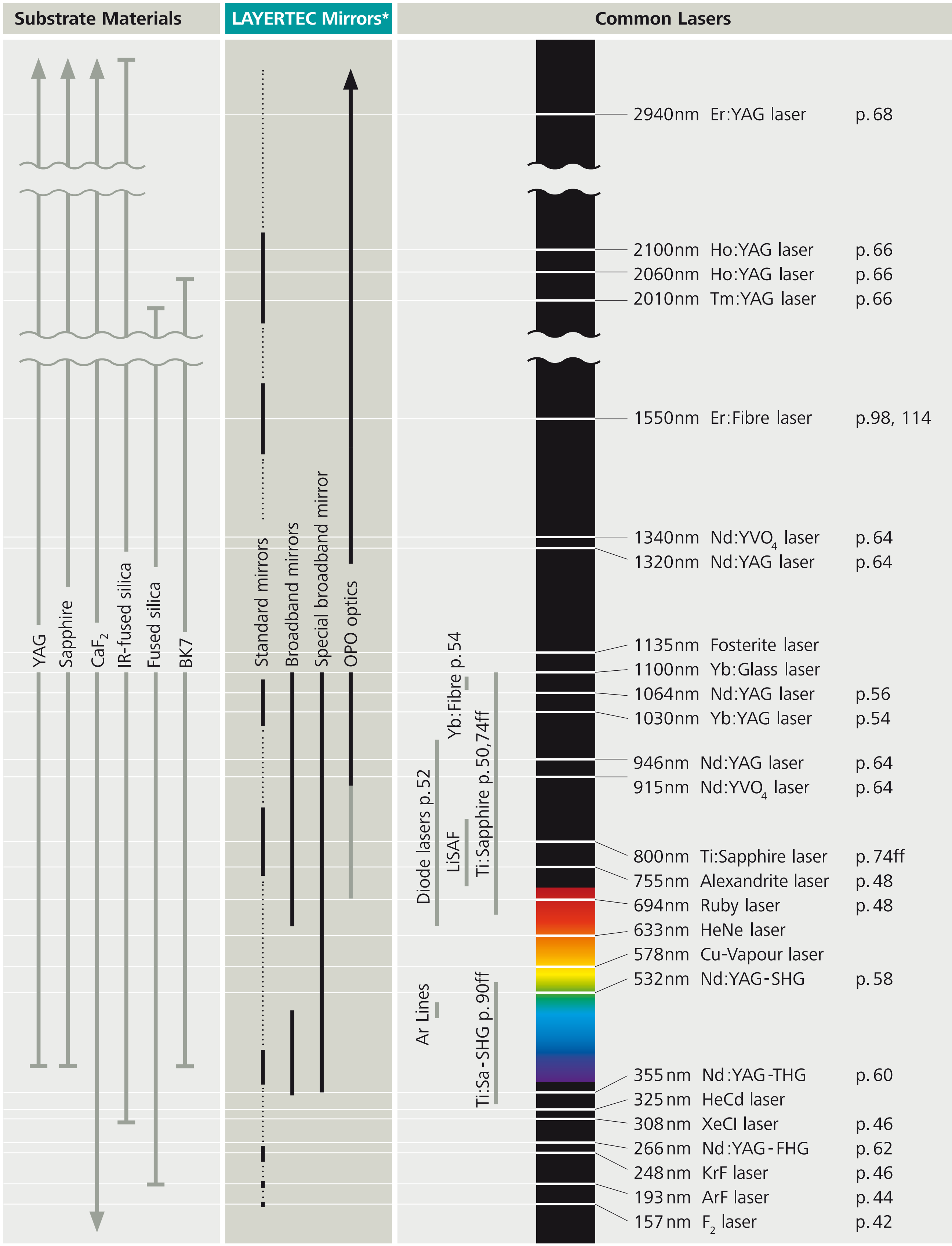


20

Cleaning of concave surfaces:

- Use a less often folded tissue that can be slidely bent (17)
- Clean analog to (9) … (12)
- Use your thumb to gently press the tissue onto the curved surface (18, 19)
- Use tissue only one time
- A concave support helps holding the sample (20)

REGISTER



*Bandwidths of selected LAYERTEC mirrors