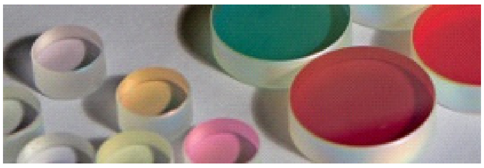
■高端应用镜片 --Layertec 产品

德国 Layertec 公司于 1990 年成立于德国 Jena，是专业生产各种高品质光学镜片的厂家。 主要产品有：常规激光光学元件、飞秒激光光学元件及特殊应用光学元件。产品的工作波长覆盖深紫外 VUV（157nm）到近红外 NIR（～4um）。

从 1990 年开始，Layertec 就和很多大学和研究机构的激光部门合作，目前员工超过 125 人。强大的研发队伍使我们不但能够提供各种标准产品，还能满足客户的各种定制要求。

一、超快激光应用



飞秒激光光学元件按照其工作特行来划分，主要包含以下几类：

- 1、标准飞秒激光应用
- 2、宽带飞秒激光应用
- 3、倍频程带宽飞秒应用
- 4、银镜
- 5、高功率飞秒激光应用
- 6、钛宝石倍频飞秒激光应用
- 7、钛宝石三倍频飞秒激光应用
- 8、钛宝石高次谐波飞秒激光应用
- 9、Gires-Tournois 干涉仪镜
- 10、1100-1600nm 飞秒激光应用

1、标准飞秒激光应用

STANDARD MIRROR AOI = 0°

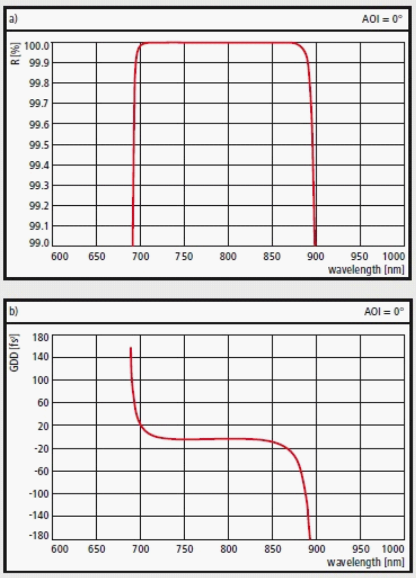


Figure 1: Reflectance and GDD spectra of a standard low dispersion femtosecond laser mirror
a) Reflectance vs. wavelength
b) GDD vs. wavelength

PUMP MIRROR AOI = 0°

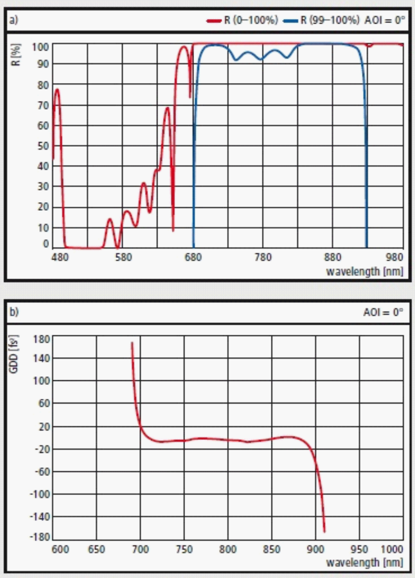


Figure 2: Reflectance and GDD spectra of a standard low dispersion pump laser mirror
a) Reflectance vs. wavelength
b) GDD vs. wavelength

TURNING MIRROR AOI = 45°

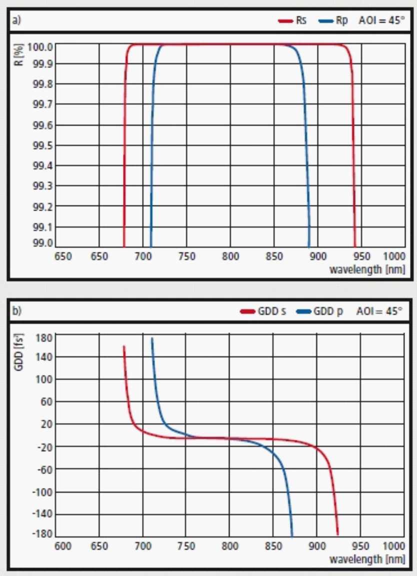


Figure 3: Reflectance and GDD spectra for a standard low dispersion turning mirror (bandwidth Rr (45°) > 99.9 % ~ 160 nm)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

OUTPUT COUPLER AOI = 0°

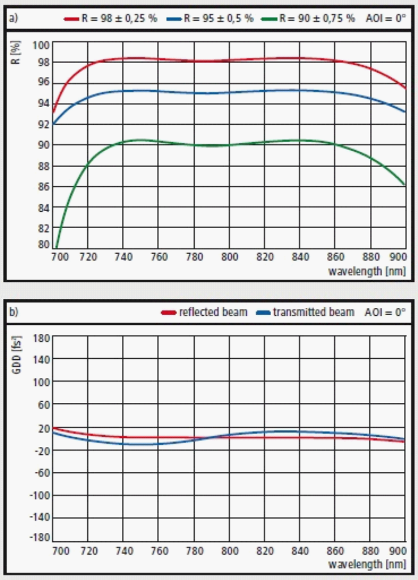


Figure 4: a) Reflectance spectra of several standard output couplers
b) GDD spectra of the output coupler with R = 98 %; the GDD spectra are similar for all levels of reflectivity

BEAM SPLITTERS FOR P-POLARIZED LIGHT AT AOI = 45°

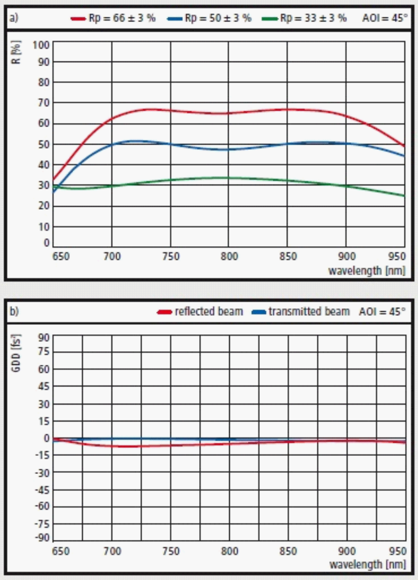


Figure 5: a) Reflectance spectra of several standard beam splitters for AOI = 45° and p-polarized light
b) GDD spectra of the beam splitter with R = 50 %; the GDD spectra are similar for all levels of reflectivity

BEAM SPLITTERS FOR S-POLARIZED LIGHT AT AOI = 45°

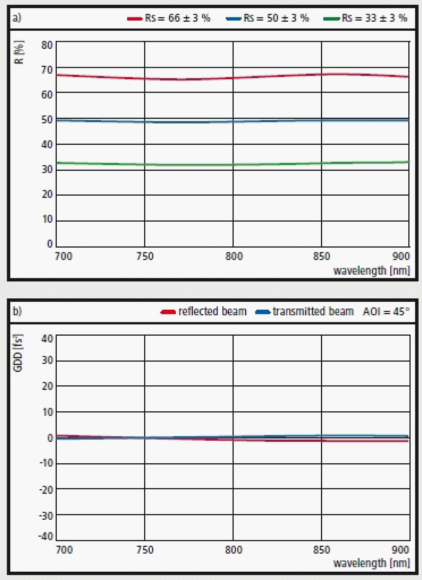


Figure 6: a) Reflectance spectra of several standard beam splitters for AOI = 45° and s-polarized light
b) GDD spectra of the beam splitter with R = 50 %; the GDD spectra are similar for all levels of reflectivity

2、宽带飞秒激光应用

MIRROR PAIR FOR AOI = 0°

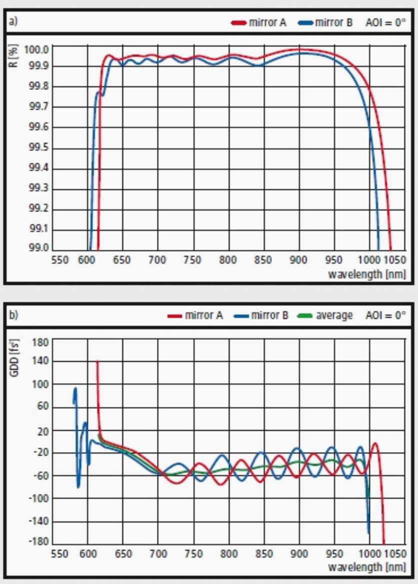


Figure 1: Reflectance and GDD spectra of a negative dispersion laser mirror pair
a) Reflectance vs. wavelength
b) GDD versus wavelength

TURNING MIRROR FOR S-POLARIZED LIGHT AT AOI = 45°

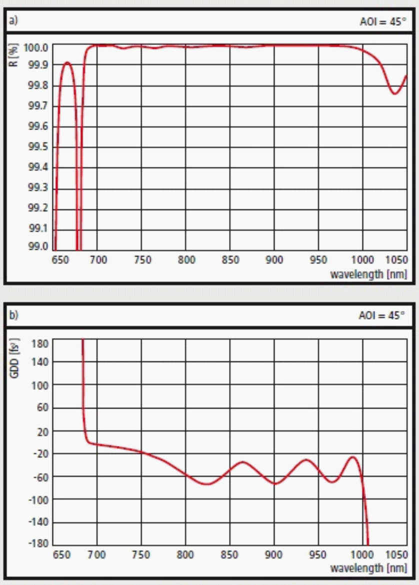


Figure 2: Reflectance and GDD spectra of a broadband turning mirror for s-polarized light
a) Reflectance vs. wavelength
b) GDD vs. wavelength

TURNING MIRROR FOR P-POLARIZED LIGHT AT AOI = 45°

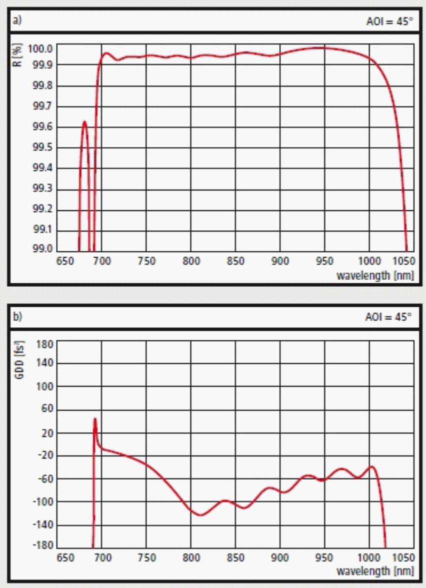


Figure 3: Reflectance and GDD spectrum of a broadband turning mirror for p-polarized light
a) Reflectance vs. wavelength
b) GDD vs. wavelength

NEGATIVE DISPERSION PUMP MIRROR PAIR FOR AOI = 0°

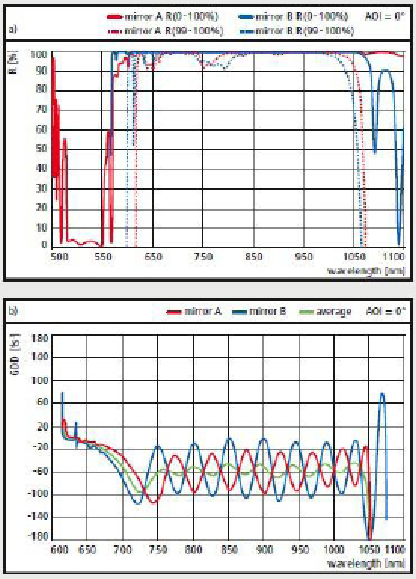


Figure 1: Reflectance and GDD spectra of a negative dispersion pump mirror pair (mirror 2 without HT- option)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

MIRROR PAIR WITH POSITIVE AVERAGE GDD

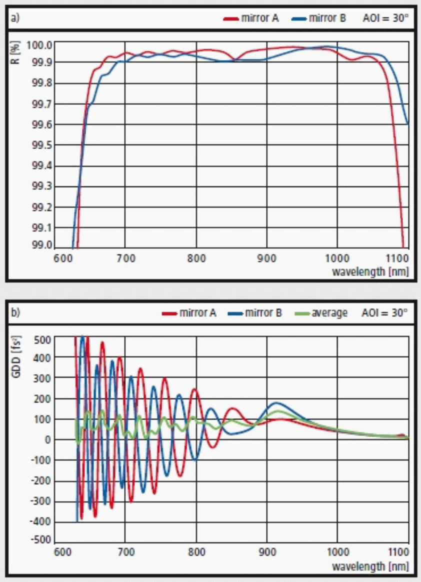


Figure 2: Reflectance and GDD spectra of a broadband mirror pair with positive average GDD for s-polarized light at AOI = 30°
a) Reflectance vs. wavelength
b) GDD vs. wavelength

THIN FILM POLARIZERS FOR AOI = 70°

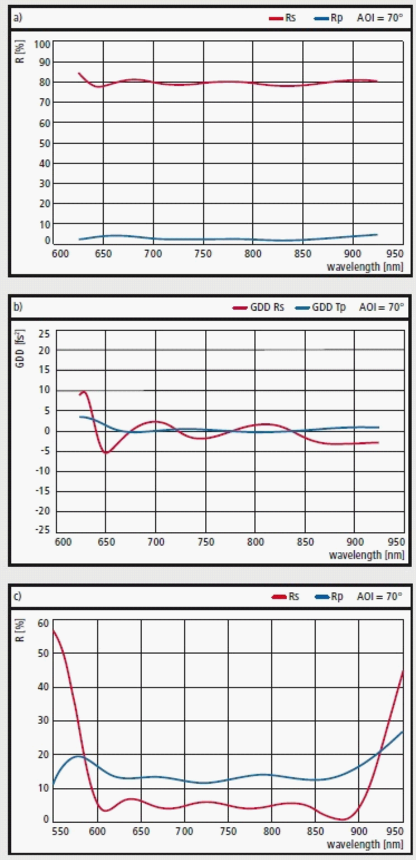


Figure 3: Reflectance and GDD spectra of a TFP (AOI = 70°, lower Rs-value to achieve a "zero" GDD for Rs and Tp, bandwidth ~ 300 nm
a) Reflectance vs. wavelength
b) GDD vs. wavelength
c) Back side AR coating for s-polarized light. Please note that this coating results in R ~ 15 % for the p-polarized component. As an AR coating for the p-polarization we suggest the use of the design from fig. 3a.

3、宽带倍频程飞秒应用

NEGATIVE DISPERSION LASER MIRROR PAIR FOR AOI = 0°

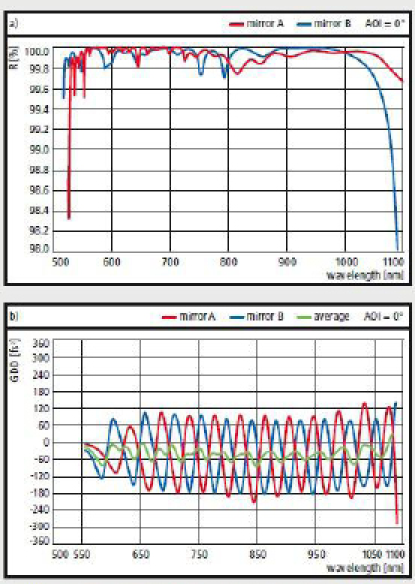


Figure 1: Reflectance and GDD spectra of an ultra broadband negative dispersion laser mirror pair
a) Reflectance vs. wavelength
b) GDD vs. wavelength

NEGATIVE DISPERSION PUMP MIRROR PAIR FOR AOI = 0°

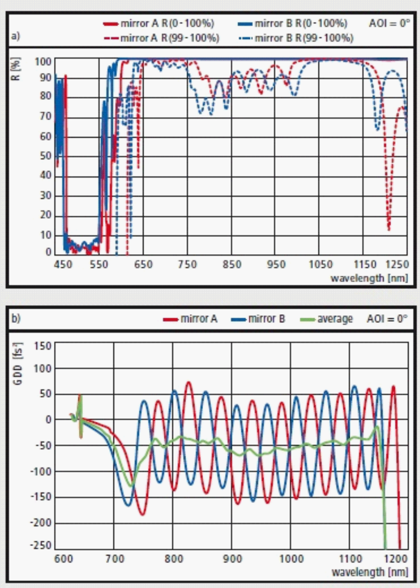


Figure 2: Reflectance and GDD spectra of an ultra broadband negative dispersion pump mirror pair
a) Reflectance vs. wavelength
b) GDD vs. wavelength

NEGATIVE DISPERSION TURNING MIRROR PAIR FOR P-POLARIZED LIGHT AOI = 45°

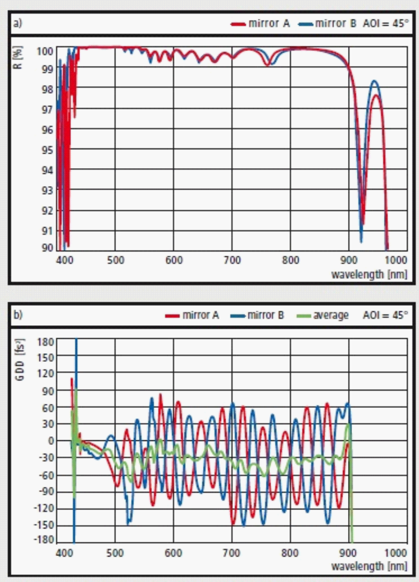


Figure 3: Reflectance and GDD spectra of an ultra broadband turning mirror pair for p-polarized light
a) Reflectance vs. wavelength
b) GDD vs. wavelength

4、银镜

SILVER MIRRORS OPTIMIZED FOR FEMTOSECOND LASER APPLICATIONS

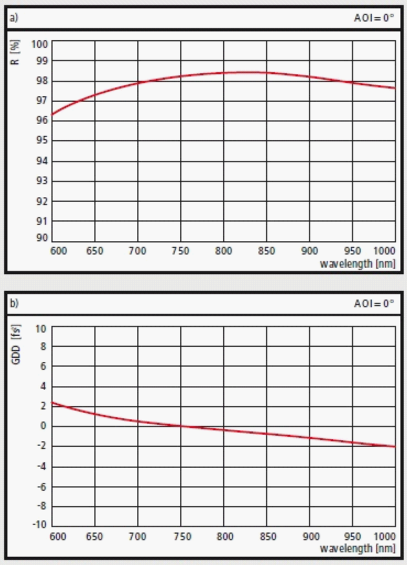


Figure 1: Reflectance and GDD-spectrum of a silver mirror optimized for use with fs-lasers in the wavelength range 600 – 1000 nm (AOI = 0°)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

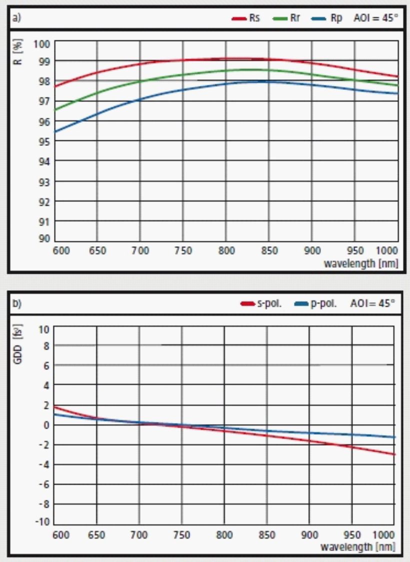


Figure 2: Reflectance and GDD-spectra of a silver mirror optimized for use with fs-lasers in the wavelength range 600 – 1000 nm (AOI = 45°)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

5、高功率飞秒激光应用

METALLIC HIGH POWER MIRRORS

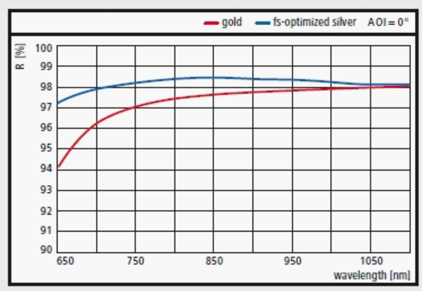


Figure 3: Reflectance spectra of bare gold and fs-optimized silver (optimized for high reflectance at 800 nm)

GDD OF HIGH POWER FEMTOSECOND LASER MIRRORS

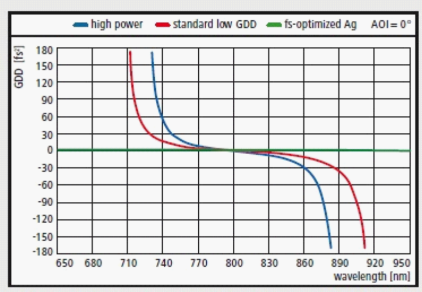


Figure 4: Group delay dispersion (GDD) of standard and high power dielectric mirrors and fs-protected silver mirrors

6、钛蓝宝石倍频飞秒激光应用

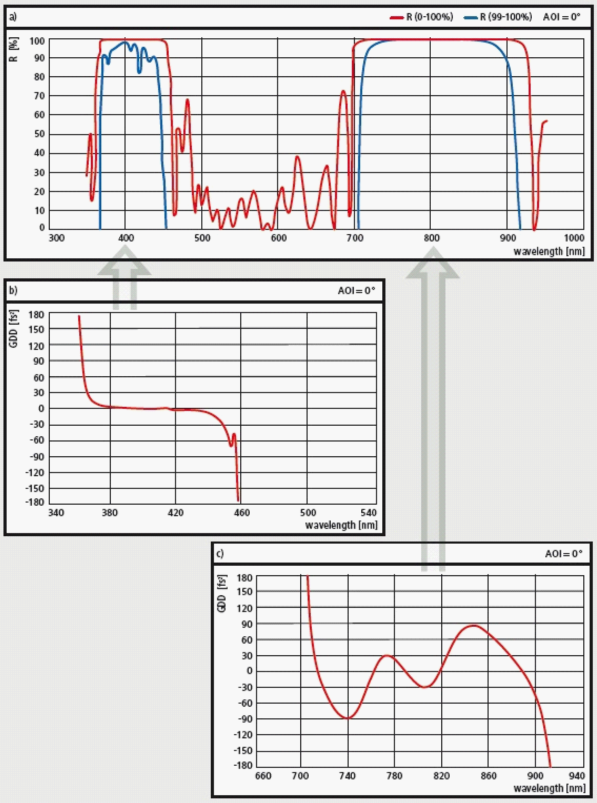


Figure 1: Reflectance and GDD spectra of a fs-optimized dual wavelength mirror for 400 nm + 800 nm at AOI = 0°
a) Reflectance vs. wavelength b, c) GDD vs. wavelength

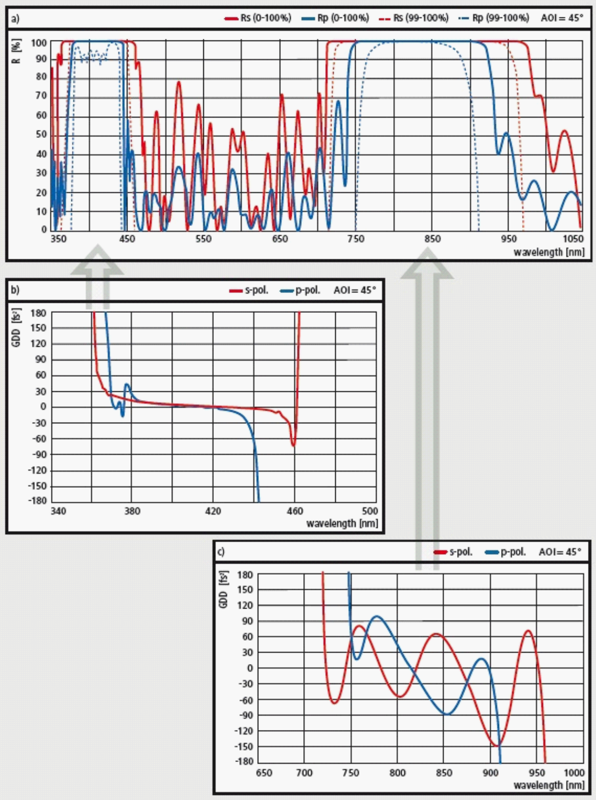


Figure 2: Reflectance and GDD spectra of a fs-optimized dual wavelength turning mirror for 400 nm + 800 nm at AOI = 45°
a) Reflectance vs. wavelength b, c) GDD vs. wavelength

7、钛宝石三倍频飞秒激光应用

DUAL WAVELENTGH TURNING MIRRORS FOR AOI = 45°

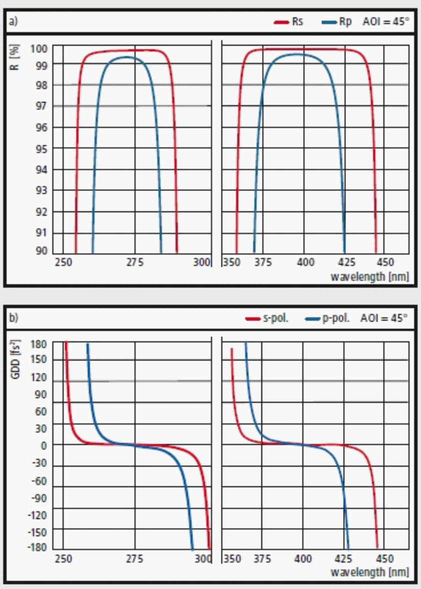


Figure 1: Reflectance and GDD spectra of a fs-optimized dual wavelength turning mirror for 270 nm + 405 nm
a) Reflectance vs. wavelength
b) GDD vs. wavelength

TRIPLE WAVELENTGH TURNING MIRRORS FOR AOI = 45°

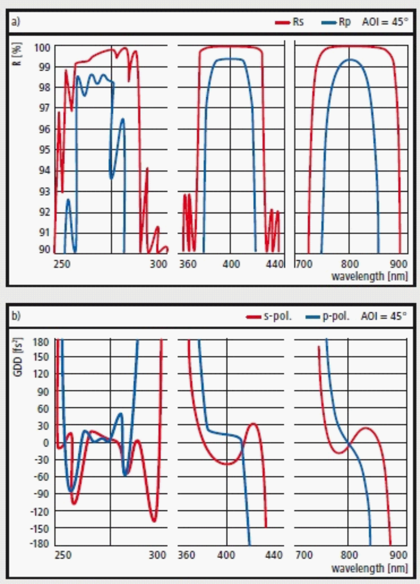


Figure 2: Reflectance and GDD spectra of a fs-optimized turning mirror for the 266 nm – 400 nm – 800 nm wavelength regions
a) Reflectance vs. wavelength
b) GDD vs. wavelength

BROADBAND LOW DISPERSION MIRRORS FOR AOI = 45°

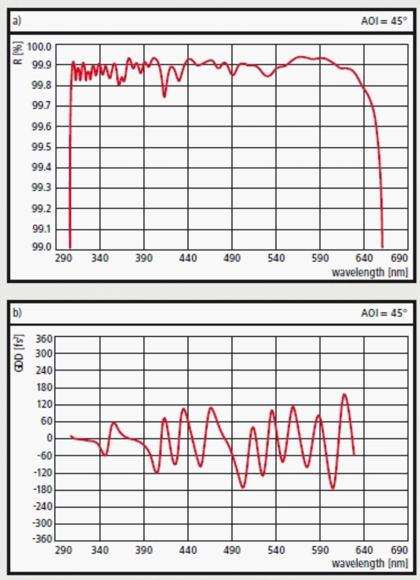


Figure 3: Reflectance and GDD spectra of a broadband negative dispersion mirror HRs (45°, 325 nm – 600 nm) with Rs > 99.7 % and low GDD
a) Reflectance vs. wavelength
b) GDD vs. wavelength

8、钛宝石高次谐波飞秒激光应用

TURNING MIRRORS AND SEPARATORS FOR THE FOURTH HARMONIC AT AOI = 45°

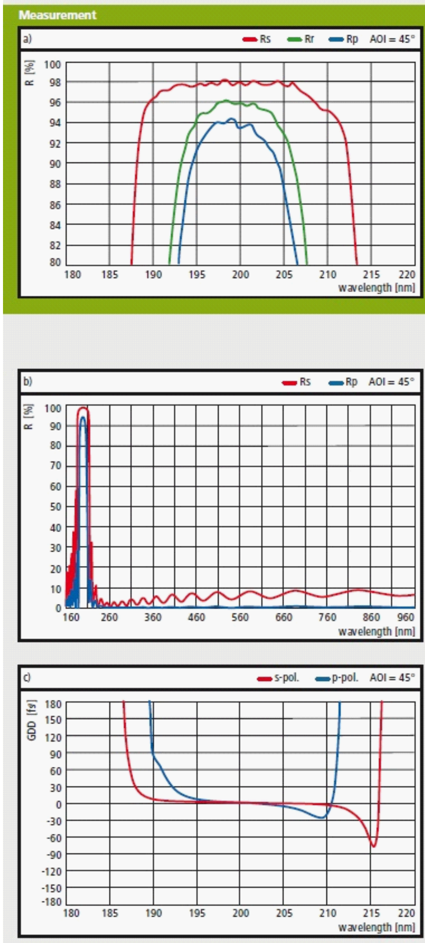


Figure 1: Reflectance and GDD spectra of a separator for the fourth harmonic from the longer wavelength harmonics and the fundamental wave (AOI = 45°)
a) Reflectance vs. wavelength (measured)
b) Reflectance vs. wavelength (calculated)
c) GDD vs. wavelength (calculated)

COMPONENTS FOR THE FIFTH HARMONIC AT AOI = 45°

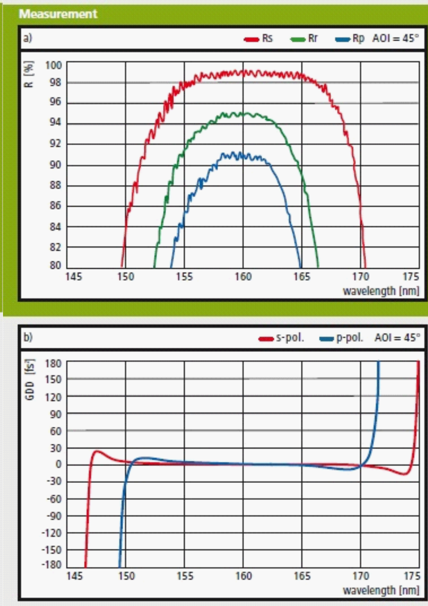


Figure 2: Reflectance and GDD spectra of a turning mirror for 160 nm (AOI = 45°)
a) Reflectance vs. wavelength (measured)
b) GDD vs. wavelength (calculated)

COMPONENTS FOR THE SIXTH HARMONIC AT AOI = 45°

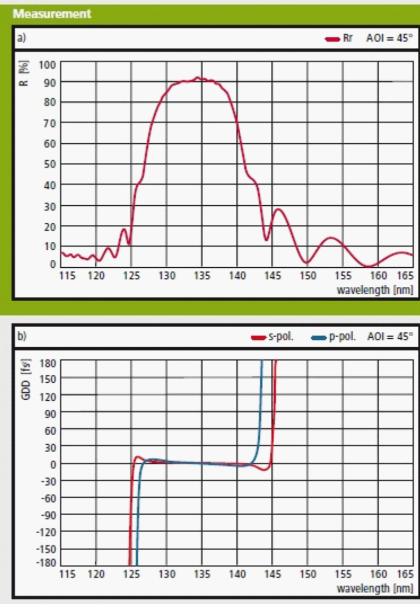


Figure 3: Reflectance and GDD spectra of a turning mirror for 133 nm (AOI = 45°)
a) Reflectance vs. wavelength (measured for unpolarized light)
b) GDD vs. wavelength (calculated)

9、Gires-Tournois 干涉仪镜

GTI-MIRRORS FOR Yb:YAG- AND Yb:KGW-LASERS

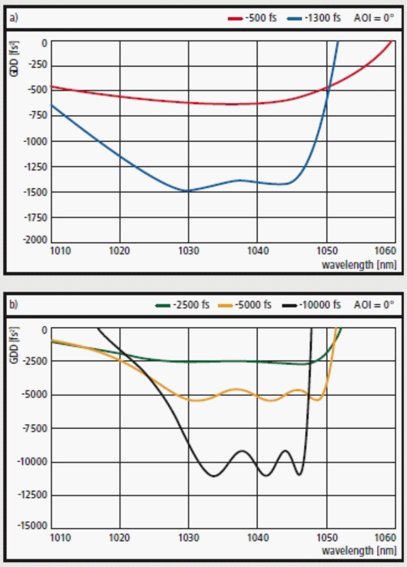


Figure 1: GDD spectra of GTI-mirrors for 1040 nm with different GDD Values

GDD [fs²]	Reflectivity [%] measured by CRD
-500	99.99
-1300	99.98
-2500	99.97
-5000	99.95
-10000	99.95

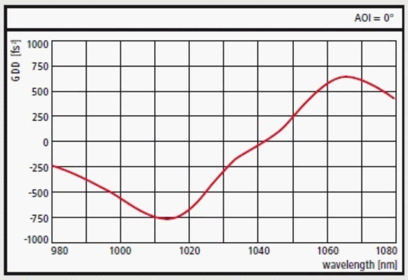


Figure 2: GTI-mirror with nearly constant TOD

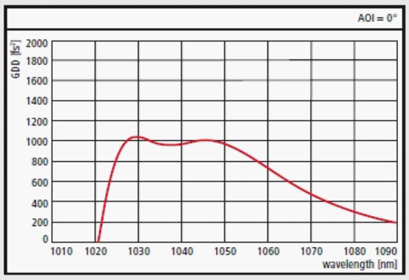


Figure 3: GTI-mirror with positive GDD

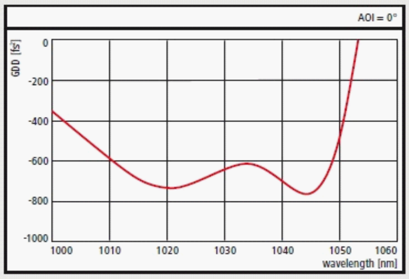


Figure 4: GDD spectrum of a rear side GTI mirror with GDD (0°- 10°, 1030 nm) ~ -700 fs². The mirror is irradiated through the substrate which has an AR coating on the front side. Back side GTI mirrors are insensitive against surface contaminations which sometimes distort the GDD spectrum of common front side GTI mirrors

10、1100-1600nm 飞秒激光应用

NEGATIVE DISPERSION LASER AND PUMP MIRRORS FOR AOI = 0°

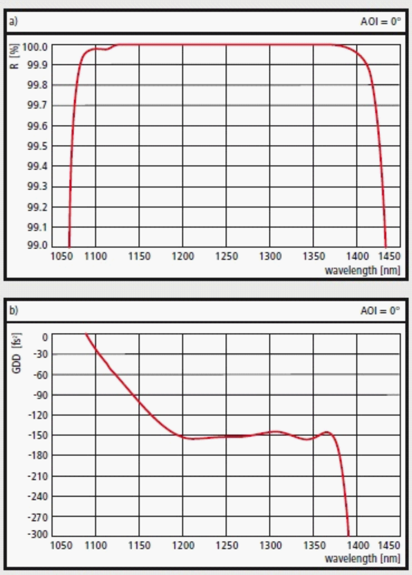


Figure 1: Reflectance and GDD spectrum of a negative dispersion laser mirror (GDD ~ -150 fs² for 1200 – 1370 nm)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

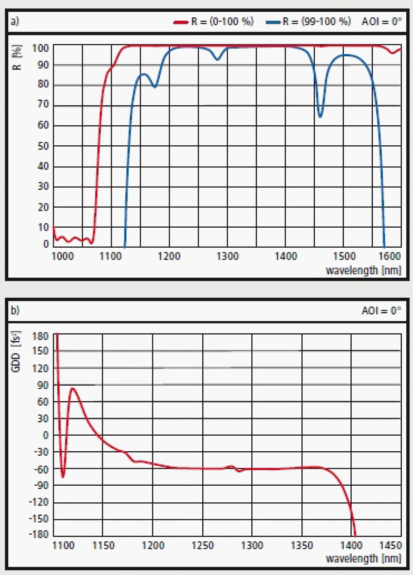


Figure 2: Reflectance and GDD spectrum of a negative dispersion pump mirror: HR (0°, 1180 – 1380 nm) > 99.8 % + R (0°, 1020 – 1070 nm) < 5 %, GDD (1180 – 1380 nm) ~ -60 fs²
a) Reflectance vs. wavelength
b) GDD vs. wavelength

GTI MIRRORS FOR AOI = 0°

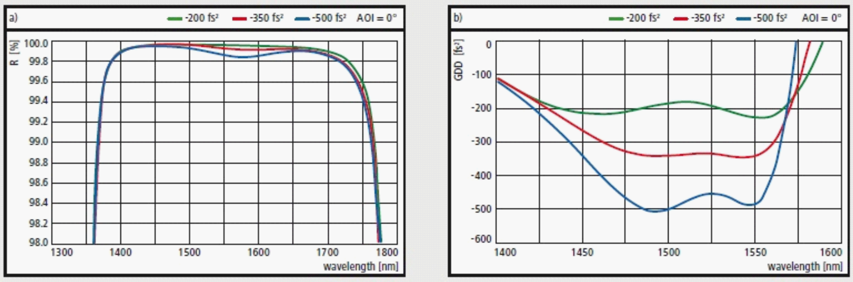


Figure 3: Reflectance and GDD spectra of GTI mirrors for 1500 nm with different GDD values
a) Reflectance vs. wavelength b) GDD vs. wavelength

BROADBAND NEGATIVE DISPERSION MIRROR PAIRS FOR AOI = 0°

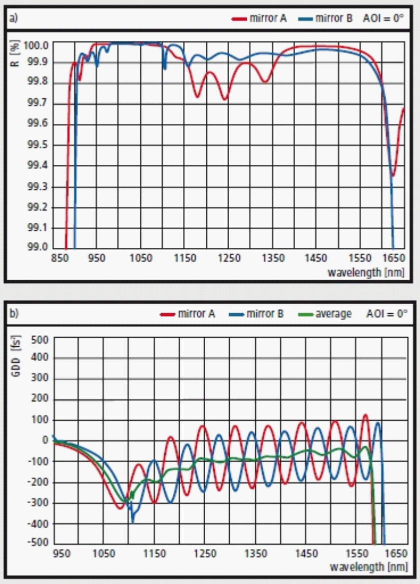


Figure 4: Reflectance and GDD spectra of a broadband negative dispersion mirror pair; single mirrors with R > 99.7 % (mirror A) and R > 99.85 % (mirror B)
a) Reflectance vs. wavelength
b) GDD vs. wavelength

BROADBAND NEGATIVE DISPERSION TURNING MIRRORS FOR AOI = 45°

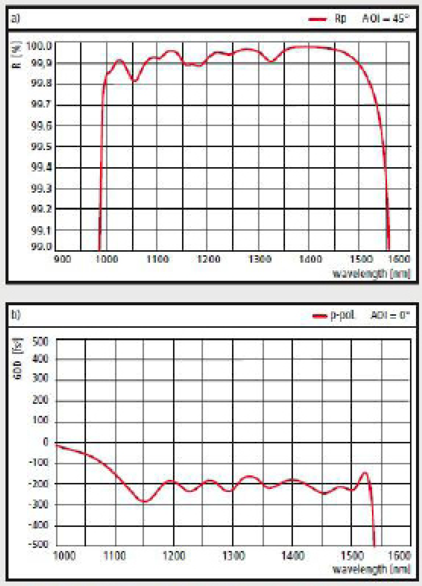


Figure 5: Reflectance and GDD spectrum of a broadband negative dispersion turning mirror for p-polarized light
a) Reflectance vs. wavelength
b) GDD vs. wavelength

SEPARATOR/COMBINER WITH NEGATIVE GDD FOR AOI = 45°

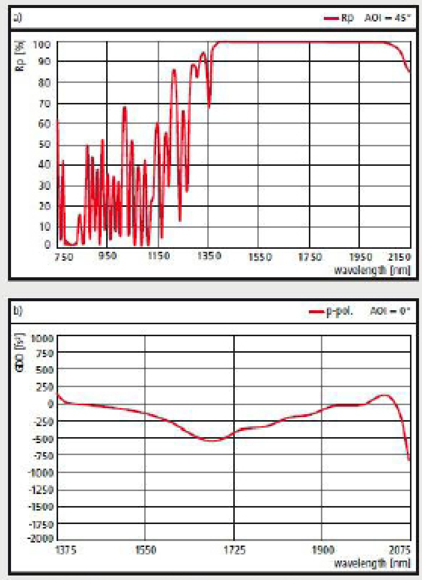


Figure 6: Reflectance and GDD spectrum of a beam combiner HRp (45°, 1500 – 2000 nm) + HT (45°, 800 nm) which shows negative GDD in the reflection band
a) Reflectance vs. wavelength
b) GDD vs. wavelength

二、常规激光光学元件

常规激光光学元件按照其工作波长划分，主要包含以下几类：

- 1、F_2 激光应用
- 2、ArF 激光应用
- 3、KrF，XeCl 和 XeF 激光应用
- 4、红宝石激光和其它宝石激光应用
- 5、纳秒钛蓝宝石激光应用
- 6、半导体激光应用
- 7、掺 Yb 激光应用
- 8、掺 Nd 激光应用
- 9、掺 Nd 和掺 Yb 激光二次谐波应用
- 10、掺 Nd 和掺 Yb 激光三次谐波应用
- 11、掺 Nd 和掺 Yb 激光高次谐波应用
- 12、掺 Nd 激光多波长应用
- 13、掺 Ho 和掺 Tm 激光应用
- 14、掺 Er 激光以及 3um 波段应用

1、F_2 激光应用

MIRRORS

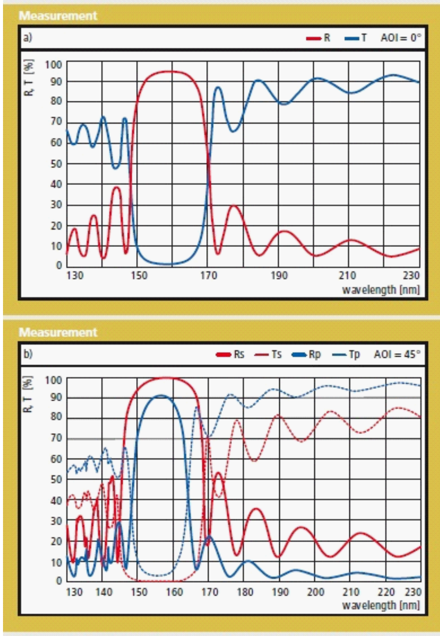


Figure 1: Measured reflectance and transmittance spectra of mirrors for 157 nm
a) Laser mirror (AOI = 0°)
b) Turning mirror (AOI = 45°)

OUTPUT COUPLERS AND LENSES

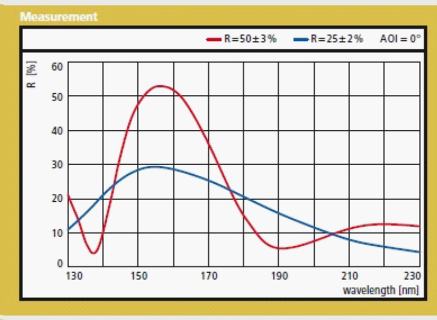


Figure 2: Measured reflectance spectra of standard output couplers with R = 50 ± 3 % and R = 25 ± 2 % (back side uncoated)

VARIABLE ATTENUATORS

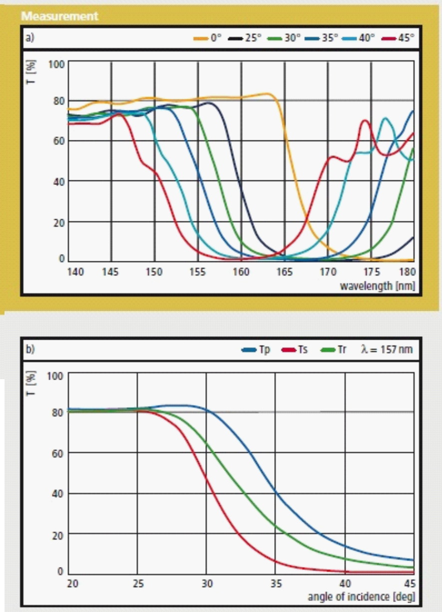


Figure 3: Measured transmittance spectra of a variable attenuator for 157 nm
a) Transmittance vs. wavelength at different AOI
b) Transmittance at 157 nm vs. AOI for different polarizations
The transmittance varies from
T > 75 % at AOI = 0° to T < 5 % at AOI = 45°

ALUMINUM MIRRORS FOR F_2 LASERS

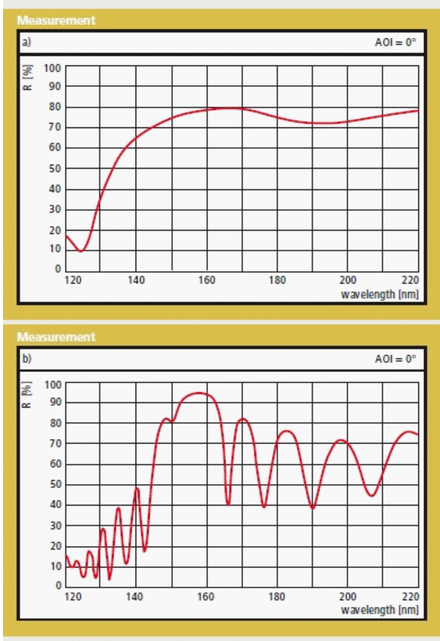


Figure 4: Reflectance spectra of aluminum mirrors
a) Protected Al mirror
b) Enhanced Al mirror for 157 nm

COMPONENTS FOR THE FIFTH AND SIXTH HARMONIC OF Ti:SAPPHIRE LASERS

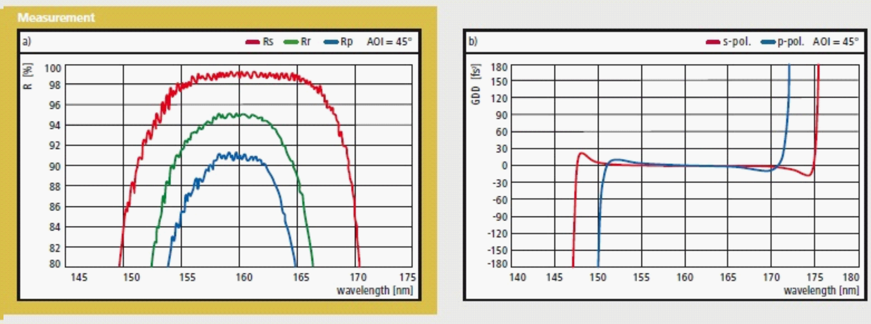


Figure 5: Reflectance and GDD - spectra of a turning mirror for 160 nm (AOI = 45°)
a) Reflectance vs. wavelength (measured)
b) GDD vs. wavelength (calculated)

2、ArF 激光应用

MIRRORS

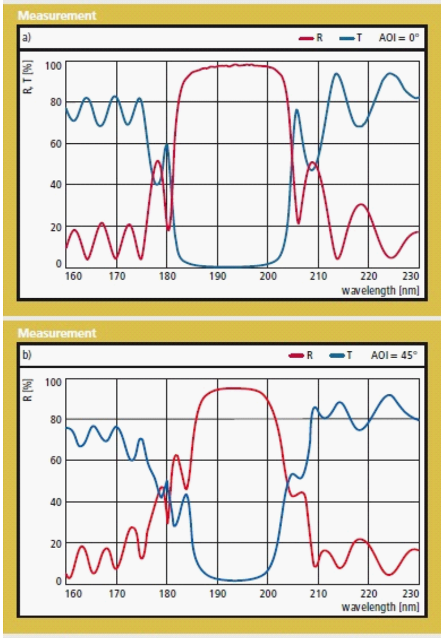


Figure 1: Measured reflectance and transmittance spectra of mirrors for 193 nm
a) Laser mirror (AOI = 0°)
b) Turning mirror (AOI = 45°, unpolarized light)

OUTPUT COUPLERS AND LENSES

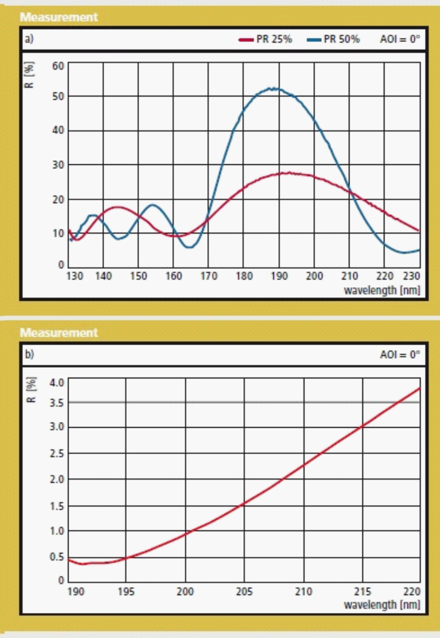


Figure 2: Measured reflectance spectra of output couplers and windows
a) Output couplers with R (0°, 193 nm) = 50 ± 3 % and R (0°, 193 nm) = 25 ± 2 % (back side uncoated)
b) CaF_2 window coated on both sides with a fluoride AR coating for 193 nm

VARIABLE ATTENUATORS

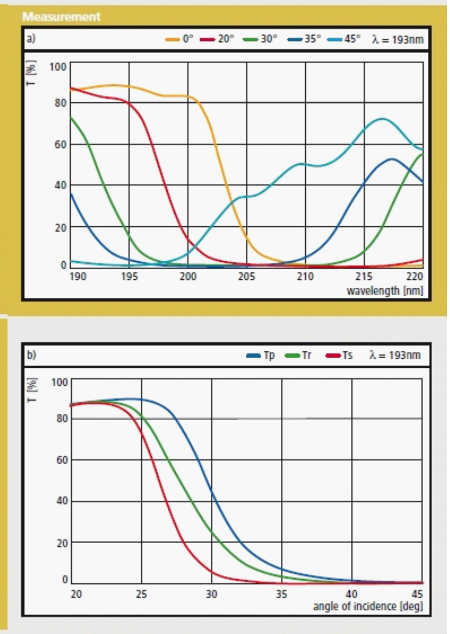


Figure 3: Measured transmittance spectra of a variable attenuator for 193 nm
a) Transmittance vs. wavelength at different AOI
b) Transmittance at 193 nm vs. AOI for different polarizations
The transmittance varies from T > 88 % at AOI = 0° to T < 2 % at AOI = 45°

ALUMINUM MIRRORS

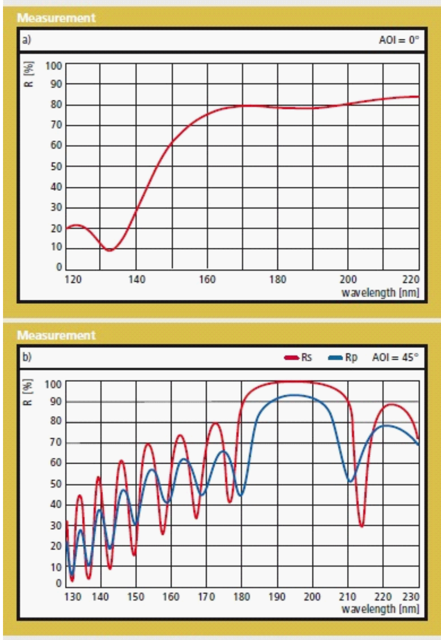


Figure 4: Reflectance spectra of aluminum mirrors
a) Protected Al mirror optimized for 193 nm
b) Enhanced Al mirror for 193 nm, AOI = 45°

COMPONENTS FOR THE 200 nm RANGE

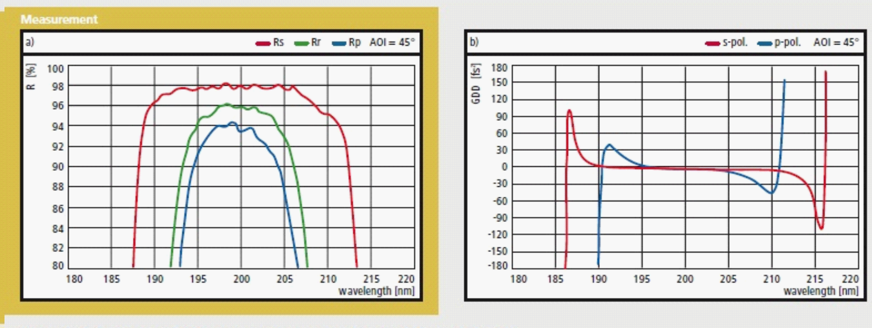


Figure 5: Reflectance and GDD - spectra of a turning mirror for 200 nm (AOI = 45°)
a) Reflectance vs. wavelength (measured)
b) GDD vs. wavelength (calculated)

3、KrF，XeCl 和 XeF 激光应用

CAVITY MIRRORS

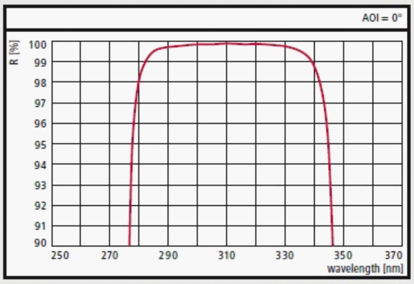


Figure 1: Reflectance spectrum of a 308 nm cavity mirror

- Oxide coatings for high mechanical stability.
- Coatings can be produced by IAD, magnetron sputtering or IBS.

OUTPUT COUPLERS

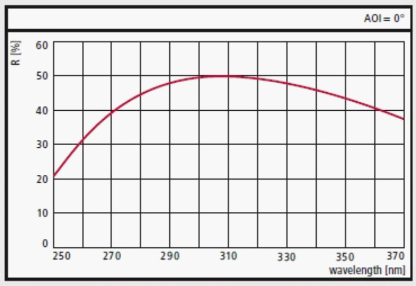


Figure 3: Reflectance spectrum of an output coupler for 308 nm R (0°, 308 nm) = 50 ± 3 %

- 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 %.

WINDOWS AND LENSES

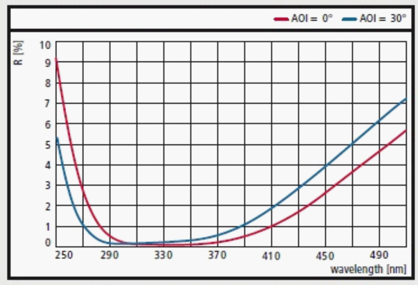


Figure 5: Reflectance spectra of an AR coating for 308 nm and AOI = 0° – 30°

- High quality mirror substrates, windows and lenses of fused silica.

FLUORINE RESISTANT CAVITY MIRRORS

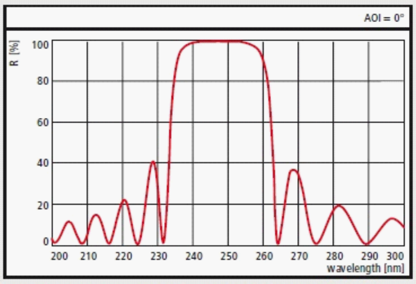


Figure 2: Reflectance spectrum of a fluoride KrF cavity mirror

- Fluoride coatings and CaF_2 substrates for high stability against fluorine and chlorine.
- Laser mirrors (R > 98% at 248 nm, 308 nm and 351 nm).

FLUORINE RESISTANT OUTPUT COUPLERS

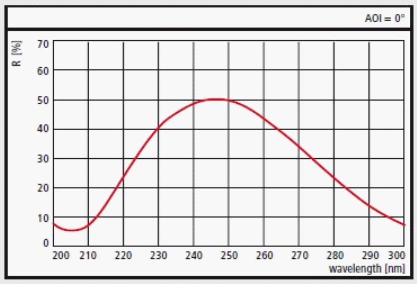


Figure 4: Reflectance spectrum of a fluoride output coupler with R (0°, 248 nm) = 50 ± 3 %

- PR coatings with tolerances of
  ± 2 % for R = 10 ... 30 %
  ± 3 % for R = 30 ... 75 %
  and ± 2 % for R = 75 ...>90 %.

FLUORINE RESISTANT WINDOW

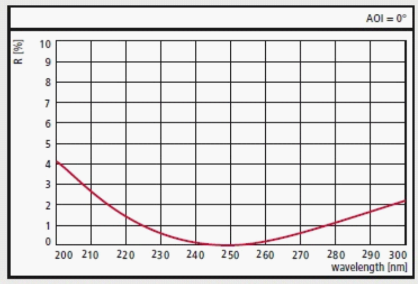


Figure 6: Reflectance spectrum of a fluoride AR coating for 248 nm

- High quality mirror substrates, windows and lenses of CaF_2 (248 nm excimer grade or UV quality, HELLMA Materials GmbH).
- Extended lifetimes at high energy densities at 248 nm.

TURNING MIRRORS

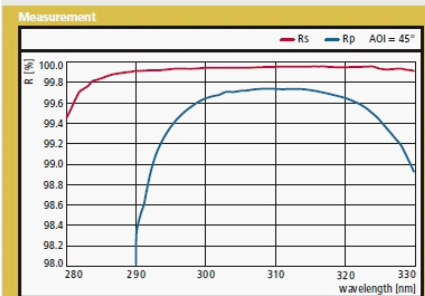


Figure 7: Reflectance spectra of a turning mirror for 308 nm produced by IBS
Reflectance measurement in s- and p-polarization by CRDS

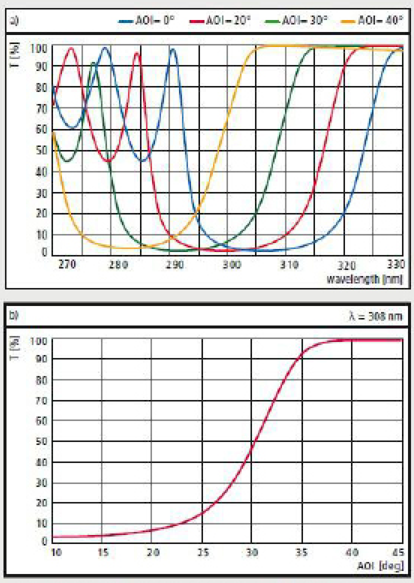


Figure 8: Measured transmittance spectra of a variable attenuator for 308 nm
a) Transmittance vs. wavelength at different AOI
b) Transmittance at 308 nm vs. AOI for unpolarized light
The transmittance varies from T < 10 % at AOI = 0° to T > 90 % at AOI = 40°

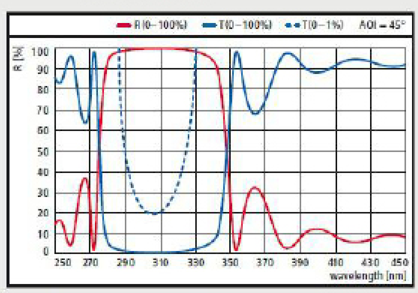


Figure 9: Transmittance spectrum of a sputtered attenuator for 308 nm with exactly adjusted and thermally stable transmittance of T = 0.2 % at AOI = 45° (unpolarized light)

4、红宝石激光和其它宝石激光应用

CAVITY MIRRORS

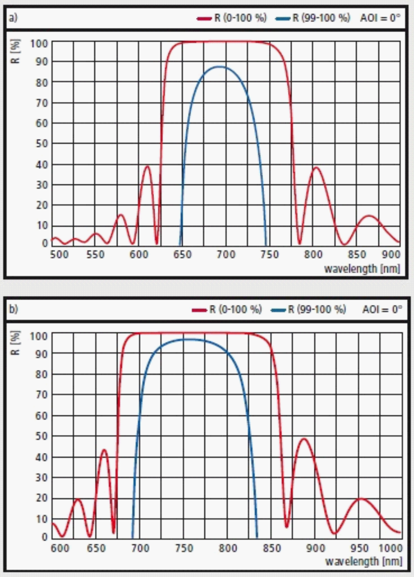


Figure 1: Reflectance spectra of cavity mirrors for
a) 694 nm
b) 755 nm

TURNING MIRRORS

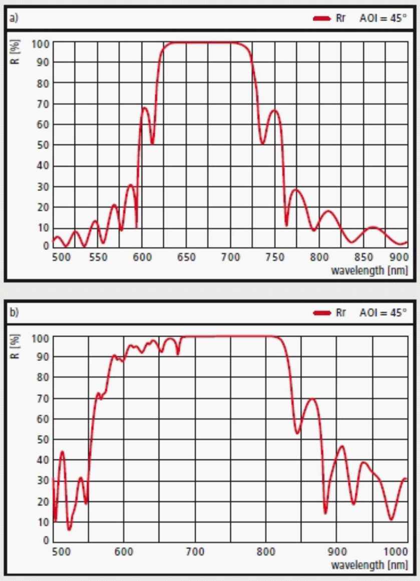


Figure 2: Reflectance spectra of turning mirrors for
a) 694 nm
b) 755 nm

BEAM COMBINERS

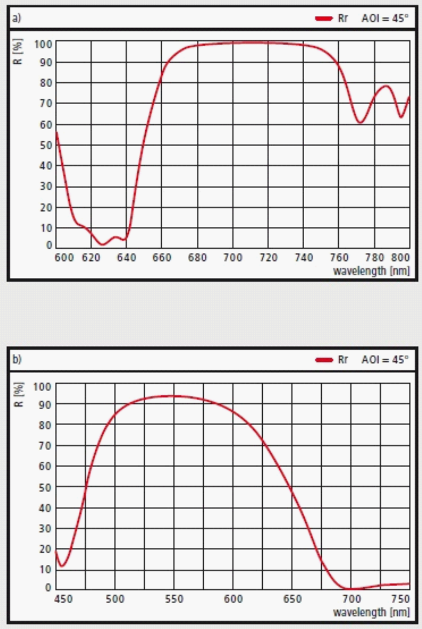


Figure 3: Reflectance spectra of special beam combiners for 694 nm and 633 nm:
a) PRr (45°, 694 nm) = 99.0 ± 0.3 % + Rr (45°, 633 nm) < 35 %
b) Rr (45°, 630 – 640 nm) > 35 % + Rp (45°, 694 nm) < 0.3 %

OUTPUT COUPLERS

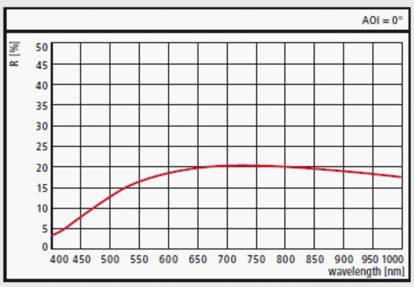


Figure 4: Reflectance spectrum of an output coupler for the ruby laser: PR (0°, 694 nm) = 20 ± 2 %

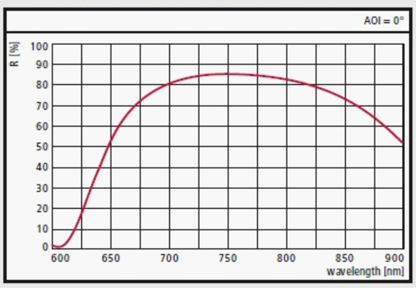


Figure 5: Reflectance spectrum of an output coupler for the alexandrite laser: PR (0°, 755 nm) = 85 ± 2 %

WINDOWS AND LENSES

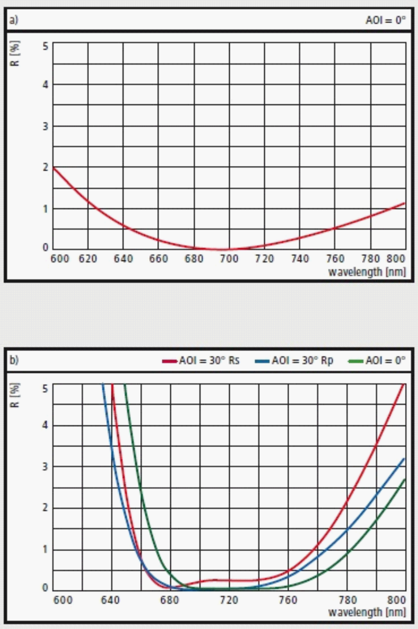


Figure 6: Reflectance spectra of AR coatings for 694 nm and 755 nm:
a) AR (0°, 694 nm) < 0.2 %,
b) AR (0° – 30°, 694 + 755 nm) < 0.5 %

5、纳秒钛宝石激光应用

CAVITY MIRRORS

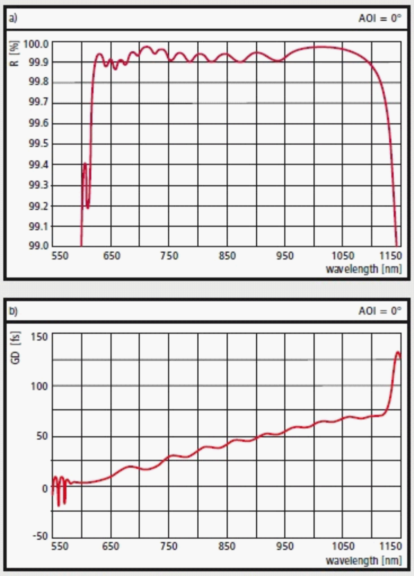


Figure1: Reflectance and GD - spectra of a broadband laser mirror
a) Reflectance vs. wavelength
b) GD vs. wavelength

PUMP MIRRORS

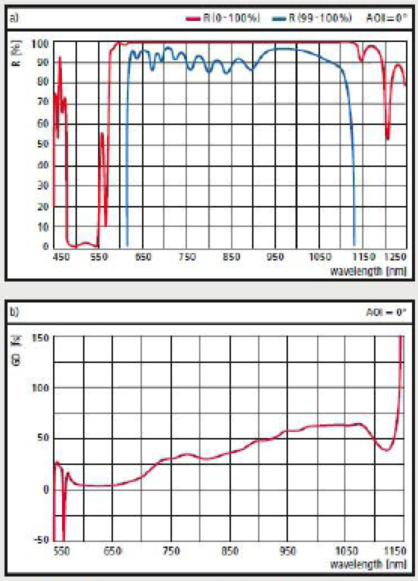


Figure 2: Reflectance spectra of a broadband pump mirror
a) Reflectance vs. wavelength
b) GD vs. wavelength

TURNING MIRRORS

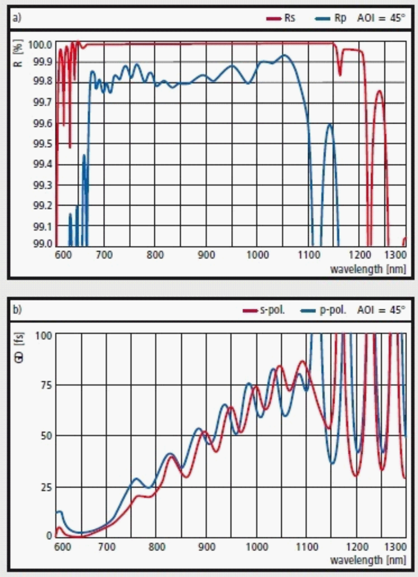


Figure 3: Reflectance and GD spectra of a broadband turning mirror
a) Reflectance vs. wavelength
b) GD vs. wavelength

6、 半导体激光应用

SCANNING MIRRORS

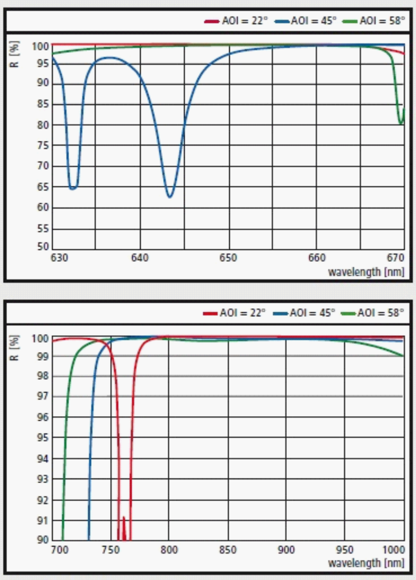


Figure 2: Reflectance spectra of a scanning mirror for diode lasers between 805 and 940 nm combined with R > 50 % between 630 and 670 nm (alignment laser):
HRr (22°– 58°, 805 – 940 nm) > 99.3 % + Rr (22°– 58°, 630 – 670 nm) > 50 %

THIN FILM POLARIZERS

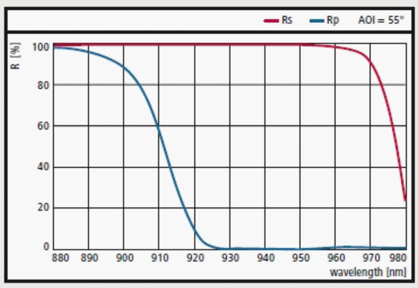


Figure 3: Reflectance spectra of a thin film polarizer for 940 nm, AOI = 55°

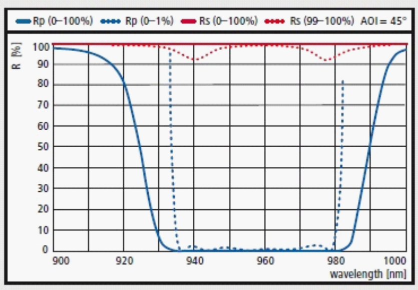


Figure 4: Reflectance spectra of a broadband thin film polarizer for 940 – 970 nm: HRs (45°, 940 – 970 nm) > 99.9 % + Rp (45°, 940 – 970 nm) < 1%

TURNING MIRRORS

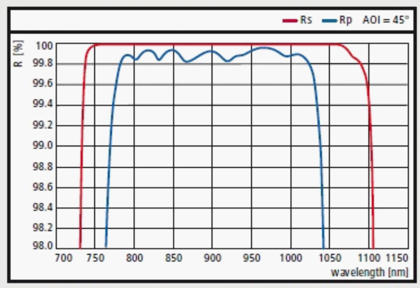


Figure 1: Reflectance spectra of a broadband turning mirror which can be used for all diode lasers between 808 nm and 980 nm (AOI = 45°, s- and p-polarization)

SPECIAL STEEP EDGE COMBINERS FOR UNPOLARIZED LIGHT

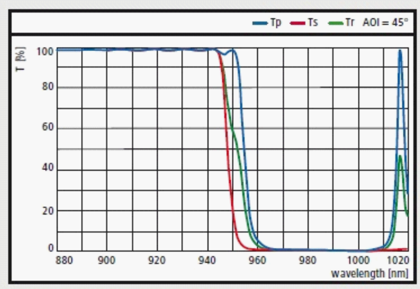


Figure 6: Transmittance spectra of a special steep edge filter HRr (45°, 980 nm) > 99.8 % + HTr (45°, 940 nm) > 97 %

CONVENTIONAL STEEP EDGE COMBINERS FOR DIODE LASERS

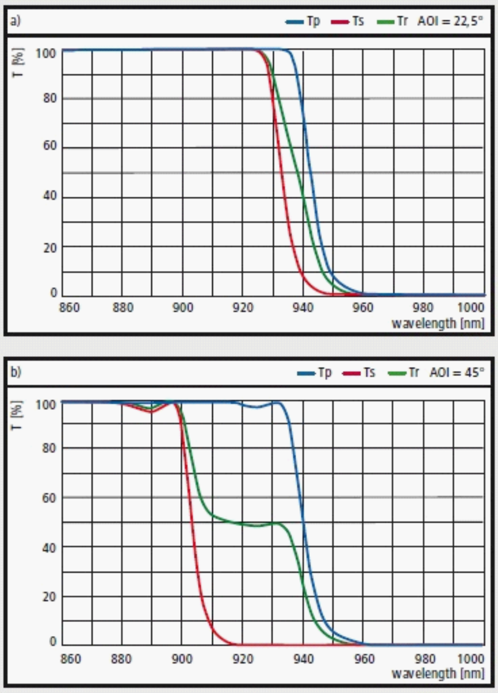


Figure 5: Transmittance spectra of conventional steep edge filters HR (980 nm) > 99.9 % + R (915 nm) < 5 % which are used as combiners for pump laser diodes at 915 nm and 980 nm;
a) HRs,p (22.5°, 980 nm) > 99.9 % + Rs,p (22.5°, 915 nm) < 2 %
b) HRs,p (45°, 980 nm) > 99.9 % + Rp (45°, 915 nm) < 2 %

7、掺 Yb 激光应用

MIRRORS

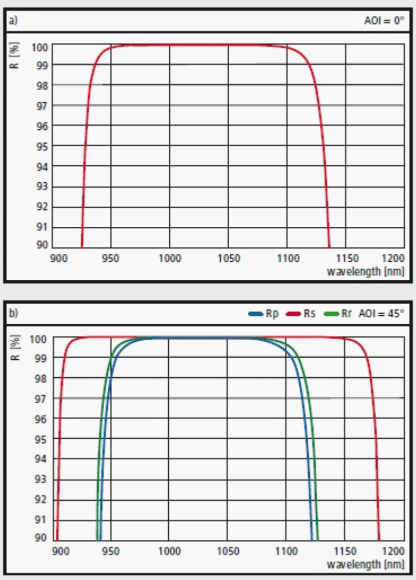


Figure 1: Reflectance spectra of HR mirrors for 1030 nm
a) Cavity mirror b) Turning mirror

EDGE FILTERS AND PUMP MIRRORS

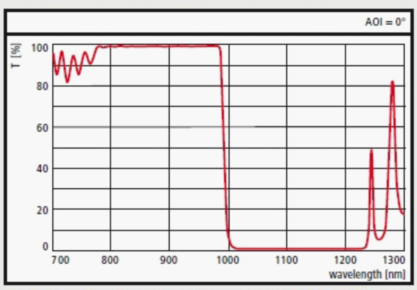


Figure 2: Transmittance spectrum of a steep edge short-wavelength pass filter with HR (0°, 1030 nm) > 99.9 % and HT (0°, 808 – 980nm) > 99.5 % (back side AR coated)

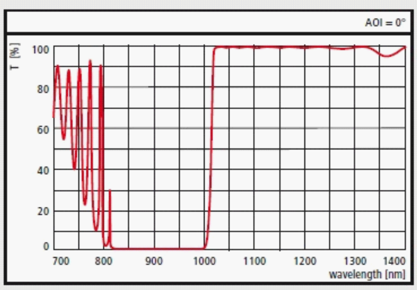


Figure 3: Transmittance spectrum of a steep edge long-wavelength pass filter with HR (0°, 915 – 980 nm) > 99.8 % and HT (0°,1030 – 1200 nm) > 97 % for use as output mirror of a fiber laser (back side AR coated)

SPECIAL OUTPUT COUPLERS

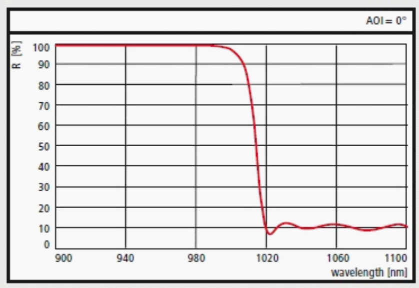


Figure 4: Reflectance spectrum of an output mirror for a fiber laser which blocks the diode radiation at 980nm and has a partial reflectivity R = 10% for 1030 –1100 nm (back side AR coated)

THIN FILM POLARIZERS

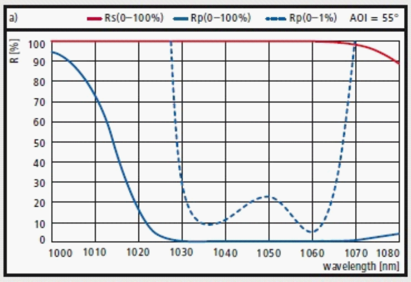


Figure 5a: Reflectance spectra for s- and p-polarized light of a broad-band thin film polarizer showing a bandwidth of 25 nm with Rp < 0.2 % (AOI = 55°)

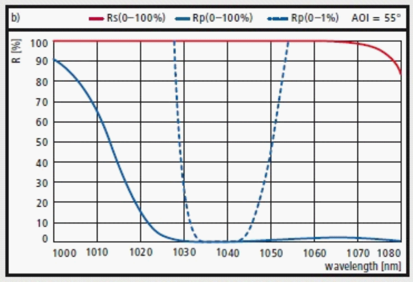


Figure 5b: Reflectance spectra for s- and p-polarized light of a narrow band thin film polarizer which is optimized for very low Rp values and easy angle tuning for the optimization of the polarizer performance (AOI = 55°)

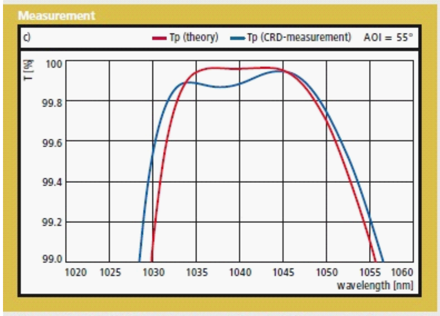


Figure 5c: Calculated and measured transmission spectra for s- and p-polarized light of a narrow band thin film polarizer according to the design shown in fig. 5b (AOI = 55°). It is clearly visible that Tp > 99.8 % is reached with a band-width of 15 nm and that Tp > 99.9 % can be achieved within a bandwidth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

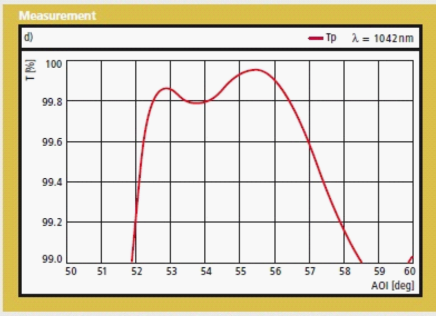


Figure 5d: Transmission spectrum Tp vs. AOI at 1042 nm **measured** at the polarizer shown in fig.5c

8、掺 Nd 激光应用

CAVITY MIRRORS

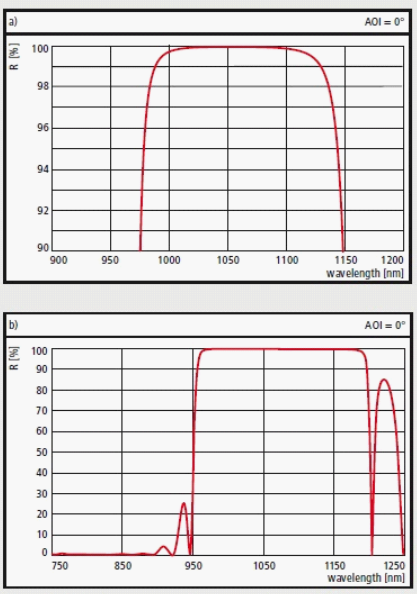


Figure 1: Reflectance spectra of HR mirrors for 1064 nm
a) High power cavity mirror
b) Pump mirror HR (0°, 1064 nm) > 99.9% + R (0°,808 nm) < 2%

TURNING MIRRORS, SEPARATORS AND COMBINERS

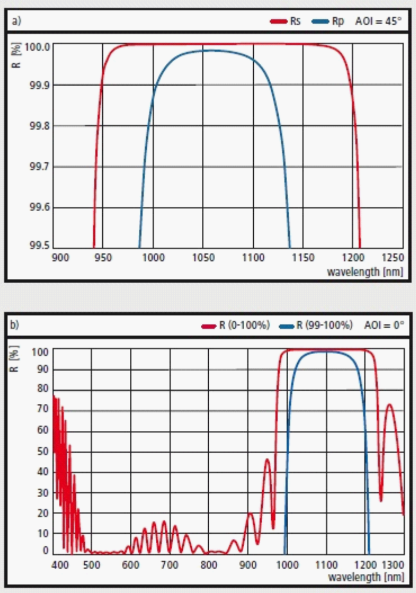


Figure 2: Reflectance spectra of special mirrors for 1064 nm
a) High power turning mirror
b) Separator for the second harmonic from the fundamental HR (0°, 1064 nm) > 99.9 % + R (0°, 532 + 808 nm) < 3 %

ALIGNMENT AND PROCESS MONITORING

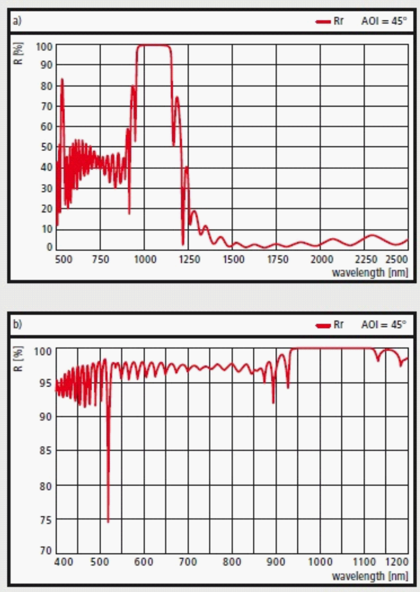


Figure 3: Reflectance spectra of turning mirrors with special features for alignment and process monitoring
a) Turning mirror for the laser beam with a partial reflector for the alignment laser and high IR transmission for process monitoring
b) Silver based turning mirror with Rr (45°, 1064 nm) > 99.8 % and with Rr > 80 % for an alignment laser in the red spectral range

THIN FILM POLARIZERS

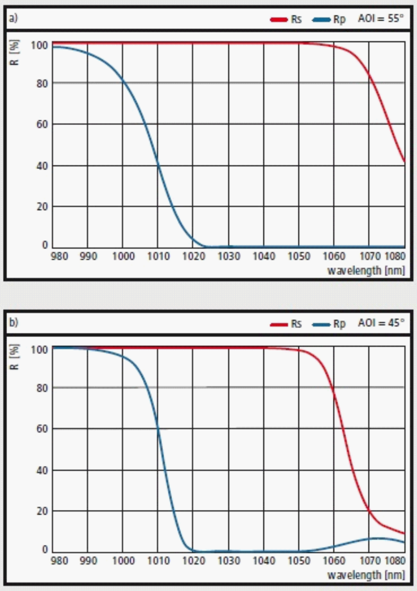


Figure 4: Reflectance spectra of thin film polarizers for 1040 nm
a) Standard TFP (AOI = 55°)
b) Special TFP (AOI = 45°)

BEAM SPLITTERS AND OUTPUT COUPLERS

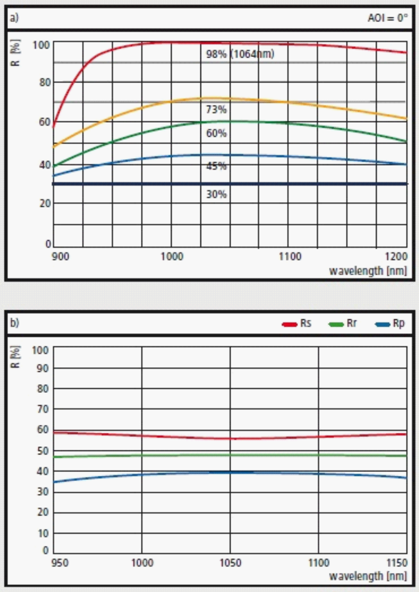


Figure 5: Reflectance spectra of output couplers and beam splitters
a) Output couplers with different degrees of reflectivity
b) Common 50 : 50 beam splitter for unpolarized light

NON-POLARIZING BEAM SPLITTERS

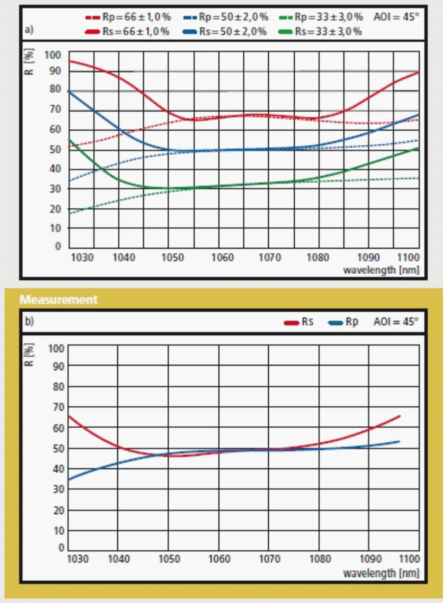


Figure 6: Non-polarizing beam splitters
a) Calculated reflectance spectra of 3 types of non-polarizing beam splitters for AOI = 45°
b) Measured reflectance spectra of the 50 % beam splitter

9、掺 Nd 和掺 Yb 激光二次谐波应用

DUAL WAVELENGTH TURNING MIRRORS

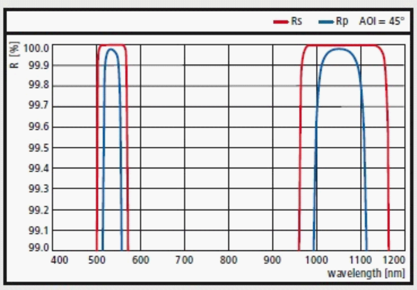


Figure 1: Reflectance spectra of a dual wavelength turning mirror HRs,p (45°, 532 + 1064 nm) > 99.9 %

DUAL WAVELENGTH CAVITY MIRRORS

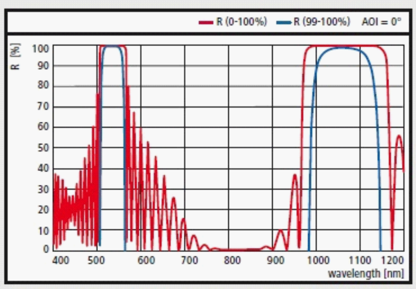


Figure 2: Reflectance spectra of a dual wavelength cavity mirror with high transmittance for the pump wavelength (808 nm)

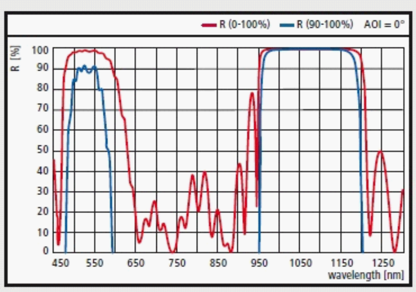


Figure 3: Reflectance spectra of a HR mirror for 1064 nm which is also an output coupler for 532 nm: HR (0°, 1064nm) > 99.9 % + R (0°, 532 nm) = 99 ± 0.3 %

SEPARATORS FOR THE SECOND HARMONIC FROM THE FUNDAMENTAL WAVE

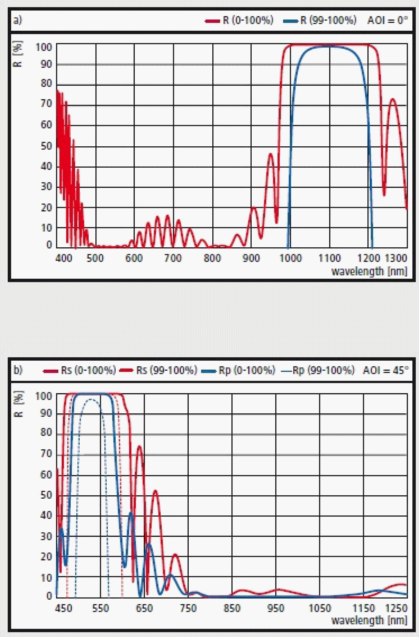


Figure 4: Reflectance spectra of separators for the second harmonic from the fundamental wavelength:
a) HR(0°, 1064 nm) > 99.9% + R (0°, 532 + 808 nm) < 3 %
b) HRs,p (45°, 532 nm) > 99.9 % + Rs,p(45°, 808 + 1064 nm) < 2 %

THIN FILM POLARIZERS

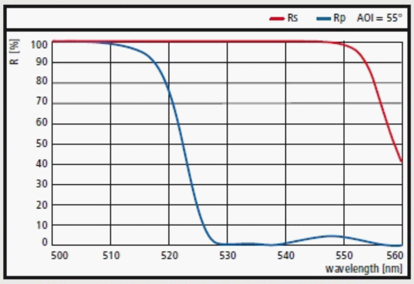


Figure 5: Reflectance spectra of a thin film polarizer for 532 nm

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

NON-POLARIZING BEAM-SPLITTERS

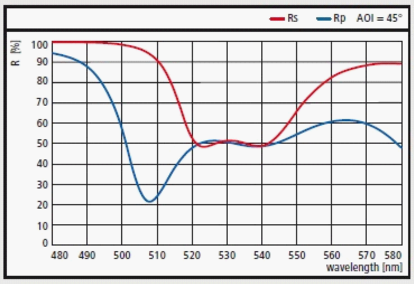
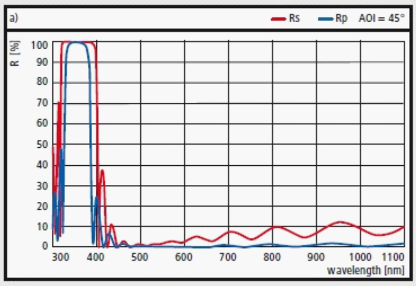


Figure 6: Reflectance spectra of a non-polarizing beam splitter for 532 nm with Rs = Rp = 50 ± 2% (|Rs - Rp| < 3 %)

COMPONENTS FOR THE SECOND AND THIRD HARMONIC



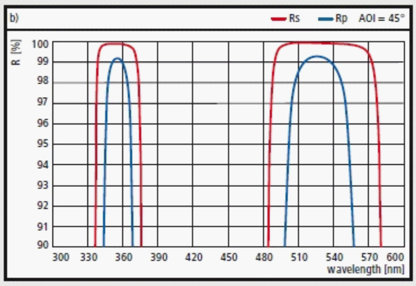


Figure 7: Reflectance spectra of mirrors and separators
a) Separator for the third harmonic from the second harmonic and the fundamental wave
b) Dual wavelength turning mirror for 355 nm and 532 nm

COATINGS ON NONLINEAR OPTICAL CRYSTALS

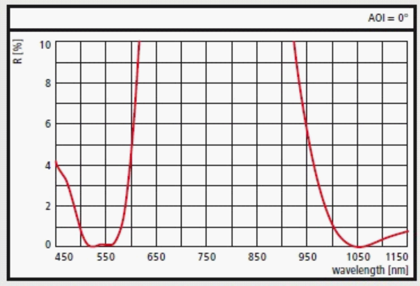


Figure 8: Reflectance spectrum of a dual wavelength antireflection coating on KTP for 532 nm and 1064 nm

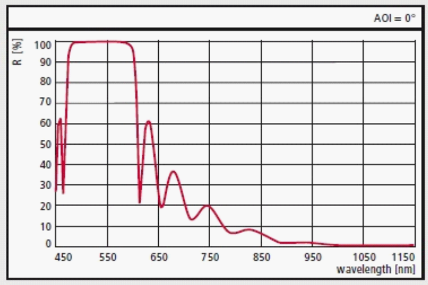


Figure 9: Reflectance spectrum of a dichroic mirror on KTP: HR (0°, 532 nm) > 99.98 % + R (0°, 1064 nm) < 0.2 % optimized for very high transmission at 1064 nm

10、掺 Nd 和掺 Yb 激光三次谐波应用

TURNING MIRRORS

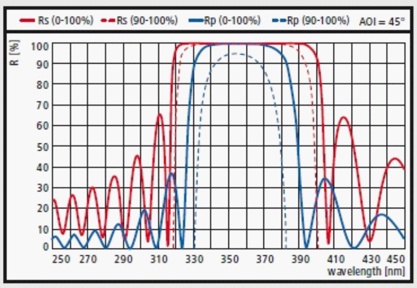


Figure 1: Reflectance spectra of a turning mirror HRs (45°, 355 nm) > 99.9 % + HRp (45°, 355 nm) > 99.5 %

STANDARD SEPARATORS

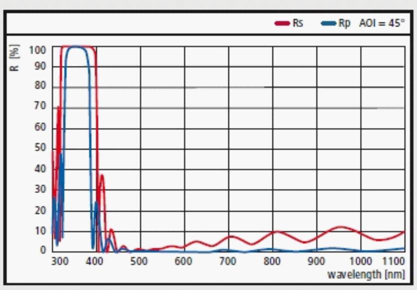


Figure 2: Reflectance spectra of a standard separator for the third harmonic from the second harmonic and the fundamental wave:
HRs (45°, 355 nm) > 99.9 % + HRp (45°, 355 nm) > 99.5 % + Rp (45°, 532 + 1064 nm) < 2 % + Rs (45°, 532 nm) < 5 % + Rs (45°, 1064 nm) < 10 %

SPECIAL SEPARATORS

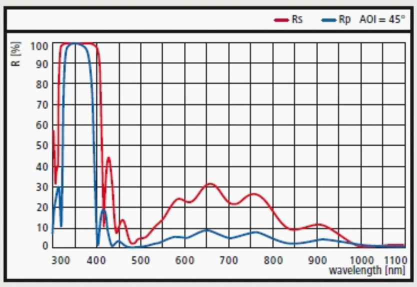


Figure 3: Reflectance spectra of a special separator which is especially optimized for low reflectance at 1064 nm:
HRs (45°, 355 nm) > 99.9 % + HRp (45°, 355 nm) > 99.5 % + Rp (45°, 532 + 1064 nm) < 2 % + Rs (45°, 532 nm) < 5 % + Rs (45°, 1064 nm) < 2 %

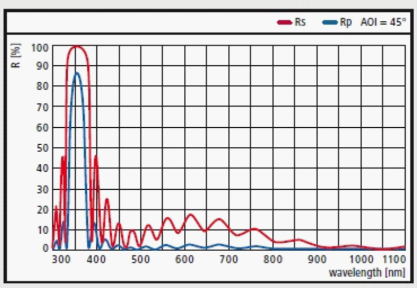


Figure 4: Reflectance spectra of a special separator for the third harmonic from the second harmonic and the fundamental wavelength:
HRs (45°, 355 nm) > 95 % + Rp (45°, 532 nm) < 2 % + Rs,p (45°, 1064 nm) < 2 %; substrate and coatings consist of fluoride materials

WINDOWS AND LENSES

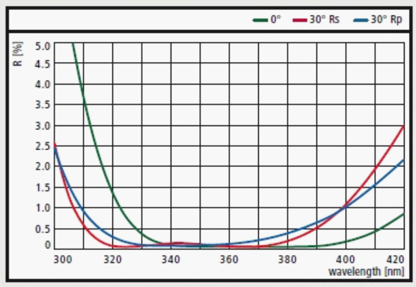


Figure 5: Reflectance spectra of a single wavelength AR coating for 355 nm optimized for AOI = 0°– 30°

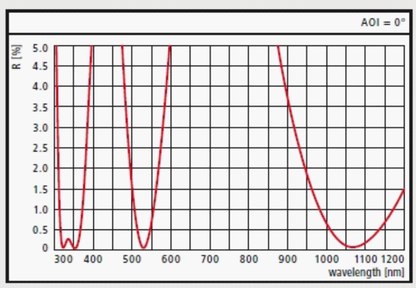


Figure 6: Reflectance spectrum of a triple wavelength antireflection coating on fused silica for 355 nm, 532 nm and 1064 nm

MULTIPLE WAVELENGTH MIRRORS

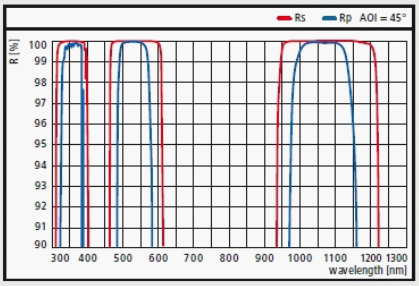


Figure 7: Reflectance spectra of a triple wavelength turning mirror for 355 nm, 532 nm and 1064 nm

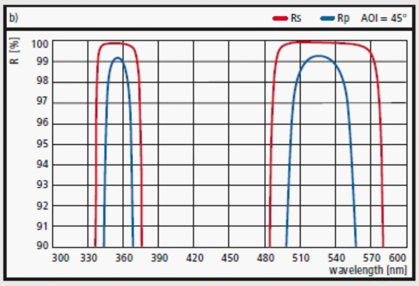


Figure 8: Reflectance spectra of a dual wavelength turning mirror for 355 nm and 532 nm

SEPARATORS WITH HIGH TRANSMISSION IN THE UV RANGE

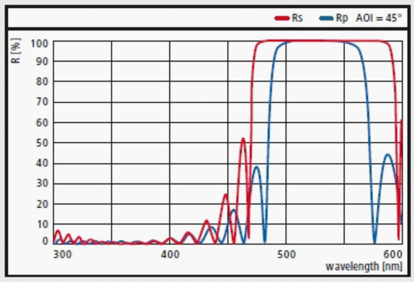


Figure 9: Reflectance spectra of a special separator for the third harmonic from the second harmonic:
HRs,p (45°, 532 nm) > 99.8 % + Rs,p (45°, 355 nm) < 2 %

THIN FILM POLARIZERS

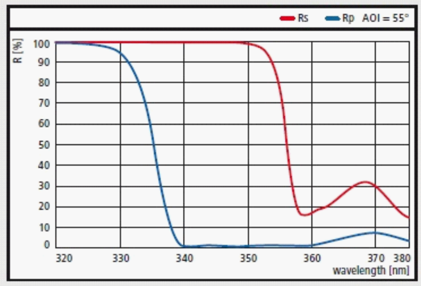


Figure 10: Reflectance spectra of a thin film polarizer for 343 nm:
HRs (55°, 343 nm) > 99.5 % + Rp (55°, 343 nm) < 2 %

11、掺 Nd 和掺 Yb 激光高次谐波应用

MULTIPLE WAVELENGTH MIRRORS

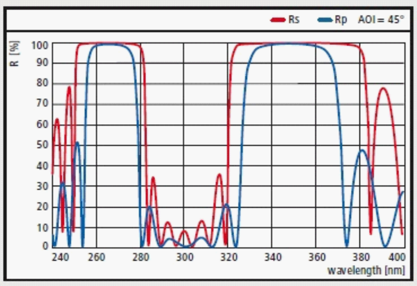


Figure 1: Reflectance spectra of a dual wavelength turning mirror for 266 nm and 355 nm

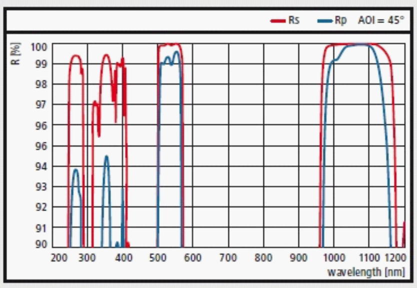


Figure 2: Reflectance spectra of a four wavelength turning mirror:
HRs (45°, 266 nm + 355 nm) > 99 %+ HRs (45°, 532 nm + 1064 nm) > 99.9 %

SEPARATORS FOR THE FOURTH HARMONIC

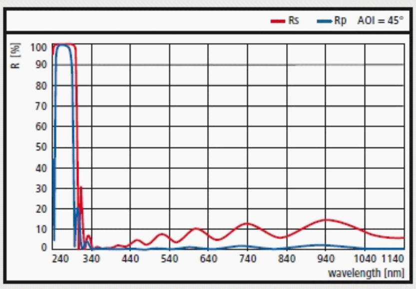


Figure 3: Reflectance spectra of a separator for the fourth harmonic from the longer wavelength harmonics and the fundamental

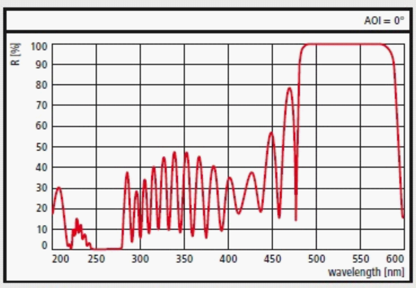


Figure 4: Reflectance spectrum of a special separator for the second harmonic from the fourth harmonic:
HR (0°, 532 nm) > 99.95 % + R (0°, 266 nm) < 5 %

SEPARATORS FOR THE FIFTH HARMONIC

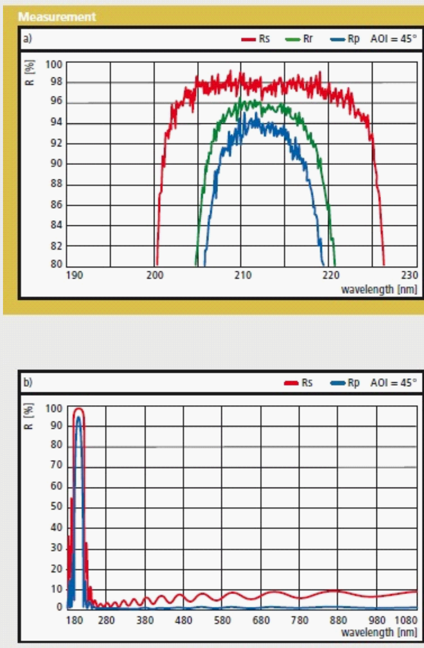


Figure 5: Measured reflectance spectra of fluoride coatings on CaF_2:
a) Turning mirror for the fifth harmonic
b) Separator for the fifth harmonic from the long wavelength harmonics and the fundamental

SPECIAL SEPARATORS

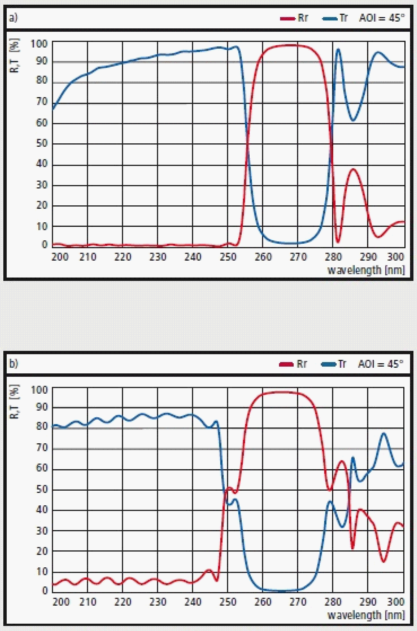


Figure 6: Reflectance spectra of separators for the fourth and fifth harmonics:
HRr (45°, 266 nm) > 98 % + Rr (45°, 213 nm) < 10 % for unpolarized light
a) Oxide coatings optimized for low stray light losses
b) Fluoride coatings for high laser induced damage thresholds

THIN FILM POLARIZERS

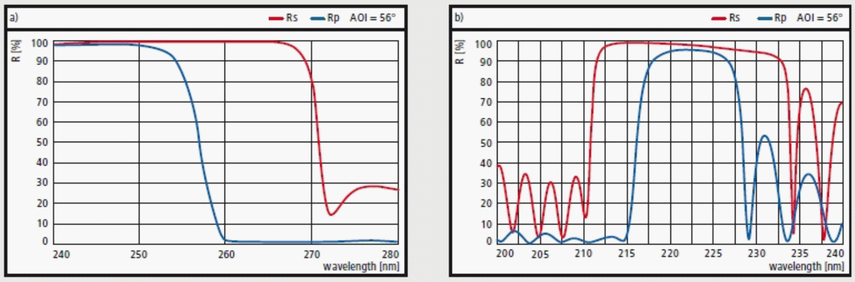


Figure 7: Reflectance spectra of thin film polarizers for 266 nm and 213 nm:
a) HRs (56°, 266 nm) > 98 % + Rp (56°, 266nm) < 5 %, Tp (56°, 266 nm) ~ 95 %
b) HRs (56°, 213 nm) > 97 % + Rp (56°, 213nm) < 5 %, Tp (56°, 213 nm) ~ 75 %

12、掺 Nd 激光多波长应用

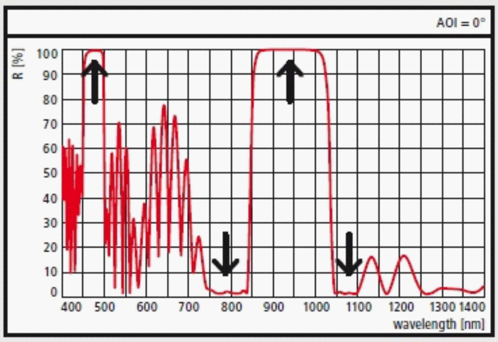


Figure 1: Reflectance spectrum of a dual wavelength mirror for a weak laser line and its second harmonic with high transmission for the pump wavelength and the strongest laser line:
HR (0°, 473 nm) > 99.85 % + HR (0°, 946 nm) > 99.95 % + R (0°, 808 nm) < 2 % + R (0°, 1064 nm) < 5 %

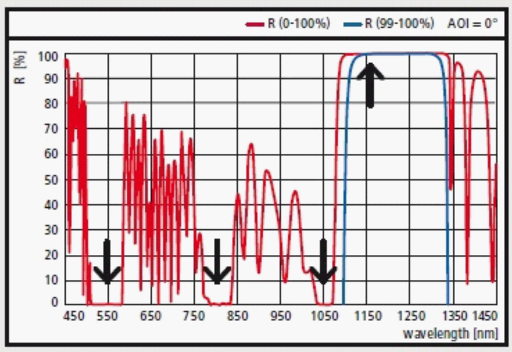


Figure 2: Reflectance spectrum of a dichroic mirror with high transmission for the pump wavelength which also suppresses the 1064 nm line:
HR (0°, 1123 nm) > 99.9 % + R (0°, 561 nm) < 2 %
+ R (0°, 808 nm) < 10 % + R (0°, 1064 nm) < 50 %

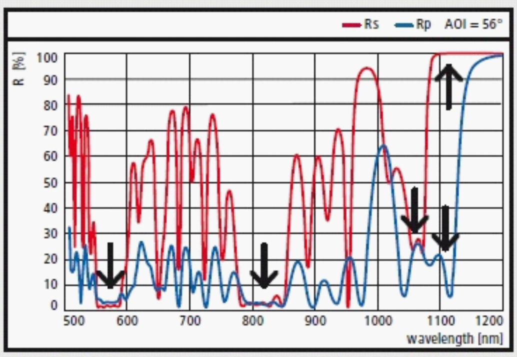


Figure 3: Reflectance spectra of a thin film polarizer with high transmission for the pump wavelength and the second harmonic which also suppresses the 1064 nm line:
HRs (56°, 1123 nm) > 99.9 % + Rp (56°, 1123 nm) < 50 %
+ Rs,p (56°, 561+ 808 nm) < 10 % + Rs,p (56°, 1064 nm) < 50 %

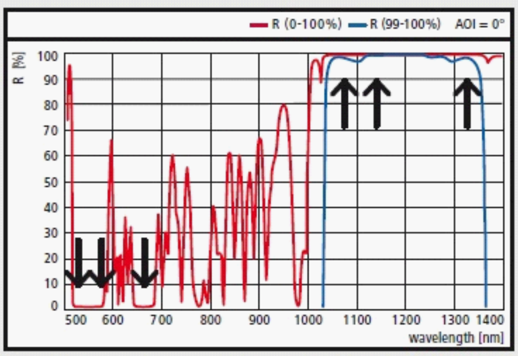


Figure 4: Reflectance spectrum of a dichroic mirror with high reflectance for the NIR wavelengths and high transmission for the corresponding second harmonic wavelengths:
HR (0°, 1064 + 1123 + 1319 nm) > 99.9 %
+ R (0°, 532– 561 + 659 nm) < 2 %

13、掺 Ho 和掺 Tm 激光应用

CAVITY MIRRORS

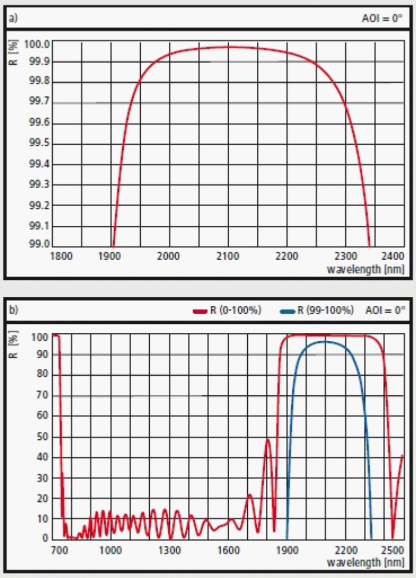


Figure 1: Reflectance spectra of cavity mirrors
a) HR cavity mirror
b) Pump mirror which has a spectral region of high transmittance around 808 nm.

TURNING MIRRORS

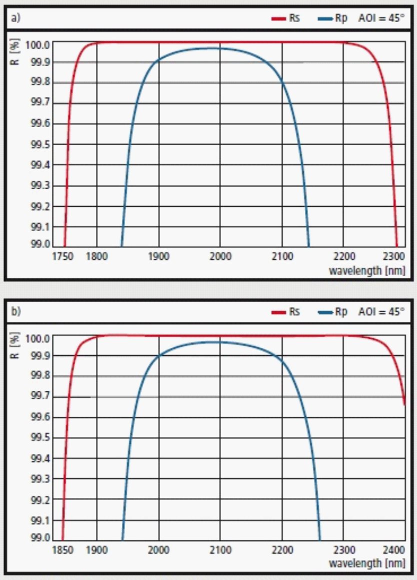


Figure 2: Reflectance spectra of turning mirrors for
a) 2010 nm
b) 2100 nm

OUTPUT COUPLERS

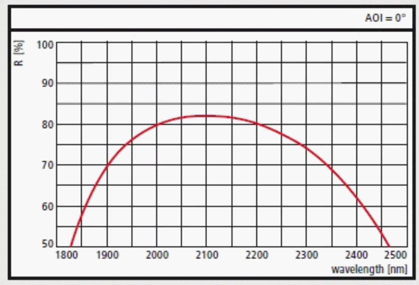


Figure 3: Reflectance spectrum of an output coupler with R = 82 % ± 1° at 2100 nm

THIN FILM POLARIZERS

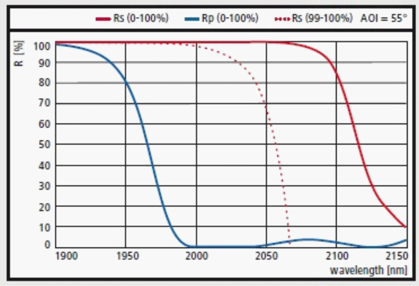


Figure 6: Reflectance spectra of a thin film polarizer for 2010 nm (Rs > 99.8 %, Rp < 2 %, AOI = 55°)

EDGE FILTERS

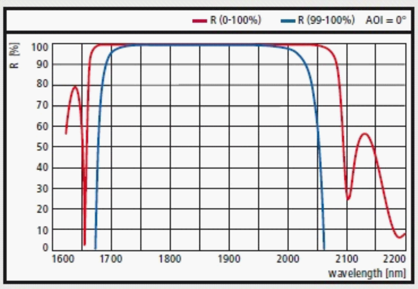


Figure 4: Reflectance spectra of a cavity mirror for 2010 nm which suppresses the 2100 nm line

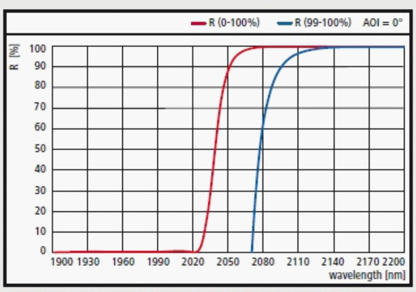


Figure 5 Reflectance spectra of a steep edge filter for the separation of the 2010 nm and 2100 nm lines

WINDOWS AND LENSES

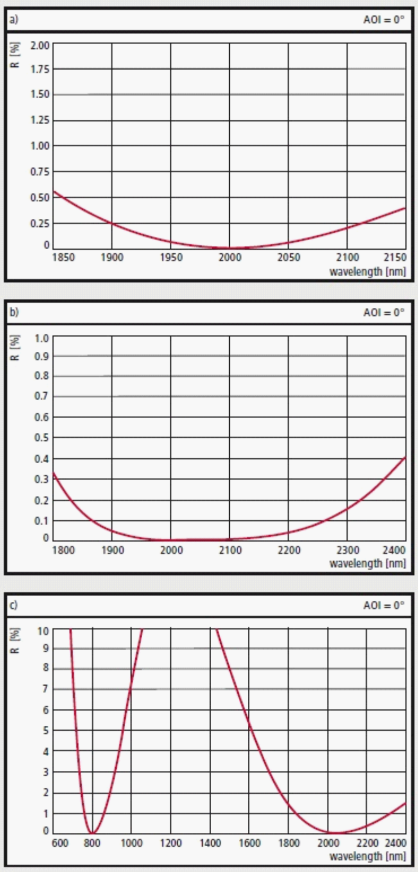


Figure 7: Reflectance spectra of typical antireflection coatings:
a) Single wavelength AR coating for 2010 nm
b) Broadband AR coating 2010 nm - 2100 nm
c) Dual wavelength AR coating for the pump and laser wavelength (808 nm + 2010 nm)

14、掺 Er 激光以及 3μm 波段应用

CAVITY MIRRORS

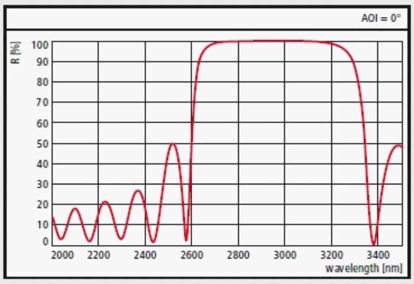


Figure 1: Reflectance spectrum of a HR cavity mirror HR (0°, 2940 nm) > 99.8 %

PUMP MIRRORS

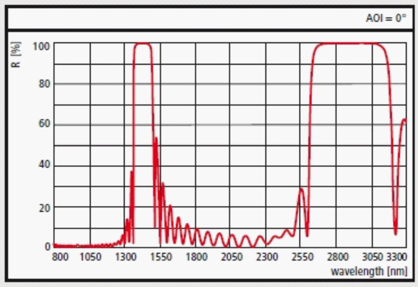


Figure 2: Reflectance spectrum of a HR cavity mirror with a HT region between 800 nm and 1100 nm

TURNING MIRRORS

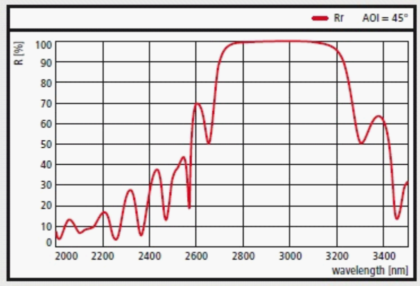


Figure 3: Reflectance spectrum of a turning mirror for unpolarized light

BEAM COMBINERS AND ALIGNMENT LASER MIRRORS

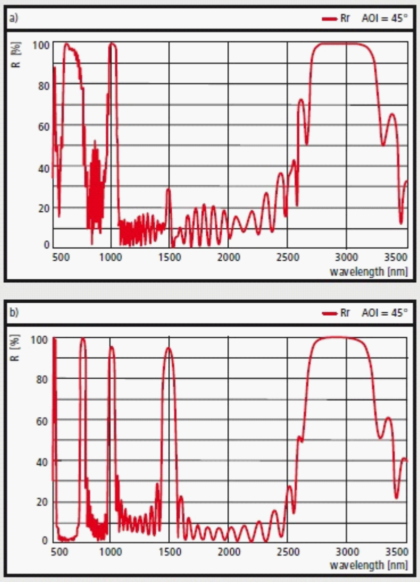


Figure 4: Reflectance spectra of beam steering mirrors
a) Dual wavelength turning mirror
b) Separator/combiner for 2940 nm and an alignment laser between 630 nm and 655 nm

OUTPUT COUPLERS AND LENSES

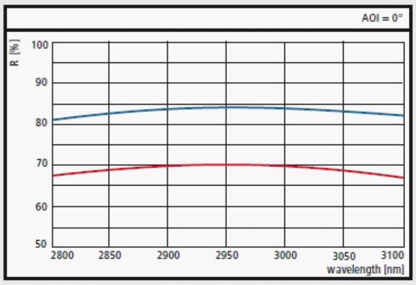


Figure 5: Reflectance spectra of output couplers with R = 70 ± 1 % and R = 84 ± 1%

- Output couplers with precisely adjusted degrees of reflectivity (tolerances of ± 1% at reflectivity values between 70 % and 90 %).

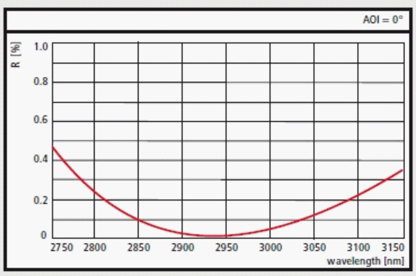


Figure 6: Reflectance spectrum of an antireflection coating for 2.94 μm on sapphire

三、特殊应用光学元件

特殊应用光学元件（飞秒激光光学元件）按照其工作特行来划分，主要包含以下几类：

- 1、光参量振荡器（OPO）激光应用
- 2、宽带和扫描镜
- 3、滤波片
- 4、薄膜偏振片
- 5、低损耗光学元件
- 6、镀膜晶体

1、光参量振荡器（OPO）激光应用

CAVITY MIRRORS FOR AOI = 0°

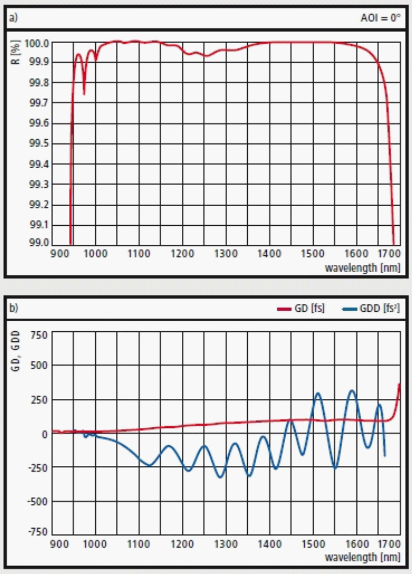


Figure 1: Reflectance, GD and GDD spectra of a broadband HR mirror for the signal wavelength: HR (0°, 1000 – 1600 nm) > 99.9 %
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

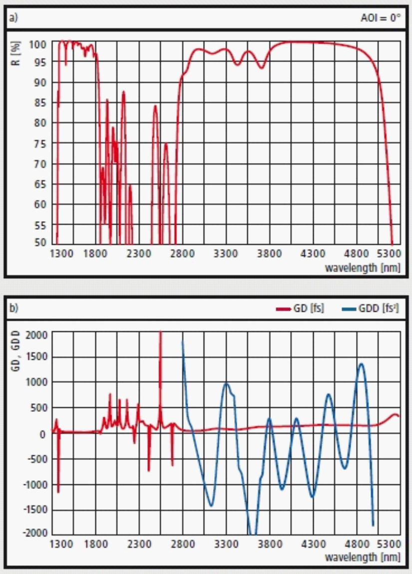


Figure 2: Reflectance, GD and GDD spectra of a dual HR mirror for the signal and idler wavelengths:
HR (0°, 1400 – 1800 nm) > 96 %
+ HR (0°, 2900 – 4900 nm) > 93 %
a) Reflectance vs. wavelength
b) GD and GDD vs. wavelength

OUTPUT COUPLERS FOR AOI = 0°

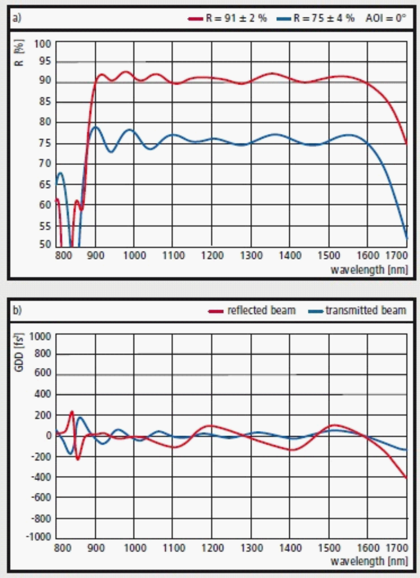


Figure 1: Reflectance and GDD spectra of different broadband output couplers for the signal wavelengths.
a) Reflectance vs. wavelength
b) GDD vs. wavelength
Please note the smooth GDD spectra. The GDD spectra shown are calculated for the 75 % output coupler, but the spectra for other reflectivity values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

BEAM SPLITTERS FOR AOI = 45°

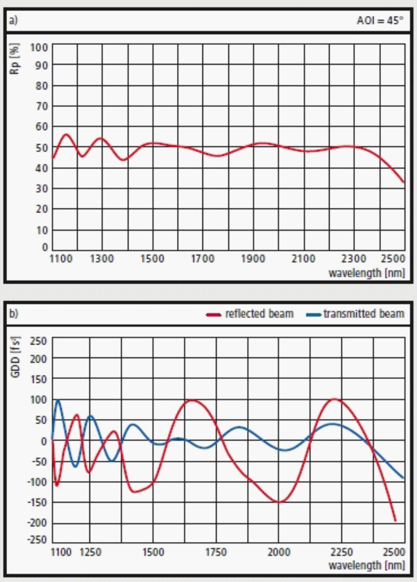


Figure 2: Reflectance and GDD spectra of a broadband beam splitter for p-polarized signal and idler radiation:
Rp (45°, 1100 – 2400 nm) = 50 ± 5 %
a) Reflectance vs. wavelength
b) GDD vs. wavelength

SPECIAL OUTPUT COUPLERS FOR AOI = 0°

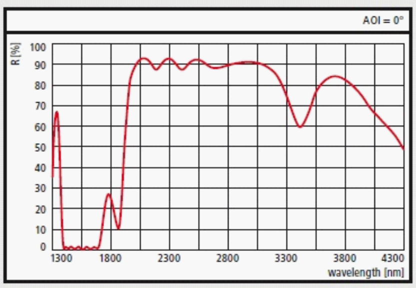


Figure 3: Reflectance spectrum of a special output coupler:
R (0°, 1400 – 1700 nm) < 3%
+ PR (0°, 2000 – 3150 nm) = 90 ± 3%

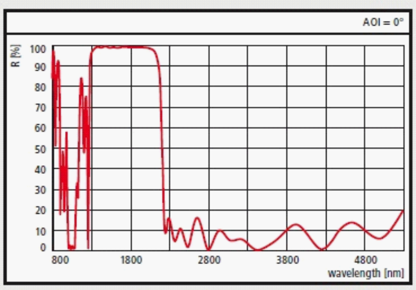


Figure 4: Reflectance spectrum of a special output coupler:
R (0°, 1000 – 1100 nm) < 3%
+ PR (0°, 1350 – 2000 nm) = 98 ± 5 %
+ R (0°, 2200 – 5000 nm) < 20 %

2、 宽带和扫描镜

BROADBAND MIRRORS

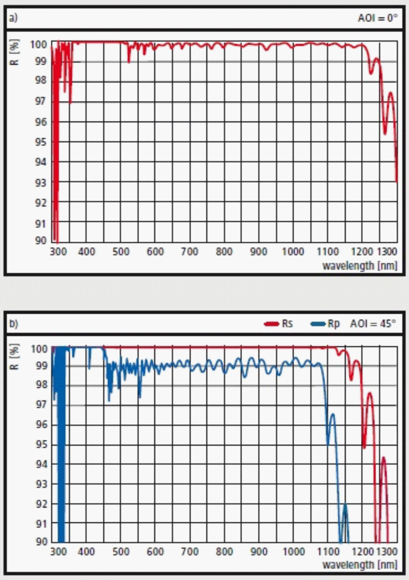


Figure 1: Reflectance spectra of an ultra broadband mirror for the NUV, VIS and NIR
a) R (0°, 360 – 1200 nm) > 99 %
b) Rs (45°, 350 – 1150 nm) > 99 %
+ Rp (45°, 350 – 1050 nm) > 97 %

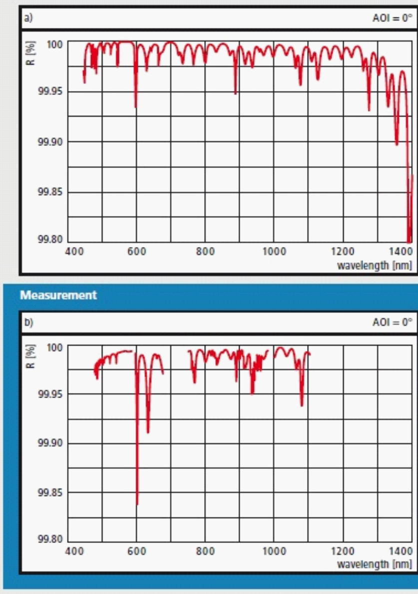


Figure 2: Reflectance spectra of a broadband mirror
HR (0°, 400 – 1400 nm) > 99.9 %
a) Calculated design
b) Broadband CRD measurement

3、滤波片

ANGLE TUNING OF NARROW BAND FILTERS

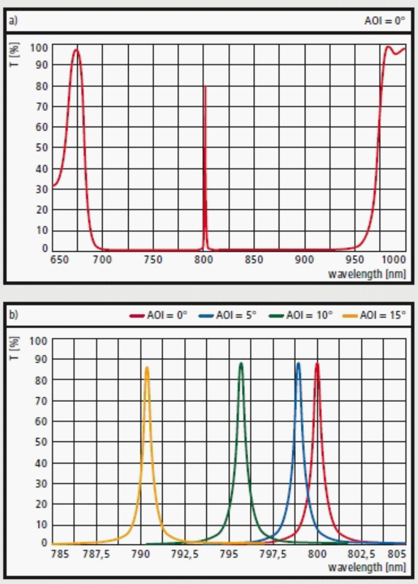


Figure 1: Transmission spectra of a narrow band filter for ~ 800 nm;
a) Transmission vs. wavelength, spectral overview
b) Transmission vs. wavelength at AOI = 0°, 5°, 10° and 15°

VARIABLE FILTERS FOR LASER APPLICATIONS

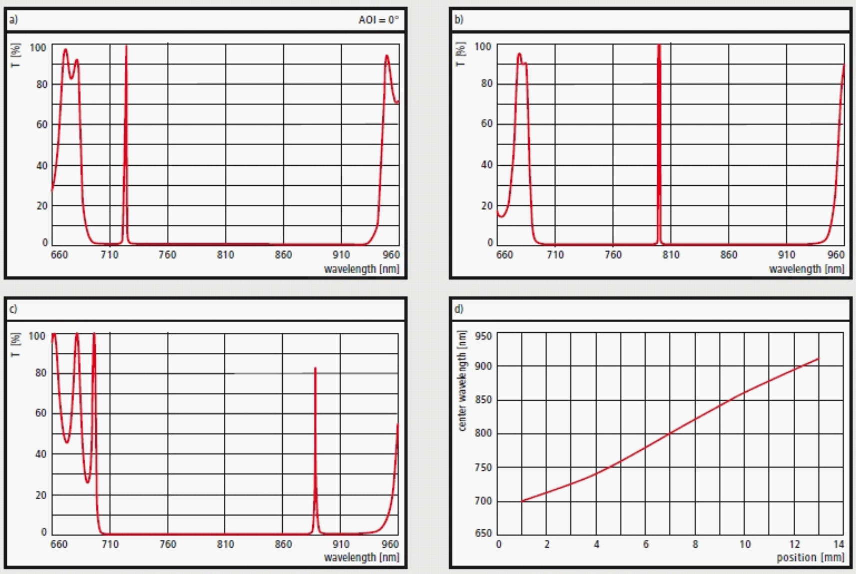


Figure 2: Transmittance spectra of a laterally variable filter for the wavelength range of the Ti:Sapphire laser taken
a) on the short wavelength side
b) in the center
c) on the long wavelength side of the filter
d) Center wavelength vs. position on the filter

STEEP EDGE FILTERS

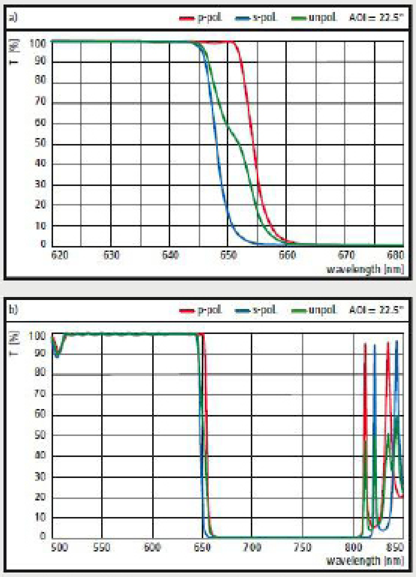


Figure 3: Transmission spectra of a steep edge short-wavelength pass filter for use as a combiner for laser diodes at 635 nm and 670 nm
HRr (22.5°, 670 nm) > 99.9 %
+ HTr (22.5°, 635 nm) > 98 %, back side AR coated)
a) Section around the edge of the blocking band
b) Spectral overview

NARROW BAND REFLECTANCE FILTERS

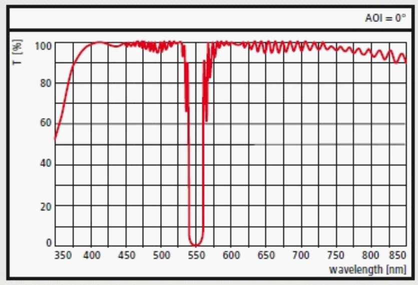
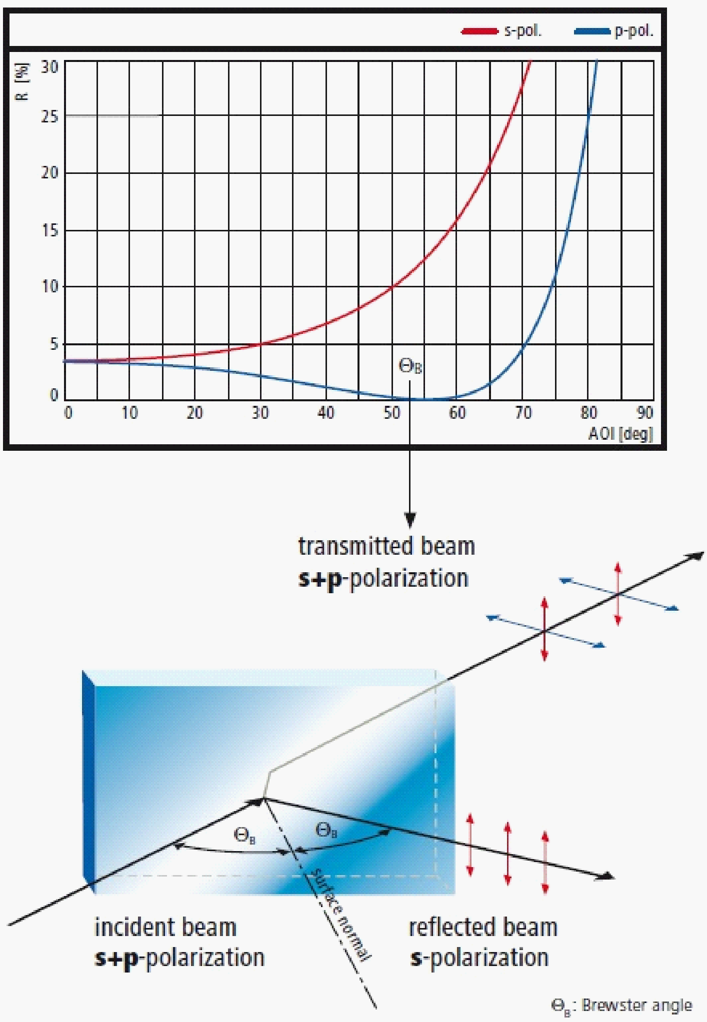


Figure 4: Transmittance spectrum of a narrowband reflectance filter for 550 nm

4、薄膜偏振片



5、低损耗光学元件

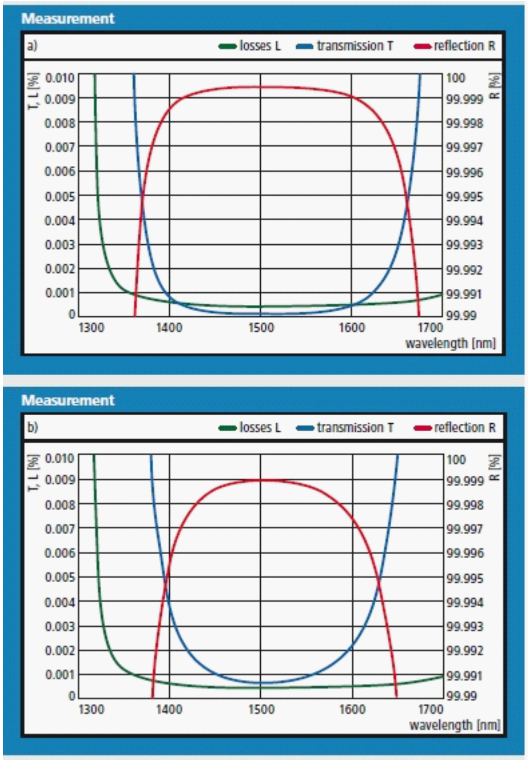


Figure 1: Reflectance, transmittance and loss spectra of low loss mirrors for 1550 nm
a) Optimized for highest reflectance (transmission ~ 0)
b) Designed for T ≈ S + A

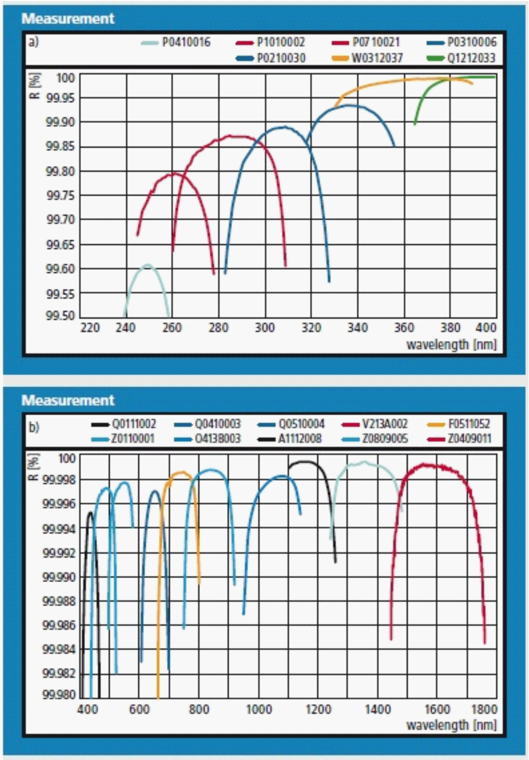


Figure 2: a) Reflectance spectra of a variety of low loss mirrors for the UV
b) Reflectance spectra of a variety of low loss mirrors for the VIS-NIR spectral range
All measurements were performed at the CRD setup which is described on pages 33 – 35. Please note that these mirrors are specially designed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

Please note that the reflectivity of the mirrors in

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

6、镀膜晶体

Crystal Type	AR/BBAR	Single HR optional with HT	Double HR/BBHR optional with HT
a-SiO_2	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		
LMA	x		
Nd:LSB	x	x	x
RDP	x		
Ruby	x	x	
Ti:Sapphire	x	x	
Spinell	x	x	x
Cr:YAG	x	x	
Er:YAG	x	x	
Ho:YAG	x	x	
Nd:YAG, Yb:YAG	x	x	x
Nd:YALO (YAP)	x		
YLF	x	x	x
Nd:YVO_4	x	x	x
ZGP	x		
ZnSe	x	x	

COATINGS ON DOPED LASER CRYSTALS

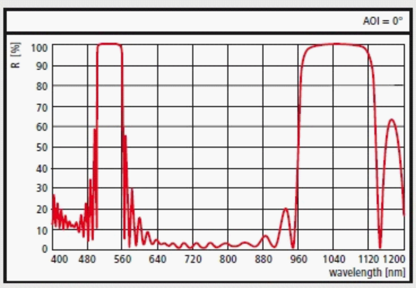


Figure 1: Reflectance spectrum of a dual HR mirror for 532 nm and 1064 nm with a HT region around 808 nm for pumping with a laser diode (on Nd:YAG)

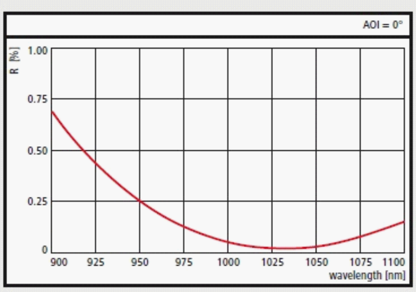


Figure 2: Reflectance spectrum of an AR coating for an Yb:KYW crystal: AR (0°, 1030 nm) < 0.2 % + AR (0° - 30°, 980 nm) < 0.2 %. Please note the large acceptance angle for the pump radiation

COATINGS ON NONLINEAR OPTICAL CRYSTALS

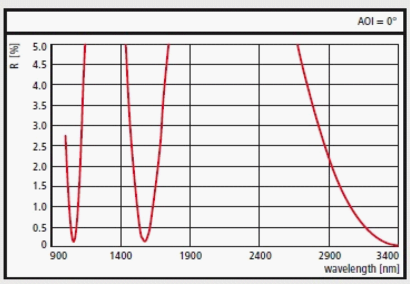


Figure 3: Reflectance spectrum of a triple wavelength AR coating on KTP:
AR (0°, 1064 nm + 1575 nm + 3400 nm) < 0.5 %

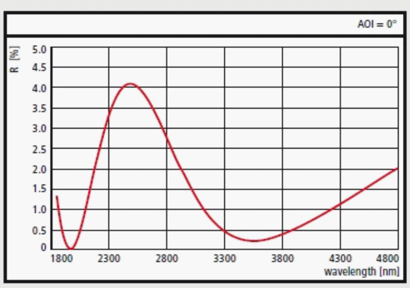


Figure 4: Reflectance spectrum of an AR coating for PPSLT:
AR (0°, 2000 nm) < 0.2 % + AR (0°, 3400 – 4400 nm) < 1.5 %

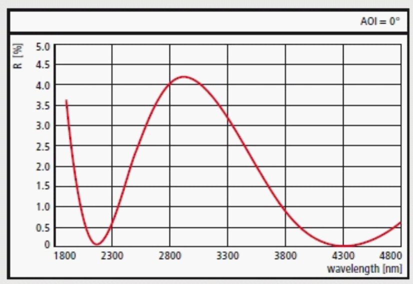


Figure 5: Reflectance spectrum of a dual wavelength AR coating on ZGP:
AR (0°, 2050 nm) < 1 % + AR (0°, 4300 nm) < 0.2 %

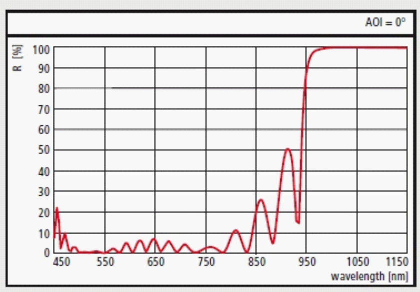


Figure 6: Reflectance spectrum of a dichroic mirror on KTP:
R (0°, 532 nm) < 1 % + HR (0°, 1064 nm) > 99.95 %