CATALOG 2011

LAYERTEC®
OPTICAL COATINGS · OPTICS

CONTENTS

COMPONENTS FOR F_2 LASERS

MIRRORS, OUTPUT COUPLERS AND LENSES

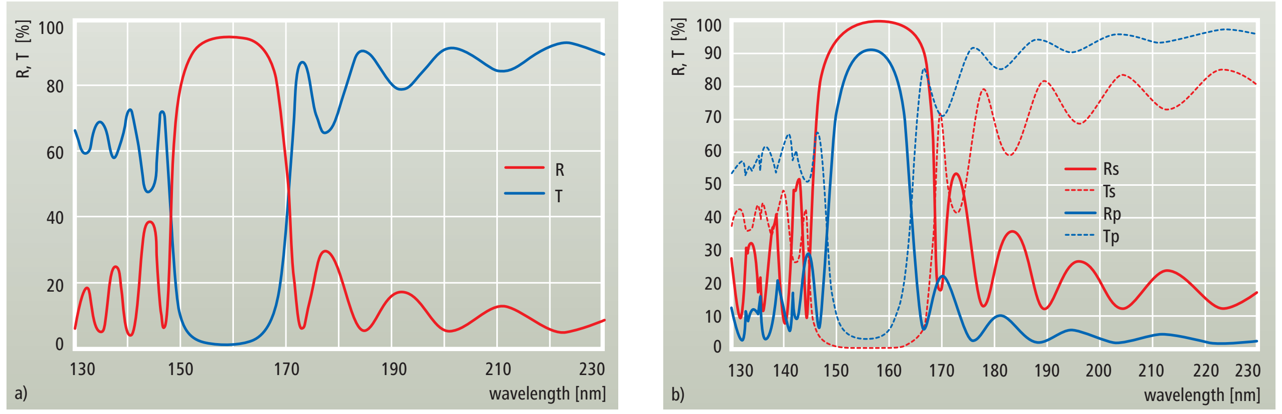


Figure 1: Measured reflectance and transmittance spectra of a laser mirror (AOI = 0°, a) and a turning mirror (AOI = 45°, b) for 157nm

- Laser mirrors: R = 92 … 95% at AOI = 0°
- Turning mirrors (AOI = 45°): R_s > 97%, R_p > 90%, R_r > 92%
- High quality mirror substrates, windows and lenses of CaF_2 (157nm excimer grade quality, HELLMA Materials GmbH)
- PR coatings with tolerances of ±2% for R = 10 ... 30%, ±3% for R = 30 ... 75% and ±2% for R = 75 ... 90%
- Development and production of customer specific components as beamsplitters and variable attenuators on request

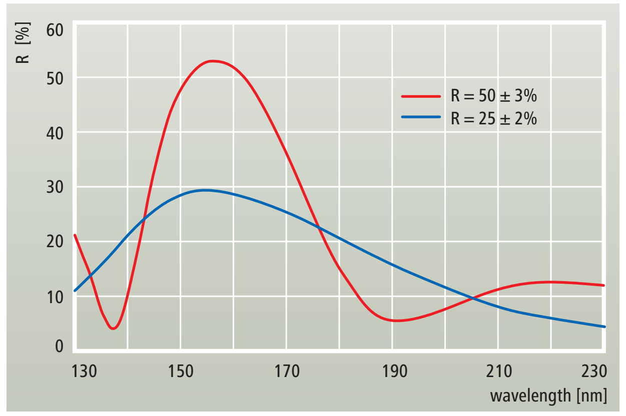


Figure 2: Measured reflectance spectra of standard output couplers with R = 50 ± 3% and R = 25 ± 2% (rear side uncoated)

VARIABLE ATTENUATORS

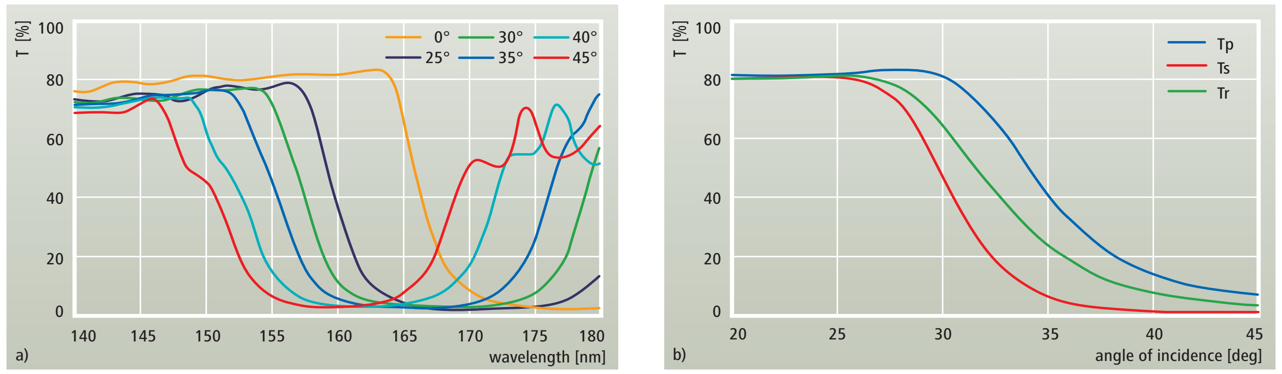


Figure 3: Measured transmittance spectra of a variable attenuator at different AOI (a) and transmittance vs. AOI (b); the transmittance varies from T > 75% at AOI = 0° to T < 5% at AOI = 45°

157 nm

ALUMINUM MIRRORS FOR F_2 LASERS

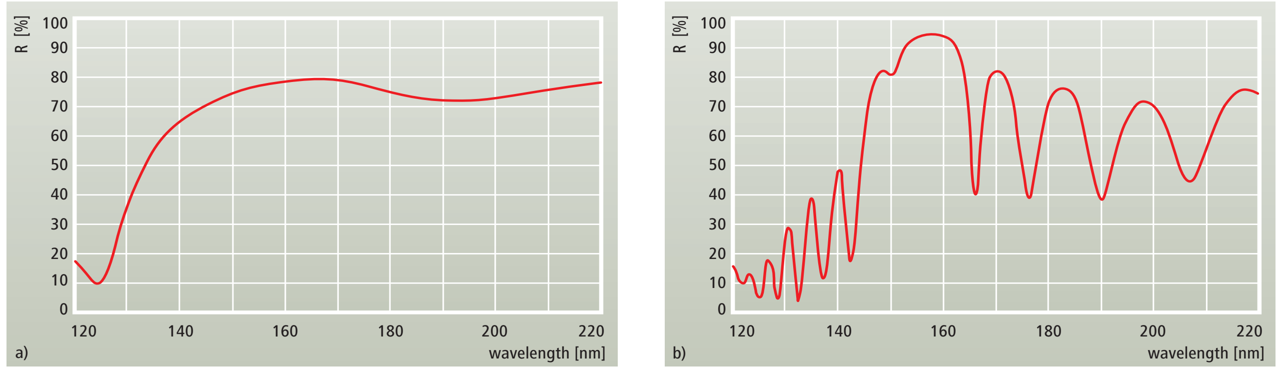


Figure 4: Reflectance spectrum of a protected Al mirror (a) and an enhanced Al mirror for 157nm (b)

Protected Al mirrors (optimized for 157nm): R = 74 … 78%
Dielectrically enhanced Al mirrors: up to R = 94% at AOI = 0°
For more information on Al mirrors see pages 96 – 97.

TECHNICAL DATA OF STANDARD F_2 LASER COMPONENTS

Coating	Spectral performance	Lifetime tests
HR(0°, 157nm)	R = 92 ... 95%	2 x 10^8 – 1 x 10^9 pulses*
HR(45°, 157nm)	R = 90 ... 94% (random pol.)	
PR(0°, 157nm)	R = 50 ± 3%	2 x 10^8 – 1 x 10^9 pulses*
PR(0°, 157nm)	R = 25 ± 3%	2 x 10^8 – 1 x 10^9 pulses*
Attenuator	T = 67 ± 3%	5 x 10^7 pulses**, no damage
Attenuator	T = 33 ± 3%	1 x 10^8 pulses***, no damage
Beam splitter	T = 20 ± 3%	1 x 10^8 pulses***, no damage
AR(0°, 157nm)	0.3 ... 0.7%	

* Energy density: 25mJ/cm², repetition rate: 800Hz, pulse duration: 15ns; tested at COHERENT AG, München
** Energy density: 15mJ/cm², rep. rate: 200Hz, pulse duration: 20ns; tested at Institut für Photonische Technologien (IPHT) Jena
*** Energy density: 20mJ/cm², rep. rate: 50Hz, pulse duration: 20ns; tested at Institut für Photonische Technologien (IPHT) Jena

COMPONENTS FOR THE FIFTH HARMONIC

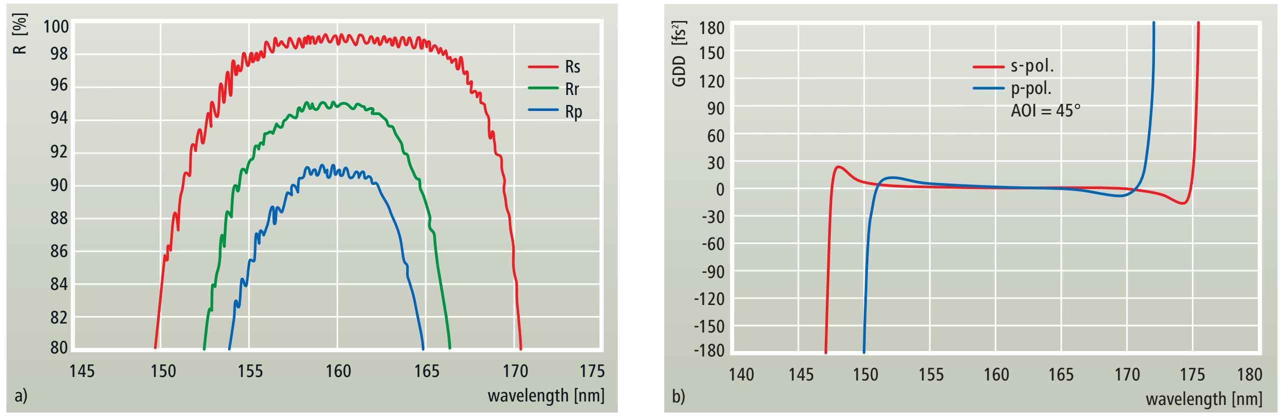


Figure 3: Reflectance (measured, a) and GDD-spectra (calculated, b) of a turning mirror for 160nm (AOI = 45°)

Mirrors and separators for the 160nm range are produced by coating techniques which were developed for F_2 laser coatings. For more information please see pages 80 – 81.

COMPONENTS FOR ArF LASERS

MIRRORS, OUTPUT COUPLERS AND LENSES

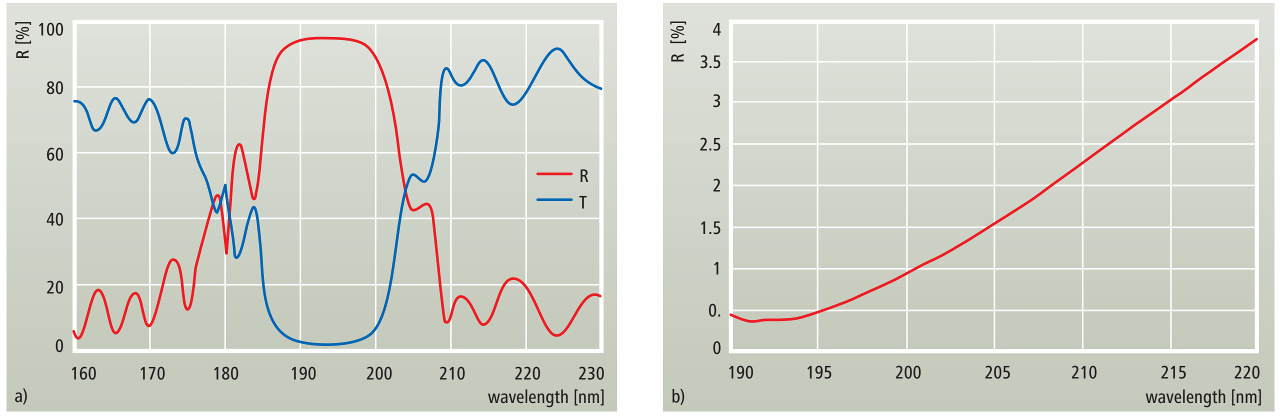


Figure 1: Measured reflectance and transmittance spectra of a turning mirror (AOI=45°) for 193nm for random polarized light (a) and a CaF_2 window coated on both sides with a fluoride AR coating for 193 nm (b)

- All fluoride systems guarantee high reflectivities and high damage thresholds
- PR coatings with tolerances of ±2% for R=10 ... 30%
  ±3% for R=30 ... 75%
  ±2% for R=75 ... 90%
  and ±1% for R>90%
- High quality mirror substrates, windows and lenses of CaF_2 (193 nm excimer grade, HELLMA Materials GmbH) and fused silica
- Development and production of customer specific components such as beamsplitters and variable attenuators on request
- Single wavelength AR coating with residual reflectivities of R<0.25% at AOI=0° and R<0.6% at AOI=45° (unpolarized light)
- Broadband and multiple wavelength AR coatings

VARIABLE ATTENUATORS

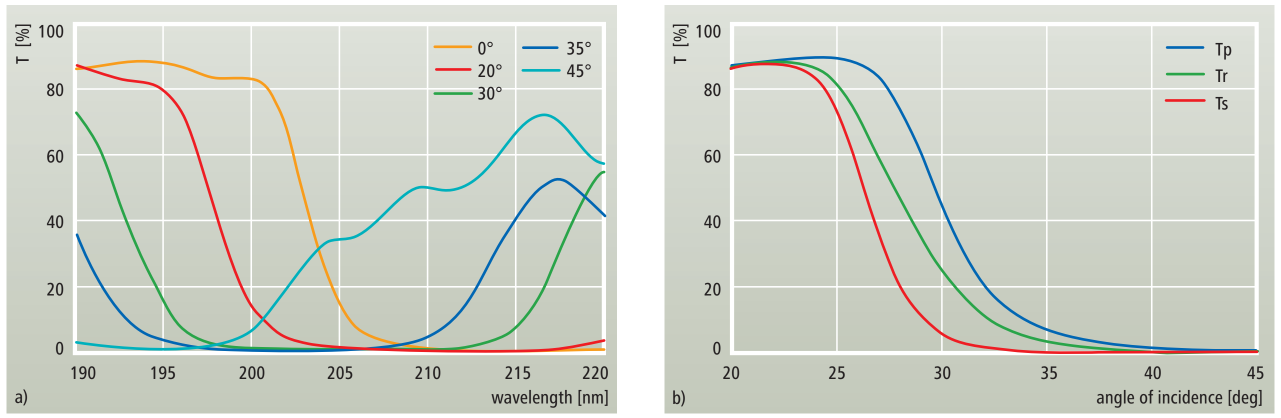


Figure 2: Measured transmittance spectra of a variable attenuator at different AOI (a) and transmittance vs. AOI (b); the transmittance varies from T>88% at AOI=0° to T<2% at AOI=45°

- Attenuators with different transmission ranges on request
- Attenuators can be delivered with AR coated compensation plates of CaF_2 of fused silica

193 nm

ALUMINUM MIRRORS

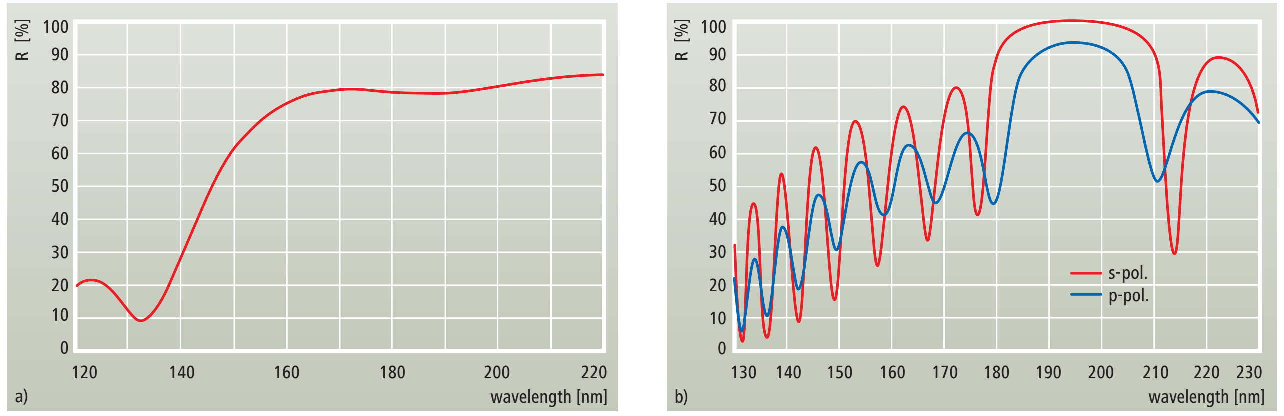


Figure 3: Measured reflectance spectra of a protected Al mirror optimized for 193nm (a) and an enhanced Al mirror for 193nm, AOI=45° (b)

Enhanced aluminum mirrors: R_p > 93%, R_s > 99%, R_r > 96%

For more information on aluminum mirrors see pages 104 – 105.

TECHNICAL DATA OF STANDARD ArF LASER COMPONENTS

Coating/reflectance	Substrate	Damage threshold*	Lifetime test
Fluoride coatings			
AR (0°, 193 nm) R<0.25%	CaF_2	4 – 5 J/cm²	10^8 pulses, no damage**
AR (0°, 193 nm) R<0.25%	fused silica	2 – 3 J/cm²	
PR (0°, 193 nm) R=25%	CaF_2	3 – 4 J/cm²	10^{10} pulses, no damage**
PR (0°, 193 nm) R=50%	CaF_2	2 – 3 J/cm²	10^{10} pulses**
HR (0°, 193 nm) R>96%	CaF_2	2 – 3 J/cm²	10^{10} pulses **, no damage 4 x 10^9 pulses ***, no damage
HR (45°, 193 nm) R>95% (random polarized)	CaF_2	2 – 3 J/cm²	
Oxide coatings			
HR (0°, 193 nm) R>92%	fused silica	<1 J/cm²	

* 1000-on-1, 14 ns; measurements were performed at Laser Labor Göttingen, Laser Zentrum Hannover and at Friedrich-Schiller-Universität Jena
** Energy density: 55 mJ/cm², repetition rate: 1 kHZ, pulse duration 15 ns; tested at COHERENT AG, München
*** Energy density: 80 mJ/cm², repetition rate: 1 kHz, pulse duration: 12 ns; tested at COHERENT AG, München

COMPONENTS FOR THE 200 nm RANGE

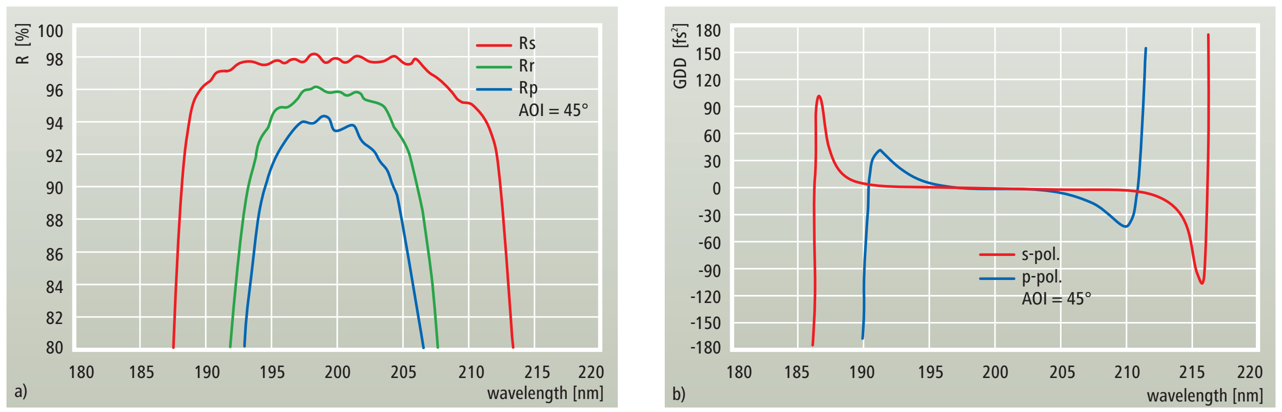


Figure 4: Reflectance (measured, a) and GDD-spectra (calculated, b) of a turning mirror for 200 nm (AOI = 45°)

Mirrors and separators for the 200 nm range are produced by coating techniques which were developed for ArF laser coatings. For more information please see pages 80 – 81.

COMPONENTS FOR KrF, XeCl and XeF LASERS

STANDARD COMPONENTS

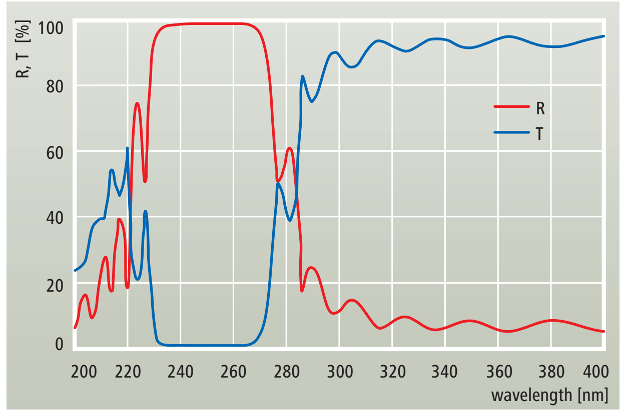


Figure 1: Reflectance and transmittance spectrum of a 248nm turning mirror (AOI = 45°) for random polarized light

- High quality mirror substrates, winwdows and lenses of fused silica
- Oxide coatings for high mechanical stability
- Sputtered components for low straylight losses
- Laser mirrors:
  - Standard mirrors: R > 99% at 248nm, R > 99.5% at 308nm and 351nm
  - Sputtered mirrors: R > 99.3% 248nm, R > 99.8% at 308nm, R > 99.9% at 351nm
- PR coatings with tolerances of
  ±2% for R = 10 ... 30%
  ±3% for R = 30 ... 75%
  ±2% for R = 75 ... 90%
  and ±1% for R > 90%
- Development and production of customer specific components

SPUTTERED ATTENUATORS PROVIDING HIGH CLIMATICAL STABILITY

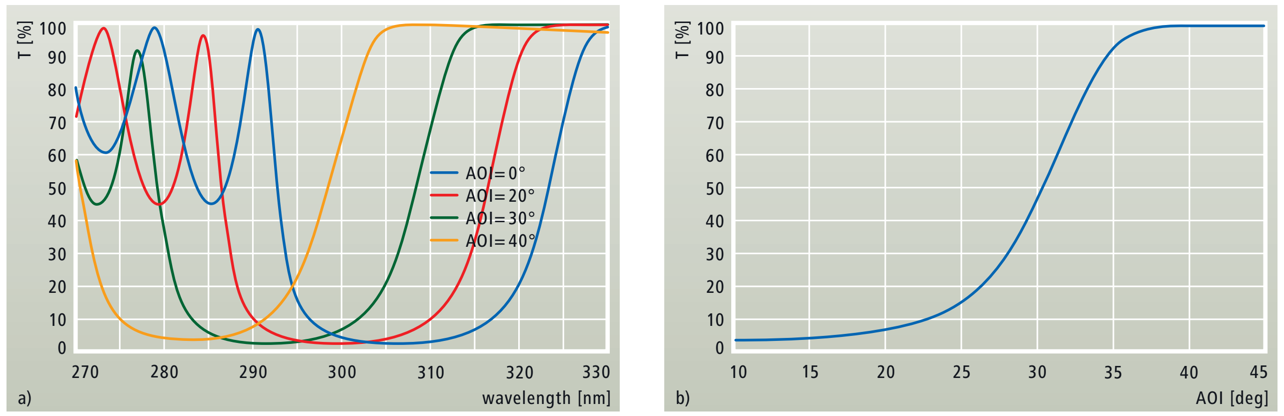


Figure 2: Transmittance spectra of a variable attenuator for 308nm at different AOI (a) and transmittance vs. AOI (b); the transmittance varies from T < 10% at AOI = 0° to T > 90% at AOI = 40° (unpolarized light)

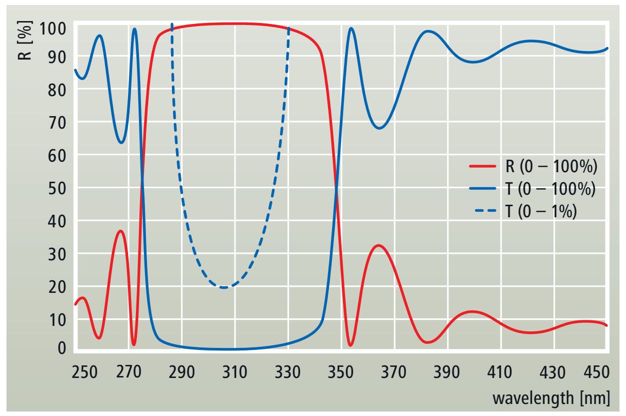


Figure 3: Transmittance spectrum of a sputtered attenuator for 308nm with exactly adjusted and thermally stable transmittance of T = 0.2% at AOI = 45° (unpolarized light)

248 nm, 308 nm, 351 nm

FLUORINE RESISTANT CAVITY OPTICS

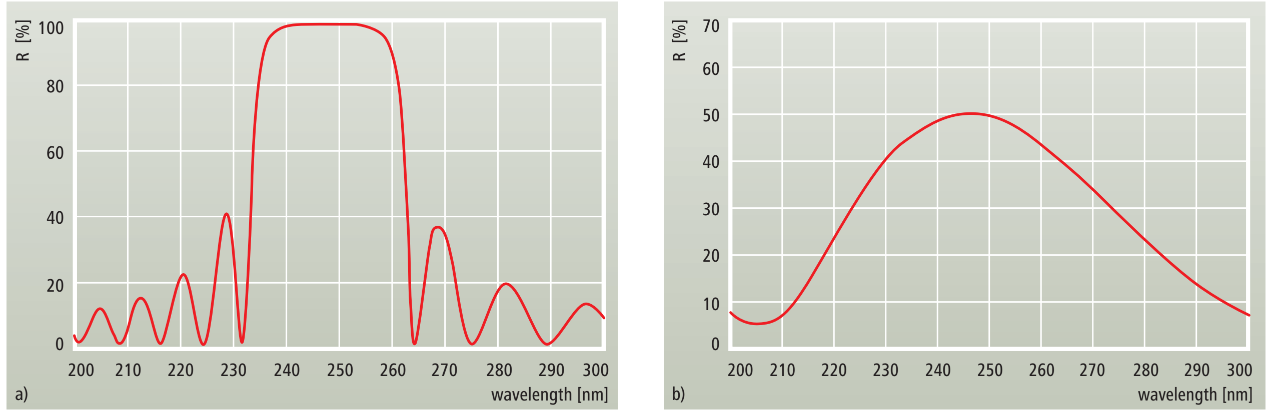


Figure 4: Reflectance spectrum of a fluoridic KrF laser mirror (a) and an output coupler with R = 50 ± 3% (b)

- Fluoride coatings and CaF_2 substrates for high stability against fluorine and chlorine
- laser mirrors (R > 98% at 248nm and 308nm, R > 96% at 351nm)
- High quality mirror substrates, windows and lenses of CaF_2 (248nm excimer grade or UV quality, HELLMA Materials GmbH)
- PR coatings with tolerances of
  ±2% for R = 10 ... 30%
  ±3% for R = 30 ... 75%
  and ±2% for R = 75 ... > 90%

TECHNICAL DATA OF KrF, XeCl AND XeF LASER COMPONENTS

Coating	Materials	Reflectance	Damage threshold*	Lifetime tests
HR (0°, 248nm)	oxides, standard	> 99%	10 J/cm^2, 1-on-1,20ns 5 J/cm^2, 1000-on-1	
HR (0°, 248nm)	oxides, sputtered	> 99,5%		
HR (45°, 248nm)	oxides, standard	> 99% (random pol.)	10 J/cm^2, 1-on-1,20ns	
HR (0°, 248nm)	fluorides	R > 98%		2 x 10^8 pulses**
PR (0°, 248nm)	fluorides	R = 50 ± 3%		2 x 10^8 pulses**
AR (0°, 248nm)	fluorides	R < 0.25%		2 x 10^8 pulses**
HR (0°, 308nm)	fluorides	R > 98%		2 x 10^8 pulses***
HR (0°, 351nm)	fluorides	R > 96%		2 x 10^8 pulses***
PR (0°, 351nm)	fluorides	R = 25 ± 3%		2 x 10^8 pulses***

* Measurements were performed at Laser Labor Göttingen and at Friedrich-Schiller Universität Jena
** Energy density: 100 mJ/cm^2, rep. rate: 100Hz, pulse duration: 15ns; tested at **COHERENT AG, München**
*** Energy density: 55 mJ/cm^2, rep. rate: 100Hz, pulse duration: 15ns; tested at **COHERENT AG, München**

Components for the fourth harmonic of Nd:YAG lasers, i.e. for 266nm can be produced by all of the coating technologies stated on these pages. For every component we select the technology which is most advantageous with respect to the coating performance and to the price. For more information on such coatings please see pages 52 – 53.

COMPONENTS FOR RUBY AND ALEXANDRITE LASERS

Ruby and Alexandrite Lasers are especially used for medical laser applications and work at 694 nm and 755 nm, respectively. LAYERTEC offers a wide range of laser optics for both wavelengths with high laser induced damage thresholds and long lifetimes.
Besides typical combinations with wavelengths for the alignment of the optical system (e.g. 694 nm + 633 nm) a special feature of LAYERTEC products are the variety of combinations with other common wavelengths used for medical applications in the same device, but from different laser sources (e.g. 532 nm + 694 nm).

CAVITY MIRRORS

- Reflectivity: R>99.8...R>99.9% at AOI=0° using evaporation and sputtering
- High damage thresholds (800MW/cm², 35 ns pulse length)

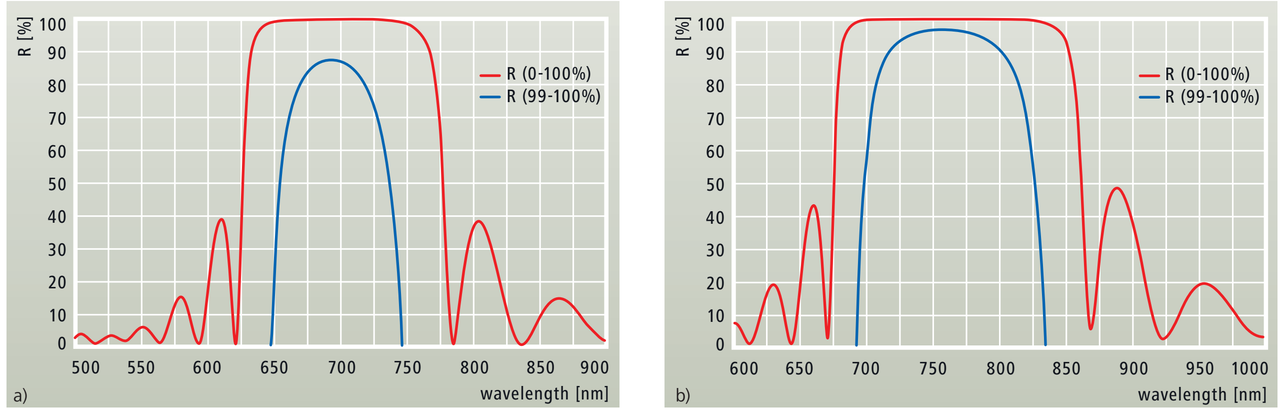


Figure 1: Reflectance spectra of cavity mirrors for 694 nm (a) and 755 nm (b)

TURNING MIRRORS

- Reflectivity: R>99.5% at AOI=45° for random polarized light
- Integrated pilot laser beam alignment (e.g. at 630 – 650 nm)
- High damage thresholds (800MW/cm², 35 ns pulse length)

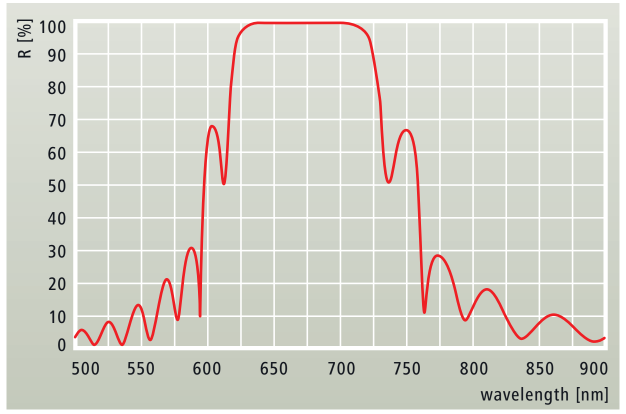


Figure 2: Reflectance spectra of a turning mirror for 694 nm in combination with a pilot laser at 633 nm (unpolarized light)

694 nm, 755 nm

BEAM COMBINERS

- Precisely adjusted degree of reflectivity by using sputtering technology
- Integrated pilot laser beam alignment (e.g. at 635 nm)
- High performance and cost-optimized solutions with special designs

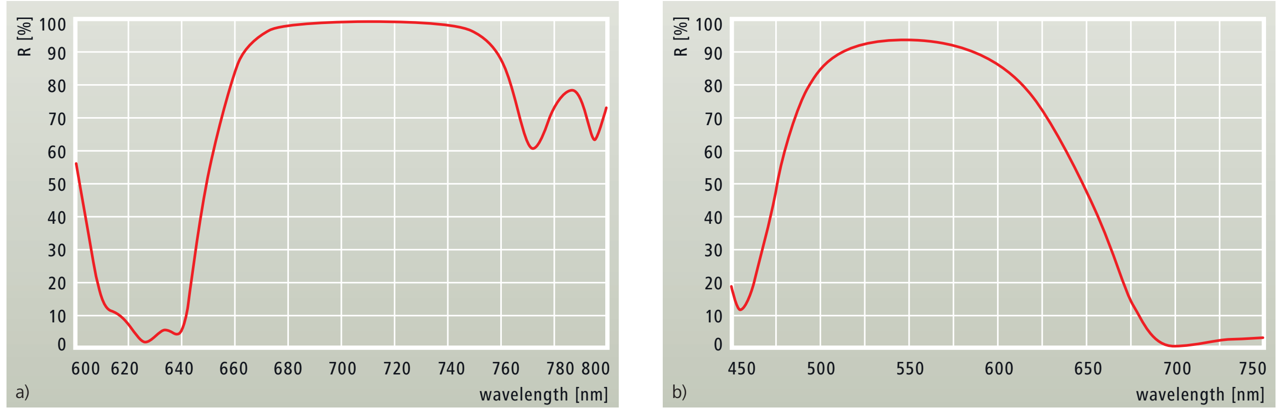


Figure 3: Reflectance spectra of special beam combiners for 694 nm and 633 nm:
a) PRr(45°,694 nm) = 99.0% + Rr(45°,633 nm) < 35%
b) Rr(45°,630 – 640 nm) > 35% + Rp(45°,694 nm) < 0.3%

OUTPUT COUPLERS AND LENSES

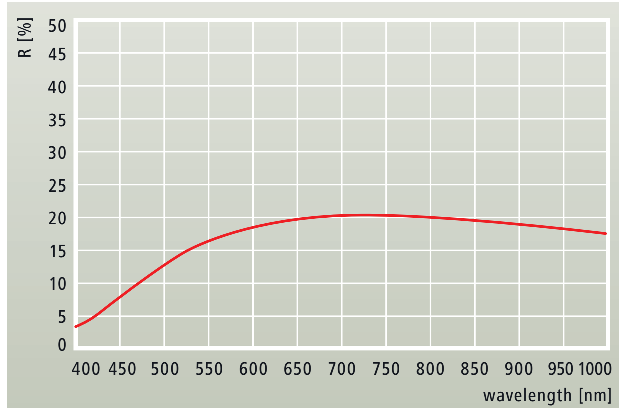


Figure 4: Reflectance spectrum of an output coupler with R=20 ±1%

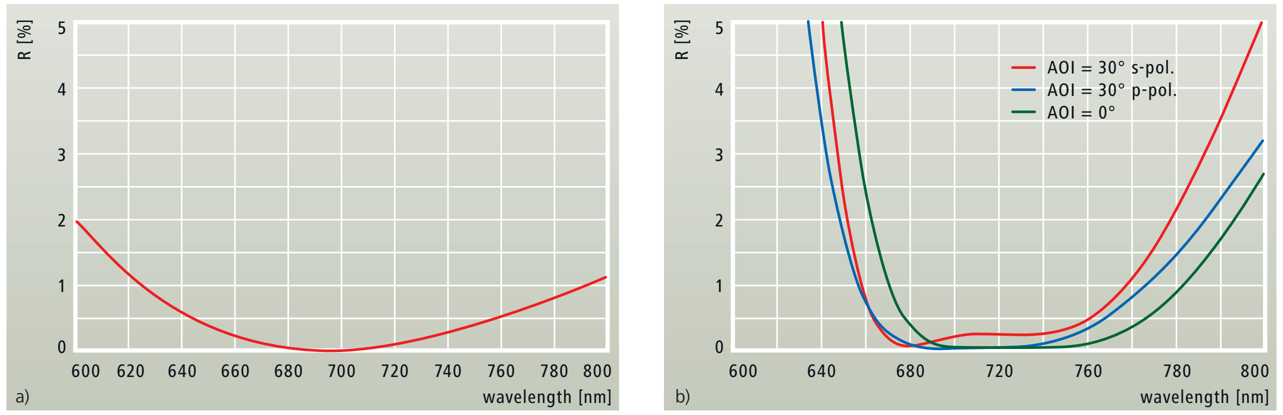


Figure 5: Reflectance spectra of AR coatings for 694 nm and 755 nm: a) AR(0°,694 nm) < 0.2 %, b) AR(0° – 30°, 755 nm) < 0.5 %

- Output couplers with precisely adjusted degree of reflectivity
- AR coatings with residual reflectivities R<0.2 % on the rear side of output couplers as well as on both sides of lenses and windows made of fused silica

COMPONENTS FOR Ti:SAPPHIRE LASERS OPERATED IN THE ns REGIME

On these pages we present optical components for Ti:Sapphire lasers which are operated with ns pulses. Please note that all of these components are optimized for smooth group delay (GD) spectra in order to achieve wide tuning ranges. However, these components are not optimized for group delay dispersion (GDD). Such optics which are necessary for fs pulses are introduced on pages 60 – 73.

MIRRORS

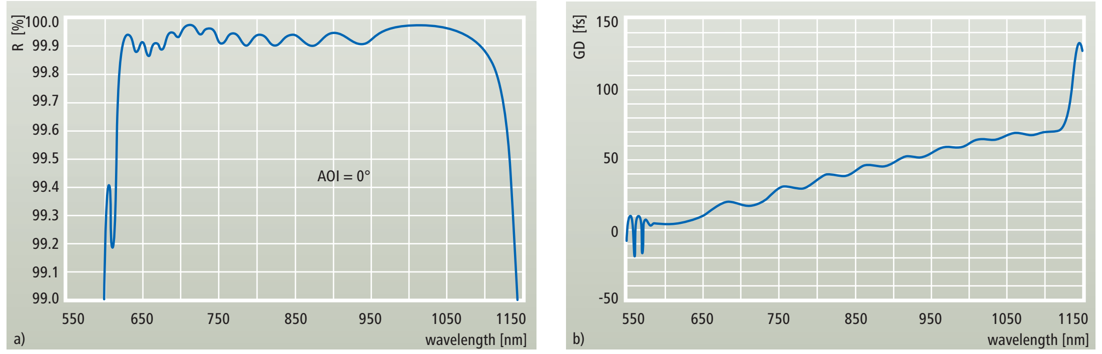


Figure1: Reflectance (a) and GD (b) spectra of a broadband laser mirror

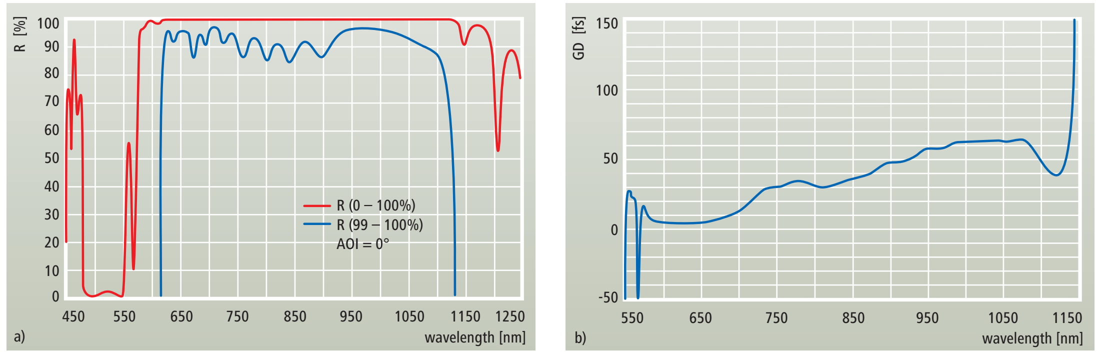


Figure 2: Reflectance (a) and GD (b) spectra of a broadband pump mirror

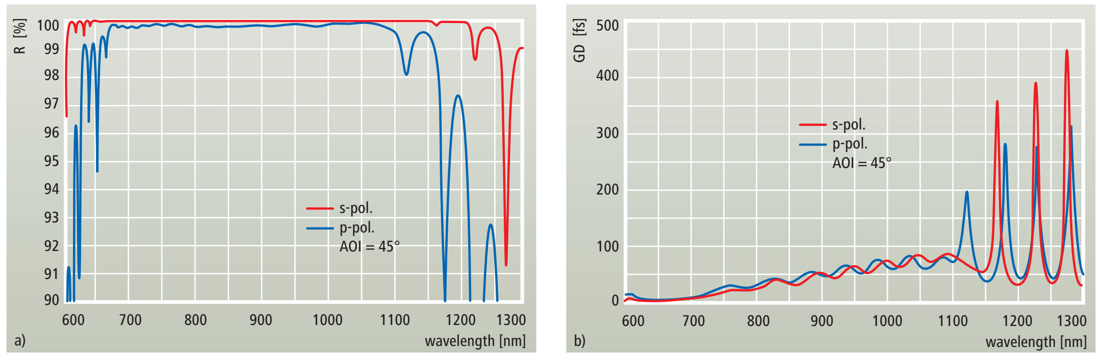


Figure 3: Reflectance (a) and GD (b) spectra of a broadband turning mirror

Special features:

- Very high reflectance of the mirrors (R > 99.9 % … R > 99.98 % depending on the design)
- Spectral tolerance: 1% of centre wavelength
- Centre wavelength, bandwidth and reflectivity of partial reflectors according to customer specification

550 – 1100 nm

OUTPUT COUPLERS AND BEAMSPLITTERS

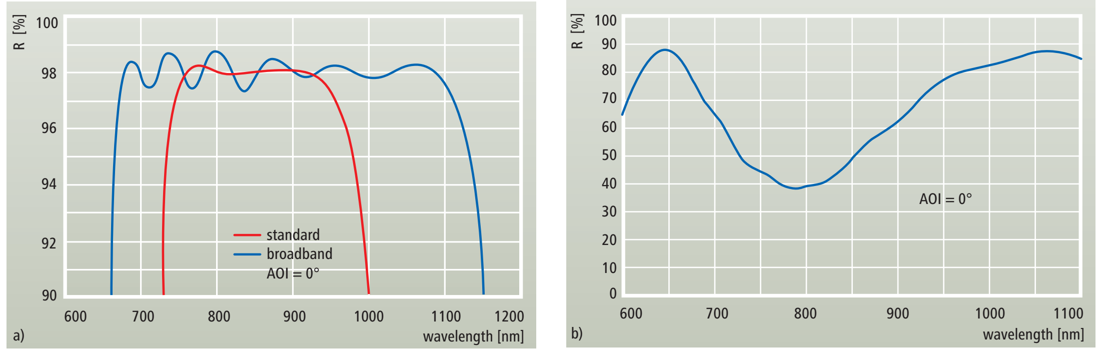


Figure 4: Reflectance spectra of a standard and a broadband output coupler (a) and of an output coupler with a special reflectance profile which enables the compensation of the amplification characteristics of the laser (b); see also B. Jungbluth, J. Wueppen, J. Geiger, D. Hoffmann, R. Poprawe: "High Performance, Widely Tunable Ti:Sapphire Laser with Nanosecond Pulses" in: Solid State Lasers XV: Technology and Devices, Proc. of SPIE Vol. 6100, 6100-20, San Jose 2006

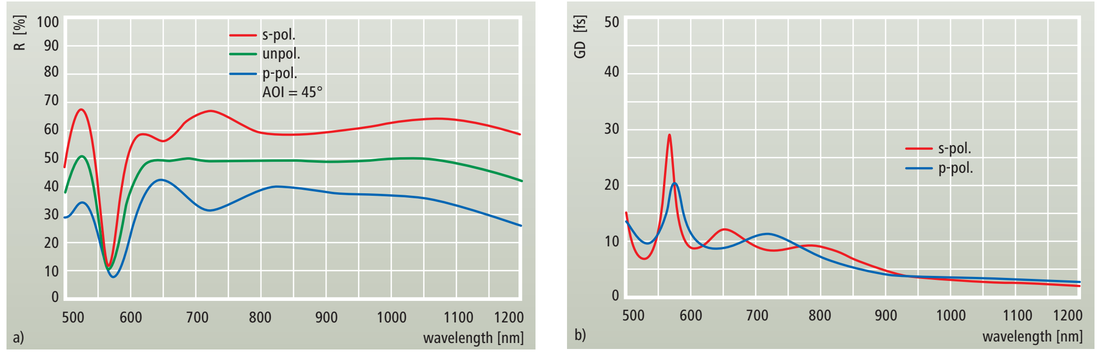


Figure 5: Reflectance (a) and GD (b) spectra of a broadband beam splitter PR(45°, 650 – 1050 nm) = 50 ± 3%

Tolerances:

- Standard output couplers (bandwidth: 120 – 150 nm):

R = 10 … 70 %	± 2.5 %
R = 70 … 90 %	± 1.5 %
R = 90 … 95 %	± 0.75 %
R = 95 … 98 %	± 0.5 %
R > 98 %	± 0.25 %

- Broadband output couplers (bandwidth: 200 – 600 nm):

R = 10 … 70 %	± 3 %
R = 70 … 90 %	± 2 %
R = 90 … 95 %	± 1 %
R = 95 … 98 %	± 0.5 %

SPECIAL COMPONENTS

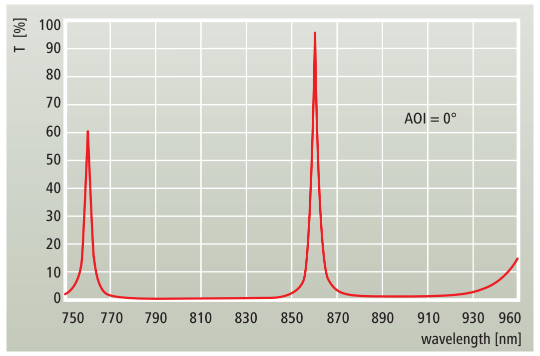


Figure 6: Transmittance spectrum of a narrow band intra cavity filter for 860 nm which is used to select one wavelength from the Ti:Sapphire spectrum

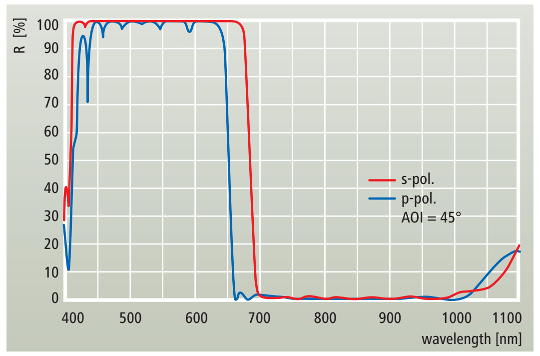


Figure 7: Reflectance spectrum of a special turning mirror which separates the visible part of the Ti:Sapphire laser radiation from the NIR part

COMPONENTS FOR DIODE LASERS

Diode lasers are widely used for measurement applications, as pilot lasers, for pumping of solid state lasers and for direct materials processing. Although diode lasers do not require external resonator optics and are mostly coupled to fibres, many applications require high quality beam steering optics such as beam combiners or scanning mirrors which are shown on the following pages. For more information on pump mirrors for solid state lasers and combiners for diode lasers please see also pages 44 – 47 and 94 – 95.

TURNING MIRRORS

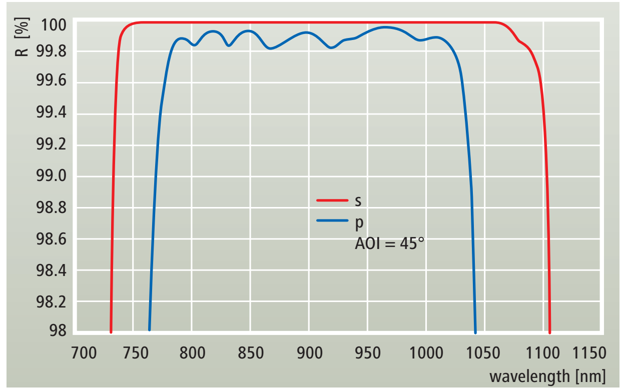


Figure 1: Reflectance spectra of a broadband turning mirror which can be used for all diode lasers between 808 nm and 980 nm (AOI = 45°, s- and p-polarization)

SCANNING MIRRORS

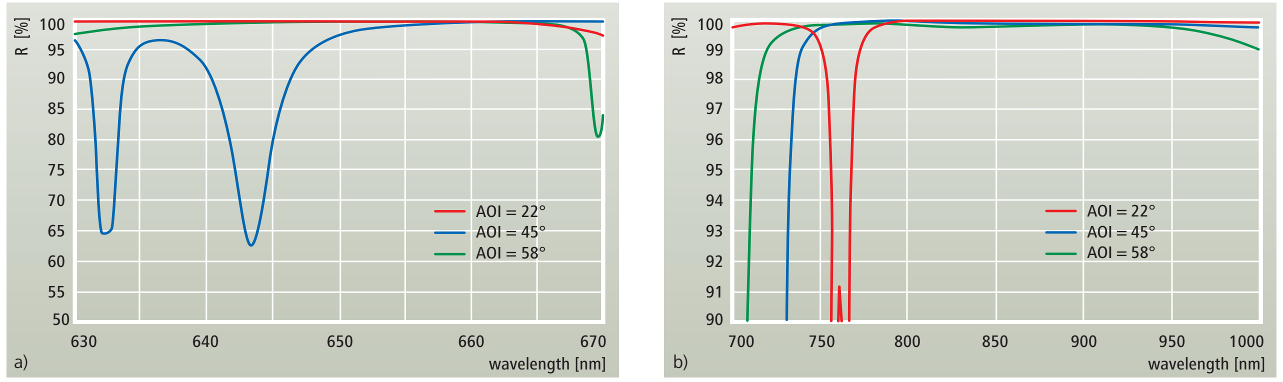
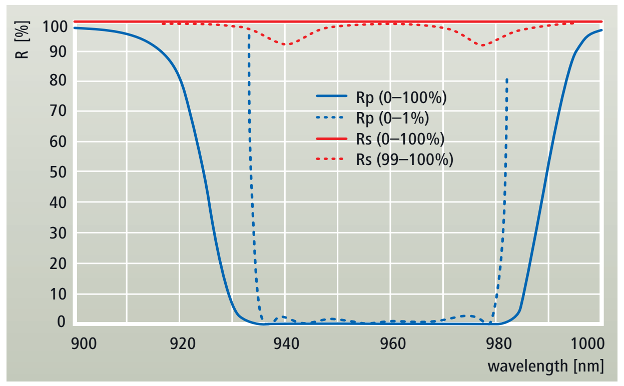


Figure 2: Reflectance spectra of a scanning mirror for diode lasers between 805 and 940 nm combined with R > 50 % between 630 and 670 nm (pilot laser): HRr (22° – 58°, 805 – 940 nm) > 99.3 % + Rr (22° – 58°, 630 – 670nm) > 50 %

- Scanning mirrors with other specifications on request
- For more information and examples on scanning mirrors please see pages 92 – 93 and 102 – 103

THIN FILM POLARIZERS

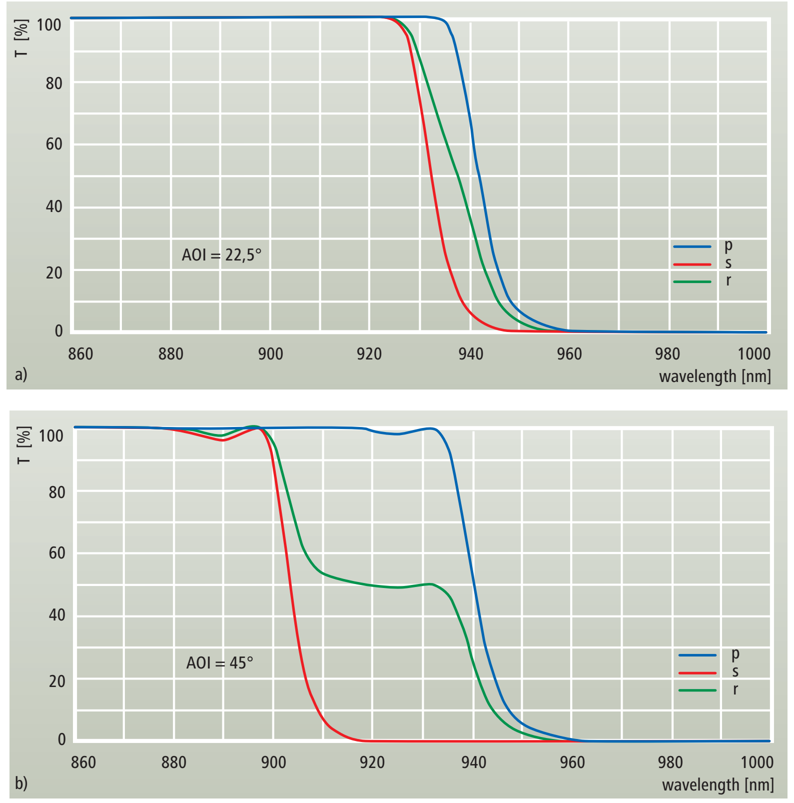


- Thin film polarizers are especially useful for pola-rization coupling of high power laser diodes
- For high power 940 nm radiation we recommend to use SUPRASIL 300 or SUPRASIL 3001/3002 as substrate material, because standard fused silica shows an absorption band around this wavelength (see page 15)

Figure 3: Reflectance spectra of a broadband thin film polarizer for 940 – 970 nm:
HRs(45°, 940 – 970 nm) > 99.9% + Rp(45°, 940 – 970 nm) < 1%

620 – 680 nm , 808 – 990 nm

CONVENTIONAL STEEP EDGE COMBINERS FOR DIODE LASERS



- At AOI = 22.5° the conventional steep edge filter separates 915 nm and 980 nm for p- and s-polarized and thus also for unpolarized light
- To preserve the steep edge at AOI = 45° the radiation must be polarized and only one polarization can be used. Unpolarized light changes the slope of the edge significantly

Figure 4: Transmittance spectra of a conventional steep edge filter HR (980 nm) > 99.9 % and HT (915nm) > 95 % which is used as combiner for pump laser diodes at 915 nm and 980 nm; AOI = 22.5° (a) and AOI = 45° (b)

SPECIAL STEEP EDGE COMBINERS FOR UNPOLARIZED LIGHT

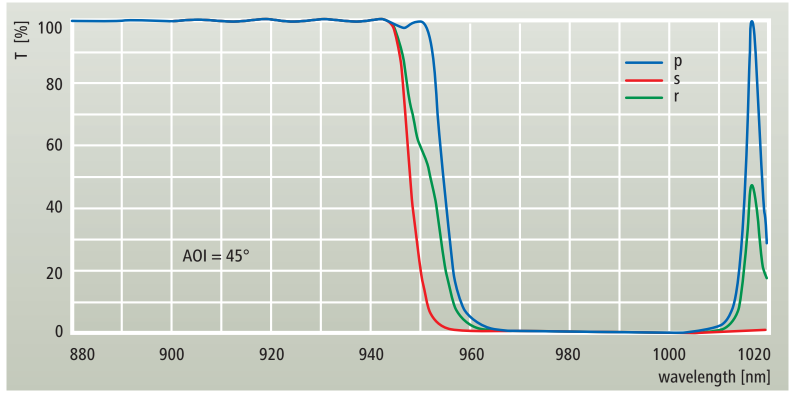


Figure 5: Transmittance spectra of a special steep edge filter HRr (45°, 980 nm) > 99.8% + HTr (45°, 940nm) > 97%

- Filters of this type can be used as separators or combiners for s- and p-polarized light even at 45° incidence
- The cut on / cut off edges for the two polarizations show only a spectral distance of about 10 nm
- Consequently, these filters can be applied as combiners for unpolarized light of 940 nm and 980 nm diodes at AOI = 45°

COMPONENTS FOR Yb:YAG; Yb:KGW AND Yb DOPED FIBRE LASERS

Lasers on the basis of Yb doped crystals or fibres have gained increasing importance over the recent years. High power cw lasers were developed on the basis of Yb:YAG as well as with Yb doped fibres. Yb:YAG and Yb:KGW lasers can also be operated as high power ns, ps or fs lasers.

MIRRORS

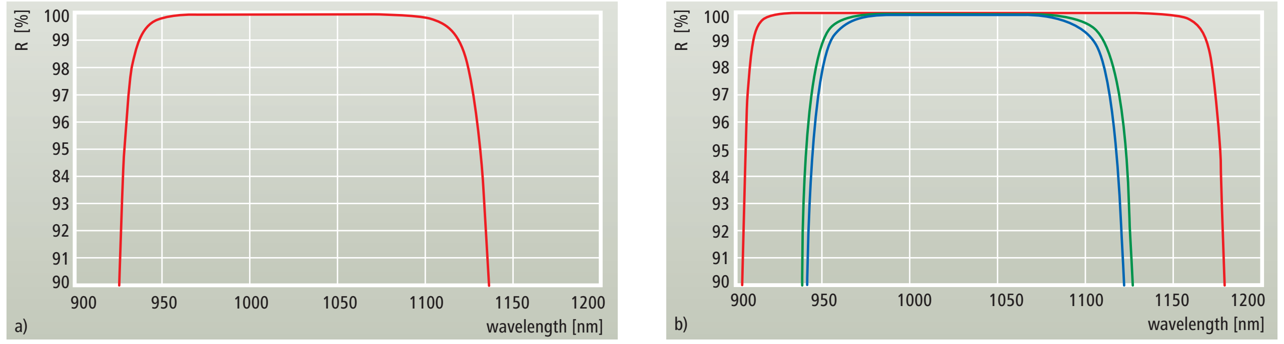


Figure 1: Reflectance spectra of a HR cavity mirror (a) and a HR turning mirror (b)

Lasers with **extremely high output power** (e.g. >10kW cw) are often based on Yb:YAG. LAYERTEC has developed different coating designs for handling extraordinary high fluences. The designs are **optimized either for cw-radiation or ns-pulses or ps-pulses**.

EDGE FILTERS AND PUMP MIRRORS

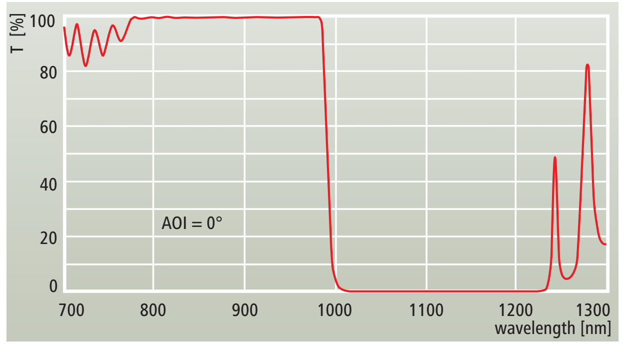


Figure 2: Transmittance spectrum of a steep edge short wavelength pass filter with HR(0°, 1030nm) > 99.9% and HT(0°,808 – 980nm) > 99.5% (rear side AR coated)

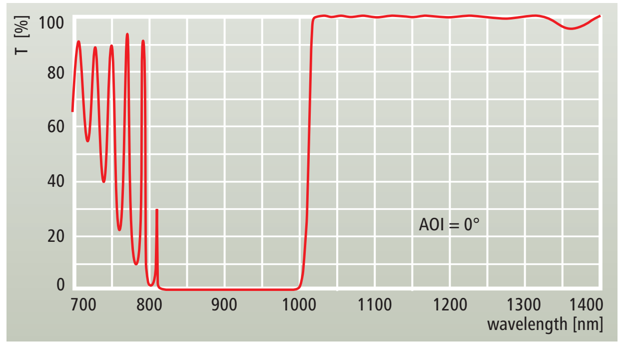


Figure 3: Transmittance spectrum of a steep edge long wavelength pass filter with HR(0°, 915–980nm)>99.8% and HT(0°,1030–1200nm)>97% for use as output mirror of a fibre laser (rear side AR coated)

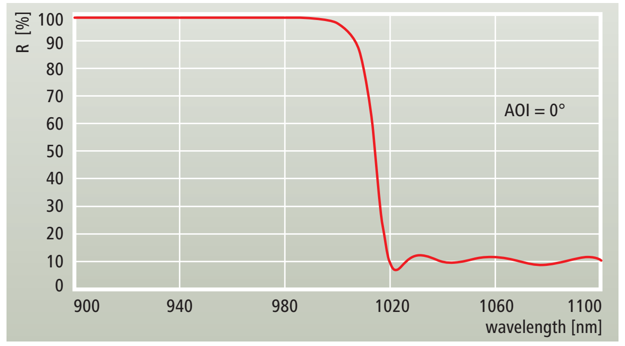


Figure 4: Reflectance spectrum of an output mirror for a fibre laser which blocks the diode radiation at 980nm and has a partial reflectivity R=10% for 1030–1100nm (rear side AR coated)

Special features:

- Short wavelength pass filters with very steep edge for use as pump mirror for solid state lasers on the basis of Yb-doped materials (e.g. Yb:YAG, Yb:KGW, Yb-doped fibers)
- Also useful for Nd-doped and Yb-Nd-co-doped materials
- Transmittance T > 99% at 808nm – 990nm, reflectance R > 99.9% at 1030nm, i.e. transition from the high transmittance range to the high reflectance range within 4% of the laser wavelength
- Superior laser damage thresholds (100MW/cm² cw at 1064nm*)
- Thermally and climatically stable

* Measured with a high power fiber laser at Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

1020 – 1080 nm

THIN FILM POLARIZERS

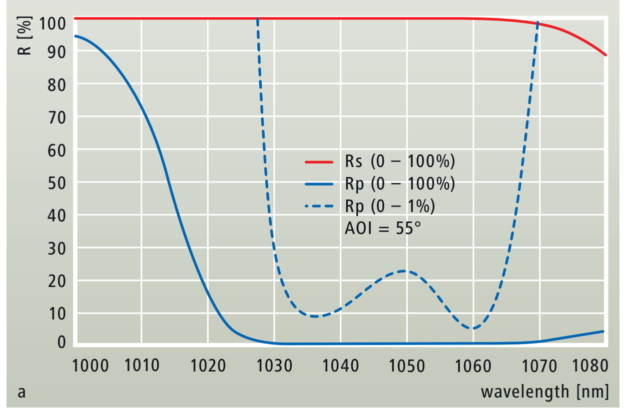


Figure 5a: Reflectance spectra for s- and p-polarized light of a broad band thin film polarizer showing a bandwidth of 25nm wit Rp<0.2% (AOI=55°)

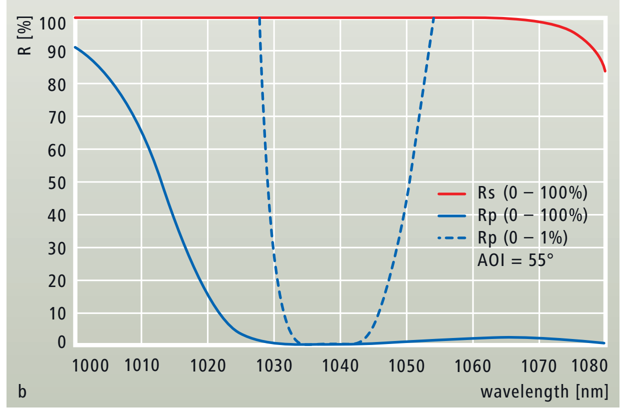


Figure 5b: Reflectance spectra for s- and p-polarized light of a narrow band thin film polarizer which is optimized for very low Rp values and easy angle tuning for the optimization of the Polarizer performance (AOI=55°)

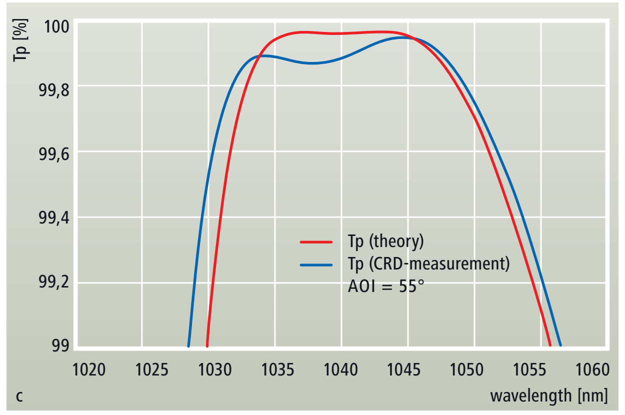


Figure 5c: Calculated and measured transmission spectra for s- and p-polarized light of a narrow band thin film polarizer according to the design shown in fig. 5b (AOI=55°). It is clearly visible that Tp>99.8% is reached with a bandwidth of 15nm and that Tp>99.9% can be achieved within a bandwidth 5nm. The spectral position of this transmission maximum can be adjusted to any wavelength in the between 1035 nm and 1045 nm by angle tuning.

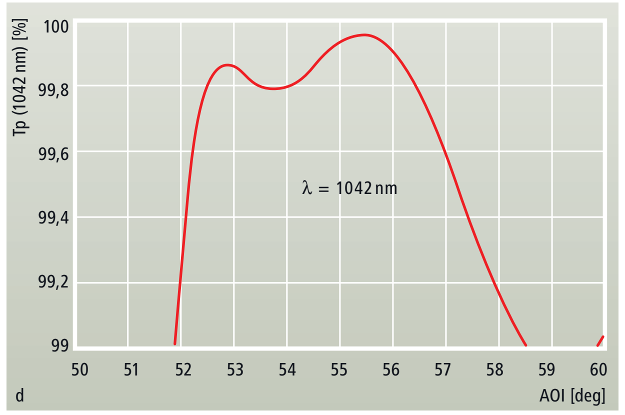


Figure 5d: Transmission spectrum Tp vs. AOI at 1042 nm **measured** at the polarizer shown in fig.5c

Thin film polarizers are key elements for regenerative amplifiers in ns- and ps-lasers. LAYERTEC has optimized its polarizer designs for high laser induced damage thresholds. Figure 5 shows as examples a broadband polarizer with Rp(55°)<0.2% within a bandwidth of 25nm in the wavelength range of Yb-doped fibre lasers (fig.5a) and a narrow band polarizer which is optimized for very low Rp values at a single wavelength (fig.5b). Figure 5c shows a comparison of the calculated transmission spectrum for p-polarized light and a measurement in a CRD setup, figure 5d shows Tp vs. AOI for the same polarizer (measured at 1042nm). These measurements prove that **Tp > 99.9%** can be reached by **angle tuning**. This is especially important for intra cavity applications.

PICOSECOND LASERS ON THE BASIS OF Yb DOPED MATERIALS

Picosecond lasers, i.e. lasers with pulse lengths of some hundred fs to 10ps can be built on the basis of Yb:YAG-, Yb:KGW- and Yb:KYW. These lasers enable materials processing without unwanted thermal effects such as melting, which results in unprecedented accuracy of the processes. Moreover, picosecond lasers don´t require chirped pulse amplification which reduces the costs compared to fs-lasers and the laser crystals don´t show thermal lenses which enables high output power. Recently, it was demonstrated that lasers with an average power of 400W (770fs, 1MHz) are possible on the basis of Yb:YAG slab crystals. Picosecond laser optics require specially designed optics to achieve high laser damage thresholds. For detailed information please see pages 74–75.
For GTI mirrors which are often used for pulse compression from the ps range down to a few hundred fs please see pages 82–83.

COMPONENTS FOR Nd:YAG/Nd:YVO$_4$ LASERS

CAVITY MIRRORS, SEPARATORS AND COMBINERS

- HR cavity and turning mirrors with R>99.9% at AOI=0° and at AOI=45° for s- and p-polarized light
- Typical reflectivity: R>99.95%
- For special demands we guarantee R>99.99% (delivery with cavity ring down measurement)
- Spectral bandwidth of about 70 nm, 1-on1 - LIDT >50 MW/cm² (cw) and >50 J/cm² (10 ns)
- Pump mirrors HR (0°, 1064 nm)>99.9% + R (0°, 808 nm) <2%
- Beam splitters, beam combiners and scanning mirrors
- Optics for the harmonics of the Nd:YAG / Nd:YVO$_4$ laser are presented on pages 48 – 53

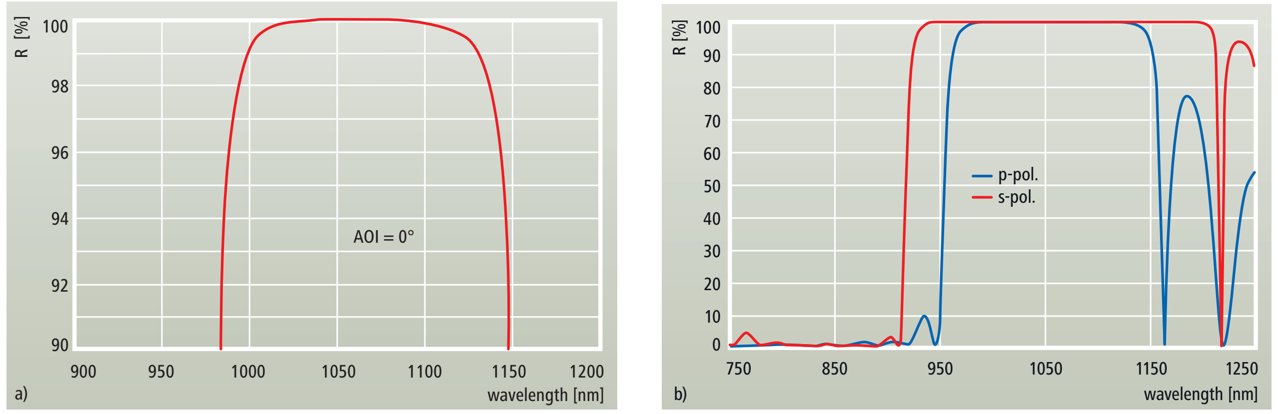


Figure 1: Reflectance spectra of a high power cavity mirror (a) and of a separator / combiner for pump and laser beam (b)

BEAM SPLITTERS AND OUTPUT COUPLERS

Beam splitters and output couplers can be produced with precisely adjusted degree of reflectivity:

Reflectance	Tolerance
R>95%	±0.5%
R=80 ... 95 %	±1%
R=10 ... 80%	±2%

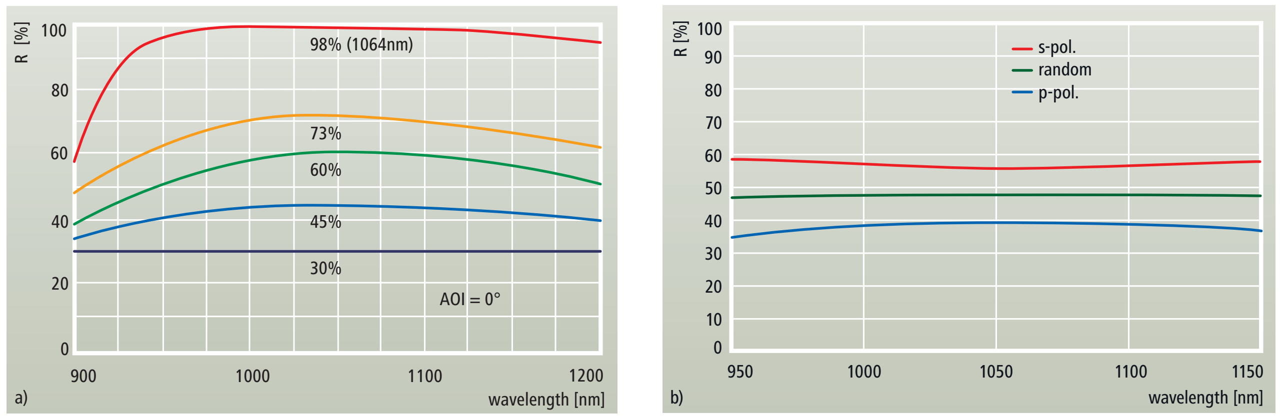


Figure 2: Reflectance spectra of output couplers with different degrees of reflectivity (a) and a common 1:1 beam splitter for random polarization (b)

1064 nm

NON-POLARIZING BEAM SPLITTERS

- Beam splitters with Rs ~ Rp (|Rs-Rp|< 1.5%) for AOI=45° and different degrees of reflectivity
- Most common types: Rs,p = 66 ± 1%
  Rs,p = 50 ± 2%
  Rs,p = 33 ± 3%
- All non-polarizing beam splitters with rear side AR (Rs~Rp ≤ 0.6%)

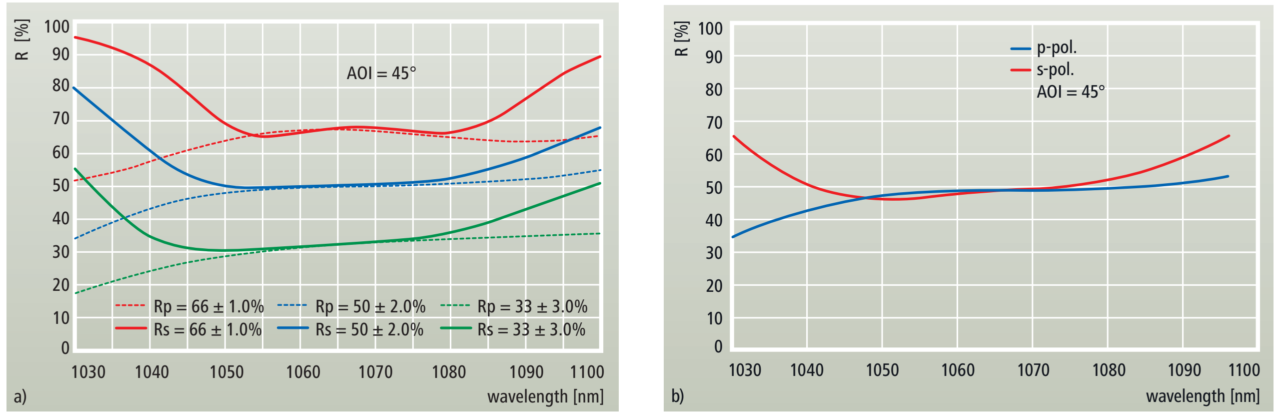


Figure 3: Calculated reflectance spectra of 3 types of nonpolarizing beam splitters for AOI = 45° (a) and measured reflectance spectra of the 50% beam splitter (b)

ALIGNMENT AND PROCESS MONITORING

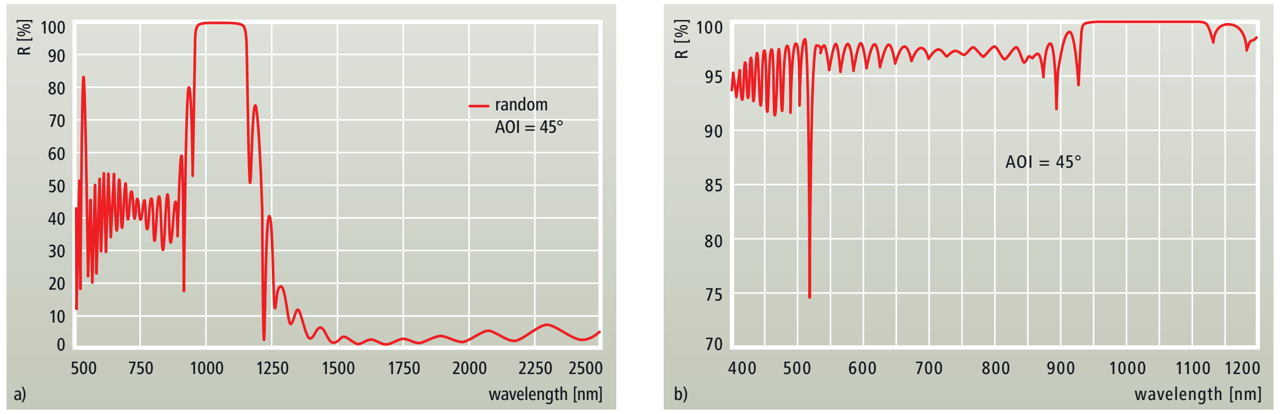


Figure 4: Reflectance spectra of a turning mirror for the laser beam with a partial reflector for the pilot laser and high IR transmission for process monitoring (a) and silver based turning mirror for 1030 nm with R>80% for a pilot laser in the red spectral range (b)

COMPONENTS FOR THE SECOND HARMONIC OF Nd:YAG, Nd:YVO$_4$ AND Yb:YAG LASERS

The harmonics of Nd:YAG, Nd:YVO$_4$ and Yb:Yag lasers are widely used for materials processing as well as for measurement applications. Moreover, the second harmonic of these lasers laser is often used as pump source for Ti:Sapphire lasers. On these pages we introduce optics for 532nm: dual wavelength mirrors, separators, thin film polarizers and non-polarizing beam splitters, but also cavity optics for compact diode pumped lasers of different configurations. Coatings for 515 nm are available as well. All designs are calculated according to customer specification.

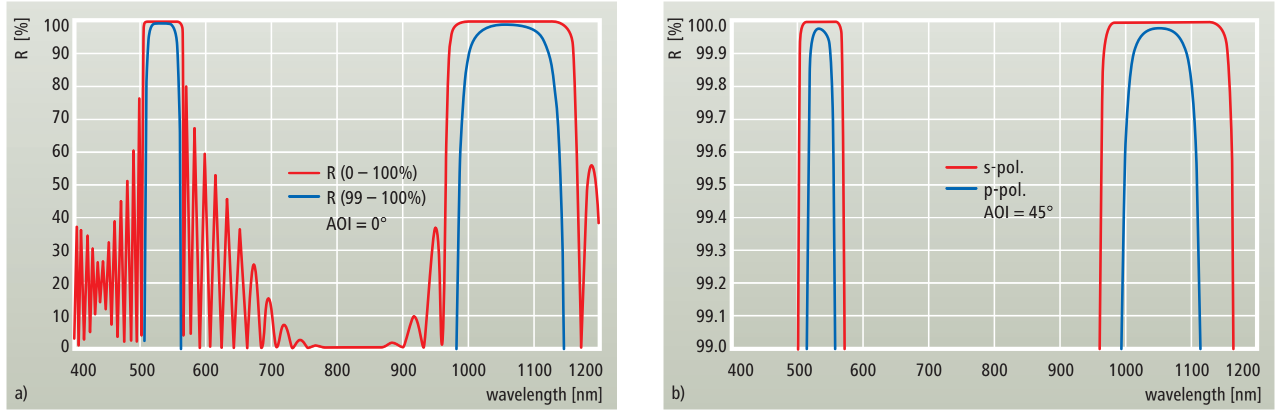


Figure 1: Reflectance spectra of a dual wavelength cavity mirror with high transmittance for the pump wavelength (808 nm) (a) and a dual wavelength turning mirror (b)

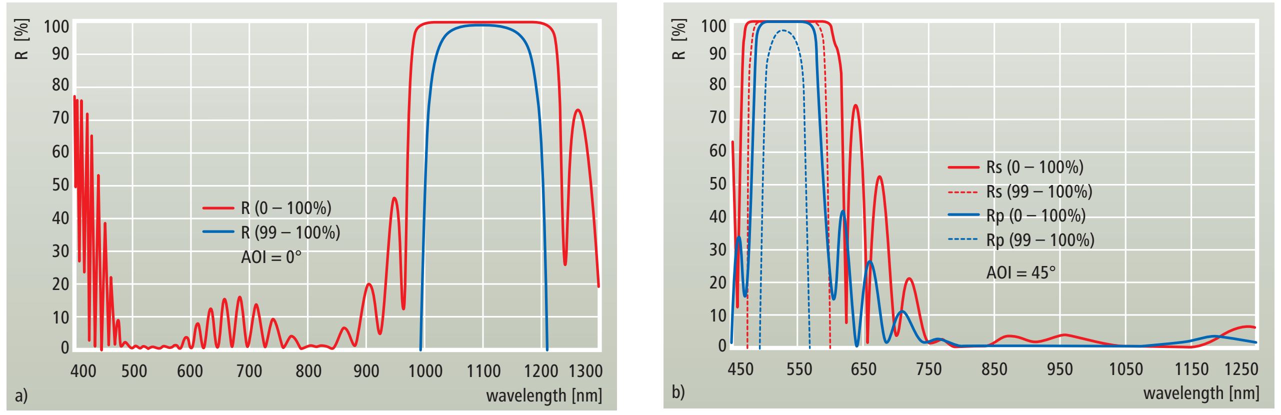


Figure 2: Reflectance spectra of separators for the second harmonic from the ground wavelength:
(a): HR(0°, 1064 nm) > 99.9% + R(0°, 532 + 808 nm) < 3%
(b): HRs + p(45°, 532 nm) > 99.9% + Rs + p(45°, 808 +1064 nm) < 2%

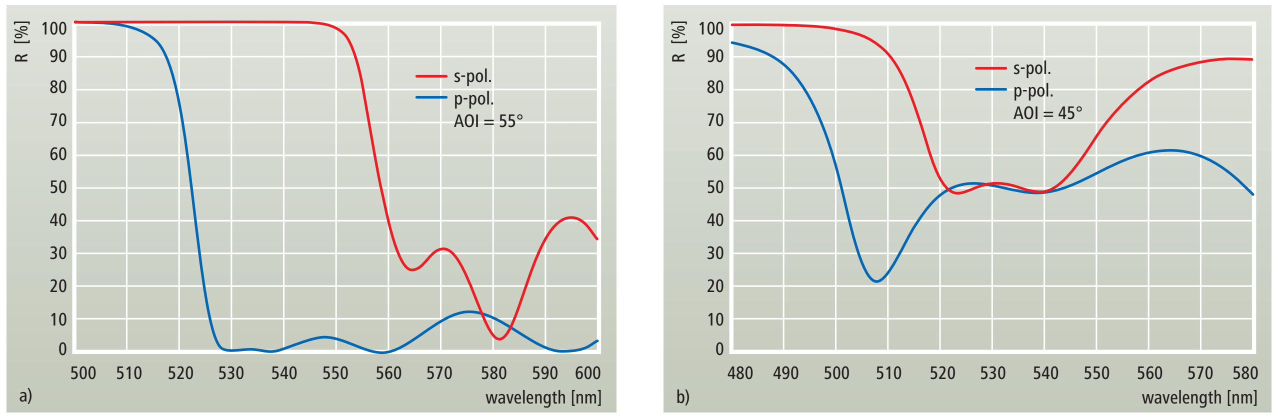


Figure 3: Reflectance spectra of a thin film polarizer (a) and of a non-polarizing beamsplitter (b) for 532 nm with Rs = Rp = 50 ± 2% (|Rs - Rp| < 3%)

The transmission of thin film polarizers for p-polarized light can be measured with high accuracy by a modified cavity Ring-Down setup.

515 nm, 532 nm

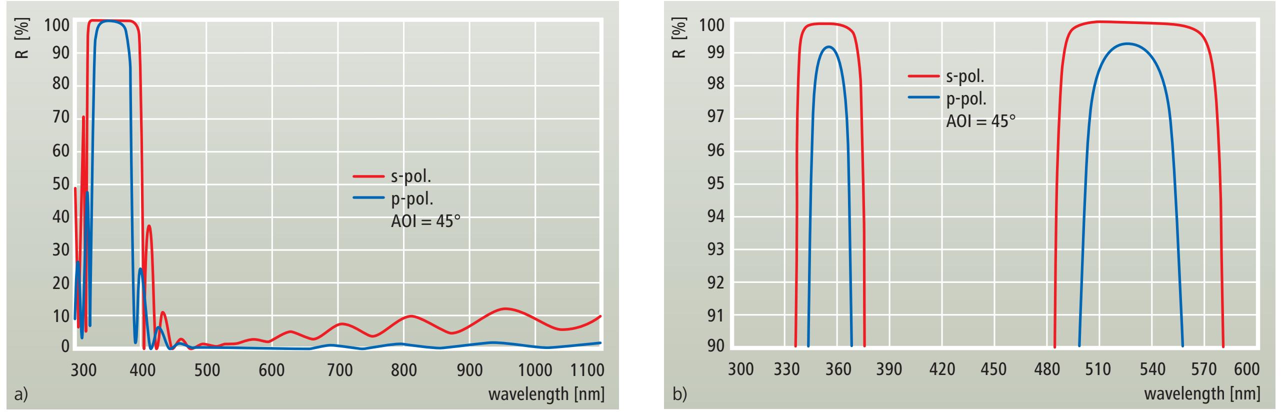


Figure 4: Reflectance spectra of separator for the third harmonic from the second harmonic and the ground wave (a) and of a dual wavelength turning mirror for 355nm and 532nm (b)

For common specifications of separators for the harmonics in the UV spectral range please see table on page 44. Please do not hesitate to contact us for separators or mirrors with other angles of incidence.

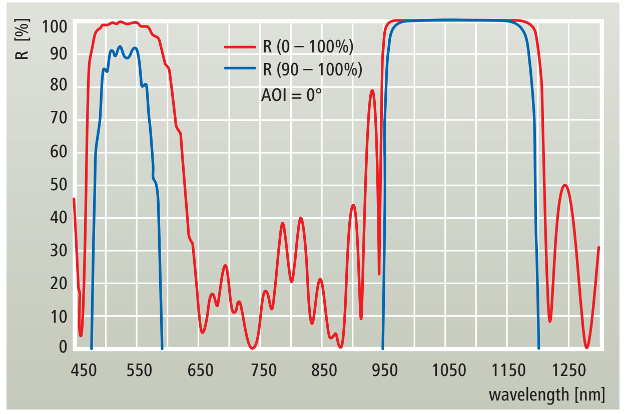


Figure 5: Reflectance spectrum of a HR mirror for 1064nm which is also an output coupler for 532 nm:
HR(0°, 1064 nm) > 99.9% + R(0°, 532 nm) = 99%

COATINGS ON NONLINEAR OPTICAL CRYSTALS

Nonlinear optical crystals are the key elements for frequency conversion. LAYERTEC offers a variety of coatings on crystals like KTP and lithium niobate

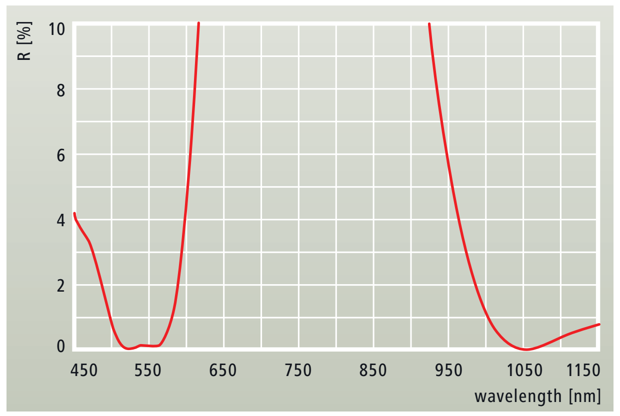


Figure 6: Reflectance spectrum of a dual antireflection coating on KTP for 532 nm and 1064 nm

For more information on coatings on crystals see pages 100 – 101.

COMPONENTS FOR THE THIRD HARMONIC OF Nd:YAG, Nd:YVO_4 AND Yb:YAG LASERS

343 nm, 355 nm

The third harmonic of Nd:YAG, Nd:YVO_4 and Yb:YAG lasers has gained increasing importance in the field of materials processing as well as for measurement applications and as pump source for optical parametric oscillators. On these pages we introduce optics for 355 nm: single and multiple wavelength mirrors, separators, thin film polarizers and anti reflection coatings. The coating designs shown here are calculated for 355 nm, but designs for 343 nm are available as well. All designs are calculated according to customer specification.

STANDARD COMPONENTS

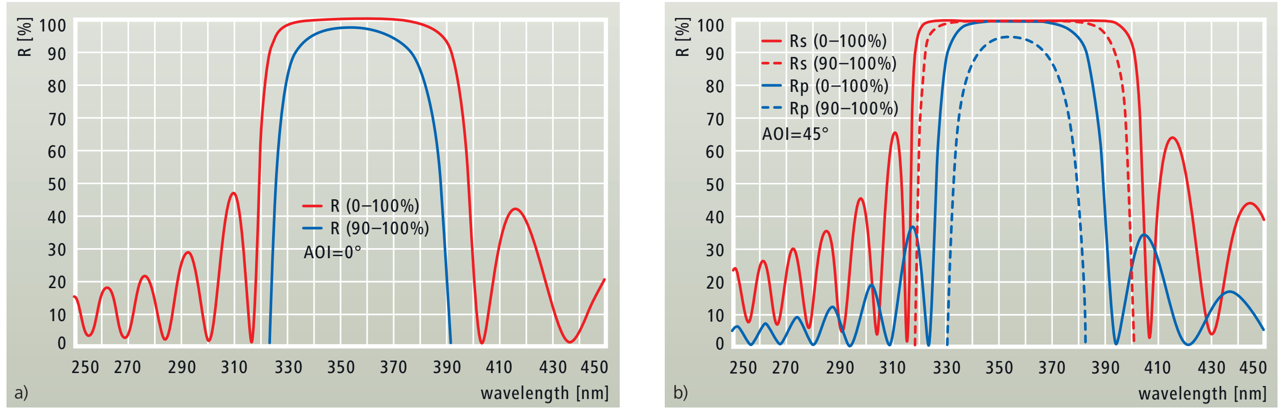


Figure 1: Reflectance spectra of a single wavelength mirror for normal incidence (a) and of a turning mirror (b)

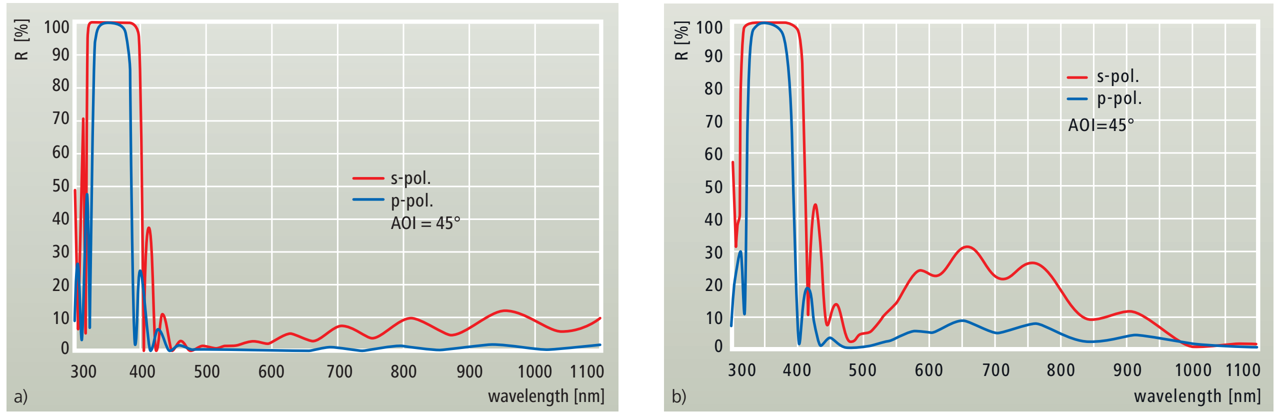


Figure 2: Reflectance spectra of separators for the third harmonic from the second harmonic and the ground wavelength: (a): standard type (b): separator which is especially optimized for low reflectance at 1064 nm

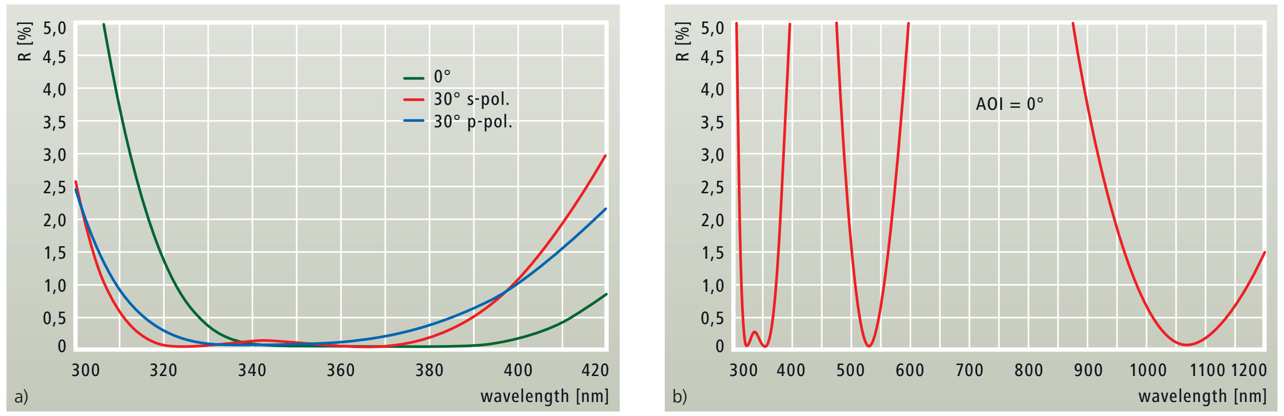


Figure 3: Reflectance spectra of a single wavelength AR coating for 355 nm optimized for AOI = 0° – 30° (a) and of a triple wavelength antireflection coating on fused silica for 355 nm, 532 nm and 1064 nm.

For common specifications of separators for the harmonics in the UV spectral range please see table on page 52. Please do not hesitate to contact us for separators or mirrors with other angles of incidence.

SPUTTERED COMPONENTS

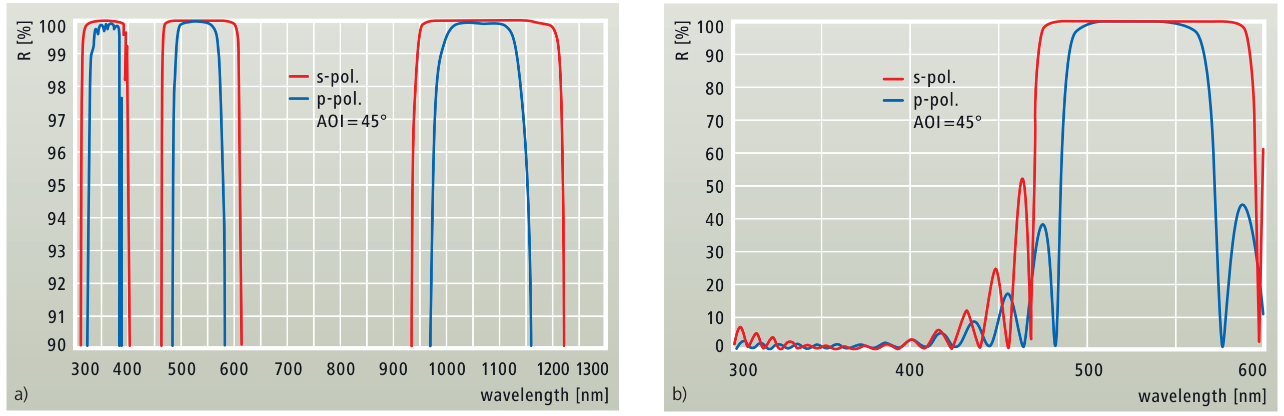


Figure 4: Reflectance spectra of a triple wavelength turning mirror for 355 nm, 532 nm and 1064 nm (a) and of a special separator for the third harmonic from the second harmonic: HR(45°, 532 nm) > 99.8 nm + R(45°, 355 nm) < 5% (b). For a dual wavelength mirror see page 49 fig.2b.

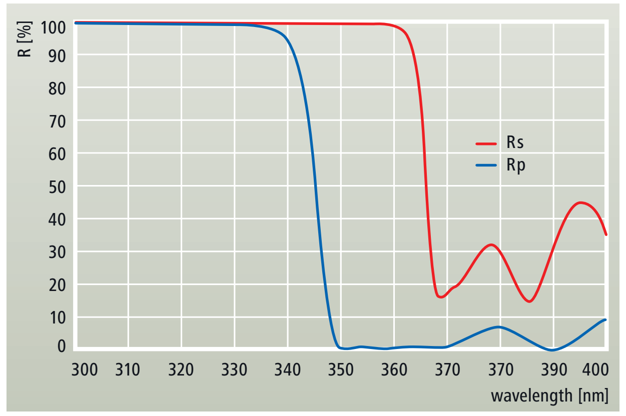


Figure 5: Reflectance spectrum of a thin film polarizer for 355 nm: HRs (55°, 355 nm) > 99,5% + Rp (55°, 355 nm) < 2%

The transmission of the p-polarized light can be optimized by angle tuning. Tilting the polarizer by ±2° shifts the minimum of Rp to longer or shorter wavelengths which can improve the polarization ratio significantly.

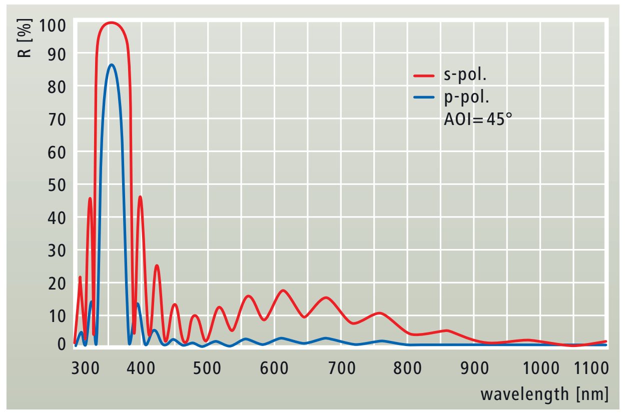


Figure 6: Reflectance spectra of special separators for the third harmonic from the second harmonic and the fundamental wavelength: Flouridic Separator HRs (45°, 355 nm) > 95% + Rp (45°, 532 nm) < 2% + Rs,p (45°, 1064 nm) < 2%

Fluoridic separators show an extended lifetime at high power densities.

Type of coating	Standard	Sputtered
Mirror for AOI = 0°	R > 99.5%	R > 99.9%
Turning mirror	Rs > 99.7%, Rp > 99%	Rs > 99.95%, Rp > 99.8%
Separator AOI = 45°	Rs (355 nm) > 99.7% Rp (355 nm) > 99% Rs (532 nm) < 5% Rp (532 nm) < 2% Rs (1064 nm) < 10%, Rp (1064 nm) < 2%	Rs (355 nm) > 99.9% Rp (355 nm) > 99.7% Rp (532 nm) < 2% Rp (532 nm) < 1% Rs (1064 nm) < 2%, Rp (1064 nm) < 1%

COMPONENTS FOR HIGHER HARMONICS OF Nd:YAG AND Nd:YVO_4 LASERS

The harmonics of Nd:YAG and Nd:YVO_4 lasers are widely used for materials processing as well as for measurement applications. On these pages we introduce dual wavelength mirrors and separators for the fourth (266nm) and fifth harmonic (213nm). All designs are calculated according to customer specification.

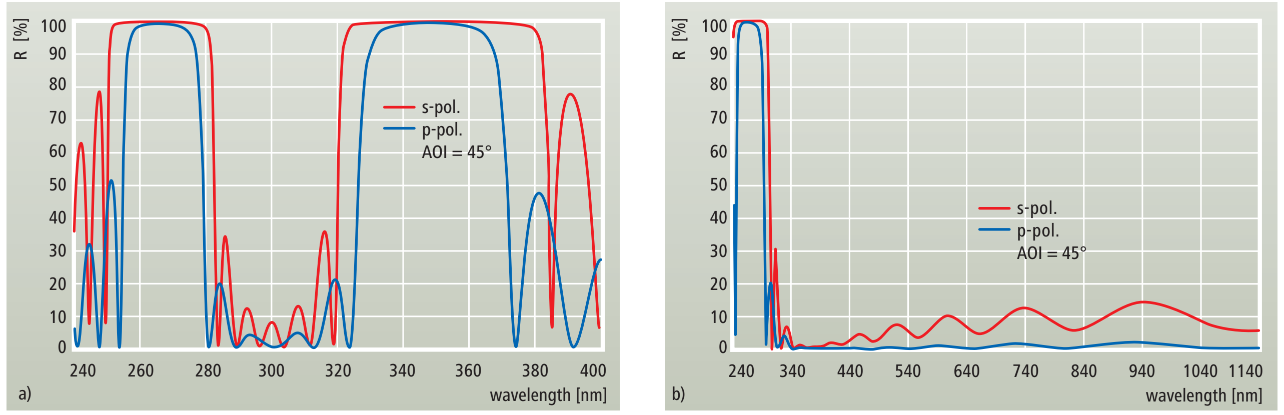


Figure 1: Reflectance spectra of a dual wavelength turning mirror for 266nm and 355nm (a) and a separator for the fourth harmonic from the long wavelength harmonics and the ground wavelength (b)

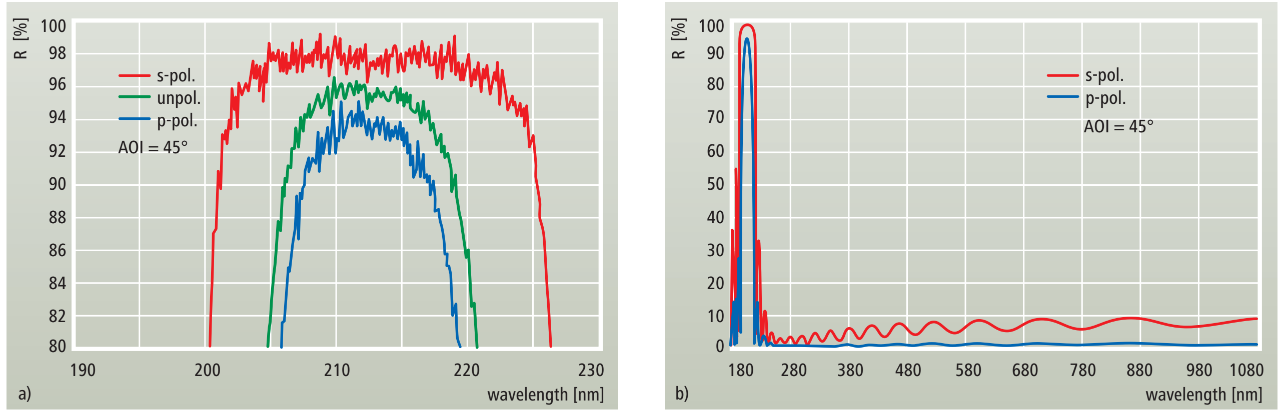


Figure 2: Measured reflectance spectra of a turning mirror for the fifth harmonic (a) and of a separator for the fifth harmonic from the long wavelength harmonics and the ground wavelength (b); fluoridic coatings on CaF_2

Common specifications of separators for the harmonics in the UV spectral range:

Separator type	type	Reflectance at centre wavelength [%]		Reflectance at the corresponding longer Nd:YAG wavelengths [%]							
				266nm		355nm		532nm		1064nm	
		Rs	Rp	Rs	Rp	Rs	Rp	Rs	Rp	Rs	Rp
3rd harmonic, 355nm	standard	> 99.7	> 99					< 5	< 2	< 10	< 2
	sputtered	> 99.9	> 99.8					< 2	< 1	< 2	< 1
4th harmonic, 266nm	standard	> 99.7	> 99			< 5	< 2	< 10	< 2	< 10	< 2
	sputtered	> 99.7	> 99			< 5	< 1	< 2	< 1	< 2	< 1
5th harmonic, 213nm*	standard	> 97	> 93	< 5	< 2	< 10	< 2	< 10	< 2	< 10	< 2

Table 1: Common specifications of separators for the harmonics in the UV *Fluoridic coating on CaF_2

213 nm, 266 nm

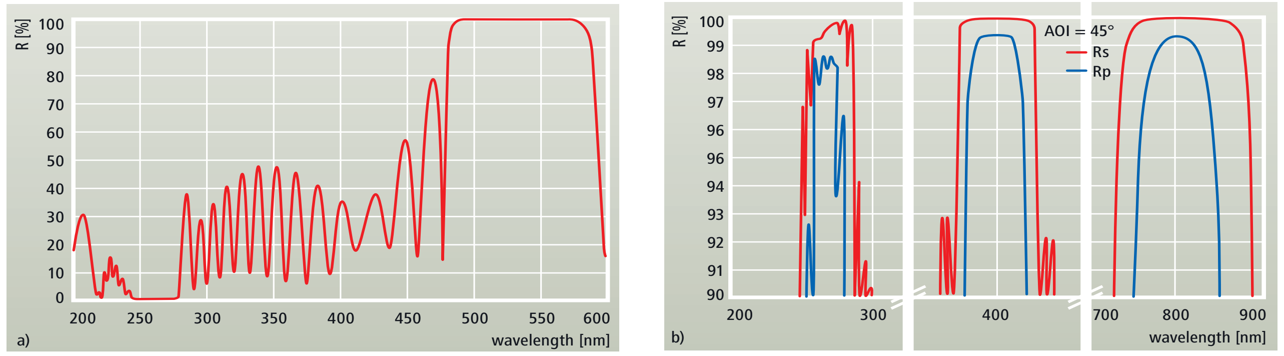


Figure 3: Reflectance spectra of a special separator for the second harmonic from the fourth harmonic: HR (0°, 532nm) > 99.95% + R (0°, 266nm) < 5% (rear side uncoated) (a) and of a triple wavelength band turning mirror for 800nm + 400nm + 270nm (b)

Recent research results on sputtered coatings for the UV enable LAYERTEC to offer separators with a very high reflectivity (R>99.95%) in the VIS, which have excellent transmission (T>90%) in the UV (see figure3). The sputtering techniques can also be applied for components for the third harmonic of Ti:Sapphire lasers. Figure 3b shows the reflectance spectrum of a low GDD triple wavelength band turning mirror for the Ti:Sapphire-laser fundamental wavelength, the second and the third harmonic. For more information about such coatings please see pages 78 – 79.

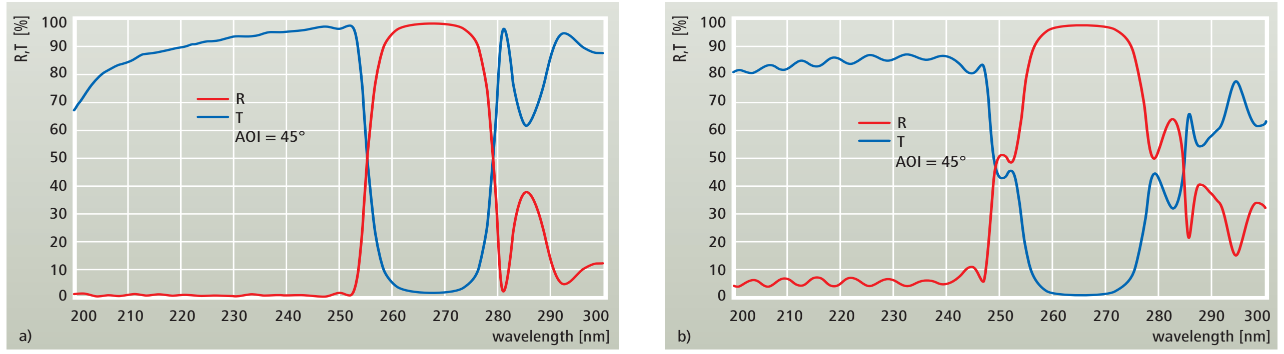


Figure 4: Reflectance spectra of separators for the fourth and fifth harmonics: HRr(45°, 266nm) > 98% + Rr(45°, 213nm) < 10% for unpolarized light
a) oxide coatings optimized for low straylight losses (rear side uncoated)
b) fluoride coatings for high laser induced damage thresholds (rear side uncoated)

The fifth harmonic at 213nm is a critical wavelength for oxide coatings, because the absorption edge of aluminum oxide begins in this wavelength range. For high power applications we recommend fluoridic coatings on calcium fluoride which are produced according to the technology of ArF-excimer laser mirrors.

THIN FILM POLARIZERS

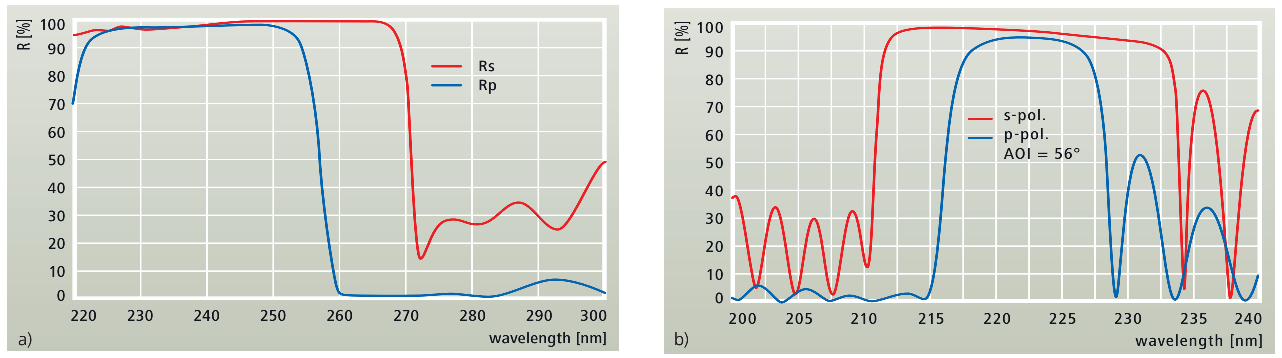


Figure 5: Reflectance spectra of thin film polarizers for 266nm (a) and 213nm (b):
a) HRs (56°, 266nm) >98% + Rp (56°, 266nm) <5%, Tp (56°, 266nm) ~ 95%
b) HRs (56°,213nm)>97% + Rp (56°, 213nm) <5%, Tp (56°, 213nm) ~ 75%

Sputtering techniques enable us to offer thin film polarizers also for the fourth and fifth harmonic of the Nd:YAG laser.

COMPONENTS FOR WEAK Nd:YAG OR Nd:YVO_4 LASER LINES

Neodymium doped crystals show laser transitions at different wavelengths. Table 1 gives an overview about the laser wavelengths of the most common Nd doped materials Nd:YAG and Nd:YVO_4.

Nd:YAG		Nd:YVO_4	
Laser lines	**Second harmonic**	**Laser lines**	**Second harmonic**
946 nm	473 nm	915 nm	457 nm
1064 nm	532 nm	1064 nm	532 nm
1123 nm	561 nm		
1319 nm	659 nm	1340 nm	670 nm

Table 1: Laser lines and corresponding wavelengths of the second harmonic of Nd:YAG and Nd:YVO4

As can be seen, a variety of laser lines in the VIS and NIR can be obtained from these crystals. This phenomenon is used to build compact diode pumped solid stated lasers with a variety of wavelengths which are used for measurement applications as well as for projection systems (RGB lasers).

The strongest laser transition in both materials is the 1064 nm line. Efficient laser radiation at the other wavelengths is only possible by suppressing this line. LAYERTEC offers a variety of laser mirrors for this application.

Compact laser designs include also the pump diode (808 nm) and a unit for the second harmonic generation. This is the reason, why coatings for Nd:YAG or Nd:YVO_4 wavelengths apart from 1064 nm mostly show several spectral regions of high transmission as well as of high reflection. In the following we present some examples of such coatings. All coatings are designed according to customer specifications, because the specifications depend on the laser design. All examples on these pages are for Nd:YAG wavelengths. Coatings for Nd:YVO_4 can be designed and produced as well.

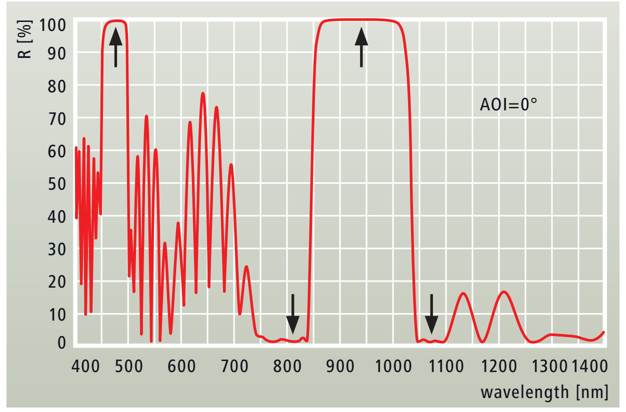


Figure 1: Reflectance spectrum of a dual wavelength mirror for a weak laser line and its second harmonic with high transmission for the pump wavelength and the strongest laser line:
HR(0°, 473 nm) > 99.85 % + HR(0°, 946 nm) > 99.95% + R(0°, 808 nm) < 2% + R(0°, 1064 nm) < 5%

Feature	Reflectivity
Suppression of the strongest laser line	R(0°,1064 nm) < 5%
HR mirror for the weak laser line	R(0°,946 nm) > 99.95%
High transmission for the pump wavelength	R(0°,808 nm) < 2%
HR mirror for the second harmonic of the weak laser line	HR(0°,473 nm) > 99.85%

915 nm, 946 nm, 1123 nm, 1340 nm

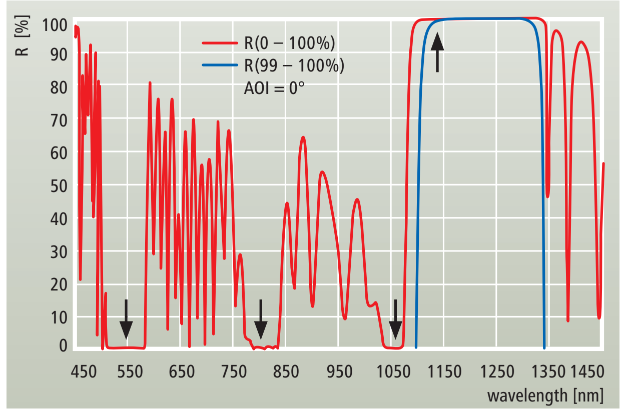


Figure 2: Reflectance spectrum of a dichroic mirror with high transmission for the pump wavelength which also suppresses the 1064 nm line:
HR(0°, 1123 nm) > 99.9% + R(0°, 561 nm) < 2% + R(0°, 808 nm) < 10% + R(0°, 1064 nm) < 50%

Feature	Reflectivity
HR mirror for the weak laser line	HR(0°, 1123 nm) > 99.9%
Suppression of the strongest laser line	R(0°, 1064 nm) < 50%
High transmission for the pump wavelength	R(0°, 808 nm) < 10%
High transmission for the second harmonic of the weak laser line	R(0°, 561 nm) < 2%

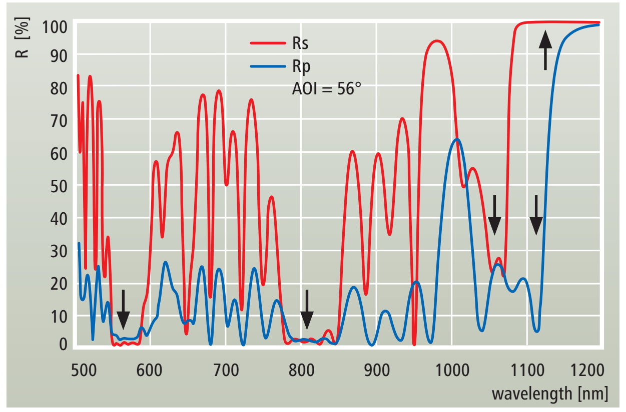


Figure 3: Reflectance spectra of a thin film polarizer with high transmission for the pump wavelength and the second harmonic which also suppresses the 1064 nm line:
HRs(56°, 1123 nm) > 99.9% + Rp(56°, 1123 nm) < 50% + Rs,p(56°, 561 + 808 nm) < 10% + Rs,p(56°,1064 nm) < 50%

Feature	Reflectivity
HR for s-polarized light of the weak laser line	HRs(56°, 1123 nm) > 99.9%
Suppression of p-polarized light of the weak laser line	Rp(56°, 1123 nm) < 50%
Suppression of the strongest laser line	Rs+p(56°, 1064 nm) < 50%
High transmission for the pump wavelength	Rs+p(56°, 808 nm) < 10%
High transmission for the second harmonic of the weak laser line	Rs+p(56°, 561 nm) < 10%

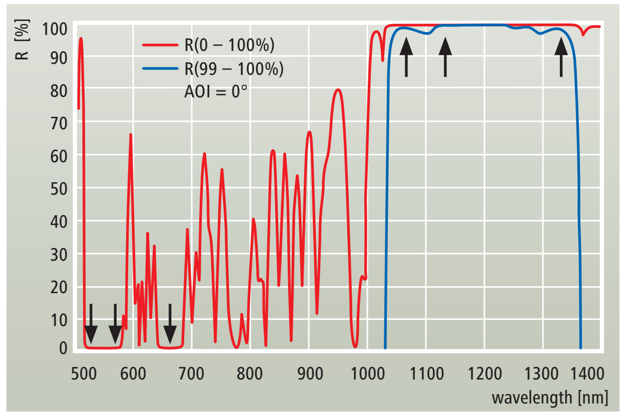


Figure 4: Reflectance spectrum of a dichroic mirror with high reflectance for the NIR wavelengths and high transmission for the corresponding second harmonic wavelengths:
HR(0°, 1064+1123+1319 nm) > 99.9% + R(0°, 532−561+659 nm) < 2%

Feature	Reflectivity
Broadband HR mirror for several laser lines	HR(0°, 1064+1123+1319 nm) > 99.9%
High transmission for the second harmonics of these laser lines	R(0°, 532−561+659 nm) < 2%

COMPONENTS FOR Ho:YAG AND Tm:YAG LASERS

Ho:YAG and Tm:YAG lasers emitting at wavelengths of 2010 nm and 2100 nm are widely used for medical applications. LAYERTEC offers optical coatings for this wavelength range with high laser induced damage thresholds and long lifetimes.

MIRRORS

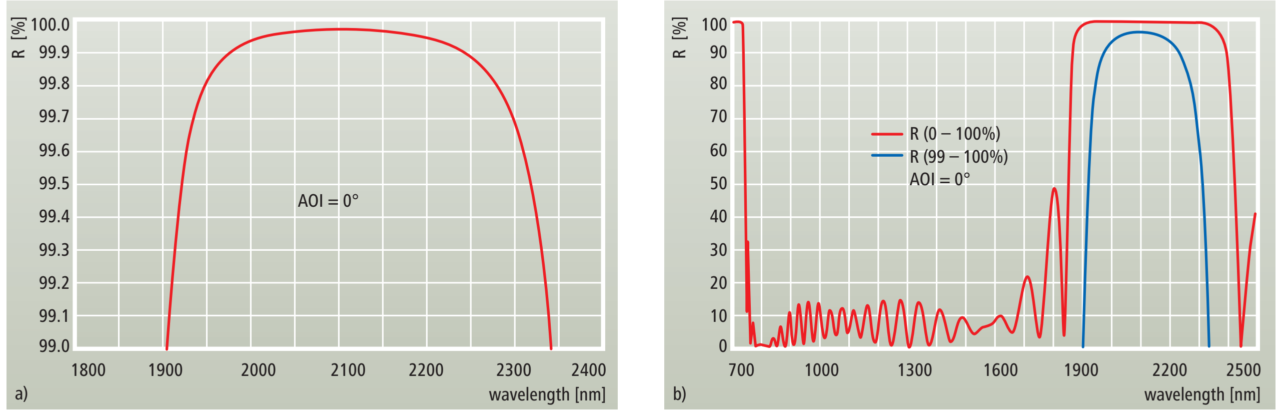


Figure 1: Reflectance spectra of a cavity mirror (a) and a pump mirror (b) which has a region of high transmittance around 808 nm.

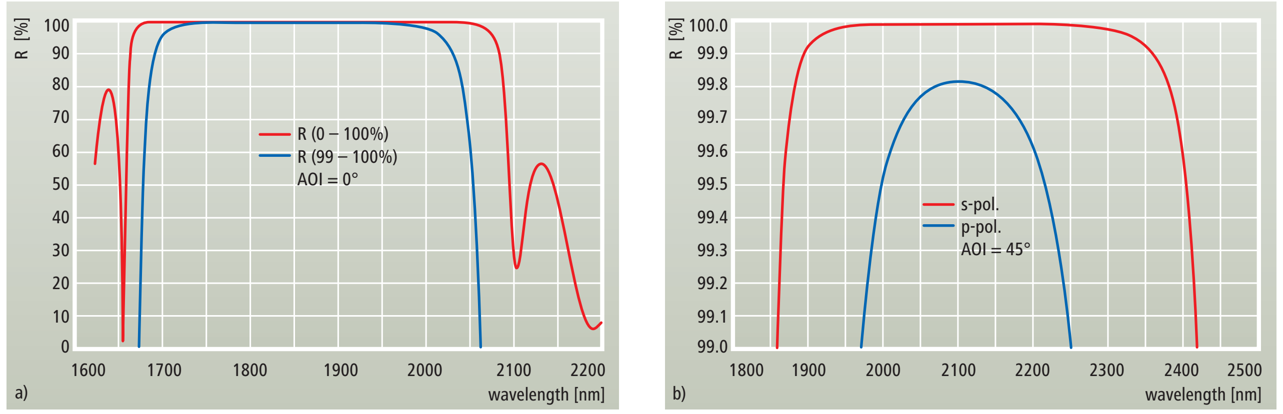


Figure 2: Reflectance spectra of a cavity mirror for 2010 nm which supresses the 2100 nm line (a) and a turning mirror for 2100 nm (b)

- HR cavity, pump and turning mirrors with R>99.9% at AOI=0° and at AOI=45° for s-polarization, R>99.8% at AOI=45° for p-polarized light
- High laser induced damage thresholds

2010 nm, 2100 nm

OUTPUT COUPLERS AND BEAMSPLITTERS

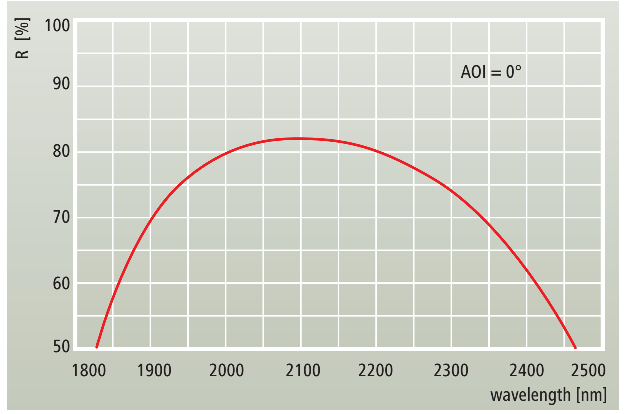


Figure 3: Reflectance spectrum of an output coupler with R = 82 % at 2100 nm

Beam splitters and output couplers with precisely adjusted degrees of reflectivity:

Reflectance	Tolerance
R>95 %	±0.5 %
R=80 ... 95 %	±1 %
R=10 % ... 80 %	±2 %

THIN FILM POLARIZERS AND EDGE FILTERS

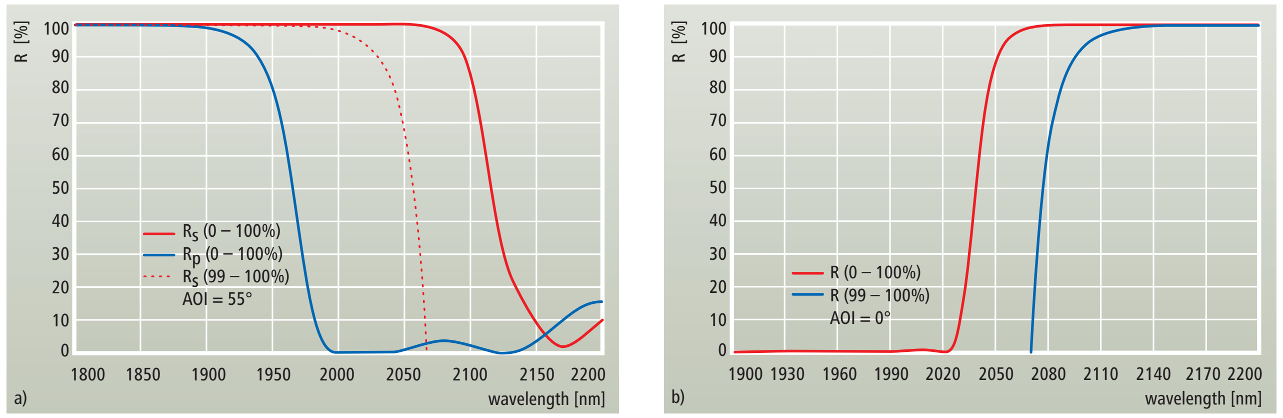


Figure 4: Reflectance spectra of a thin film polarizer for 2010 nm (Rs>99.8 %, Rp<2 %, AOI=55°) (a) and a steep edge filter for the separation of the 2010 nm and 2100 nm lines (b)

Thin film polarizers:

- Separation of the s- and p-polarized component of the light (s-polarized light is reflected and p-polarized light is transmitted)
- TFPs can be produced for AOI>40°, but polarization is most efficient and appears in a broad wavelength range if AOI≈55° (Brewster angle) is used

COMPONENTS FOR Er:YAG LASERS AND THE 3 µm REGION

COMPONENTS FOR Er:YAG LASERS

- HR cavity and turning mirrors
- Reflectivity: R > 99.9 % at AOI = 0°, R > 99.8 % at AOI = 45° for random polarized light
- High damage thresholds (400 J/cm² at 400 µs)
- Pump mirrors with high transmittance between 800 nm and 1100 nm for pumping with a Nd:YAG laser or a diode laser

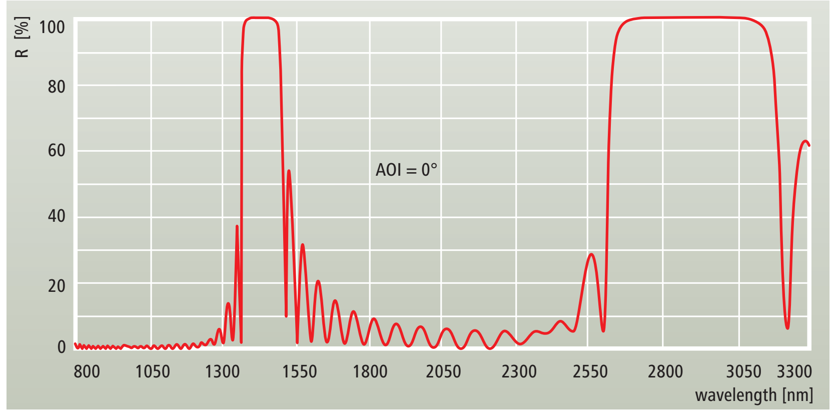


Figure 1: Reflectance spectrum of a HR cavity mirror with a HT region between 800 nm and 1100 nm

- Dual wavelength turning mirrors, e.g. HRr (45°, 2940 nm) > 99.5 % + Rr (45°, 630 − 655 nm) > 95 %
- Beam splitters and beam combiners, e.g. HRr (45°, 2940 nm) > 99% + Rr (45°, 630 − 655 nm) < 20 %
- These components allow to use a He-Ne laser or a diode laser between 635 nm − 655 nm for the alignment of the optical system

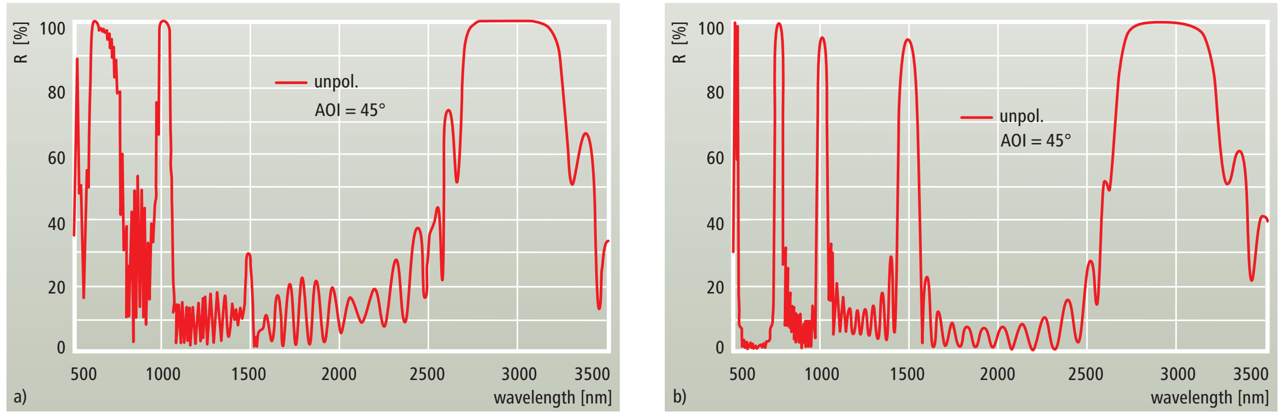


Figure 2: Reflectance spectra of a dual wavelength turning mirror (a) and a separator/combiner for 2940 nm and a pilot laser between 630 nm and 655nm (b)

2940 nm

OUTPUT COUPLERS AND LENSES

- Output couplers with precisely adjusted degrees of reflectivity (tolerances of ±1% at reflectivities between 70 % and 90 %)
- AR coatings with residual reflectivities R < 0.2 % on the rear side of output couplers as well as on lenses and windows made of sapphire, undoped YAG, CaF_2 or Infrasil® (for substrate materials see pages 14 – 15)

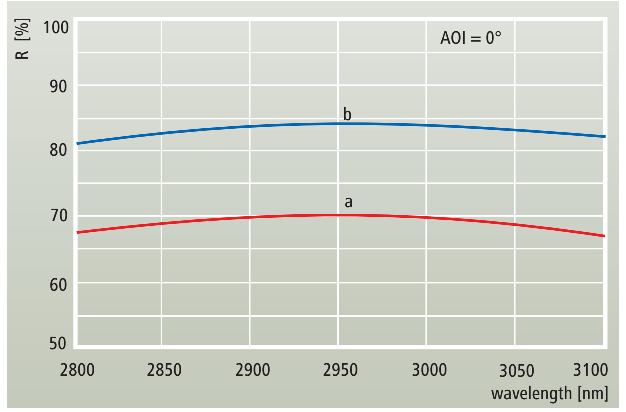


Figure 3: Reflectance spectra of output couplers with R =70% (a) and R = 84% (b)

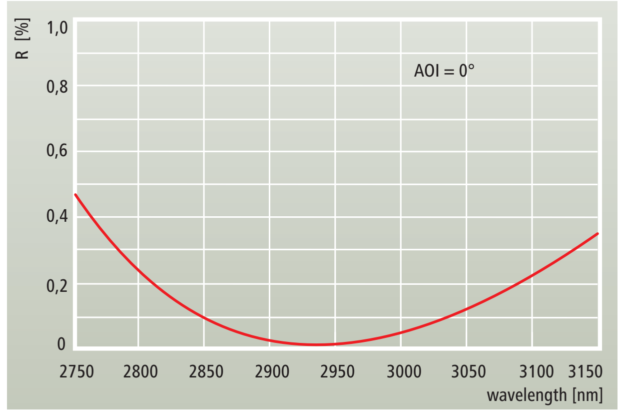


Figure 4: Reflectance spectrum of an AR-coating for 2,94 µm on sapphire

COMPONENTS FOR OTHER LASERS AROUND 3µm

The fundamental effect which is especially used for the medical application of lasers emitting light between 2.6 − 3.4µm is the strong absorption of water in this wavelength range. Between 2.6µm and 2.8µm the absorption of water is still stronger than at 2.94 µm (Er:YAG laser) which makes lasers working in this wavelength range (e.g. the Er:Cr:YSGG laser) promising candidates for future applications.

However, the strong absorption of water is also the most serious problem with respect to laser damage. Therefore, it is essential to keep the layer system free of water. LAYERTEC uses magnetron sputtering for the production of coatings for the 3 µm region. The high atomic density of sputtered layers which is close to that of bulk material suppresses the diffusion of water into the layer systems.

This enables LAYERTEC to offer also coatings for the critical 2.6 − 2.8 µm region. Figure 5 shows as an example a HR mirror centered at 2.8 µm with a reflectivity R > 99.7 %.

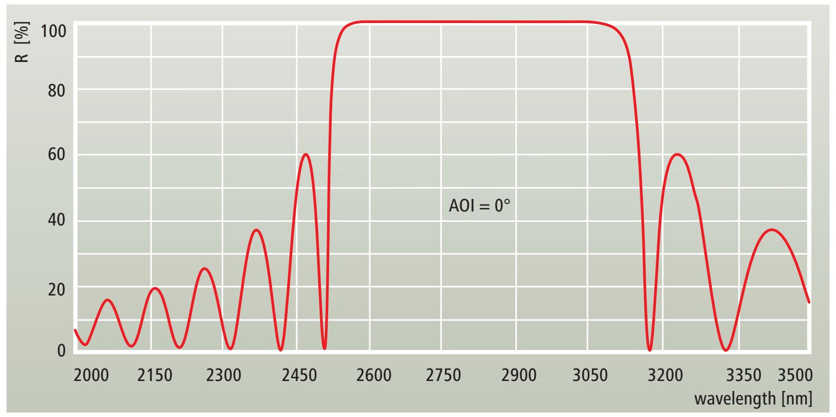
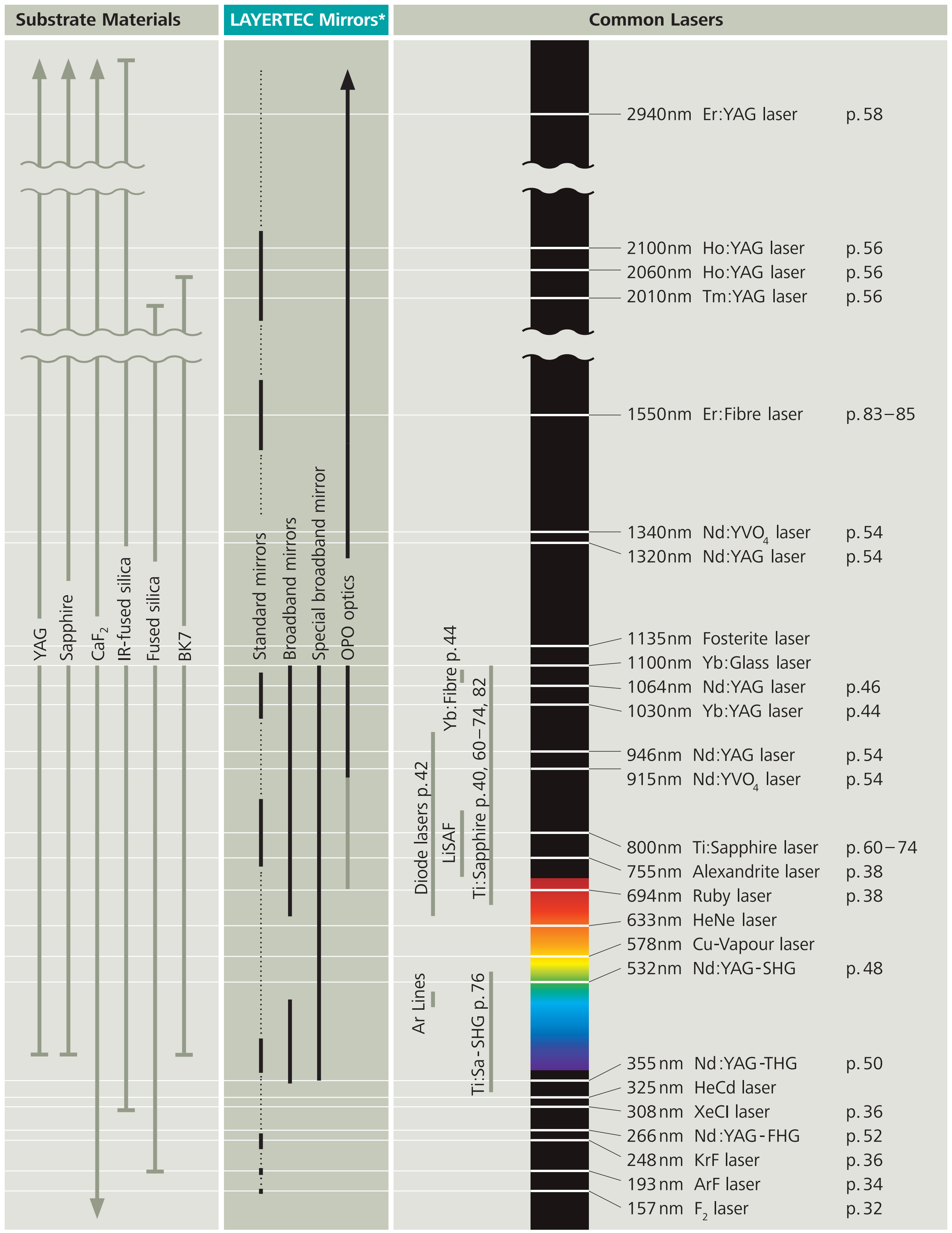


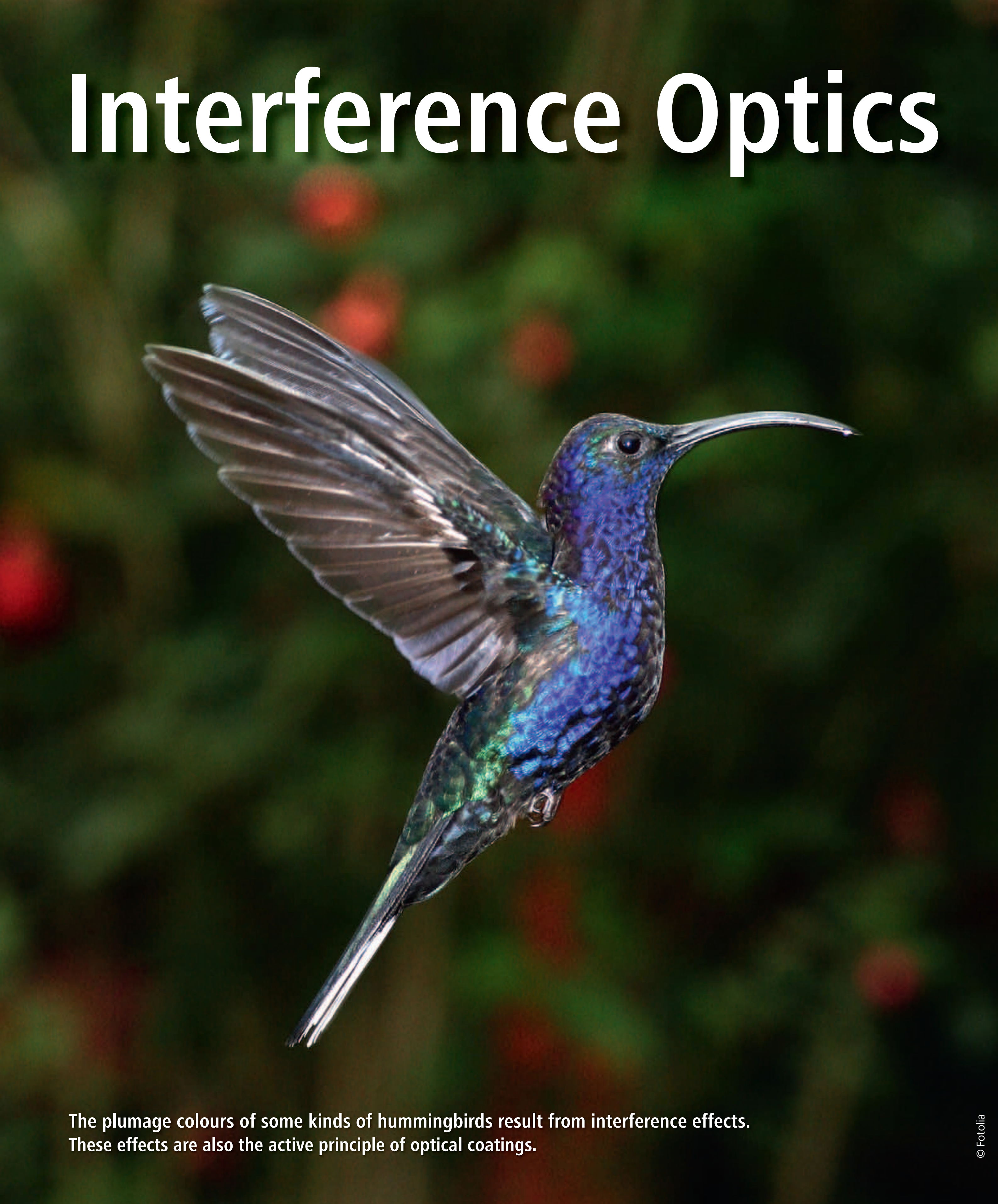
Figure 5: Reflectance spectrum of a HR mirror for 2.8 µm with R > 99.7 %

REGISTER

LAYERTEC MIRRORS



*Bandwidths of selected LAYERTEC mirrors


Interference Optics
The plumage colours of some kinds of hummingbirds result from interference effects.
These effects are also the active principle of optical coatings.
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