FEMTO OPTICS
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FEMTO OPTICS™

2015 | 2016

We LIVE in an ULTRAFAST world™

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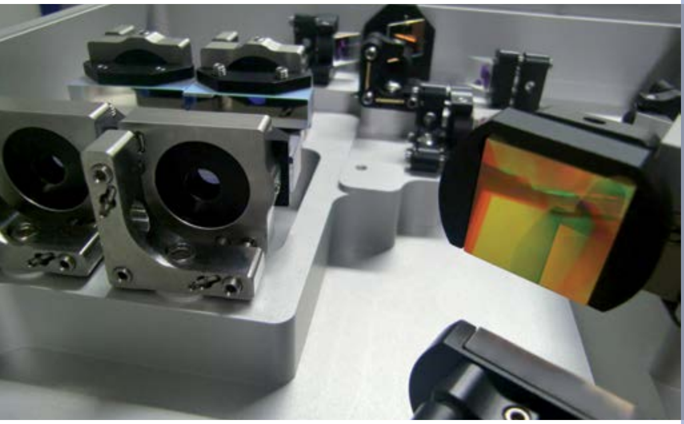
FEMTO OPTICS™

2015 | 2016

Content

Content



OEM and custom solutions

Our valued OEM customers will find the design, characterization, production, and quality control of FEMTOOPTICS unique in the ultrafast lasers and optics industries. With more than 40 employees, clean room manufacturing area, and experience gained from 15 years of leadership in ultrafast laser equipment, the unbeatable duo FEMTOLASERS™ and FEMTOOPTICS™ offers an unmatchable advantage for your OEM application.

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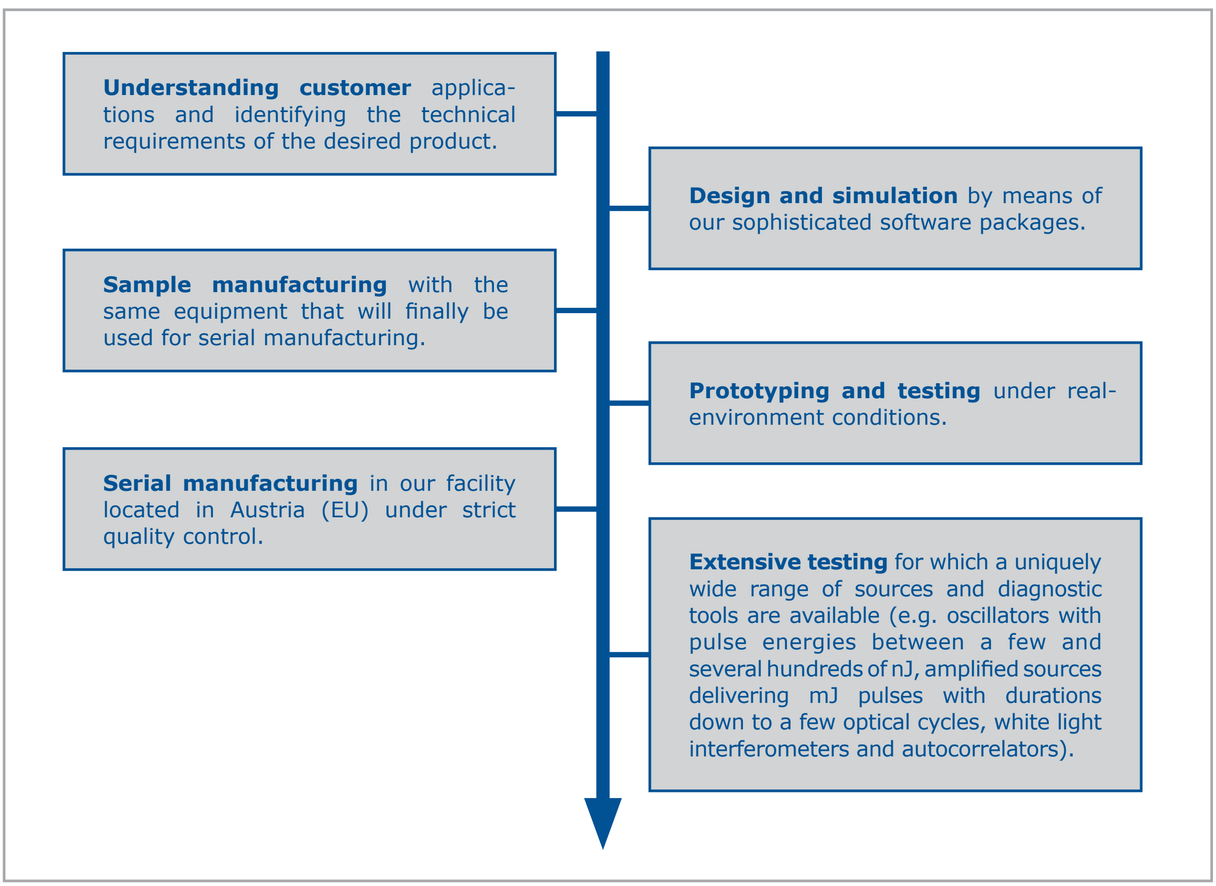
FEMTOOPTICS™ offers OEM customers the opportunity to purchase complex assemblies from one company, which usually required the involvement of several suppliers. The main advantage, however, is the result-oriented approach, which guarantees a working solution, on top of fulfilling specifications for single optical components. By this approach, integration risk at the customer side is reduced dramatically and allows our OEM customers to focus on their challenges, rather than on “reinventing the wheel” of optical assemblies we have already developed.

Ranging from tailored multilayer filters to sophisticated optical assemblies, all our OEM products rigorously undergo our development process consisting of:



We are looking forward to respond to your OEM equipment requests!

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Low dispersion broadband 800 nm optics

Applications

Distortion free manipulation of ultrashort femtosecond pulses

Special features

Broadband low dispersion coatings

Ultrathin substrates for transmissive components

Low dispersion components minimize the distortion experienced in the time-domain by femtosecond pulses in an optical setup.

FEMTOOPTICS™ broadband reflectors, beam splitters and windows are optimized to provide maximum bandwidth and minimum Group Delay Dispersion (GDD) in a wavelength range centered at 800 nm.

Ultra broadband dielectric 0° mirrors

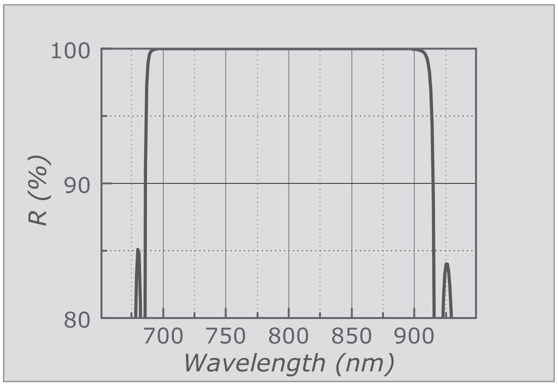
Mirrors based on a quarter-wavelength single-stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of approximately 200 nm centered at 800 nm. This is -with the current state of technology- the maximum bandwidth achievable with absorption free dielectric non dispersive mirrors. Larger bandwidth can only be achieved with either metallic reflectors or dispersive dielectric mirrors. A bandwidth of 200 nm centered at 800 nm supports minimum pulse durations ranging from 9 fs to 12 fs, depending on the spectral shape.

Special features

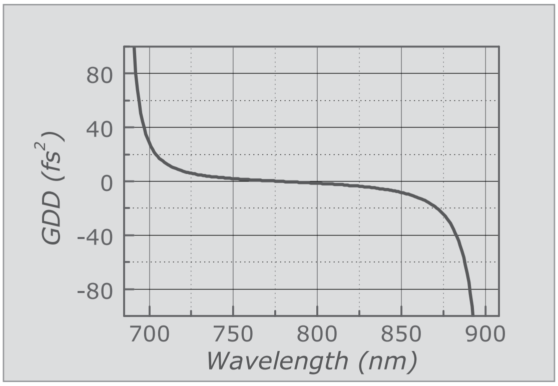
- Maximum bandwidth achievable with non dispersive dielectric mirrors
- High reflectance

Applications

- Distortion free manipulation of ultra short femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 0° mirrors.



Typical GDD vs. wavelength of ultra broadband dielectric 0° mirrors.

Order code	OA018	OA017	VO010	OA979	OA212	OA216
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat					L/10 at 633 nm | 20-10 scratch-dig | flat
Surface S2	inspection polishing | flat			matt | flat		
Coating on S1	R > 99.5 % and low GDD in the wavelength range 700 (± 10) nm - 900 (± 10) nm AOI = 0° T > 90 % in the wavelength range 480 nm - 540 nm AOI = 0°					
Coating on S2	none					
Substrate material	fused silica or BK7					
Diameter	0.5 "	1 "	30 mm	1.5 "	2 "	3 "
Thickness	6.35 mm	6.35 mm	10 mm	12 mm	12 mm	20 mm
Wedge angle	< 5 '					

Ultra broadband dielectric 45° mirrors

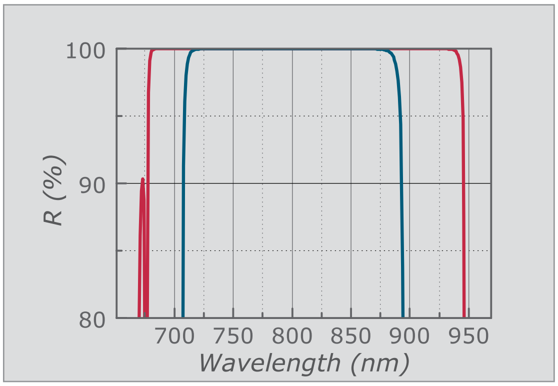
Mirrors based on a quarter wavelength single-stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of ~ 160 nm centered at 800 nm for an angle of incidence of 45° with p-polarized light. This bandwidth supports minimum pulse durations ranging from 15 to 20 fs, depending on the spectral shape. For s-polarized light, the bandwidth of 45° non-dispersive reflectors extends to ~ 250 nm. Irrespective of polarization, larger bandwidth can only be achieved with either metallic reflectors or dispersive dielectric mirrors.

Special features

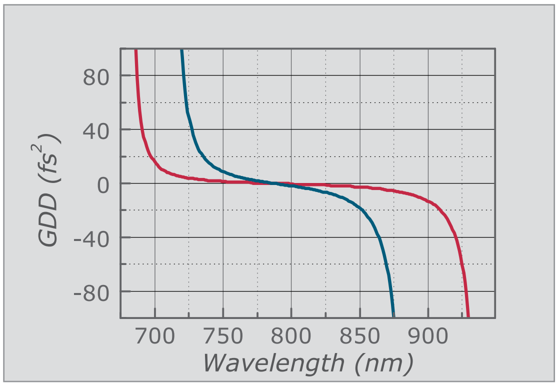
- Maximum bandwidth achievable with non dispersive dielectric mirrors
- High reflectance

Applications

- Distortion free manipulation of ultra short femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 45° mirrors for p-polarized (blue) and s-polarized light (red).



Typical GDD vs. wavelength of ultra broadband dielectric 45° mirrors for p-polarized (blue) and s-polarized light (red).

Order code	OO102	OA019	VO033	OA980	VO007	OA217
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat					L/10 at 633 nm | 20-10 scratch-dig | flat
Surface S2	inspection polishing | flat			matt | flat		
Coating on S1	R > 99.5 % and low GDD in the wavelength range 720 (± 10) nm - 880 (± 10) nm AOI = 45° | p-polarized R > 99.5 % and low GDD in the wavelength range 680 (± 10) nm - 930 (± 10) nm AOI = 45° | s-polarized					
Coating on S2	none					
Substrate material	fused silica or BK7					
Diameter	0.5 ''	1 ''	30 mm	1.5 ''	2 ''	3 ''
Thickness	6.35 mm	6.35 mm	10 mm	12 mm	12 mm	20 mm
Wedge angle	< 5 '					

Ultra broadband dielectric 45° prism mirrors

Mirrors based on a quarter wavelength single stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of ~ 160 nm centered at 800 nm for an angle of incidence of 45° with p-polarized light. For s-polarized light, the bandwidth of 45° non-dispersive reflectors extends to ~ 250 nm.

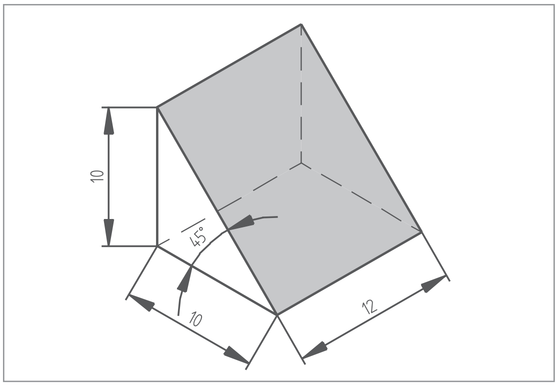
The reflective coating is deposited on the hypotenuse of right angle prisms, in order to enable robust beam steering in most compact setups. These components are not suitable to be used as total internal reflection prisms.

Special features

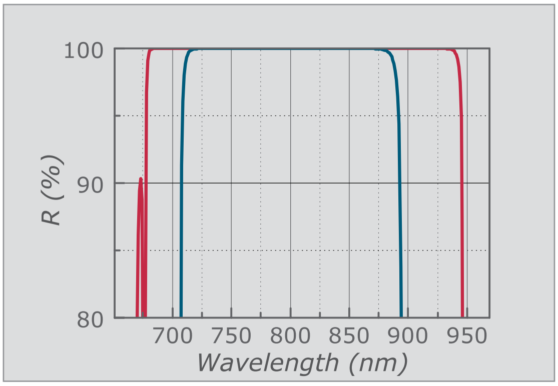
- Maximum bandwidth achievable with non dispersive dielectric mirrors
- Substrate shape that enables compact beam steering

Applications

- Beam steering in compact setups
- Input/output coupling in mirror telescopes



HR coated Prism - conceptual drawing.



Typical reflectance vs. wavelength of ultra broadband dielectric 45° prism mirrors for p-polarized (blue) and s-polarized light (red).

Order code	VO028
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat
Other surfaces	inspection polishing | flat | uncoated
Coating on S1	R > 99.5 % and low GDD in the wavelength range 720 (± 10) nm - 880 (± 10) nm AOI = 45° | p-polarized R > 99.5 % and low GDD in the wavelength range 680 (± 10) nm - 930 (± 10) nm AOI = 45° | s-polarized
Substrate material	BK7
Dimensions	12 mm x 10 mm x 10 mm

Dielectric 0.7 % beam splitters | sub-7 fs | p-polarized

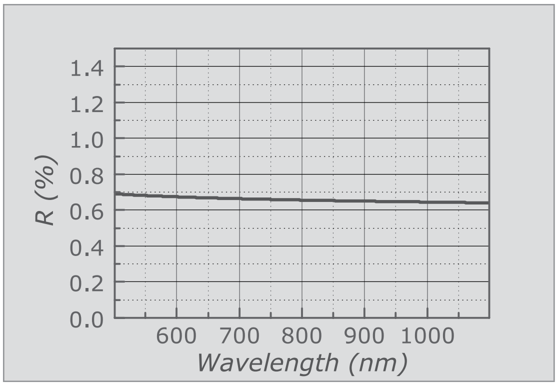
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

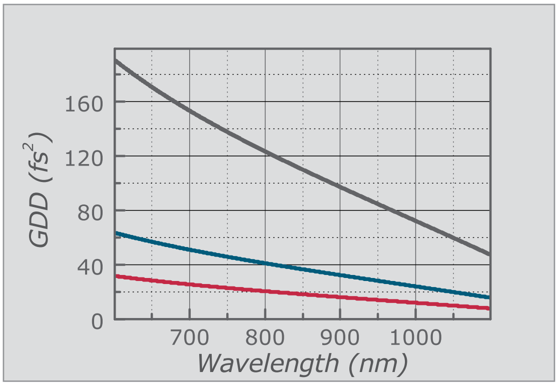
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 0.7 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) and 3mm (gray) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA042	OA043	OA514	OA516
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	none, Fresnel reflectance R = 0.7 % | GDD = 0 fs² in the wavelength range 650 nm - 950 nm | AOI = 45° | p-polarized			
Coating on S2	R < 0.15 % in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Substrate material	fused silica			
Diameter	0.5 "	1 "	30 mm	2 "
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 "			

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Dielectric 2 % beam splitters | sub-7 fs | p-polarized

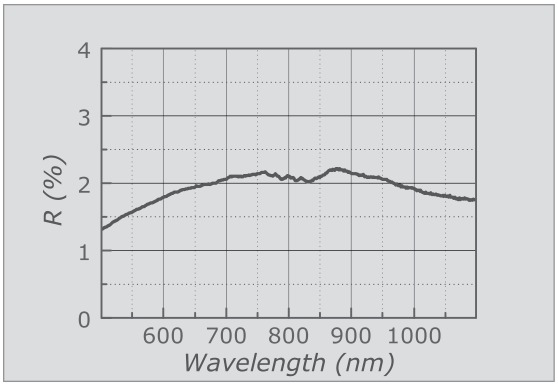
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

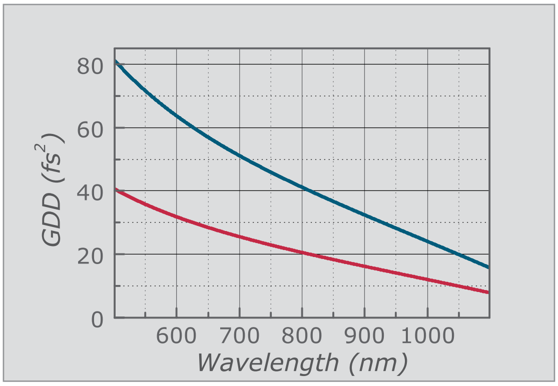
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 2 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA038	OA039	OA533
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Coating on S1	R = 2 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized		
Coating on S2	R < 0.15 % in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized		
Substrate material	fused silica		
Diameter	0.5 ''	1 ''	30 mm
Thickness	500 µm	1 mm	1 mm
Wedge angle	< 30 ''		

Dielectric 5 % beam splitters | sub-7 fs | p-polarized

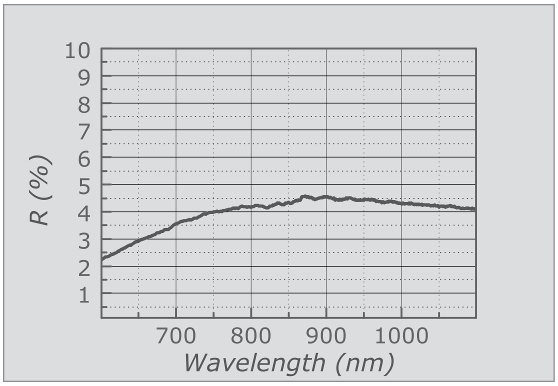
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

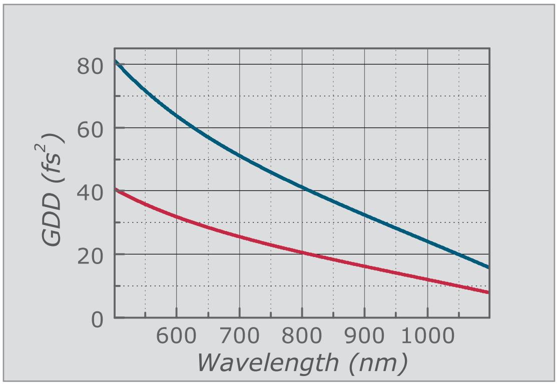
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 5 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA040	OA041	OA240	OA1104
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	R = 5 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Coating on S2	R < 0.15 % in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Substrate material	fused silica			
Diameter	0.5 "	1 "	30 mm	2 "
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 "			

Dielectric 10 % beam splitters | sub-7 fs | p-polarized

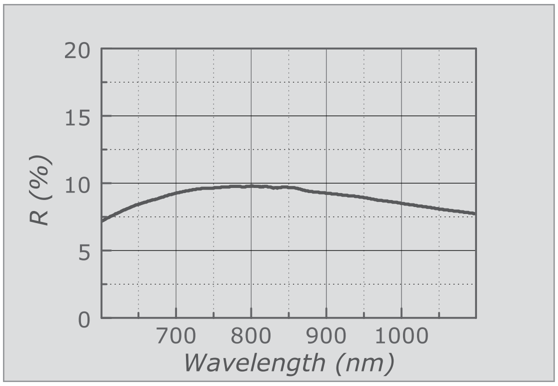
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra-thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

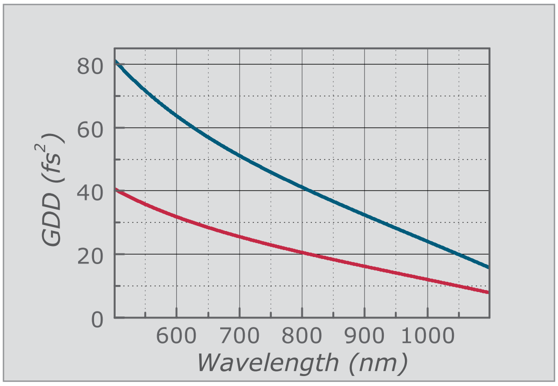
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 10 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA099	OA078	OA515	OA1103
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	R = 10 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Coating on S2	R < 0.15 % in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Substrate material	fused silica			
Diameter	0.5 "	1 "	30 mm	2 "
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 "			

Dielectric 25 % beam splitters | sub-7 fs |p-polarized

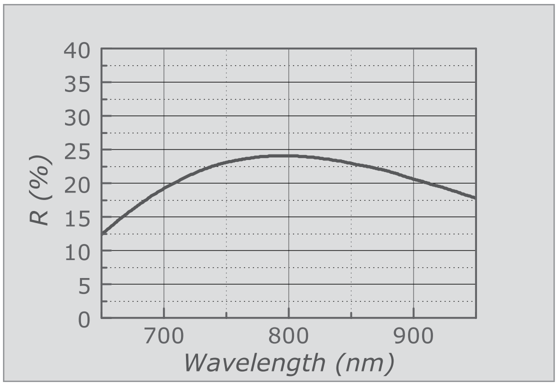
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

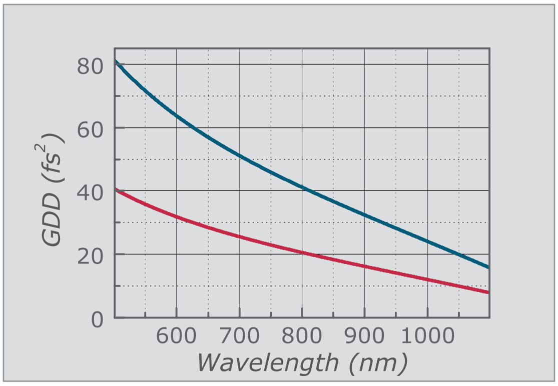
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 25 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA134	OA135	OA241	OA854
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	R = 25 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Coating on S2	R < 0.15 % in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Substrate material	fused silica			
Diameter	0.5 ''	1 ''	30 mm	2 ''
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 ''			

Dielectric 37 % beam splitters | sub-7 fs | p-polarized

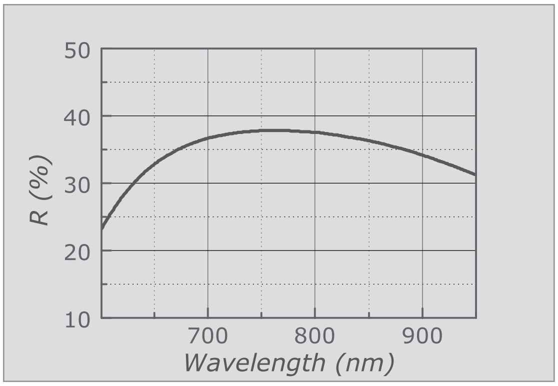
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

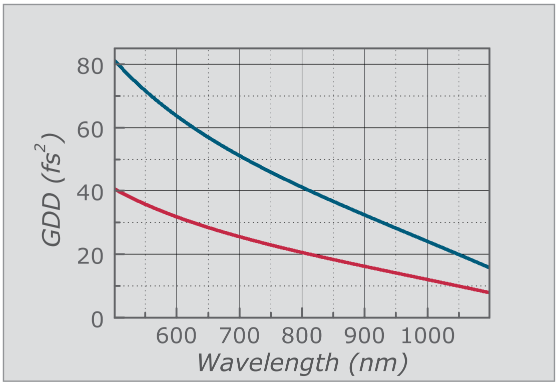
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 37 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA202	OA089	OA242	OA855
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	R = 37 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Coating on S2	none			
Substrate material	fused silica			
Diameter	0.5 "	1 "	30 mm	2 "
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 "			

Dielectric 50 % beam splitters | sub-7 fs | p-polarized

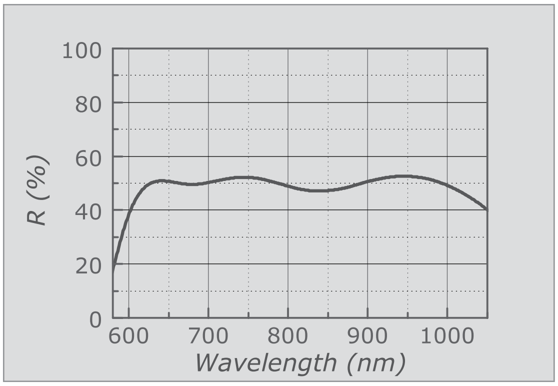
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

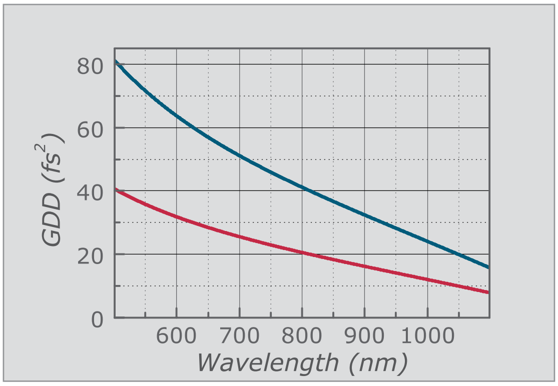
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 50 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA065	OA037	OA237	OA856
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat			
Coating on S1	R = 50 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized			
Coating on S2	none			
Substrate material	fused silica			
Diameter	0.5 "	1 "	30 mm	2 "
Thickness	500 µm	1 mm	1 mm	3 mm
Wedge angle	< 30 "			

Dielectric 50 % beam splitters | sub-7 fs | p-polarized

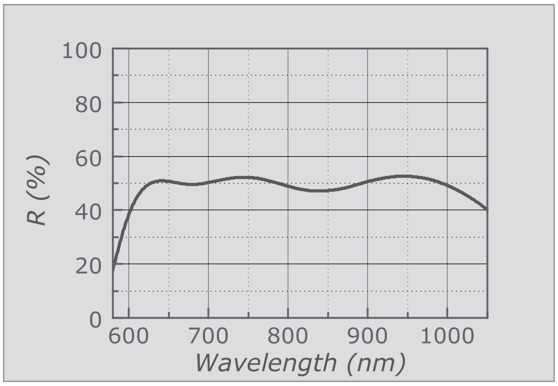
In dispersion-balanced Michelson interferometers it is essential to have identical beam paths for the beams propagating in the two interferometer arms. To this end we have designed a 50 % beam splitter deposited on a rectangular substrate. Each surface has a coated and uncoated section, such that the need for using an additional compensation plate is obviated if each beam interacts once with each section of the beam splitter.

Special features

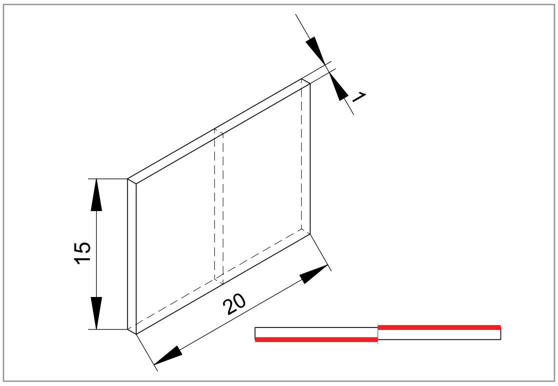
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Dispersion balanced Michelson interferometers



Typical reflectance vs. wavelength of ultra broadband dielectric 50 % beam splitters for an angle of incidence of 45° and p-polarized light.



Schematic representation of FO002. The red lines depict the coated sections of the beam splitter.

Order code	**FO002**
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Coating on S1	R = 50 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized (see drawing above)
Coating on S2	R = 50 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | p-polarized (see drawing above)
Substrate material	fused silica
Dimension	15 mm x 20 mm
Thickness	1 mm
Wedge angle	< 30 ''

Dielectric 67 % beam splitters | sub-25 fs | p-polarized

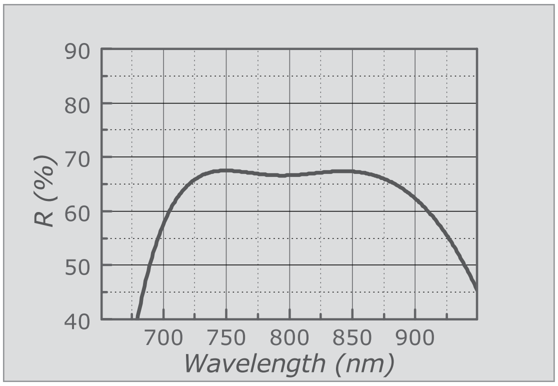
Owing to the slightly increased substrate thickness that prevents thermally induced deformation and to the coating materials employed these beam splitters are well suited for use with intense pulses with durations down to 25 fs and less. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Special care should be taken when mounting the beam splitters, since mechanical tension may lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on opto-mechanical adapters on page 95.

Special features

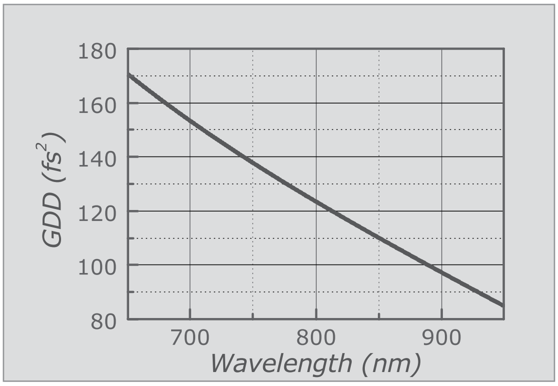
- Constant splitting ratio over the specified bandwidth
- minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for intense pulses down to 25 fs and less



Typical reflectance vs. wavelength of ultra broadband dielectric 67 % sub-25-fs beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 3 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA971	OA972
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 67 % and low GDD in the wavelength range 725 nm -875 nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica	
Diameter	1 ''	2 ''
Thickness	3 mm	
Wedge angle	< 30 ''	

Dielectric 75 % beam splitters | sub-25 fs | p-polarized

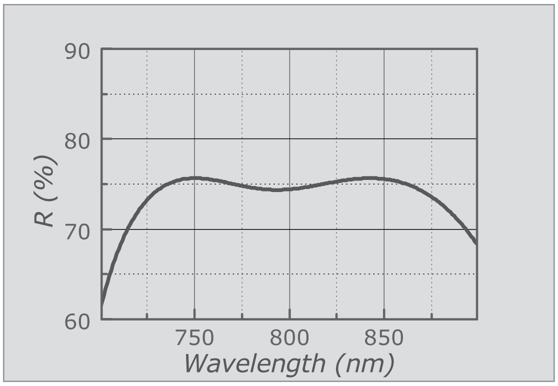
Owing to the slightly increased substrate thickness that prevents thermally induced deformation and to the coating materials employed these beam splitters are well suited for use with intense pulses with durations down to 25 fs and less. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Special care should be taken when mounting the beam splitters, since mechanical tension may lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on opto-mechanical adapters on page 95.

Special features

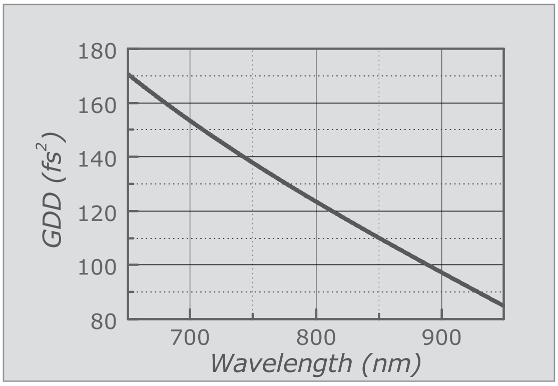
- Constant splitting ratio over the specified bandwidth
- minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for intense pulses down to 25 fs and less



Typical reflectance vs. wavelength of ultra broadband dielectric 75 % sub-25-fs beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 3 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA973	OA974
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 75 % and low GDD in the wavelength range 730 nm -870 nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica	
Diameter	1 ''	2 ''
Thickness	3 mm	
Wedge angle	< 30 ''	

Dielectric 80 % beam splitters | sub-25 fs | p-polarized

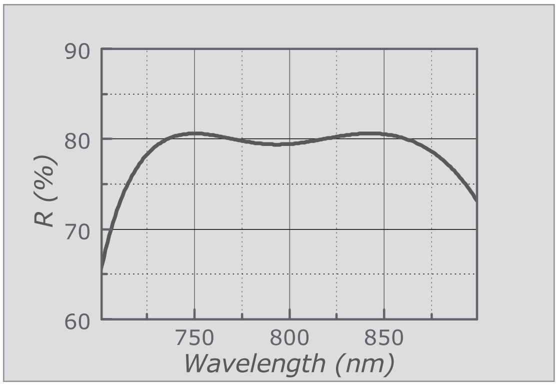
Owing to the slightly increased substrate thickness that prevents thermally induced deformation and to the coating materials employed these beam splitters are well suited for use with intense pulses with durations down to 25 fs and less. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Special care should be taken when mounting the beam splitters, since mechanical tension may lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on opto-mechanical adapters on page 95.

Special features

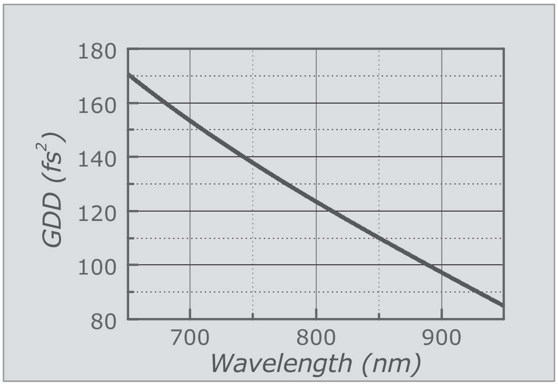
- Constant splitting ratio over the specified bandwidth
- minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for intense pulses down to 25 fs and less



Typical reflectance vs. wavelength of ultra broadband dielectric 80 % sub-25-fs beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 3 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA975	OA976
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 80 % and low GDD in the wavelength range 730 nm -870 nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica	
Diameter	1 ''	2 ''
Thickness	3 mm	
Wedge angle	< 30 ''	

Dielectric 90 % beam splitters | sub-25 fs | p-polarized

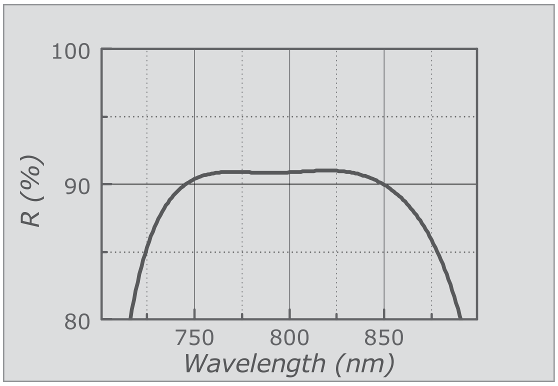
Owing to the slightly increased substrate thickness that prevents thermally induced deformation and to the coating materials employed these beam splitters are well suited for use with intense pulses with durations down to 25 fs and less. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Special care should be taken when mounting the beam splitters, since mechanical tension may lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on opto-mechanical adapters on page 95.

Special features

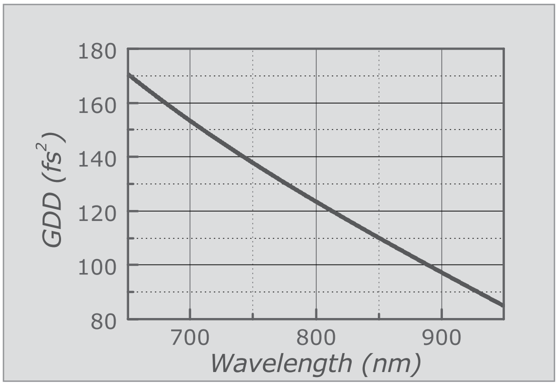
- Constant splitting ratio over the specified bandwidth
- minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for intense pulses down to 25 fs and less



Typical reflectance vs. wavelength of ultra broadband dielectric 90 % sub-25-fs beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 3 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA977	OA978
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 90 % and low GDD in the wavelength range 750 nm -850 nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica	
Diameter	1 ''	2 ''
Thickness	3 mm	
Wedge angle	< 30 ''	

Dielectric 8 % beam splitters | sub-7 fs | s-polarized

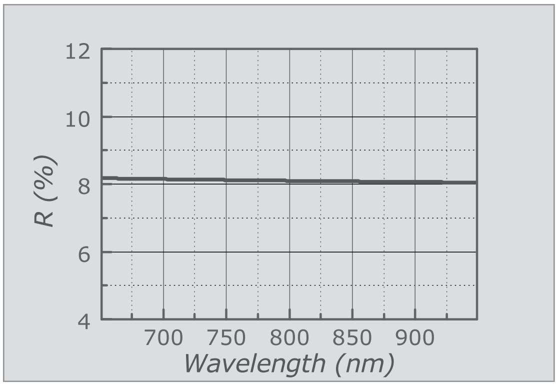
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted s-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates were used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

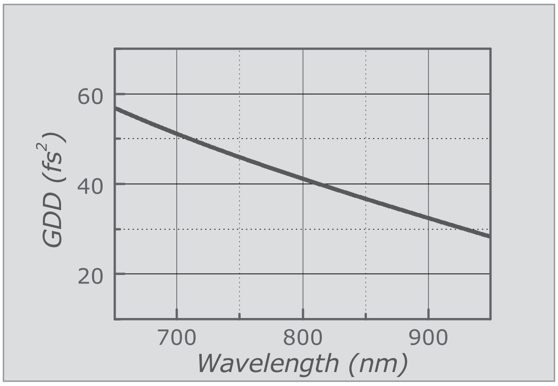
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling of femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 8 % sub-7-fs beam splitters for an angle of incidence of 45° and s-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA255	OA355
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	none | Fresnel reflectance R = 8% GDD = 0 fs² in the wavelength range 650 nm - 950 nm AOI = 45° | s-polarized	
Coating on S2	R < 1.5 % in the wavelength range 650 nm - 950 nm | s-polarized	
Substrate material	fused silica	
Diameter	1 ''	30 mm
Thickness	1 mm	
Wedge angle	< 30 ''	

Dielectric 18 % beam splitters | sub-7 fs | s-polarized

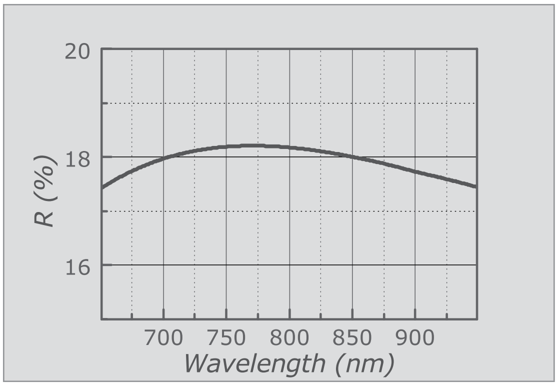
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted s-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates were used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

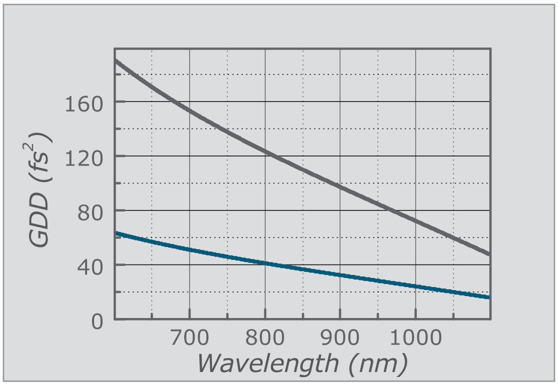
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling of femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 18 % sub-7 fs beam splitters for an angle of incidence of 45° and s-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 3 mm (gray) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA360	OA361	OA981
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Coating on S1	R = 18 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | s-polarized		
Coating on S2	R < 1.5 % in the wavelength range 650 nm - 950 nm | s-polarized		
Substrate material	fused silica		
Diameter	1 "	30 mm	2 "
Thickness	1 mm		3 mm
Wedge angle	< 30 "		

Dielectric 30 % beam splitters | sub-7 fs | s-polarized

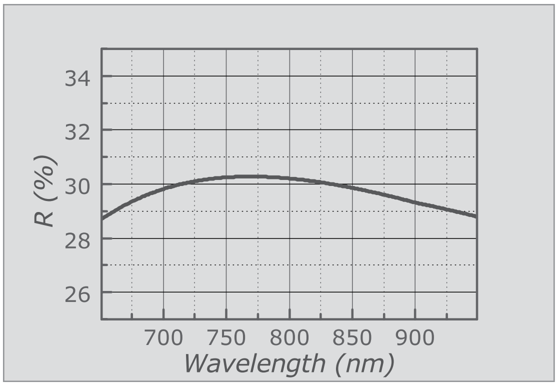
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted s-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates were used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

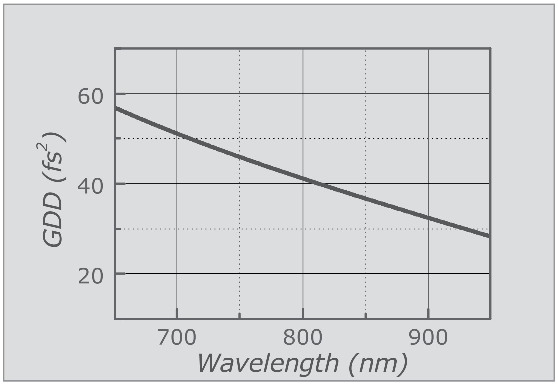
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling of femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 30 % sub-7 fs beam splitters for an angle of incidence of 45° and s-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA257	OA256
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 30 % and low GDD in the wavelength range 650 nm - 950 nm AOI = 45° | s-polarized	
Coating on S2	R < 1.5 % in the wavelength range 650 nm - 950 nm | s-polarized	
Substrate material	fused silica	
Diameter	1 ''	30 mm
Thickness	1 mm	
Wedge angle	< 30 ''	

Dielectric 50 % beam splitters | sub-7 fs | s-polarized

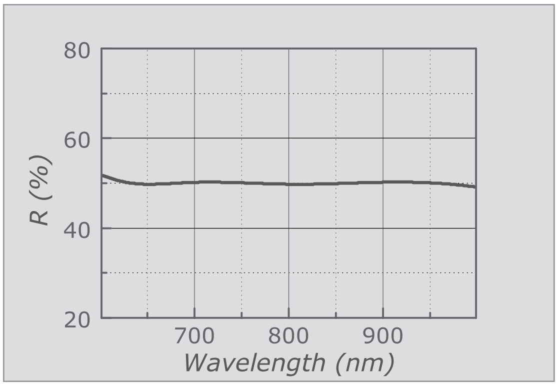
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted s-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates were used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

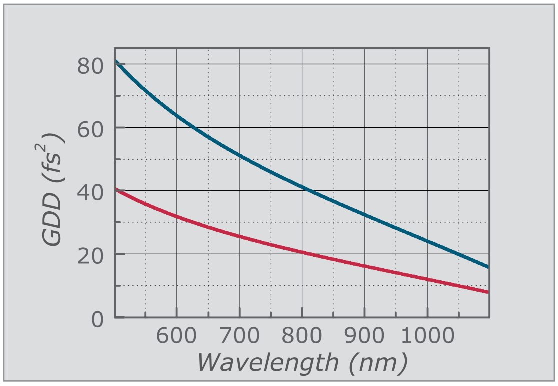
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling of femtosecond pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 50 % sub-7 fs beam splitters for an angle of incidence of 45° and s-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA353	OA253	OA354
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Coating on S1	R = 50 (± 5) % in the wavelength range 650 nm - 950 nm AOI = 45° | s-polarized		
Coating on S2	R < 1.5 % in the wavelength range 650 nm - 950 nm s-polarized		
Substrate material	fused silica		
Diameter	0.5 ''	1 ''	30 mm
Thickness	0.5 mm	1 mm	1 mm
Wedge angle	< 30 ''		

Metallic beam splitters

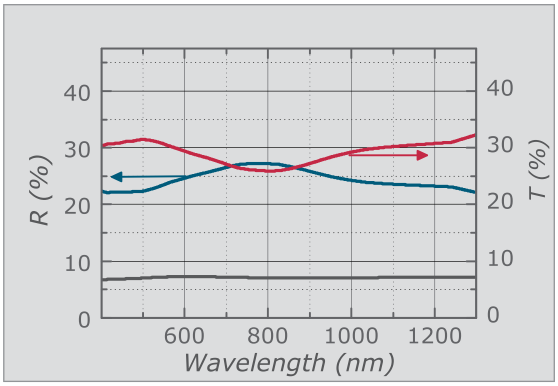
Metallic beam splitters exhibit a constant splitting ratio over bandwidths that can not be achieved with dielectric coatings. This comes at the expense of non-negligible absorption losses. Metallic beam splitters are mainly suitable for diagnostic devices where a high throughput is dispensable. Ultrathin substrates are used to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

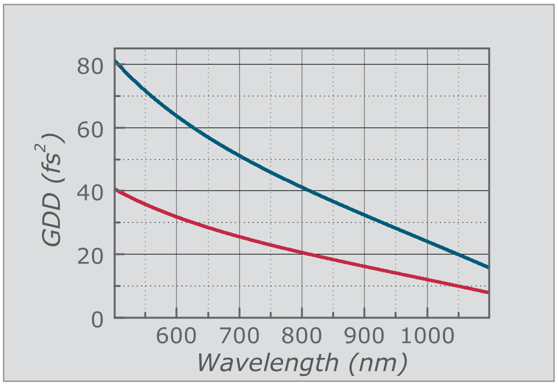
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- beam splitting and sampling of femtosecond pulses
- temporal characterization of few-cycle pulses



Typical reflectance (blue), transmittance (red) and reflectance x transmittance product (black) of ultra broadband metallic beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) at 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA927	OA827	OA215
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat		
Coating on S1	metallic R = 27 (± 2) % in the wavelength range 600 nm - 950 nm | AOI = 45° | p-polarized T = 27 (± 2) % in the wavelength range 600 nm - 950 nm | AOI = 45° | p-polarized A = 46 (± 3) % in the wavelength range 600 nm - 950 nm | AOI = 45° | p-polarized		
Coating on S2	none		
Substrate material	fused silica		
Diameter	0.5 "	1 "	rectangular | 15 x 20 mm Each surface has a 15 x 10 mm coted surface.
Thickness	0.5 mm	1 mm	1 mm
Wedge angle	< 30 "		

Compensation plates

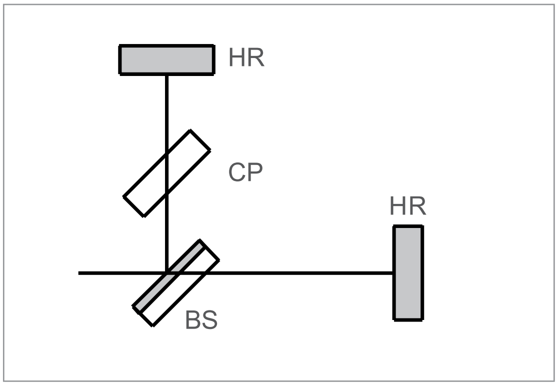
The compensation plates are identical to the substrates of the FEMTOOPTICS™ beam splitters. In dispersion balanced interferometric measurements a compensation plate identical to the substrate of the beam splitter has to be inserted in the interferometer arm containing the beam reflected off the beam splitter.

Special features

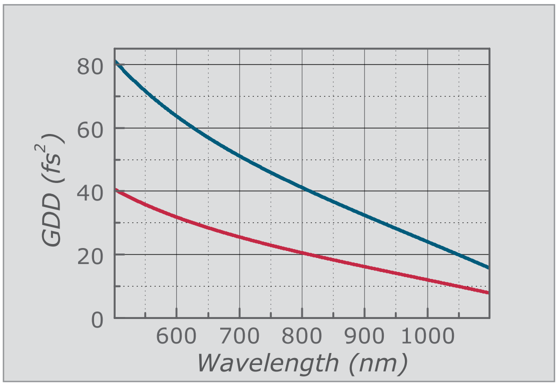
- Identical to the substrates of the FEMTO-OPTICS™ beam splitters

Applications

- Dispersion balanced interferometric measurements



Schematic of a dispersion compensated interferometer (HR = high reflector, BS = beam splitter, CP = compensation plate).



GDD vs. wavelength experienced by the transmitted beam for compensation plates with a thickness of 1 mm (blue) and 0.5 mm (red) for an angle of incidence of 45°.

Order code	OA915	OA815
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	none	
Coating on S2	none	
Substrate material	fused silica	
Diameter	0.5 ''	1 ''
Thickness	0.5 mm	1 mm
Wedge angle	< 30 ''	

Ultra thin AR coated windows

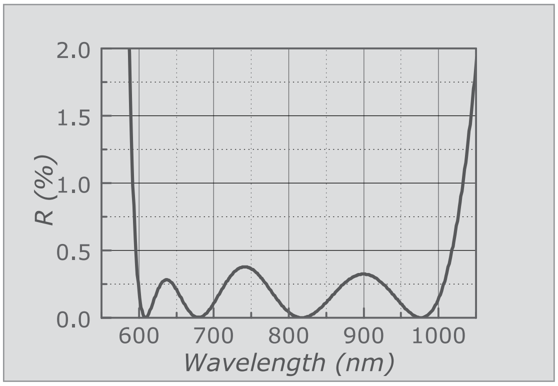
The amount of positive GDD of an optical setup can be minimized by employing these ultra thin windows. The broadband AR-coating applied on both surfaces allows nearly loss-free transmission of sub-10 fs pulses.

Special features

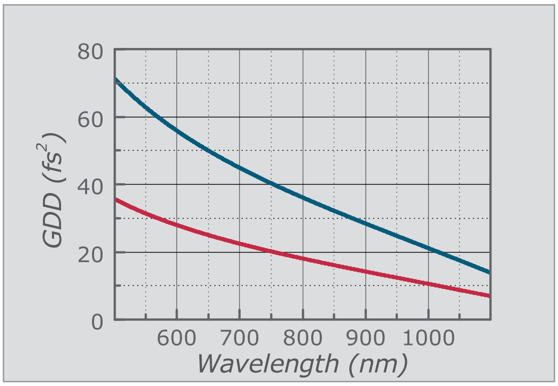
- Reduced thickness
- Broadband anti reflection coating

Applications

- Low dispersion, low loss coupling of light into chambers



Typical residual reflectance vs. wavelength of antireflection coated windows.



GDD vs. wavelength of AR-coated windows with a thickness of 1 mm (blue) and 0.5 mm (red).

Order code	OA223	OA222	OA221
Surface S1	better than L/6 at 633 nm in transmittance 10-5 scratch-dig | flat		
Surface S2	better than L/6 at 633 nm in transmittance 10-5 scratch-dig | flat		
Coating on S1	R < 0.4 % in the wavelength range 620 nm - 980 nm AOI 0 to 20°		
Coating on S2	R < 0.4 % in the wavelength range 620 nm - 980 nm AOI 0 to 20°		
Substrate material	fused silica		
Diameter	0.5 ''	1 ''	30 mm
Thickness	0.5 mm	1 mm	1 mm
Wedge angle	< 30 ''		

Ultra thin Brewster angle windows

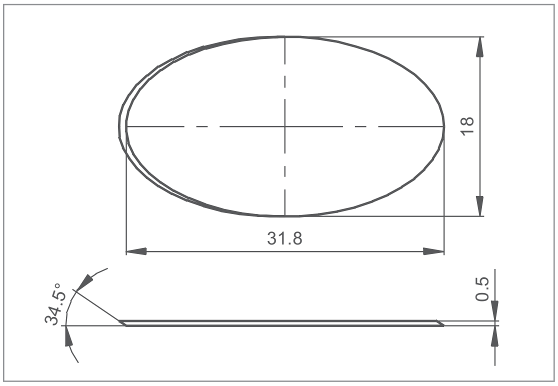
Reflection losses and dispersion induced pulse broadening experienced by laser beams upon coupling into chambers can be minimized by employing Brewster angled ultra thin fused silica windows.

Special features

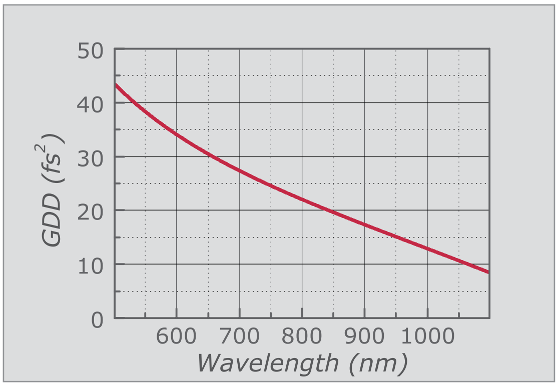
- Reduced thickness
- Elliptical shape resulting in circular aperture at the Brewster angle

Applications

- Low dispersion, loss free coupling of light into chambers



Brewster angle window - conceptual drawing.



GDD vs. wavelength of Brewster-angle windows (the optical path lengthening due to refraction was taken into account).

Order code	OA024
Surface S1	better than L/6 at 633 nm in transmittance 10-5 scratch-dig | flat
Surface S2	better than L/6 at 633 nm in transmittance 10-5 scratch-dig | flat
Coating on S1	none
Coating on S2	none
Substrate dimensions	elliptical, long axis 31.8 mm, short axis 18 mm
Free aperture	18 mm (for Brewster AOI = 56°)
Thickness	0.5 mm
Wedge angle	< 30 ''

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Broadband focusing optics

Applications

Beam focussing

THz generation

Materials processing

Special features

Achromatic components

Minimal dispersion

Two aspects call for special care when femtosecond pulses are focused: the focusing component must be achromatic over the full bandwidth of the pulse and the GDD introduced by lenses has to be pre-compensated in order to achieve the shortest pulse duration in the focus.

The OA046 achromatic triplet lens has been optimized to introduce minimum chromatic aberrations in the wavelength range 650 nm - 950 nm supporting thus the bandwidth required by sub-12 fs pulses. The precisely known GDD of the lens can be pre-compensated with our ECDC mirror sets.

For less demanding applications, spherical focusing mirrors provide a convenient alternative, since they introduce basically no GDD upon reflection. However the angle of incidence has to be kept small, in order to minimize astigmatism.

Off-axis parabolic focusing mirrors introduce an angle of 90° between the incident and the reflected (focused) beam. Extremely tight, astigmatism free focusing (down to < 5 µm) can be achieved if the full aperture of the metal coated parabolic mirrors OA027 or OA175 is illuminated.

Broadband achromatic triplet lens 800 nm | sub-10 fs

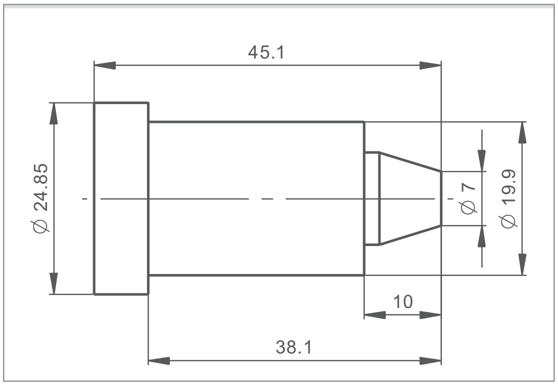
This achromatic triplet lens allows focusing sub-10 fs pulses to less than 5 µm (focal spot diameter at the $1/e^2$ level). Being precisely known, the GDD of the lens can be pre-compensated with ECDC dispersive mirror sets in order to achieve a bandwidth limited pulse duration in the focus. This lens is also supplied within the dispersion compensated focusing kit OA333 (see the following page).

Special features

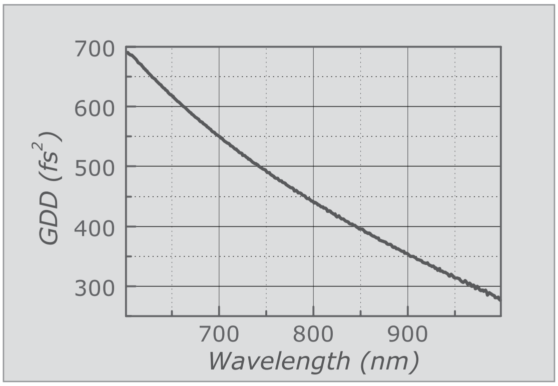
- Large numerical aperture
- Achromatic behavior over a wide spectral range

Applications

- Fiber coupling
- Beam focusing for material processing, THz generation



Broadband achromatic triplet lens - conceptual drawing.



GDD vs. wavelength of the broadband achromatic triplet lens OA046.

Order code	OA046
Type	achromatic triplet lens infinity corrected
Wavelength range	650 nm - 950 nm
Numerical aperture	0.2
Working distance	1.7 mm
Effective focal length	6 mm
Free aperture	4 mm
Mount	black anodized Al

Dispersion compensated achromatic triplet lens

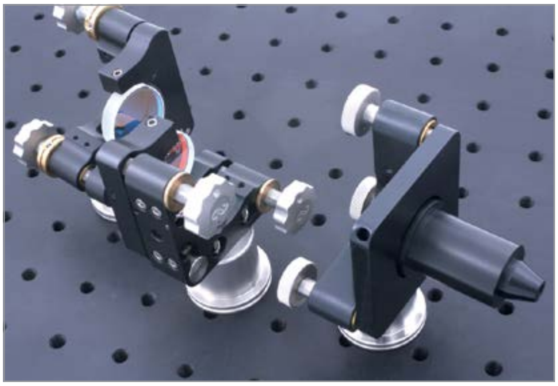
Consisting of a broadband achromatic triplet lens, a specially optimized mirror compressor and a pair of glass wedges for fine GDD tuning, this set enables preserving a sub-10 fs in-focus pulse duration while focusing a beam to less than 5 µm. Each set is individually tested in our labs and supplied with the measured autocorrelation.

Special features

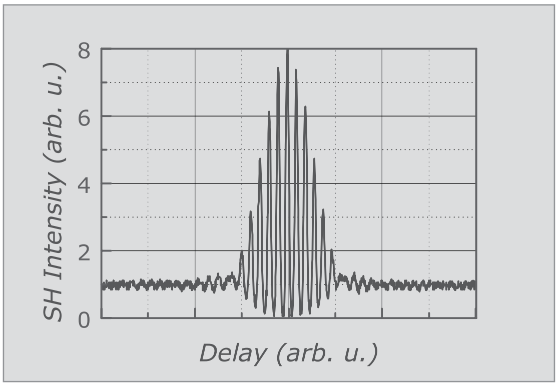
- Unique dispersion compensated sub-5 µm focusing setup
- Each set individually tested for the specified pulse duration

Applications

- Materials processing
- THz generation



Typical setup employing the kit OA333. The thin wedges are not shown in the photograph.



Typical second order interferometric autocorrelation recorded with a two-photon diode at the focus of a setup employing the kit OA333.

Order code	OA333
Description	Set consisting of: 1 pc. broadband achromatic triplet lens OA046 1 pc. dispersive mirror compressor (2 mirrors) 2 pc. thin fused silica wedges OA924
Laboratory test	measured in-focus interferometric autocorrelation supplied
Wavelength range	650 nm - 950 nm
Supported pulse duration	< 10 fs
Insertion loss	< 15 %
Free aperture	4 mm
Optomechanical parts	mounts and posts are not included | can be supplied upon request
Installation	not included | can be supplied upon request

Enhanced Ag focusing mirrors

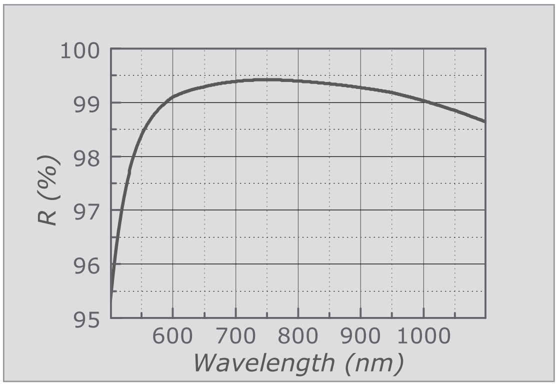
Silver focusing mirrors are the tool of choice when few cycle femtosecond pulses or light continua need to be focused. Owing to a dielectric multilayer overcoating reflectance losses and GDD are minimized over the full fluorescence range of Ti:Sapphire. In order to avoid astigmatism, the angle of incidence on the focusing mirror can be effectively minimized by using dielectrically enhanced silver prism mirrors (FO009).

Special features

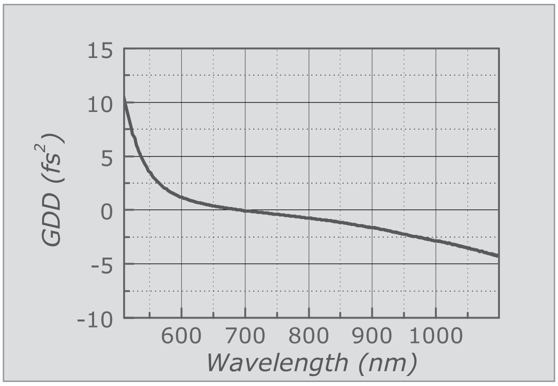
- Low losses and minimized GDD in the visible and near infrared spectral range
- Wide range of radii of curvature available from the stock

Applications

- Distortion free focusing of pulses down to less than 6 fs



Typical reflectance vs. wavelength of enhanced silver focusing mirrors calculated for an angle of incidence of 0°.



Typical GDD vs. wavelength of enhanced silver focusing mirrors calculated for an angle of incidence of 0°.

Order code		OA054	OA055	OA056	OA151	OA823	OA825	OA058	OA059	OA060	OA061
Surface S1	ROC (mm)	-100	-150	-300	-500	-600	-700	-800	-1000	-2000	-3000
	f (mm)	50	75	150	250	300	350	400	500	1000	1500
	L/10 at 633 nm | 10-5 scratch-dig										
Surface S2	fine grinded										
Coating on S1	$-5\ fs^2 < GDD < 5\ fs^2$ in the wavelength range 550 nm - 1050 nm AOI = 0° R > 99 % in the wavelength range 600 nm - 1000 nm AOI = 0°										
Coating on S2	none										
Substrate material	fused silica or BK7										
Diameter	1 ''										
Thickness	6.35 mm										
Wedge angle	not applicable										

Protected Al focusing mirrors

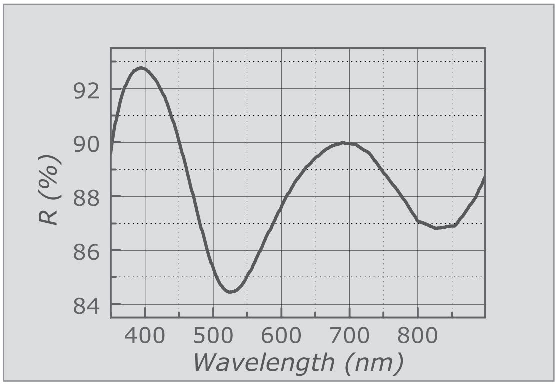
Protected aluminum focusing mirrors are the tool of choice when light continua or nonlinearly converted light extending down to 350 nm need to be focused, since the reflectance remains reasonably high in the range. The protective coating was optimized to maintain constant reflectance also in the visible and near infrared spectral ranges.

Special features

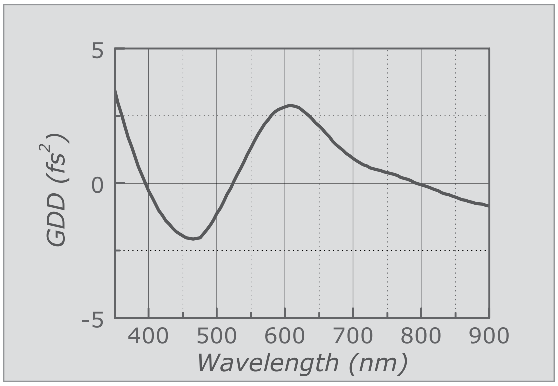
- Reflectance range extended towards shorter wavelengths

Applications

- Distortion free focusing of pulses with spectra extending to 350 nm
- Beam recollimation after nonlinear frequency conversion



Typical reflectance vs. wavelength of protected aluminum focusing mirrors calculated for an angle of incidence of 0°.



Typical GDD vs. wavelength of protected aluminum focusing mirrors calculated for an angle of incidence of 0°.

Order code	OA154
Surface S1	L/10 at 633 nm 10-5 scratch-dig ROC = -32 mm
Surface S2	inspection polishing
Coating on S1	protected aluminium R > 90 % and -3 fs^2 < GDD < 3 fs^2 in the wavelength range 350 nm - 450 nm R > 86 % and -3 fs^2 < GDD < 3 fs^2 in the wavelength range 600 nm - 1200 nm
Coating on S2	none
Substrate material	fused silica or BK7
Diameter	0.5 ''
Thickness	5 mm
Wedge angle	not applicable

Off axis metallic parabolic mirrors

Off axis metallic parabolic mirrors are non dispersive components enabling high numerical aperture, astigmatism free focusing. A focal spot diameter of less than 4 µm can be achieved if the full optical aperture of the mirrors is used. Two types of coatings are available, the choice depending on the wavelength range of interest.

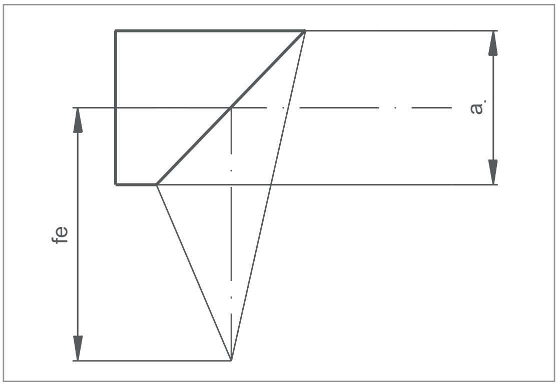
Special features

- Large numerical aperture
- Dispersion free, broadband focusing

Applications

- Distortion free focusing of few cycle pulses
- THz generation

Off-axis parabolic mirror.



Off-axis parabolic mirror (fe = reflected effective focal length, a = diameter).

Order code	OA027	OA175
Type	off-axis parabolic focusing mirror	
Angle of reflectance	90°	
Focal length	50 mm (reflected effective focal length)	
Diameter	1 ''	
Coating	protected Aluminum (Al)	protected Gold (Au)

fs-optimized off axis parabolic mirrors

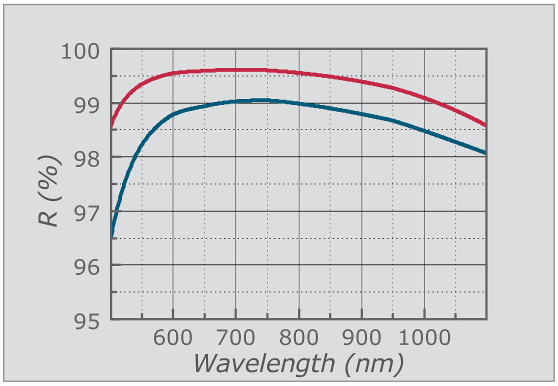
These components combine the advantages of off-axis parabolic mirrors (large numerical aperture, minimum astigmatism) with the features of femtosecond-optimized ultra broadband dielectrically enhanced Ag coatings type I. OA028 off-axis parabolic mirrors exhibit a reflectance closely approaching that of dielectric mirrors and low GDD over bandwidths spanning approximately one optical octave. They enable dispersion-free focusing of pulses with durations down to 4 fs.

Special features

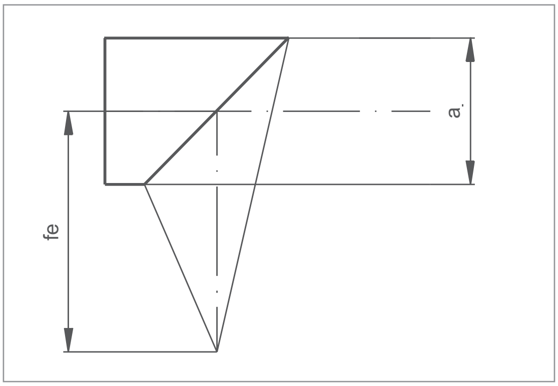
- High reflectance and low GDD over the full fluorescence spectrum of Ti:Sapphire
- Large numerical aperture

Applications

- Distortion free focusing of few cycle pulses
- THz generation



Typical reflectance vs. wavelength of OA028 off-axis parabolic mirrors (red: s-polarized, blue: p-polarized).



Off-axis parabolic mirror (fe = reflected effective focal length, a = diameter).

Order code	OA028
Type	off-axis parabolic focusing mirror
Angle of reflectance	90°
Focal length	50 mm (reflected effective focal length)
Diameter	1 ''
Coating	dielectrically enhanced Ag coating type I -5 fs² < GDD < 5 fs² in the wavelength range 550 nm - 1050 nm R > 98.5 % in the wavelength range 580 nm - 1000 nm AOI = 45° | p-polarized R > 99 % in the wavelength range 540 nm - 1000 nm AOI = 45° | s-polarized

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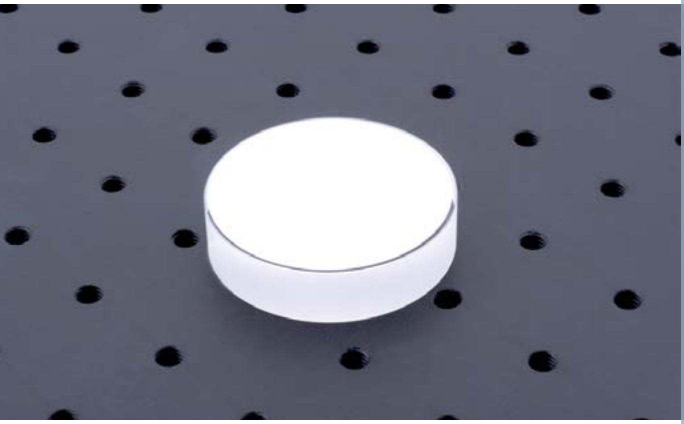


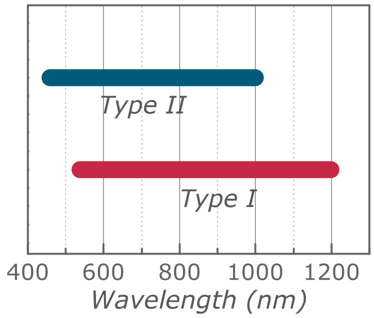
Enhanced Ag mirrors

Applications

Distortion-free manipulation of few cycle pulses

Special features

High reflectance and low GDD over ~ one optical octave



Wavelength ranges covered by the dielectrically enhanced silver mirrors type 1 (red) and type 2 (blue) at normal incidence.

Enhanced silver mirrors are used whenever the bandwidth of low dispersion dielectric coatings becomes insufficient. Owing to a special reflectance enhancing dielectric multilayer overcoating, silver FEMTOOPTICS™ mirrors exhibit reflectance closely approaching that of dielectric mirrors and low GDD over bandwidths spanning approximately one optical octave.

Mirrors of type I are optimized for the fluorescence range of Ti:Sapphire while mirrors of type II are matched to typical hollow fiber continua.

Dielectrically enhanced Ag mirrors Type I

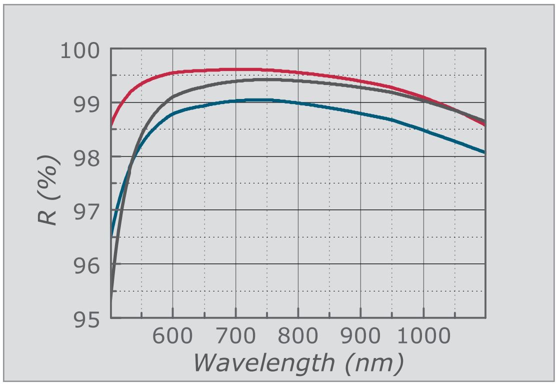
Enhanced silver mirrors are used whenever the bandwidth of low dispersion dielectric coatings becomes insufficient. Owing to a special reflectance enhancing dielectric multilayer overcoating, silver FEMTOOPTICS™ mirrors exhibit reflectance closely approaching that of dielectric mirrors and low GDD over bandwidths spanning approximately one optical octave. Mirrors type I are optimized for the fluorescence range of Ti:Sapphire.

Special features

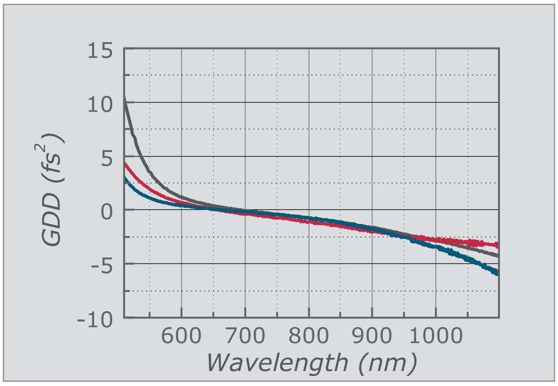
- High reflectance and low GDD over the full fluorescence spectrum of Ti:Sapphire

Applications

- Distortion free manipulation of few cycle pulses



Typical reflectance vs. wavelength of enhanced silver mirrors type I calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).



Typical GDD vs. wavelength of enhanced silver mirrors type I calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).

Order code	OA121	OA022	OA247	OA248	OA249
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat				L/10 at 633 nm | 20-10 scratch-dig | flat
Surface S2	inspection polishing		fine grinded		
Coating on S1	-5 fs² < GDD < 5 fs² in the wavelength range 550 nm - 1050 nm AOI = 0° to 45° R > 99 % in the wavelength range 600 nm - 1000 nm AOI = 0° R > 98.5 % in the wavelength range 580 nm - 1000 nm AOI = 45° | p-polarized R > 99 % in the wavelength range 540 nm - 1000 nm AOI = 45° | s-polarized				
Coating on S2	none				
Substrate material	fused silica or BK7				
Diameter	0.5 "	1 "	30 mm	2 "	3 "
Thickness	6.35 mm	6.35 mm	10 mm	10 mm	20 mm
Wedge angle	< 5 '				

Dielectrically enhanced Ag mirrors Type II

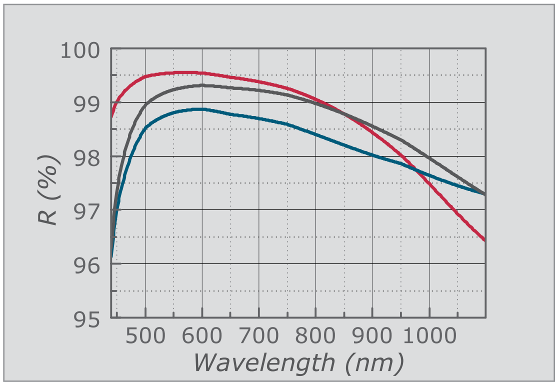
Enhanced silver mirrors are used whenever the bandwidth of low dispersion dielectric coatings becomes insufficient. Owing to a special reflectance enhancing dielectric multilayer overcoating, silver FEMTOOPTICS™ mirrors exhibit reflectance closely approaching that of dielectric mirrors and low GDD over bandwidths spanning approximately one optical octave. Mirrors type II are matched to the spectra of typical hollow fiber compressors and to the spectra of certain parametric sources.

Special features

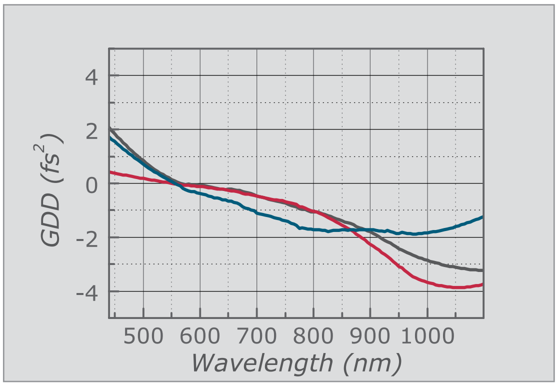
- High reflectance and low GDD over ~ one optical octave

Applications

- Distortion free manipulation of few cycle pulses



Typical reflectance vs. wavelength of enhanced silver mirrors type II calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).



Typical GDD vs. wavelength of enhanced silver mirrors type II calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).

Order code	OA095	OA093	OA090	OA602
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat			L/10 at 633 nm | 20-10 scratch-dig | flat
Surface S2	fine grinded			
Coating on S1	-5 fs² < GDD < 5 fs² in the wavelength range 450 nm - 1100 nm AOI = 0° to 45° R > 97 % in the wavelength range 470 nm - 1000 nm AOI = 0° R > 96 % in the wavelength range 480 nm - 1100 nm AOI = 45° | p-polarized R > 98 % in the wavelength range 460 nm - 890 nm AOI = 45° | s-polarized R > 96 % in the wavelength range 430 nm - 1000 nm AOI = 45° | s-polarized			
Coating on S2	none			
Substrate material	fused silica or BK7			
Diameter	0.5 "	1 "	2 "	3 "
Thickness	6.35 mm	6.35 mm	10 mm	20 mm
Wedge angle	< 5 '			

Dielectrically enhanced Ag prism mirrors

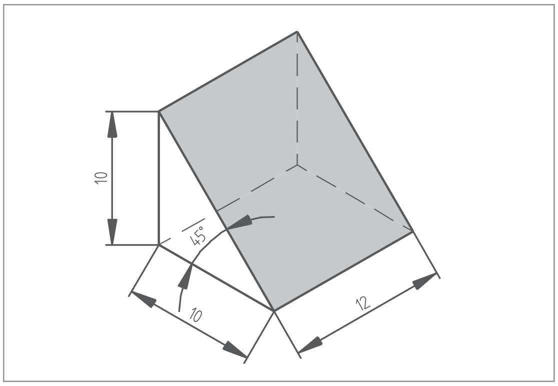
Enhanced silver mirrors are used whenever the bandwidth of low dispersion dielectric coatings becomes insufficient. Owing to a special reflectance enhancing dielectric multilayer overcoating, silver FEMTOOPTICS™ mirrors exhibit reflectance closely approaching that of dielectric mirrors and low GDD over bandwidths spanning approximately one optical octave. The reflective coating is deposited on the hypotenuse of right angle prisms, in order to enable robust beam steering in most compact setups. These components are not suitable to be used as total internal reflection prisms.

Special features

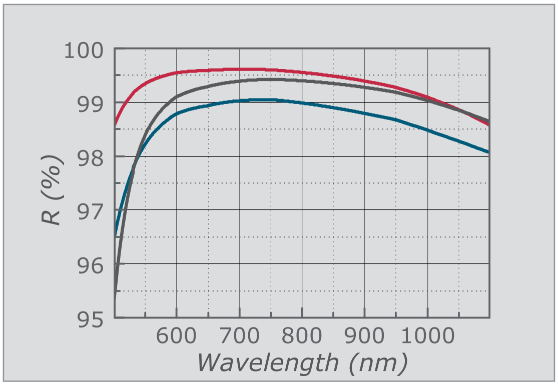
- High reflectance and low GDD over ~ one optical octave
- Substrate shape that enables compact beam steering

Applications

- Beam steering in compact setups
- Input/output coupling in mirror telescopes



Dielectrically enhanced Ag prism mirror - conceptual drawing.



Typical reflectance vs. wavelength of enhanced silver prism mirrors type I calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).

Order code	FO009
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat
Other surfaces	inspection polishing | flat | uncoated
Coating on S1	-5 fs² < GDD < 5 fs² in the wavelength range 550 nm - 1050 nm AOI = 0° to 45° R > 99 % in the wavelength range 600 nm - 1000 nm AOI = 0° R > 98.5 % in the wavelength range 580 nm - 1000 nm AOI = 45° | p-polarized R > 99 % in the wavelength range 540 nm - 1000 nm AOI = 45° | s-polarized
Substrate material	BK7
Dimensions	12 mm x 10 mm x 10 mm

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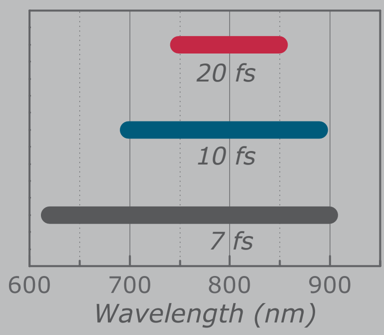


Optics for dispersion management

Applications

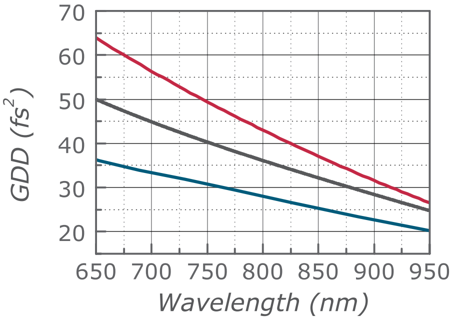
Dispersion pre-compensation in femtosecond laser systems

Special features

High throughput

Compact compressor

Accurate control of higher order dispersion



GDD vs. wavelength per 1 mm for frequently used optical glasses (red: BK7, black: fused silica, blue: calcium fluoride).

Dispersion management becomes straight forward by employing FEMTOLASERS' proprietary dispersive mirror technology. Matched mirror sets supporting pulse durations down to less than 7 fs are available from stock.

Custom mirror compressors can be tailored to compensate the dispersion of a given optical setup, up to several thousand fs^2 Group Delay Dispersion (GDD). Compared to alternatives such as prism compressors, these all mirror compressors offer accuracy, compactness, user friendliness, stability, and high throughput.

FEMTOLASERS has a decade long experience in the design, characterization and implementation of dispersive mirror compressors.

Dispersive mirror modules for sub-7 fs pulses | 800 nm

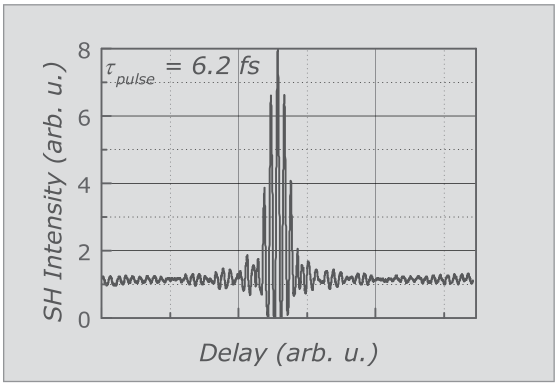
Prism compressors are not suitable for dispersion pre-compensation of sub-10 fs pulses because of the higher order (mainly third order) dispersion they introduce. Dispersive mirror sets with sufficient bandwidth and controlled third order dispersion make dispersion compensation straight forward even at pulse durations below 7 fs. For optimum fine tuning of the GDD a pair of thin fused silica wedges (OA124, not included) should be used in conjunction with the mirror compressor.

Special features

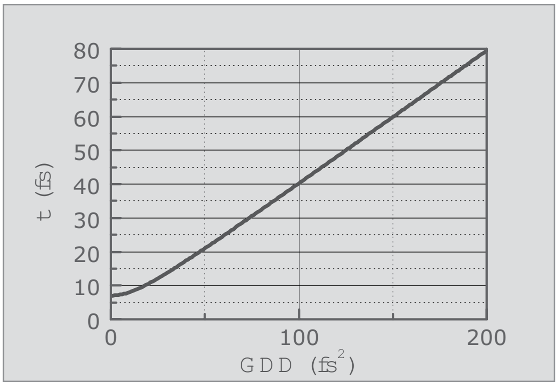
- High throughput, compact compressor
- Accurate control of higher order dispersion
- Customized mirror sets can be supplied upon request

Applications

- Dispersion pre-compensation for sub-7 fs pulses



Typical second order interferometric autocorrelation trace obtained at the output of a dispersive mirror compressor for sub-7 fs pulses.



Output pulse duration as a function of the GDD of the optical setup for a 7 fs bandwidth-limited Gaussian input pulse.

Order code	GSM015	GSM014	GSM214
Wavelength range	620 nm - 920 nm		
Average GDD/bounce	- 45 (± 10) fs² at 800 nm		
Reflectance	> 99.5 % per bounce		
Supported pulse duration	< 7 fs *(if spectrum and wavelength range match)*		
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized		
Number of mirrors	2		
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating		
Surface S2	inspection polishing | flat | uncoated		
Substrate material	fused silica		
Free aperture	> 85 % of the diameter		
Diameter	0.5 ''	1 ''	2 ''
Thickness	6.35 mm	6.35 mm	9 mm or 12.6 mm
Wedge angle	< 5 '		

Dispersive mirror modules for sub-10 fs pulses | 800 nm

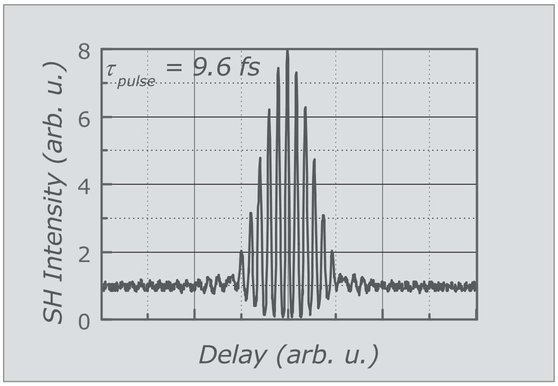
Prism compressors are not suitable for dispersion pre-compensation with sub-10 fs pulses because of the higher order (mainly third order) dispersion they introduce. Dispersive mirror sets with sufficient bandwidth and controlled third order dispersion make dispersion compensation straight forward even at pulse durations below 7 fs. For optimum fine tuning of the GDD a pair of thin fused silica wedges (OA124 or OA924, not included) should be used in conjunction with the mirror compressor.

Special features

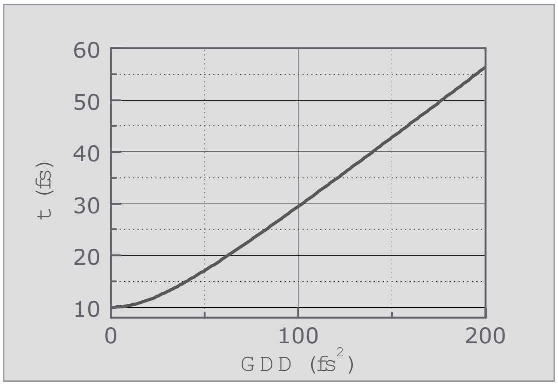
- High throughput, compact compressor
- Accurate control of higher order dispersion
- Customized mirror sets can be supplied upon request

Applications

- Dispersion pre-compensation for sub-10 fs pulses



Typical second order interferometric autocorrelation trace obtained at the output of a dispersive mirror compressor for sub-10 fs pulses and 45°.



Output pulse duration as a function of the GDD of the optical setup for a 10 fs bandwidth-limited Gaussian input pulse.

Order code	GSM008	GSM007	GSM207
Wavelength range	700 nm - 890 nm		
Average GDD/bounce	- 45 (± 10) fs² at 800 nm		
Reflectance	> 99.5 % per bounce		
Supported pulse duration	< 10 fs *(if spectrum and wavelength range match)*		
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized		
Number of mirrors	2		
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating		
Surface S2	inspection polishing | flat | uncoated		
Substrate material	fused silica		
Free aperture	> 85 % of the diameter		
Diameter	0.5 "	1 "	2 "
Thickness	6.35 mm	6.35 mm	9 mm or 12.6 mm
Wedge angle	< 5 '		

Dispersive mirror modules for sub-20 fs pulses | 800 nm

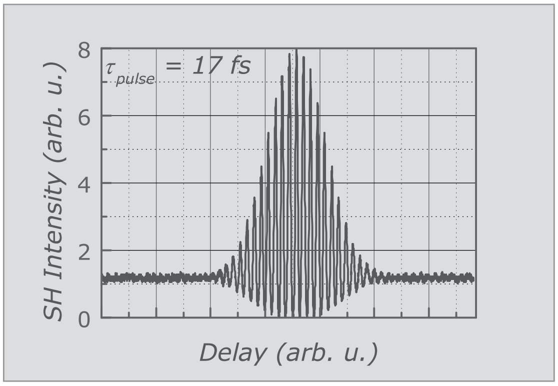
Mirror dispersion compensation modules are compact, user friendly and cost effective alternative to prism pairs in applications that require dispersion pre-compensation for sub-20 fs pulses. Custom, laboratory-tested mirror sets compensating a specified amount of GDD and TOD can also be supplied upon request.

Special features

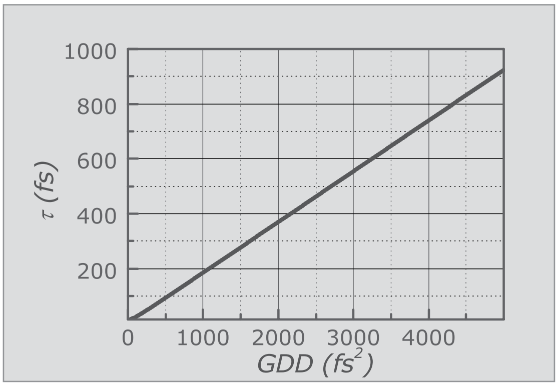
- High throughput, compact compressor
- Accurate control of higher order dispersion

Applications

- Dispersion pre-compensation for sub-20 fs pulses



Typical second order interferometric autocorrelation trace obtained at the output of a dispersive mirror compressor for sub-20 fs pulses.



Output pulse duration as a function of the GDD of the optical setup for a 20 fs bandwidth-limited Gaussian input pulse.

Order code	GSM004	GSM003	GSM208
Wavelength range	750 nm - 850 nm		
Average GDD/bounce	- 45 (± 10) fs² at 800 nm		
Reflectance	> 99.5 % per bounce		
Supported pulse duration	< 20 fs *(if the spectrum matches the wavelength range)*		
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized		
Number of mirrors	2		
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating		
Surface S2	inspection polishing | flat | uncoated		
Substrate material	fused silica		
Free aperture	> 85 % of the diameter		
Diameter	0.5 "	1 "	2 "
Thickness	6.35 mm	6.35 mm	9 mm or 12.6 mm
Wedge angle	< 5 '		

High dispersion mirror modules for sub-15 fs pulses | 800 nm

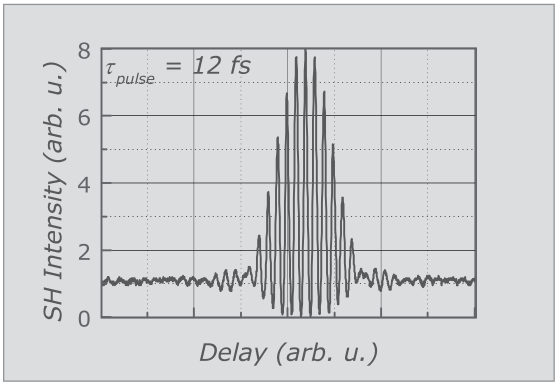
Mirror pairs capable to compensate several hundreds of fs^2 enable the distortion free delivery of sub-15 fs pulses via complex optical systems like e.g. achromatic lenses. Fine tuning of the dispersion can be achieved by using these mirrors in conjunction with a pair of AR-coated wedges (OA324, OA325).

Special features

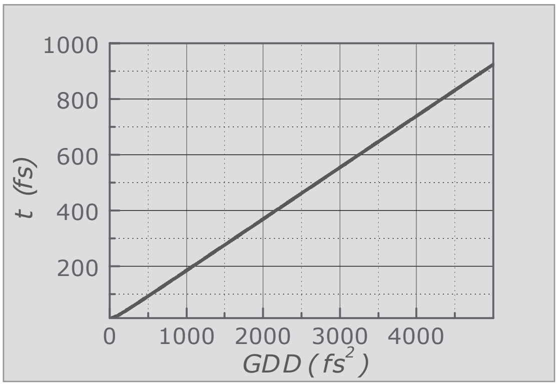
- High throughput, compact compressor
- Accurate control of higher order dispersion

Applications

- Dispersion pre-compensation in complex optical systems



Typical second order interferometric autocorrelation trace obtained at the output of a high-GDD mirror compressor for sub-15 fs pulses. A total GDD of 640 fs^2 was compensated in this example.



Output pulse duration as a function of the GDD of the optical setup for a 15 fs bandwidth-limited Gaussian input pulse.

Order code	GSM216	GSM217
Wavelength range	720 nm - 880 nm	
Average GDD/bounce	< -250 (± 20) fs^2 at 800 nm	
Reflectance	> 99 % per bounce	
Supported pulse duration	< 15 fs *(if the spectrum matches the wavelength range)*	
Angle of incidence	7° (± 3°) p-polarized	
Number of mirrors	2	
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating	
Surface S2	inspection polishing | flat | uncoated	
Substrate material	fused silica	
Free aperture	> 85 % of the diameter	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	
Wedge angle	< 5 '	

Dispersive mirror modules for sub-10 fs pulses | 800 nm | 45°

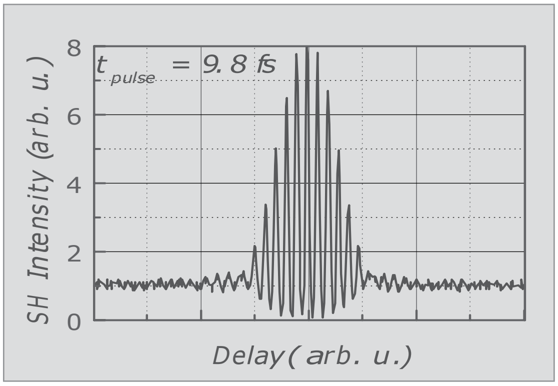
These mirrors simultaneously provide low loss beam steering and dispersion pre-compensation over a bandwidth sufficiently large to support sub-10 fs pulses. Their use is limited to p-polarized light - the polarization state supplied by most lasers.

Special features

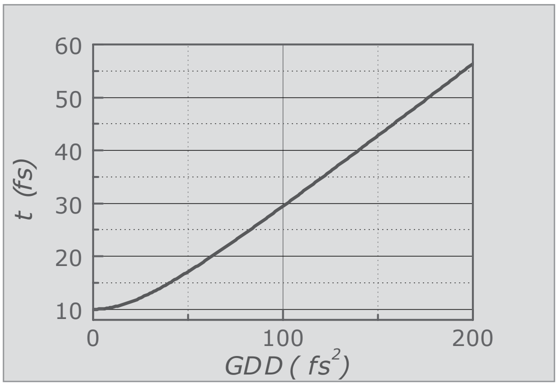
- Low loss, enhanced bandwidth folding mirrors

Applications

- beam steering and dispersion pre-compensation for sub-10 fs pulses



Typical second order interferometric autocorrelation trace obtained at the output of a dispersive mirror compressor for sub-10 fs pulses and 45°.



Output pulse duration as a function of the GDD of the optical setup for a 10 fs bandwidth-limited Gaussian input pulse.

Order code	GSM021	GSM022	GSM023
Wavelength range	670 nm - 1070 nm		
Average GDD/bounce	- 60 (± 15) fs² at 800 nm		
Reflectance	> 99.5 % per bounce		
Supported pulse duration	< 10 fs *(if the spectrum matches the wavelength range)*		
Angle of incidence	45 (± 3) ° | p-polarized		
Number of mirrors	2		
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating		
Surface S1	inspection polishing | flat | uncoated		
Substrate material	fused silica		
Free aperture	> 85 % of the diameter		
Diameter	0.5 "	1 "	2 "
Thickness	6.35 mm	6.35 mm	12.7 mm
Wedge angle	< 5 '		

Dispersive mirror set for hollow fiber compression

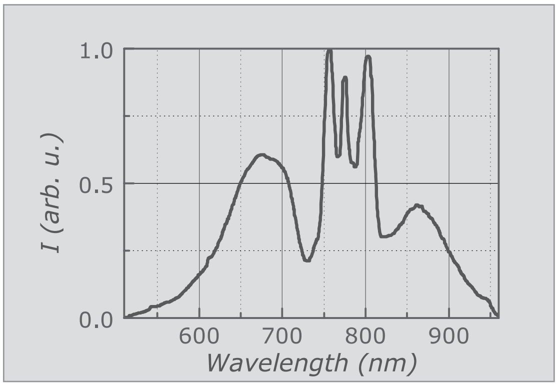
This broadband dispersive mirror set can be used for recompressing pulses spectrally broadened in a nonlinear medium (e.g. gas filled hollow fiber) and/or for pre-compensating a dispersive setup. The sets are tested in our labs and supplied with a measured autocorrelation. Sets for different spectral ranges (centered at wavelengths between 650 nm and 800 nm) are available. We can customize the compressors based on the spectrum and a description of the dispersive optical path.

Special features

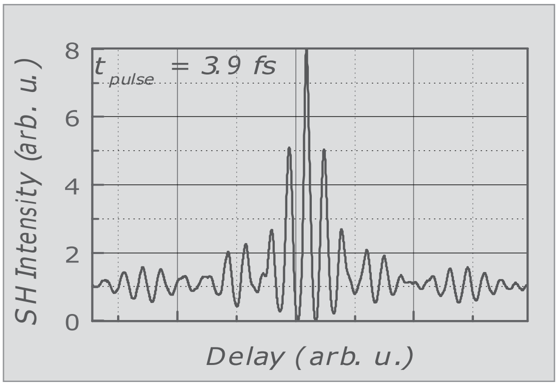
- High throughput, compact compressor
- Accurate control of higher order dispersion

Applications

- Hollow fiber compression
- Dispersion pre-compensation for sub-7 fs pulses



Hollow fiber compressor spectrum spectrum supported by the dispersive mirror compressors GSM010 and GSM020.



Second order interferometric autocorrelation obtained by compressing the continuum generated in a Ne-filled hollow fiber by means of the mirror compressor GSM010.

Order code	GSM010	GSM020
Wavelength range	620 nm - 920 nm	
Total GDD	< -300 (± 20) fs² at 800 nm	
Throughput	> 92 %	
Supported pulse duration	< 7 fs *(measured autocorrelation included)*	
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized	
Number of mirrors	6	
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating	
Surface S2	inspection polishing | flat | uncoated	
Substrate material	fused silica	
Free aperture	> 85 % of the diameter	
Diameter	1 ''	2 ''
Thickness	6.35 mm	9 mm - 12.7 mm
Wedge angle	< 5 '	

MOSAIC™ OS
Octave spanning GDD module

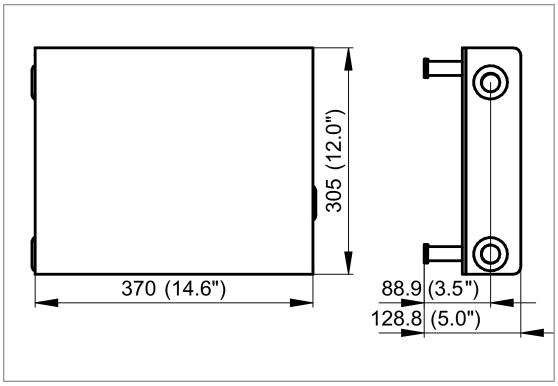
MOSAIC™ OS enables the formation of pulses down to < 4 fs from the output of KALEIDOSCOPE™ compressors. The employed dispersive mirrors exhibit high reflectance over 600 nm between 400 nm and 1000 nm and controlled GDD over more than one optical octave, between 450 nm and 960 nm. The dispersion of the compressor is matched to the typical chirp of pulses generated from hollow fiber compressors seeded with sub-30 fs, mJ-level pulses. The compressor is pre-aligned in a compact, robust housing. MOSAIC™ OS is the octave spanning upgrade to the current dispersive mirror set of your KALEIDOSCOPE™ compressor.

Special features

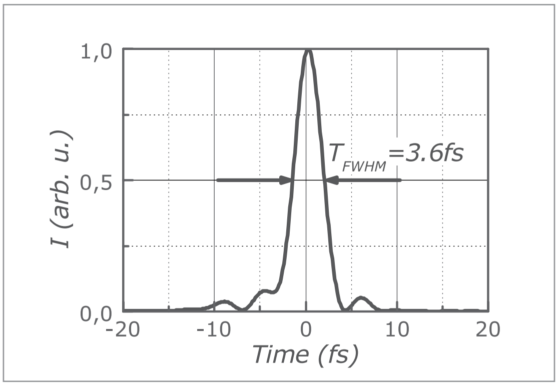
- Octave spanning GDD management
- High throughput
- Compact prealigned housing

Applications

- Hollow fiber compression
- Dispersion pre-compensation



Footprint and dimensions of the MOSAIC™ OS mirror compressor housing.



Temporal intensity of pulses compressed with MOSAIC™ OS retrieved from a FROG measurement. Data C/O Dr. A. Cavalieri, Max-Planck Research Department for Structural Dynamics.

Order code	GSM033
Wavelength range	high reflectance between 400 nm and 1000 nm | Controlled GDD between 450 nm and 960 nm
Compensated dispersion	GDD and TOD correspond to the typical hollow fiber compressor chirp and ≈ 3 mm Fused Silica and 2 m of air
Number of mirrors	11
Polarization	P
Housing	black anodized housing consisting of base plate, cover, mirror mounts
Footprint	30 cm x 30 cm
Input and output beam	Lateral shift between input and output beam: 23 cm | the output beam is counter-propagating with respect to the input beam
Mechanical setup	The compressor is supplied in a prealigned housing

Ultra thin wedges for dispersion fine tuning

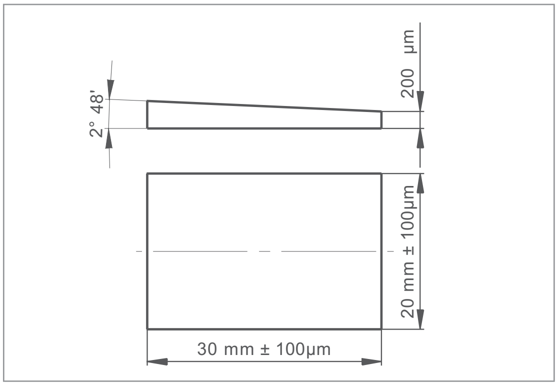
Pairs of ultra thin wedges allow fine, continuous tuning of the GDD. The extremely accurate GDD control enabled by thin glass wedges in conjunction with broadband dispersive mirrors is indispensable for the generation/manipulation of sub-10 fs pulses. Furthermore, thin glass wedges can be used for rough tuning of the Carrier Envelope Phase. Insertion losses can be minimized by using the wedges under Brewster angle. Two pieces are required in order to compensate the angular dispersion.

Special features

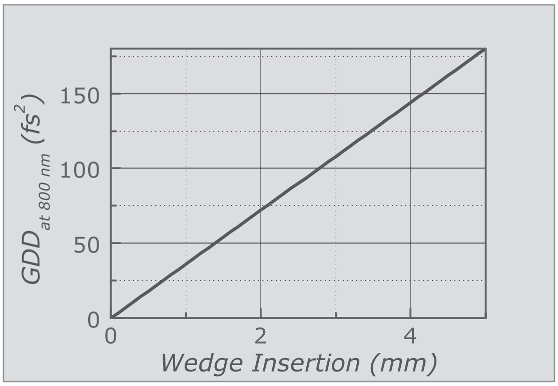
- Ultra thin, small wedge angle

Applications

- Dispersion fine tuning
- CEP control



Ultra thin wedge - conceptual drawing.



GDD vs. material insertion for the ultra thin wedges OA124, OA924.

Order code	OA124	OA924
Surface S1	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Surface S2	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Coating on S1	none	
Coating on S2	none	
Substrate material	fused silica	
Dimensions	30 mm x 20 mm | minimum/maximum thickness 200 µm / 1.65 mm	
Wedge angle	2° 48 '	
Adapter	none	black anodized Al | glued to the wedge | fits into any standard 0.5 '' mirror holder

Large aperture wedges for dispersion fine tuning

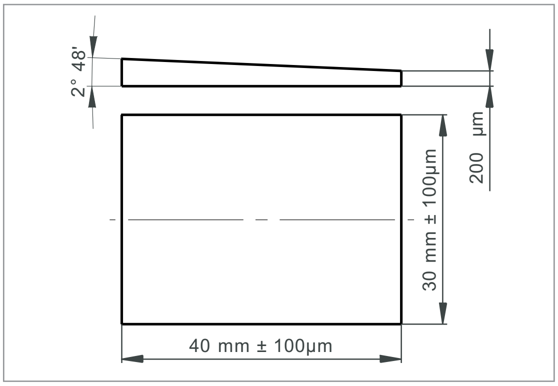
Pairs of large aperture, ultra-thin wedges allow fine, continuous tuning of the GDD. The extremely accurate GDD control enabled by thin glass wedges in conjunction with broad-band dispersive mirrors is indispensable for the generation/manipulation of sub-10 fs pulses. Furthermore, thin glass wedges can be used for rough tuning of the Carrier-Envelope Phase. Insertion losses can be minimized by using the wedges under Brewster angle. Two pieces are required in order to compensate the angular dispersion.

Special features

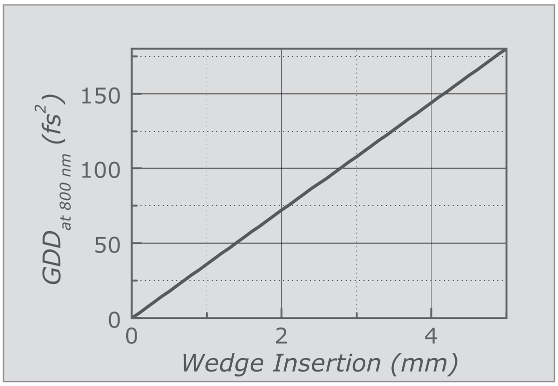
- Ultra thin, small wedge angle
- Large optical aperture

Applications

- Dispersion fine tuning
- CEP control



Large aperture, ultra thin wedge - conceptual drawing



GDD vs. material insertion for the ultra thin wedges OA125, OA925.

Order code	OA125	OA925
Surface S1	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Surface S2	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Coating on S1	none	
Coating on S2	none	
Substrate material	fused silica	
Dimensions	30 mm x 40 mm | minimum thickness 200 µm	
Wedge angle	2° 48 '	
Adapter	none	black anodized Al | glued to the wedge | fits into any standard 1 '' mirror holder

AR coated wedges for dispersion fine tuning

Owing to the relatively small angle and large length of these wedges the dispersion can be finely tuned over a wide dynamic range. A broadband AR coating minimizes the insertion losses at near normal incidence.

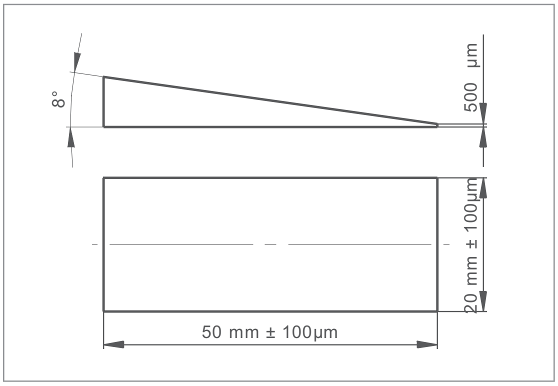
Due to the large GDD tuning range these wedges are particularly useful in conjunction with high dispersion mirrors or MOSAIC™ modules. Two pieces are required in order to compensate the angular dispersion.

Special features

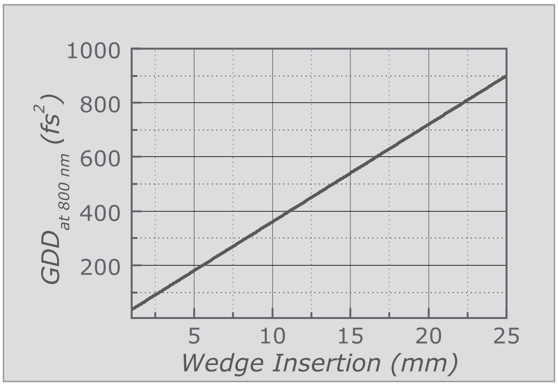
- Broadband AR coating
- Large GDD tuning range

Applications

- Dispersion fine tuning over a wide dynamic range



Ultra thin AR coated wedge - conceptual drawing.



GDD vs. material insertion for the AR-coated wedges OA324, OA325.

Order code	OA324	OA325
Surface S1	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Surface S2	L/6 at 633 nm in transmittance | 10-5 scratch-dig | flat	
Coating on S1	R < 0.5 % in the range 650 nm - 1040 nm | AOI = 0° - 8°	
Coating on S2	R < 0.5 % in the range 650 nm - 1040 nm | AOI = 0° - 8°	
Substrate material	BK7	
Dimensions	50 mm x 20 mm | minimum thickness 500 µm	
Wedge angle	8°	
Adapter	none	black anodized Al | glued to the wedge | fits into any standard 1 '' mirror holder

Housing for mirror compressors

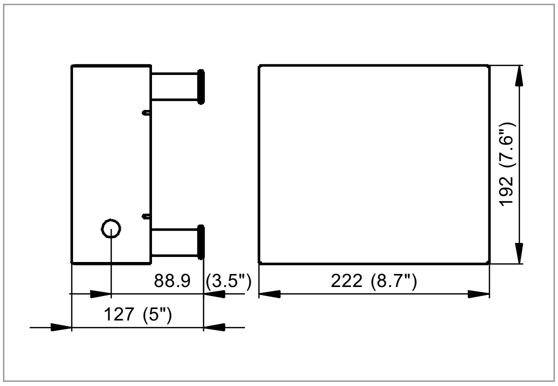
In this robust mirror compressor housing the distance between mirrors was minimized while using ideal angles of incidence. Apart from resulting in a compact setup, this approach reduces the beam path within the mirror compressor and therewith the amount of positive dispersion introduced by air. If ordered in conjunction with GSM010 or a Femtolasers custom 1'' mirror compressor the mirrors will be mounted in the housing and factory-pre-aligned.

Special features

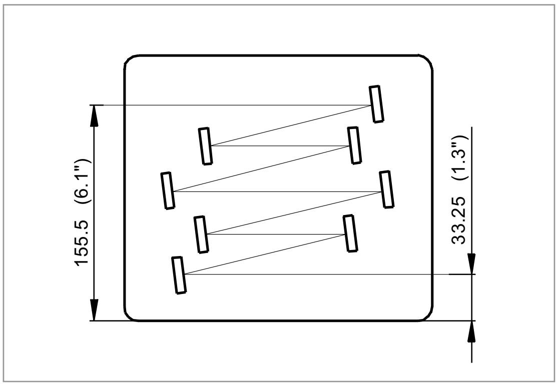
- Compact, robust housing
- Minimized beam path length in air

Applications

- Dispersion pre-compensation



Footprint and dimensions of the mirror compressor housing (applies both to OM201 and OM202; pedestals are not included with the product).



Principle drawing depicting the mirror configuration and beam path inside the mirror compressor housing OM201.

Order code	OM201	OM202
Footprint	19 cm x 22 cm	
Minimum beam height	2 '' | pedestals not included	
Number of mirror mounts	8	6
Suitable mirror size	diameter 1 '' | thickness 6.35 mm	
Parallel beam displacement	12 cm	9.2 cm
Description	black anodized Al housing | equipped with entrance and exit iris apertures	
Mirror mounts	4 pcs. fixed | 4 pcs. adjustable	3 pcs. fixed | 3 pcs. adjustable
Angle of incidence	7° (applies to all mirrors)	
Installation	not included	

Application notes

The group velocity of light is frequency-dependent in any propagation medium except vacuum. Consequently, various spectral components of a short laser pulse experience different delays when linearly propagating in optical media, resulting in pulse broadening (Fig. 1). Since this effect is linear, pulses can be recompressed to the minimum pulse duration supported by their spectral width (the so-called bandwidth-limited duration) by means of specially designed delay lines.

The dispersive properties of optical media are quantified by means of the group delay dispersion (GDD, the second derivative of the spectral phase with respect to the angular frequency) and higher (e.g. third order) dispersion terms. With decreasing pulse duration dispersion terms of higher order need to be compensated with increasing accuracy.

Components introducing angular dispersion, like gratings or prisms were traditionally used to compensate for dispersion effects and recompress the pulses temporally. In this concept the first element is used to angularly disperse the beam, the different spectral components being now spatially resolved can experience different geometrical paths and thus different delays. A second identical element is employed to compensate for the angular dispersion. An identical sequence (or reflecting the beam back on the same path) must be used in order to remove the spatial variation of laser frequency (spatial chirp). Lack of accuracy in the control of higher order dispersion terms limits the use of these compressors mainly to pulses longer than 20 fs. Furthermore, grating- and prism-compressors are large and alignment-sensitive - a major drawback particularly for commercial laser systems.

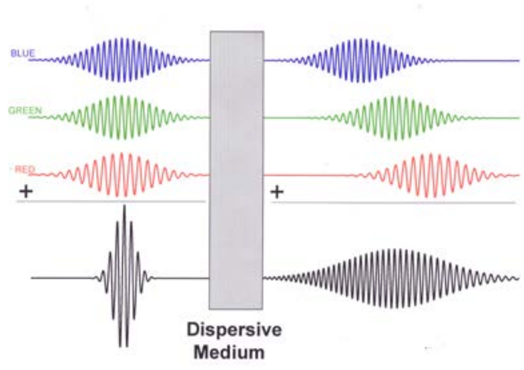


Fig. 1: A short laser pulse is modeled as a linear superposition of quasi-monochromatic wavepackets that experience different delays upon linear propagation through a medium that exhibits group delay dispersion, leading to pulse broadening.

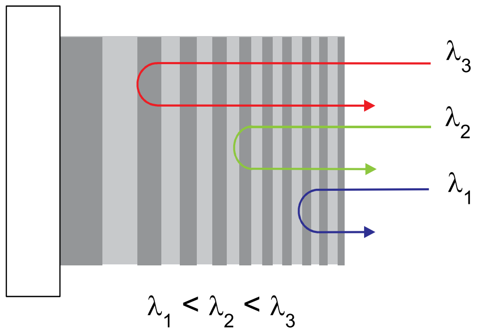


Fig. 2: The group delay dispersion introduced upon reflection by dispersive multilayer mirrors is controlled by means of the penetration depth of the different wave packets.

Application notes

In contrast to grating- and prism-based compressors Dispersive Mirrors (DMs termed „chirped mirrors") [1] allow independent engineering of GDD, TOD and even fourth order dispersion (FOD) over bandwidths approaching one optical octave. With a compressor merely consisting of one mirror pair, compactness and user-friendliness are obviously dramatically improved. DMs rely on the finding that the GDD introduced by dielectric multilayer reflectors can be controlled by means of wavelength-dependence of the penetration depth of the electric field (Fig. 2). A mirror will introduce negative GDD (as required by most applications) if short-wavelength components are substantially reflected already by the top layers whereas long-wavelength wave packets penetrate deeper into the multilayer structure before being reflected, experiencing thus a longer delay. Design algorithms and manufacturing methods have been dramatically improved over the past 10 years [2,3] resulting in bandwidth in excess of 170 THz at 800 nm and accurate higher order dispersion control. The process of designing a dispersive mirror compressor consists of the following steps:

- **Measurement** of the spectrum of the pulses to be manipulated.
- **Identification and characterization** of the transmissive optical parts of a setup; ideally the thickness and type of glass should be known for each component. This information is provided with each FEMTO-OPTICS™ component but may not be available for components supplied by other manufacturers. FEMTOLASERS experts offer assisance evaluating the dispersion of your optical setup.
- **Choosing a mirror compressor** corresponding to the bandwidth limited duration of your pulses and to the total GDD that has to be compensated. FEMTOLASERS™ offers pre-tested mirror sets for sub-20, sub-15, sub-10 and sub-7 fs pulses with different substrate sizes.
- **Setting up the mirror compressor** and characterization of the pulses at the target, e.g. by means of a Femtometer autocorrelator.
- **Fine tuning** of the GDD by means of glass wedges is mostly required for pulses in the sub-15 fs range.

FEMTOLASERS™ designs and tests custom compressors, providing a wide range of services, including -upon request- installation and characterization in customer's facility.

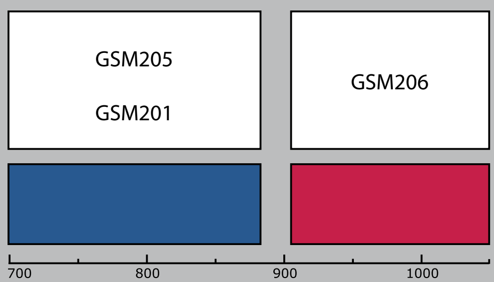
References

[1] R. Szipöcs, K. Ferencz, C. Spielmann, F. Krausz, „Chirped multilayer coatings for broadband dispersion control in femtosecond lasers," Opt. Lett. 19, 201-203 (1994)

[2] V. Yakovlev and G. Tempea, „Chirped Mirror Optimization", Appl. Opt. 41, 6514 (2002)

[3] G. Tempea, V. Yakovlev, F. Krausz, „Interference Coatings for Ultrafast Optics", in „Optical Interference Coatings", N. Kaiser and H. Pulker, editors, Springer Series in Optical Sciences, Springer Berlin Heidelberg (2003)

Optics for nonlinear microscopy



Applications

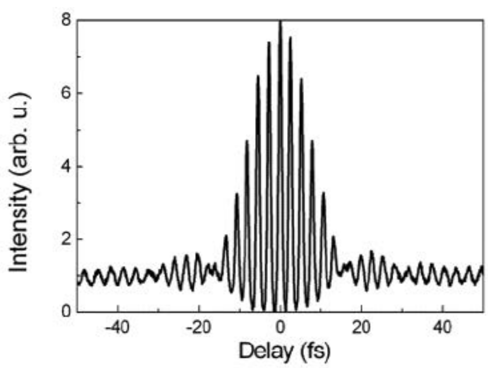
Nonlinear microscopy

Dispersion management

Special features

High -dispersion mirrors

High throughput



Autocorrelation of an 11.7 fs pulse measured directly at the focus of a scanning laser micro-scope equipped with a 40x NA1.2 objective. The dispersion of the setup amounting to 4400 fs² has been compensated with dispersive mirrors.

Latest generations of Dispersive Mirrors (DM) exhibit significantly higher dispersion, resulting in compact and efficient dispersion compensation modules. Only by employing DMs can dispersion properties be tailored for precise compensation of complex optical setups (such as microscopes) without unwanted side effects such as the introduction of high order dispersion. This is a prerequisite for the undistorted delivery of pulses having a duration of only a few tens of femtoseconds.

High dispersion mirror compressor for sub-8 fs pulses

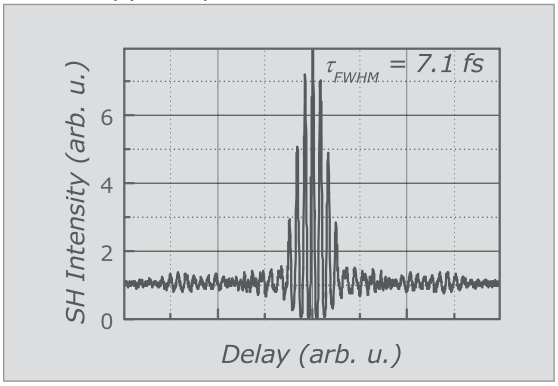
Recently developed, novel dispersive mirrors with low losses and small GDD fluctuations allow for increasing the number of total bounces thus enabling significant increases in the total compensated GDD. GDD values well beyond 1000 fs^2 now can be compensated over a bandwidth in excess of 300 nm enabling for the first time the undistorted delivery of sub-8 fs pulses at the focus of selected microscope objectives. Upon request, the compressor can be customized to match exactly the dispersion of your microscopy setup.

Special features

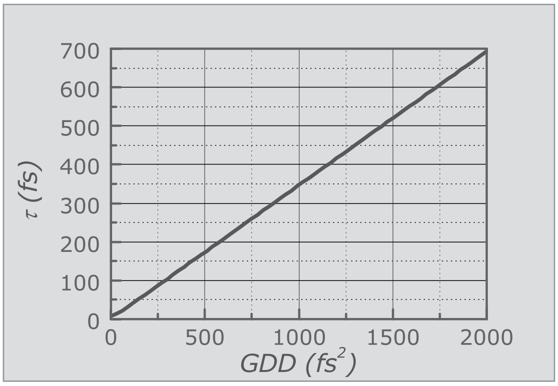
- Accurate, broadband GDD compensation beyond 1000 fs^2
- High throughput

Applications

- Focusing of sub-8-fs pulses with high-NA objectives



Second order interferometric autocorrelation trace measured at the focus of a 40x NA 0.8 microscope objective. The lens GDD (1440 fs^2) was compensated with GSM209. Data C/O Dr. A. Volkmer, University of Stuttgart.



Output pulse duration as a function of the GDD of the optical setup for a 8 fs bandwidth limited Gaussian input pulse. By compensating the GDD of a moderately dispersive objective (~ 1500 fs^2) of > 60 can be gained in peak intensity.

Order code	GSM209
Wavelength range	630 nm - 970 nm
Average GDD/bounce	- 45 (± 10) fs^2 at 800 nm
Total GDD	up to 1500 fs^2 at 800 nm
Reflectance	> 99.3 % per bounce
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized
Number of mirrors	2
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating
Surface S2	inspection polishing | flat | uncoated
Substrate material	fused silica
Substrate dimensions	20 mm x 80 mm (rectangular)
Free aperture	17mm x 76mm
Thickness	12.7 mm
Wedge angle	< 5 '

High dispersion mirror pairs for sub-15 fs pulses

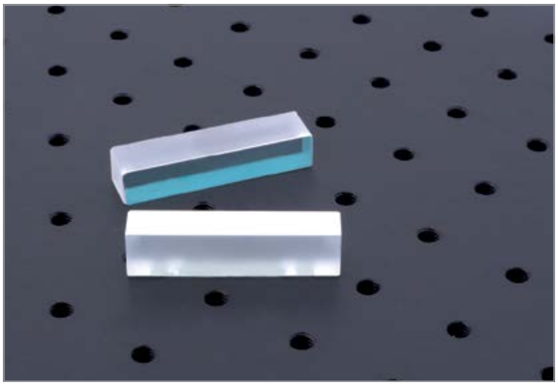
These mirror compressors are sufficiently dispersive to allow compensating the GDD of microscope objectives and microscopes for pulse durations down to less than 15 fs centered at 800 nm. Owing to the rectangular substrate shape compact multiple bounce setups can be easily realized. We develop custom mirror compressors matched to compensate your microscopy setup. Opto-mechanical parts are not included. Holder adapters for the rectangular substrates can be supplied upon request (see page 95).

Special features

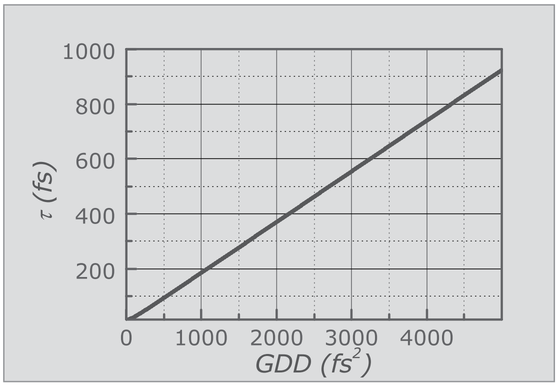
- High GDD
- Low losses
- Convenient substrate shape

Applications

- Nonlinear microscopy
- Dispersion management



High dispersion mirror pair for sub-15 fs pulses.



Output pulse duration as a function of the GDD of the optical setup for a 15 fs bandwidth limited Gaussian input pulse. By compensating the GDD of a moderately dispersive microscope (~ 5000 fs²) almost 2 orders of magnitude in peak intensity can be gained.

Order code	GSM201
Wavelength range	720 nm - 880 nm
Average GDD/bounce	< -250 (± 20) fs² at 800 nm
Reflectance	> 99 % per bounce
Supported pulse duration	< 15 fs *(if the spectrum matches the wavelength range)*
Angle of incidence	7° (± 3°)
Number of mirrors	2
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating
Surface S2	inspection polishing | flat | uncoated
Substrate material	fused silica
Substrate dimensions	rectangular | 10 mm x 50 mm x 12.6 mm

High dispersion mirror pairs for sub-100 fs pulses

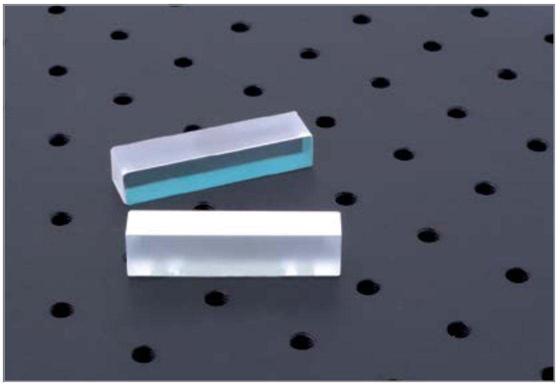
These mirror compressors are sufficiently dispersive to allow compensating the GDD of microscope objectives and microscopes for tunable pulses with durations in the 100 fs range. Owing to the rectangular substrate shape compact multiple bounce setups can be easily realized. Two different types of mirrors covering most of the Ti:Sapphire tuning range are available. Optomechanical parts are not included. Holder adapters for the rectangular substrates can be supplied upon request (see page 95).

Special features

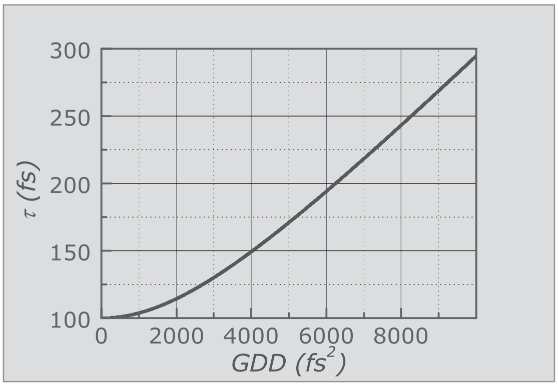
- High GDD
- Low losses
- Convenient substrate shape

Applications

- Nonlinear microscopy
- Dispersion management



High dispersion mirror pair for sub-100 fs pulses.



Output pulse duration as a function of the GDD of the optical setup for a 100 fs bandwidth limited Gaussian input pulse. By compensating the GDD of a typical microscope (~10000 fs²) a factor of 3 in peak intensity can be gained. For a 60 fs pulse the increase is > 8-fold.

Order code	GSM205	GSM206
Wavelength range	700 nm - 870 nm	910 nm - 1040 nm
Average GDD/bounce	< -250 (± 20) fs² at 800 nm	
Reflectance	> 99 % per bounce	
Supported pulse duration	< 100 fs	
Angle of incidence	7° (± 3°)	
Number of mirrors	2	
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating	
Surface S2	inspection polishing | flat | uncoated	
Substrate material	fused silica	
Substrate dimensions	rectangular | 10 mm x 50 mm x 12.6 mm	

Broadband dielectric mirrors for sub-100 fs tunable pulses | 45°

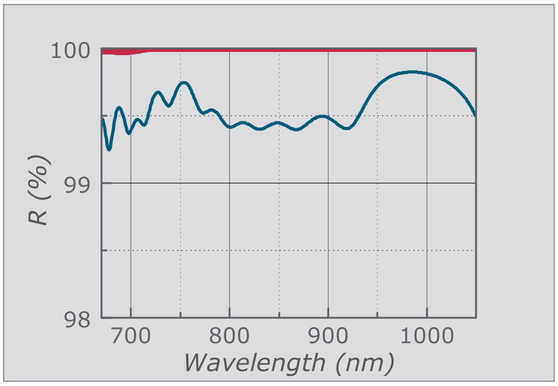
Standard Bragg reflectors have a reflectance range of only ≤ 170 nm @ 800 nm for p-polarized light under an angle of incidence of 45°. Multiple stack dielectric reflectors overcome this limitation at the expense of large phase distortions upon reflection that prevent their use with sub-100 fs pulses. Broadband dispersive mirrors optimized for p-polarized light exhibit a well behaved phase shift upon reflection. The dispersion they introduce is negligible for pulse durations > 50 fs.

Special features

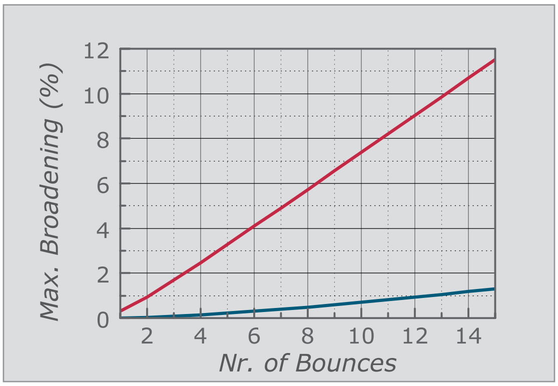
- Low losses
- Bandwidth covering the full tuning range of Ti:Sapphire

Applications

- Nonlinear microscopy with tunable sub-100 fs pulses



Typical reflectance vs. wavelength of broadband dielectric 45° mirrors for tunable pulses for an angle of incidence of 45° (blue: p-polarized light, red: s-polarized light).



Maximum temporal broadening vs. number of bounces for a 100-fs Gaussian pulse centered at wavelengths between 670 nm and 1070 nm reflecting off the broadband dielectric 45° mirrors (blue:p-polarized light, red: s-polarized light).

Order code	OA031	OA033	OA048
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat		
Surface S2	inspection polishing | flat		
Coating on S1	R > 99.5 % in the wavelength range 670 nm - 1070 nm Maximum pulse broadening for 10 bounces: < 2 % for 100 fs pulses < 7 % for 70 fs pulses AOI = 45° (± 5°) | p-polarized		
Coating on S2	none		
Substrate material	fused silica or BK7		
Diameter	0.5 ''	1 ''	2 ''
Thickness	6.35 mm	6.35 mm	12.7 mm
Wedge angle	< 5 '		

Ultra broadband low-GDD dichroic filters

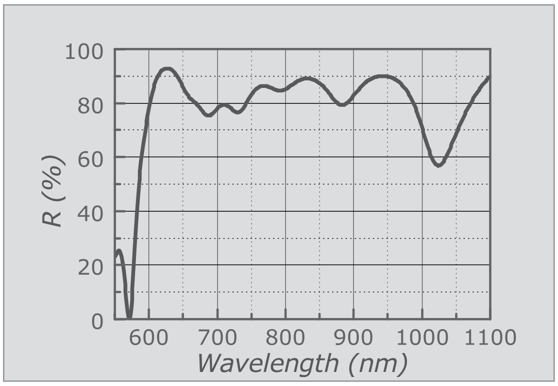
Standard dichroic filters are not suitable for nonlinear microscopy with sub-50-fs pulses since they often introduce large GDD distortions, impairing on the duration of the reflected pulses. FemtoOptics dichroic filters were optimized to preserve the laser pulse shape for pulses with durations down to 7 fs. Owing to their exceptionally large reflectance and transmittance bands they can be used for a wide range of applications in nonlinear imaging and spectroscopy.

Special features

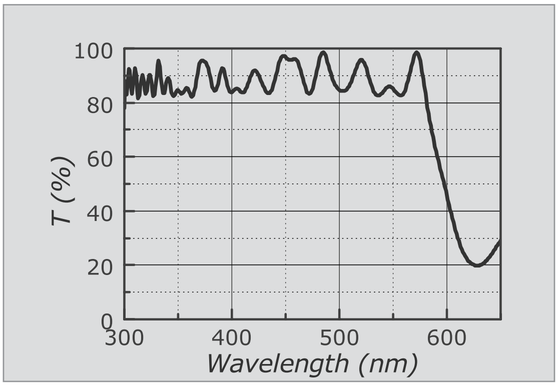
- Ultra broad transmission band
- Ultra broad reflectance band
- Low GDD within the reflectance band

Applications

- Nonlinear microscopy
- Nonlinear spectroscopy



Typical reflectance vs. wavelength of ultra broadband low-GDD dichroic filters for an angle of incidence of 45° and s-polarized light.



Typical transmission vs. wavelength of ultra broadband low-GDD dichroic filters for an angle of incidence of 45° and unpolarized light.

Order code	OA073
Surface S1	L/6 at 633 nm | 10-5 scratch-dig | flat
Surface S2	L/6 at 633 nm | 10-5 scratch-dig | flat
Coating on S1	R > 74 % in the wavelength range 600 nm – 1000 nm | AOI = 45° | s-polarized T > 80% in the wavelength range 320 nm – 580 nm | AOI = 45° | unpolarized - 40 fs^2 < GDD < 20 fs^2 in the wavelength range 600 nm – 1000 nm | AOI = 45° | s-polarized
Coating on S2	R < 1.5 % in the wavelength range 300 – 580 nm | AOI = 45°| unpolarized
Substrate material	fused silica
Substrate dimensions	25.5 mm x 36 mm x 2 mm
Wedge angle	< 30 ''

Application notes

The generation and undistorted delivery of short fs pulses are equally demanding tasks. Lack of compact and user-friendly compressors capable of compensating the dispersion of involved optical systems has prevented the use of sub-20-fs laser pulses in certain biomedical and industrial applications like nonlinear microscopy and THz spectroscopy.

Seeding nonlinear microscopes with sub-20-fs laser pulses results in a dramatic enhancement of the excitation efficiency and improved penetration depth as compared to standard systems that employ 100 to 200-fs pulses [1]. With such pulses high peak powers can be achieved at comparatively lower average power, reducing the thermal loading of the sample. The bandwidth of sub-20-fs pulses (≥ 100 nm FWHM) might allow the simultaneous excitation of several absorption lines and/or combining nonlinear imaging with Optical Coherence Tomography (OCT) [2]. Furthermore, sub-20 fs pulses are an effective tool in the targeted transfection of stem cells [3].

Until recently prism- or grating-pairs were used for dispersion management in microscopy, adding considerable complexity to the systems. Dispersive Mirrors are now capable to compensate group delay dispersion values as large as 200-300 fs^2 per bounce, providing compact, accurate and user friendly chirp compensation [4]. The implementation of mirror compressors in microscopy setups became straight-forward with the availability of the MOSAIC™ modules.

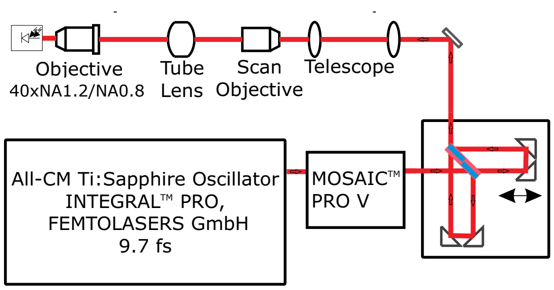


Fig. 1: Schematic representation of a setup employed for measuring the pulse duration at the focus of a dispersion-compensated microscope optics set.

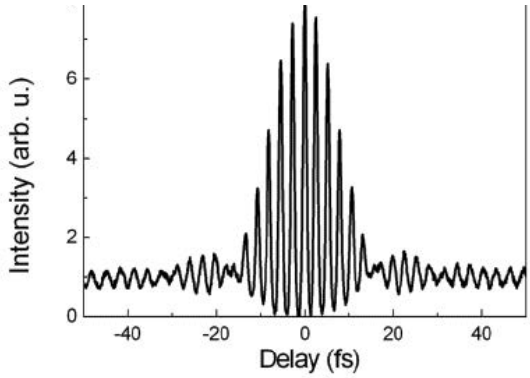


Fig. 2: Interferometric autocorrelation trace recorded with a two-photon diode at the focus of the setup depicted in Fig. 1.

Application notes

A typical setup for sub-15 fs nonlinear microscopy [5] realized in our labs is schematically depicted in Fig.1. Our breadboard-setup contained all the dispersive optics employed in a typical scanning microscope: a telescope (beam expander), a Zeiss IR scan objective, a tube lens and a 40x NA1.2 Zeiss Apochromat objective. The total GDD of the setup amounted to 4470 fs^2. A MOSAIC™ PRO V module set to introduce 4600 fs^2 (and thus slightly overcompensate the GDD of the setup) was inserted directly at the output of the laser. The throughput of the MOSAIC™ module was 89 %. The setup was seeded with 9.7 fs bandwidth-limited pulses generated from an all-chirped-mirror oscillator (INTEGRAL™ PRO, FEMTOLASERS Produktions GmbH).

In the absence of dispersion compensation, the pulse duration would be ≈ 1.3 ps at the focus of the above-described setup. Employing a dispersive mirror compressor and a pair of thin glass wedges for dispersion fine tuning we measured sub-12 fs pulses directly at the focus of the objective (Fig. 2). A dispersion-balanced interferometer (FEMTOMETER™, FEMTOLASERS Produktions GmbH) was inserted into the beam path in front of the microscope setup and the second order interferometric autocorrelation was recorded with a two-photon (GaAsP) diode placed at the focus of the microscope objective.

References

[1] *S. Tang, T. B. Krasieva, Z. Chen, G. Tempea, B. J. Tromberg, „Effect of pulse duration on two-photon excited fluorescence and second harmonic generation in nonlinear optical microscopy", J. Biomed. Opt. 11, 020501 (2006)*

[2] *S. Tang, T. B. Krasieva, Z. Chen, B. J. Tromberg, „Combined multiphoton microscopy and optical coherence tomography using a 12-fs broadband source", J.Biomed.Opt. 11, 020502 (2006)*

[3] *A. Uchugonova, K. König, R. Bueckle, A. Isemann, G. Tempea, „Targeted transfection of stem cells with sub-20 femtosecond laser pulses", Opt. Express 16, 9357 (2008)*

[4] *A. M. Larson and A. T. Yeh, „Ex vivo characterization of sub-10-fs pulses" Opt. Lett. 31, 1681 (2006)*

[5] *G. Tempea, B. Považay, A. Assion, A. Isemann, W. Pervak, M. Kempe, A. Stingl, W. Drexler, „Undistorted delivery of sub-15-fs pulses via high-numerical-aperture microscope objectives", Proc. SPIE 6442, 64420P (2007)*

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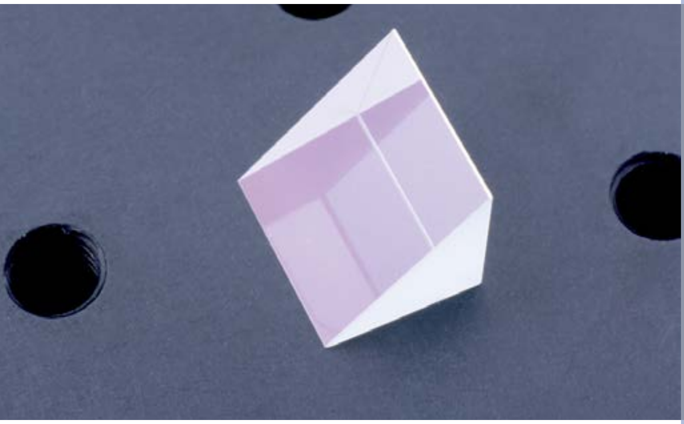


Broadband 400 nm optics

Applications

Beam manipulation at 400 nm

Special features

Low losses

Low GDD

Broadband 400 nm pulses are routinely generated via second harmonic generation with ultrashort Ti:Sapphire pulses.

The FEMTOOPTICS™ product range includes components that allow non dispersive steering, fundamental beam separation and beam splitting of broadband pulses centered at 400 nm.

Broadband dielectric 0° dichroic mirrors

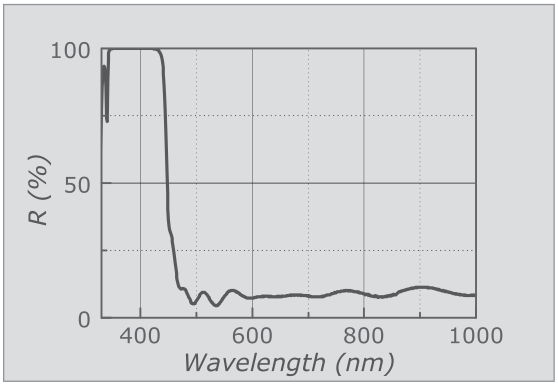
Mirrors based on a quarter wavelength single stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of approximately 80 nm centered at 400 nm. This is -with the current state of technology- the maximum bandwidth achievable in this wavelength range with absorption free dielectric non dispersive mirrors. A bandwidth of 80 nm centered at 400 nm supports minimum pulse durations ranging from 9 fs to 12 fs, depending on the spectral shape.

Special features

- Maximum bandwidth achievable with non dispersive dielectric mirrors
- High reflectance

Applications

- Distortion free manipulation of ultra short femtosecond pulses at 400 nm



Typical reflectance vs. wavelength of a broadband low dispersion dielectric 0° reflector centered at 400 nm. The reflectance in the range 500 nm - 1000 nm originates mainly from Fresnel reflection at the (uncoated) rear surface of the substrate.

Order code	OA205	OA074
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/10 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R > 99.6 % and low GDD in the wavelength range 360 (± 5) nm - 440 (± 5) nm AOI = 0° T > 96 % in the wavelength range 500 (± 10) nm - 1000 (± 10) nm AOI = 0°	
Coating on S2	none | Fresnel reflectance of approx. 3.5 % | AOI = 0°	
Substrate material	fused silica	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	6.35 mm
Wedge angle	< 5 '	

Broadband dielectric 45° dichroic mirrors

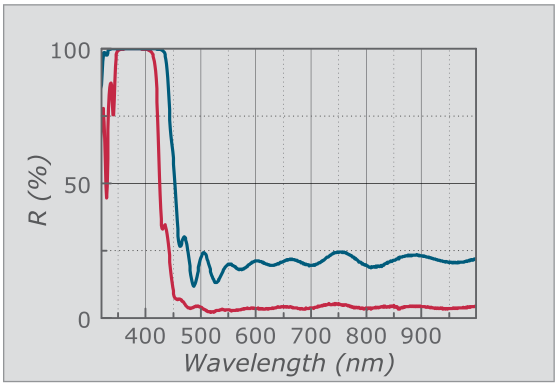
Mirrors based on a quarter wavelength single stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of approximately 60 nm centered at 400 nm for an angle of incidence of 45° and p-polarized light. For s-polarized light the bandwidth increases to 90 nm at 400 nm. This is - with the current state of technology - the maximum bandwidth achievable in this wavelength range with absorption-free dielectric non dispersive mirrors.

Special features

- Maximum bandwidth achievable with non dispersive dielectric mirrors
- High reflectance

Applications

- Distortion free manipulation of ultra short femtosecond pulses at 400 nm



Typical reflectance vs. wavelength of a broadband low-dispersion dielectric 45° reflector centered at 400 nm (blue: s-polarized light, red: p-polarized light).

Order code	OA159	OA075	OA077
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat		L/6 to L/4 at 633 nm, 10-5 scratch-dig | flat
Surface S2	L/10 at 633 nm | 10-5 scratch-dig | flat		L/6 to L/4 at 633 nm, 10-5 scratch-dig | flat
Coating on S1	R > 99.5 % in the wavelength range 350 (± 5) nm - 440 (± 5) nm AOI = 45° | s-polarized R > 99.5 % in the wavelength range 360 (± 5) nm - 420 (± 5) nm AOI = 45° | p-polarized T > 96 % in the wavelength range 500 (± 10) nm - 1000 (± 10) nm AOI = 45° | p-polarized		
Coating on S2	none | Fresnel reflectance of approx. 0.7 % in the wavelength range of 500 nm - 1000 nm | AOI = 45° | p-polarized		
Substrate material	fused silica		
Diameter	0.5 ''	1 ''	1 ''
Thickness	6.35 mm		1 mm
Wedge angle	< 5 '		

Broadband dielectric 45° prism mirrors

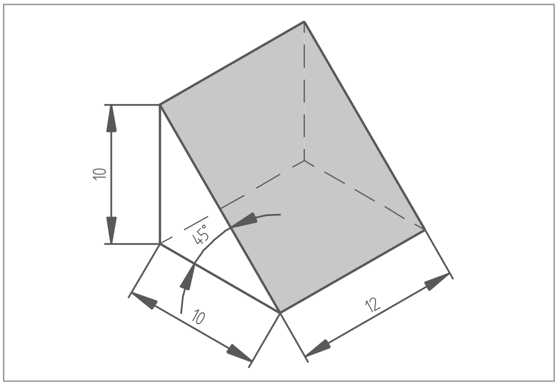
Mirrors based on a quarter wavelength single stack design provide reflectance higher than 99.5 % and low GDD in a wavelength range of approximately 60 nm centered at 400 nm for an angle of incidence of 45° and p-polarized light. For s-polarized light the bandwidth increases to 90 nm at 400 nm. This is - with the current state of technology - the maximum bandwidth achievable in this wavelength range with absorption free dielectric non dispersive mirrors.

Special features

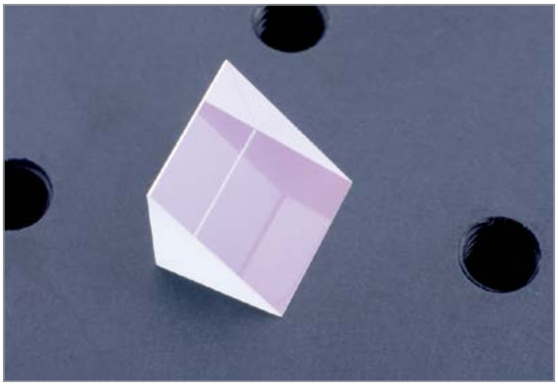
- Maximum bandwidth achievable with non dispersive dielectric mirrors
- High reflectance

Applications

- Distortion free manipulation of ultra short femtosecond pulses at 400 nm



Bradband dielectric 45° prism mirror - conceptual drawing.



Broadband dielectric 45° prism mirror.

Order code	OA076
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat
Other surfaces	inspection polishing | flat | uncoated
Coating on S1	R > 99.5 % in the wavelength range 360 nm - 420 nm AOI = 45° | p-polarized R > 99.5% in the wavelength range 350 nm - 440 nm AOI = 45° | s-polarized
Substrate material	BK7
Dimensions	12 mm x 10 mm x 10 mm

Broadband dielectric beam splitters

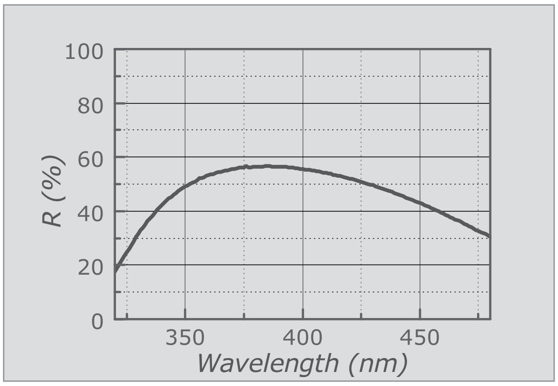
These dielectric beam splitters are optimized for femtosecond laser pulses centered at 395 nm. They exhibit constant reflectivity between 350 nm and 440 nm for p-polarized light for angles of incidence close to 45°. We minimized the amount of positive GDD picked up by the transmitted beam by employing ultra thin substrates. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

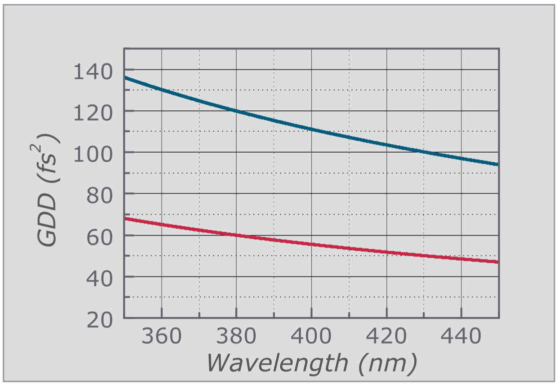
- Large bandwidth
- Ultra thin substrates

Applications

- Beam splitting at 400 nm



Typical reflectance vs. wavelength of ultra broadband 400 nm dielectric 50 % beam splitters for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength experienced by the transmitted beam for beam splitter substrates with a thickness of 1 mm (blue) and 0.5 mm (red) for an angle of incidence of 45°. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA160	OA156
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat	
Coating on S1	R = 50 (± 5) % in the wavelength range 350 (± 5) nm - 440 (± 5) nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica	
Diameter	0.5 ''	1 ''
Thickness	0.5 mm	1 mm
Wedge angle	< 30 ''	

Dispersive mirror module for sub-12 fs pulse | 400 nm

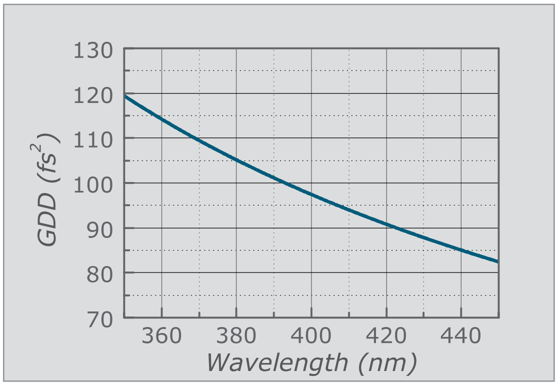
In the 400 nm spectral region the higher order dispersion of optical materials increases dramatically adversely affecting the performance of prism compressors. Dispersive mirrors that compensate GDD without introducing undesired higher order dispersion are thus indispensible in compressors for sub-12 fs pulses in the 400 nm range.

Special features

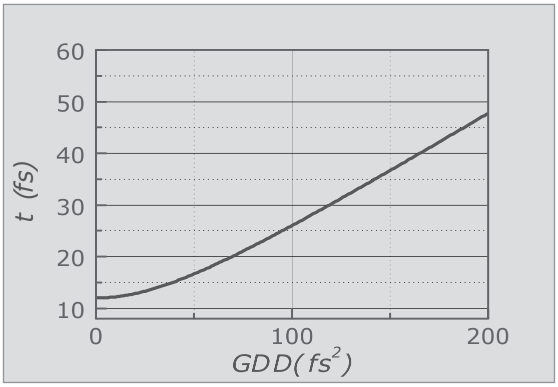
- High throughput, compact compressor
- Controlled higher order dispersion

Applications

- Broadband dispersion pre-compensation at 400 nm



GDD vs. wavelength of fused silica in the wavelength range 350 nm - 450 nm.



Output pulse duration as a function of the GDD of the optical setup for a 12 fs bandwidth-limited Gaussian input pulse.

Order code	GSM012
Wavelength range	360 nm - 440 nm
Average GDD/bounce	- 20 (± 5) fs² at 400 nm
Reflectance	> 99.5 % per bounce
Supported pulse duration	< 12 fs *(if the spectrum matches the wavelength range)*
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized
Number of mirrors	2
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating
Surface S2	inspection polishing | flat | uncoated
Substrate material	fused silica
Free aperture	> 85 % of the diameter
Diameter	1 ''
Thickness	6.35 mm
Wedge angle	< 5 '

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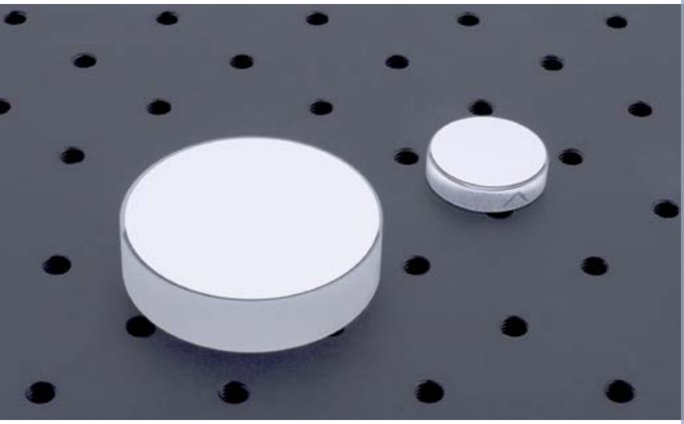


Components for the IR spectral range

Applications

Distortion free manipulation of Ultrashort femtosecond IR pulses

Special features

Broadband low dispersion coatings

Ultra thin substrates for beam splitters

With an increased number of sources (e.g. parametric amplifiers) generating ultrashort femtosecond pulses in the infrared spectral range, optics capable of handling few-cycle pulses had to be developed for this spectral range.

The FEMTOOPTICS™ product range includes low dispersion reflectors and beam splitters covering the range 1 µm - 2.5 µm.

Ultra broadband high reflectivity mirrors

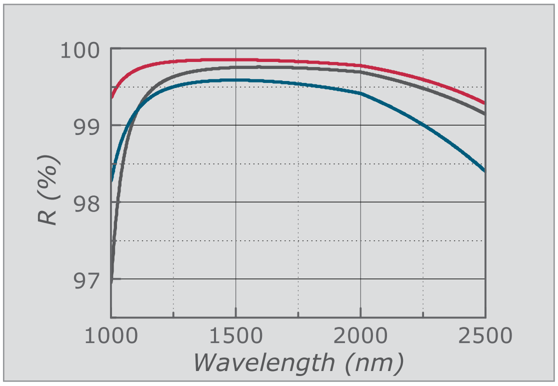
These silver mirrors employ an effective reflectance enhancing multilayer over-coating and exhibit high reflectance and negligible GDD upon reflection for angles of incidence between 0° and 45° in the wavelength range 1100 nm - 2500 nm. They can be used even for larger angles of incidence.

Special features

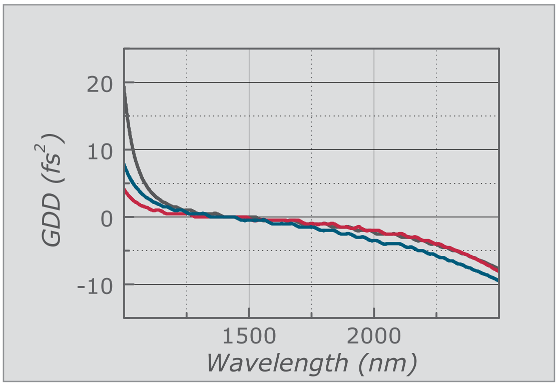
- Broadband low dispersion coating
- Low losses

Applications

- Distortion free manipulation of ultra short femtosecond IR pulses



Typical reflectance vs. wavelength of ultra broadband infrared mirrors calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).



Typical GDD vs. wavelength of ultra broadband infrared mirrors calculated for an angle of incidence of 0° (black) and 45° (red: s-polarized, blue: p-polarized).

Order code	OA096	OA094
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	inspection polishing	
Coating on S1	-10 fs² < GDD < 10 fs² in the wavelength range 1100 nm - 2500 nm AOI = 0° to 45° R > 98 % in the wavelength 1100 nm - 2500 nm AOI = 0° R > 98 % in the wavelength 1100 nm - 2500 nm AOI = 45° | p-polarized R > 98.5 % in the wavelength 1100 nm - 2500 nm AOI = 45° | s-polarized	
Coating on S2	none	
Substrate material	fused silica or BK7	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	6.35 mm
Wedge angle	< 5 '	

Ultra broadband beam splitters

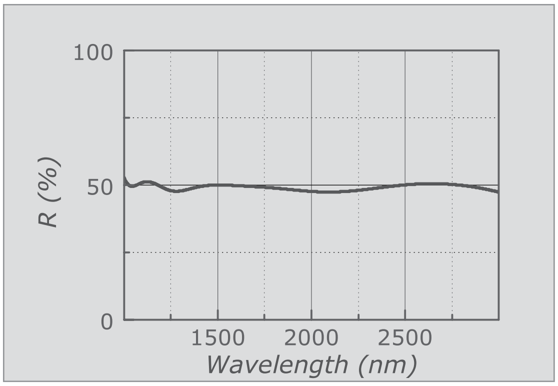
These beam splitters are optimized to exhibit a constant splitting ratio of ~ 50 % in the wavelength range 1 µm - 2.7 µm. We minimized the amount of positive GDD picked up by the transmitted beam by employing ultrathin substrates. The substrate material is substantially loss free in this wavelength range. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

- Large bandwidth
- Ultrathin substrates

Applications

- Beam splitting in the IR range



Typical reflectance vs. wavelength of the ultra broadband infrared beam splitter OA401 for an angle of incidence of 45° and p-polarized light.

Order code	OA401
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Coating on S1	R = 50 % ± 7 % in the wavelength range 1 µm - 2.7 µm AOI = 45° | p-polarized
Coating on S2	none
Substrate material	suprasil 300
Diameter	1 ''
Thickness	1 mm
Wedge angle	< 30 ''

Dispersive mirror modules for sub-15 fs pulses | IR

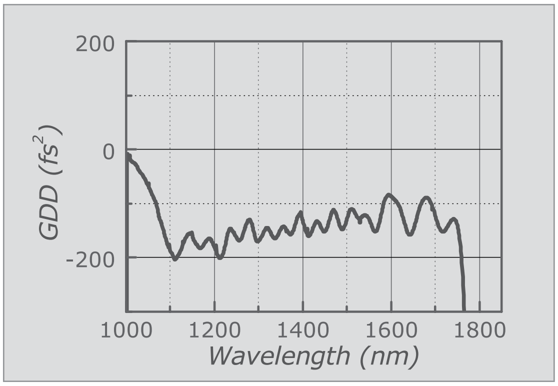
In response to the rapidly increasing demand for ultrashort fs-pulses in the infrared spectral range, FEMTOLASERS has developed DMs covering the range from 1100 nm to 1750 nm exhibiting negative GDD along with third order dispersion (TOD) matched to compensate the TOD of commonly used IR-glasses. In conjunction with an OPA-seeded hollow fiber compressor these mirrors enabled the generation of 400 µJ, 14.5 fs pulses at 1425 nm. *(M. Giguère et al., Opt. Lett. 34, 1894 <2009>)*

Special features

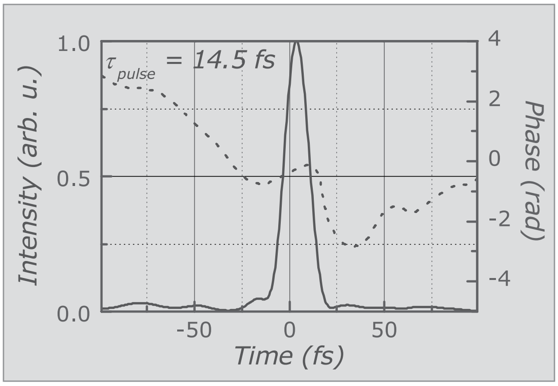
- High throughput, compact compressor
- Accurate control of higher order dispersion

Applications

- Dispersion pre-compensation for sub-15 fs IR pulses



Calculated average GDD/bounce of the mirror module GSM501.



SHG-FROG-retrieved intensity (full line) and phase (dots) of pulses generated by means of a hollow fiber compressor and compressed with GSM501 modules. (Measured data c/o B. Schmidt and F. Légaré, INRS Canada.)

Order code	GSM501
Wavelength range	1100 nm - 1750 nm
Average GDD/bounce	- 135 (± 40) fs² at 1400 nm
Reflectance	> 99 % per bounce
Supported pulse duration	< 15 fs *(if spectrum and wavelength range match)*
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized
Number of mirrors	2
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating
Surface S2	inspection polishing | flat | uncoated
Substrate material	fused silica
Free aperture	> 85 % of the diameter
Diameter	1 ''
Thickness	6.35 mm
Wedge angle	< 5 '

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Components for the visible spectral range

Applications

Distortion free manipulation of Ultrashort femtosecond pulses in the visible spectral range

Special features

Broadband dispersion management

Ultra thin substrates for beam splitters

Owing to recent developments in the field of parametric laser sources, ultrashort femtosecond pulses with wavelengths in the visible spectral range have become increasingly available. These sources found a wide range of applications in time-resolved spectroscopy where accurate dispersion management and un-distorted pulse delivery are essential. In response to this development, the FEMTOOPTICS™ product range was extended to include broadband dispersive mirrors and low-dispersion beam splitters covering a large portion of the visible spectral range.

Dielectric 50 % beam splitters | sub-7 fs | p-polarized | visible

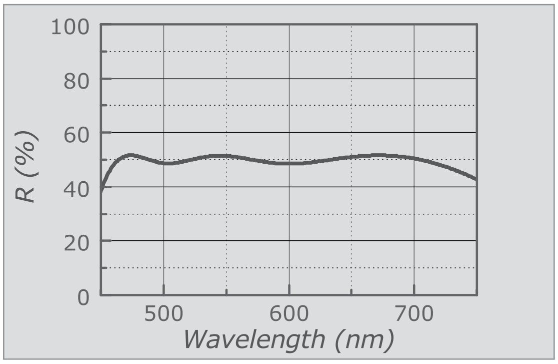
Femtosecond beam splitters are optimized to induce minimum pulse distortion both for the reflected and the transmitted p-polarized beam. The broadband partially reflecting coating introduces negligible GDD upon transmission and reflection. Furthermore, ultra thin substrates are used in order to minimize the GDD experienced by the transmitted beam. Special care should be taken when mounting the beam splitters, since mechanical tension may easily lead to surface bending. Upon request, they can be supplied mounted on black anodized aluminum rings - see the catalog section on optomechanical adapters on page 95.

Special features

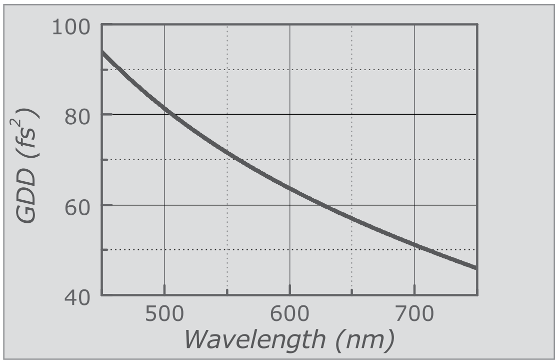
- Constant splitting ratio over a large spectral bandwidth
- Minimum GDD upon both reflection and transmission

Applications

- Beam splitting and sampling for femtosecond pulses



Typical reflectance vs. wavelength of ultra-broadband dielectric 50 % beam splitters for the visible spectral range for an angle of incidence of 45° and p-polarized light.



GDD vs. wavelength for the transmitted beam. The GDD of the coating is negligible both in reflection and transmission.

Order code	OA011
Surface S1	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Surface S2	L/6 to L/4 at 633 nm | 10-5 scratch-dig | flat
Coating on S1	R = 50 % and low GDD in the wavelength range 470 nm - 710 nm AOI = 45° | p-polarized
Coating on S2	none
Substrate material	fused silica
Diameter	1 ''
Thickness	1 mm
Wedge angle	< 30 ''

Dispersive mirror modules for sub-7 fs pulses | visible

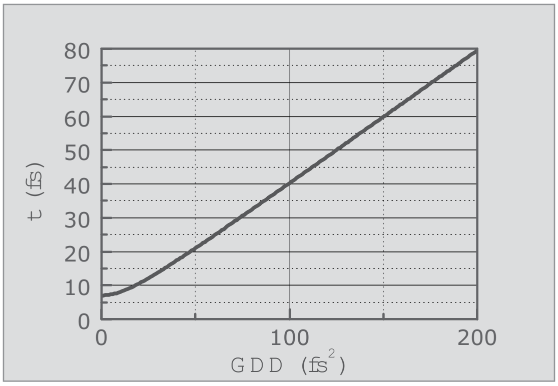
Owing to progress in the development of parametric laser sources, visible fs-pulses have become widely available. Increased higher order dispersion of optical materials and prism compressors make dispersion management particularly challenging in this wavelength range. In order to enable dispersion pre-compensation for visible pulses as short as 7 fs and below, FEMTOLASERS has developed DMs exhibiting negative GDD along with third order dispersion (TOD) matched to compensate the TOD of commonly used optical glasses over a large fraction of the visible spectrum.

Special features

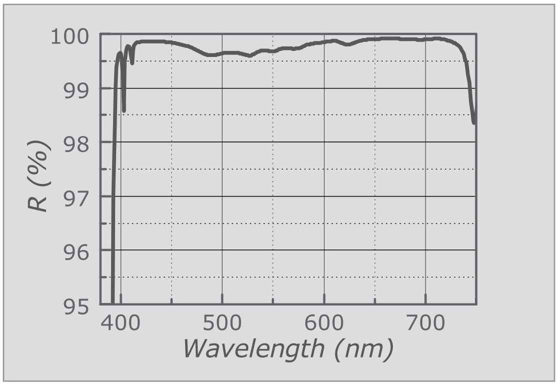
- High throughput, compact compressor
- Accurate control of higher order dispersion

Applications

- Dispersion pre-compensation for sub-7 fs pulses in the visible spectral range



Output pulse duration as a function of the GDD of the optical setup for a 7 fs bandwidth-limited Gaussian input pulse.



Average reflectance vs. wavelength of dispersive mirror pairs GSM032 at normal incidence.

Order code	GSM026	GSM032
Wavelength range	470 nm - 700 nm	
Average GDD/bounce	linearly increasing from - 40 fs² @ 470 nm to - 10 fs² @ 700 nm	
Reflectance	> 99.5 % per bounce	
Supported pulse duration	< 7 fs (if spectrum and wavelength range match)	
Angle of incidence	0° to 10° s-polarized | 0° to 15° p-polarized	
Number of mirrors	2	
Surface S1	L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating	
Surface S2	L/10 at 633 nm | 10-5 scratch-dig | flat | uncoated	
Substrate material	fused silica	
Free aperture	> 85 % of the diameter	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	

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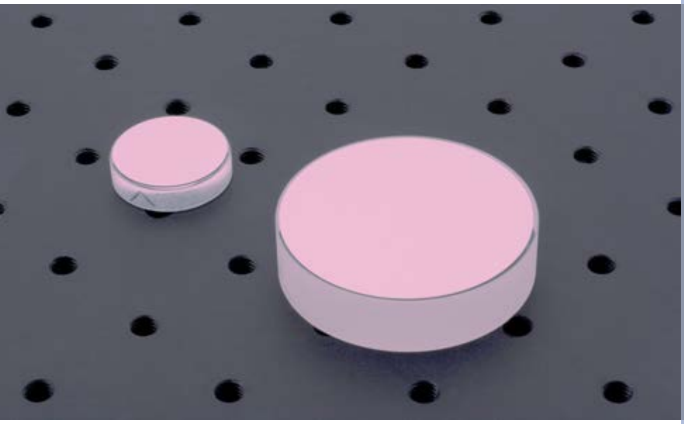


Components for the deep UV spectral range

Applications

Broadband low-dispersion coatings

Angle-tunable dispersive mirrors

Special features

Distortion-free manipulation of ultra-short femtosecond pulses

Pulse compression

Highly attractive for time-resolved measurements both in physics and chemistry, broadband pulses in the wavelength range 200 nm - 300 nm became increasingly available owing to efficient four-wave-mixing and third order harmonic generation schemes seeded with Ti:Sapphire pulses. Low-loss high reflectors and dispersive mirrors depicted in this section enable the distortion-free delivery of deep UV fs pulses.

Ultra broadband dielectric 0° mirrors

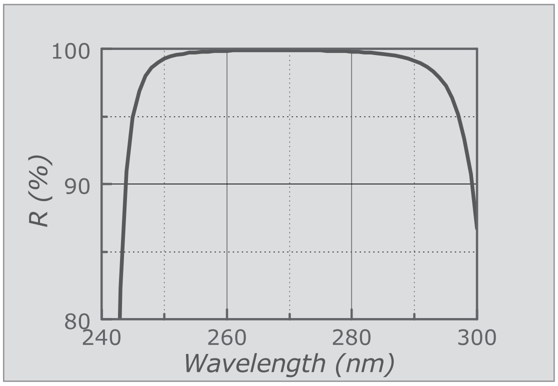
Mirrors based on a quarter-wavelength single-stack design provide high reflectance and low GDD in a wavelength range of approximately 20 nm centered at 267 nm, at near - normal incidence. These mirrors are ideally suited for the distortion-free steering of sub-20-fs deep UV pulses.

Special features

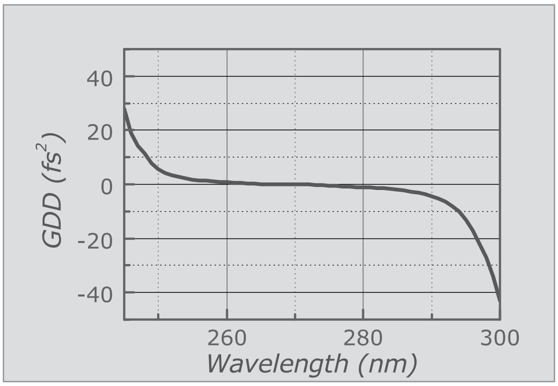
- Broadband low-dispersion coating
- Low losses

Applications

- Distortion-free manipulation of ultrashort femtosecond deep UV pulses



Typical reflectance vs. wavelength of ultra broadband dielectric normal incidence mirrors.



Typical GDD vs. wavelength of ultra broadband dielectric normal incidence mirrors.

Order code	OA014	OA015
Surface S1	better than L/10 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	inspection polishing | flat	
Coating on S1	R > 99 % and low GDD in the wavelength 257 (±2) nm - 277 (±2) nm AOI = 3.5°	
Coating on S2	none	
Substrate material	fused silica or BK7	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	
Wedge angle	< 5 '	

Ultra broadband dielectric 45° mirrors

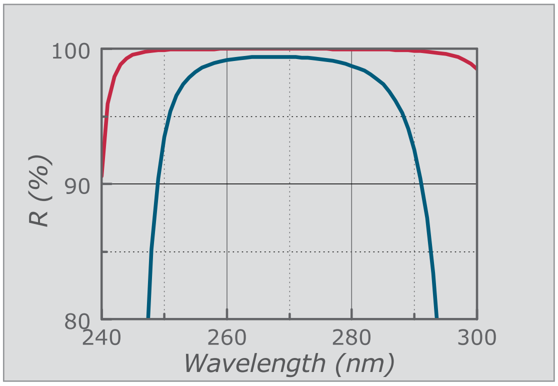
Mirrors based on a quarter-wavelength single-stack design provide high reflectance and low GDD in a wavelength range of approximately 40 nm centered at 267 nm, for an angle of incidence of 45° and s-polarized light. These mirrors are ideally suited for the distortion-free steering of sub-20-fs deep UV pulses.

Special features

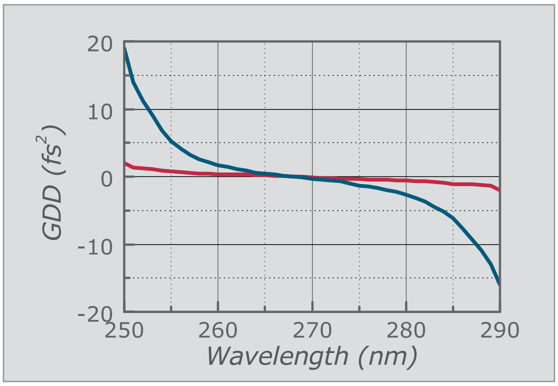
- Broadband low-dispersion coating
- Low losses

Applications

- Distortion-free steering of ultrashort femtosecond deep UV pulses



Typical reflectance vs. wavelength of ultra broadband dielectric 45° mirrors for p-polarized (blue) and s-polarized light (red).



Typical GDD vs. wavelength of ultra broadband dielectric 45° mirrors for p-polarized (blue) and s-polarized light (red).

Order code	OA012	OA013
Surface S1	better than L/10 at 633 nm | 10-5 scratch-dig | flat	
Surface S2	inspection polishing | flat	
Coating on S1	R > 99 % in the wavelength range 250 (±2) nm - 285 (±2) nm AOI = 45° | s-polarized R > 98 % in the wavelength range 259 (±2) nm - 275 (±2) nm AOI = 45° | p-polarized	
Coating on S2	none	
Substrate material	fused silica or BK7	
Diameter	0.5 ''	1 ''
Thickness	6.35 mm	
Wedge angle	< 5 '	

Dispersive mirror modules for 30 fs pulses

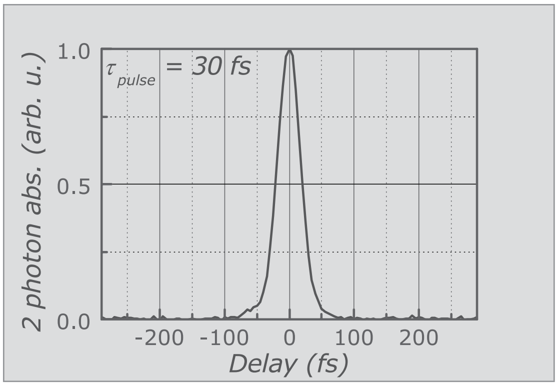
Deep UV dispersive mirrors provide a robust, user-friendly alternative to prism-pair and grating-pair compressors. Furthermore they mitigate the wavefront distortion issues inherent to these devices in this sensitive wavelength range. Employing these mirrors, 30 fs pulses were obtained by compressing light generated with a hollow fiber-based four-wave mixing device. *(C. A. Rivera et al., Optics Express 18, 18615, 2010)*

Special features

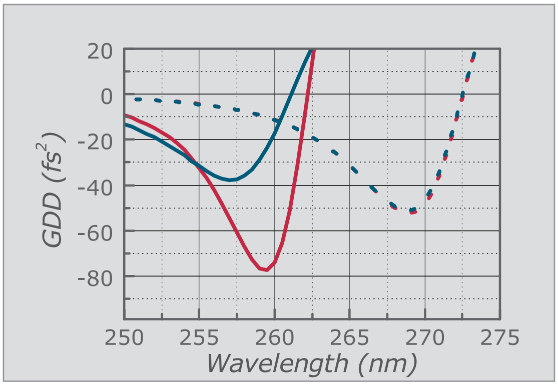
- Wavelength tunable via angle of incidence
- Compact dispersion compensation

Applications

- Compression of deep UV pulses



Intensity autocorrelation of 30 fs, 266.7 nm pulses generated via four wave mixing in a hollow fiber and compressed with Dispersive Mirrors GSM024. (Measured data c/o C. A. Rivera and S. E. Bradforth, University of Southern California, Los Angeles.)



Calculated GDD vs. wavelength of dispersive DUV mirrors at angles of incidence of 35° (full lines) and 7° (dots) for s-polarized (red) and p-polarized (blue) light.

Order code	GSM024
Wavelength range	260 nm - 270 nm at 7° | angle-tunable
GDD/bounce	GDD < -20 fs^2 in the wavelength range 261 (±2) nm – 271 (±2) nm GDD < -50 (±10) fs^2 at 269 (±2) nm at 7° | angle-tunable
Reflectance	R > 99 % per bounce
Supported pulse duration	< 30 fs (if spectrum and wavelength range match)
Angle of incidence	tunable between 7° and 35° corresponding to a wavelength blue-shift of 9 nm
Number of mirrors	2
Surface S1	better than L/10 at 633 nm | 10-5 scratch-dig | flat | dispersive coating
Surface S2	inspection polishing | flat | uncoated
Substrate material	fused silica
Free aperture	> 85 % of the diameter
Diameter	1 "
Thickness	6.35 mm
Wedge angle	< 5 '

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Optics for polarization management

Applications

Polarization control for few-cycle femtosecond pulses

Special features

Wavelength independent performance over a large bandwidth

Small GDD upon transmission

Handling the polarization of few-cycle femtosecond pulses requires retardation plates and polarizers that are at the same time achromatic over a large bandwidth and sufficiently thin to introduce only small GDD in transmission.

Responding to these requirements, the FEMTO-OPTICS™ product range includes air spaced ultra thin two material achromatic waveplates and thin film polarizers with outstanding bandwidth and extinction ratio.

Ultra broadband achromatic 800 nm waveplates

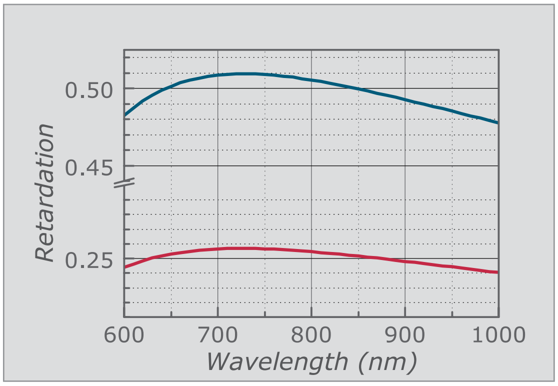
FEMTOOPTICS™ broadband achromatic waveplates are cement free, consisting of air-separated quartz and MgF_2 plates. Owing to this design, the waveplates introduce minimum GDD and are also suitable for high power applications. The dispersion of each waveplate is exactly known in the range 650 nm - 950 nm and can be easily compensated for with dispersive mirrors.

Special features

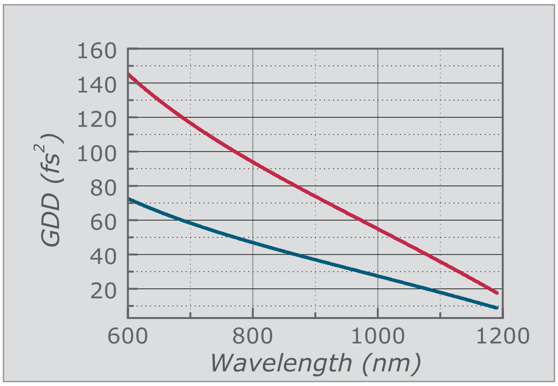
- Wavelength independent performance over a large bandwidth
- Small GDD upon transmission
- High throughput

Applications

- Polarization control for few cycle femtosecond pulses



Retardation vs. wavelength of the ultra broadband achromatic L/2 (blue) and L/4 (red) waveplates.



GDD vs. wavelength of the waveplates OA229, OA230 (blue) and OA232, OA228 (red).

Order code	OA229	OA227	OA232	OA228
Retardation	0.25 ± 0.007 orders in the wavelength range 600 nm - 950 nm		0.5 ± 0.014 orders in the wavelength range 600 nm - 950 nm	
Type	achromatic | air-spaced			
Throughput	> 98 %			
Coating	all surfaces AR-coated			
Wavefront distortion	< L/10 in transmission			
Surfaces	10-5 scratch-dig			
Free aperture	14.5 mm	19.5 mm	14.5 mm	19.5 mm
Outer diameter	25 mm	30 mm	25 mm	30 mm

Ultra broadband 800 nm reflective phase retarders

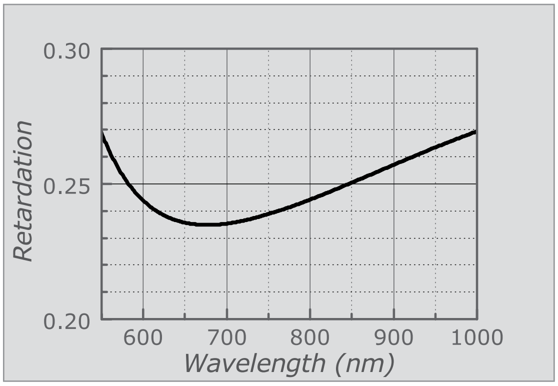
In order to enable distortion-free polarization management for energetic few-cycle laser pulses we developed thin film-based reflective phase retarders introducing a retardation of $\lambda/4$ ±6 % in the wavelength range 570 nm – 970 nm. In contrast to conventional transmissive phase retardation plates, these reflective phase retarders introduce no group delay dispersion (consequently preserving the pulse duration), exhibit no nonlinear effects, have large laser induced damage threshold and can be almost arbitrarily scaled in size.

Special features

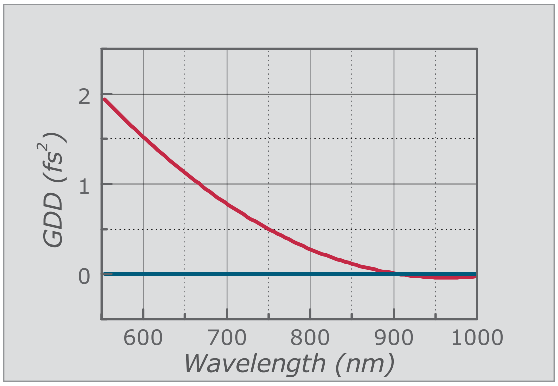
- Negligible dispersion
- Large bandwidth

Applications

- Polarization management of intense few-cycle pulses



Retardation vs. wavelength of ultrabroadband L/4 reflective phase retarders



GDD vs. wavelength of ultrabroadband L/4 reflective phase retarders (red: s-polarized light, blue: p-polarized light).

Order code	OA1100	OA1101	OA1102
Retardation	0.25 ± 0.015 orders in the wavelength range 570 nm - 970 nm		
Angle of incidence	68.4°		
Insertion loss	< 2 %		
Surface S1	L/10 @ 633 nm | 10-5 scratch-dig		
Surface S2	fine grinded | uncoated		
Coating on S1	phase retarding reflective coating		
Free aperture (under AOI = 68.4°)	≥ 9 mm	≥ 19 mm	≥ 28 mm
Diameter	1 "	2 "	3 "
Thickness	6.35 mm	10 mm	20 mm

Zero order 400 nm waveplates

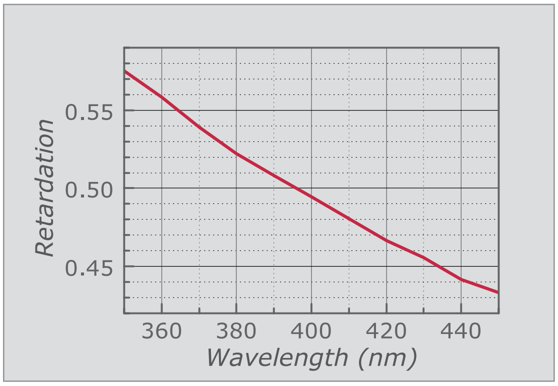
A design consisting of two air spaced quartz plates is employed for the zero order 400 nm waveplate in order to minimize the dispersion. The retardation remains close to half-wavelength in the vicinity of 400 nm making this waveplates suitable for sub-20 fs pulses.

Special features

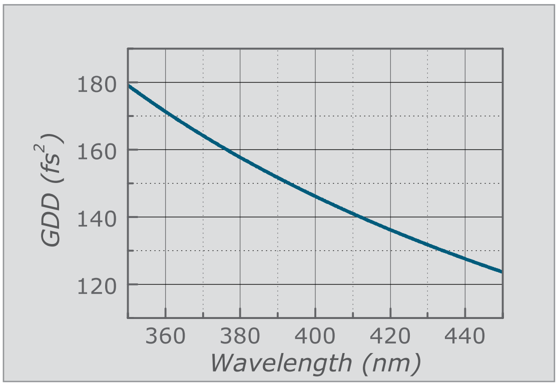
- Zero order retardation plate at 400 nm
- Small GDD upon transmission
- High throughput

Applications

- Polarization control for sub-20 fs femto-second pulses at 400 nm



Retardation vs. wavelength of the single order L/2 waveplate OA196.



GDD vs. wavelength of the single order L/2 waveplate OA196.

Order code	OA196
Retardation	0.5 (± 0.006) orders at 400 nm
Type	zero-order | air-spaced
Throughput	> 98 %
Coating	all surfaces AR-coated
Wavefront distortion	< L/6 in transmission
Surfaces	10-5 scratch-dig
Free aperture	15 mm
Outer diameter	1 ''

Ultra broadband thin film polarizers for sub-10 fs pulses | 800 nm

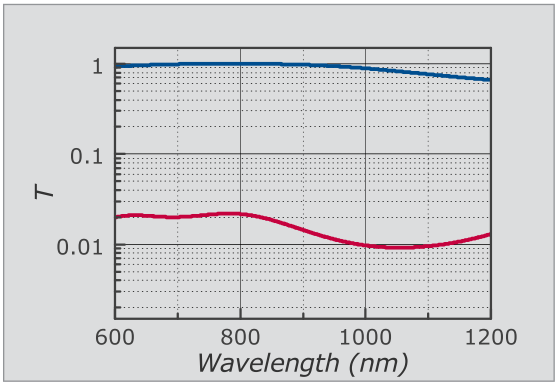
FEMTOOPTICS™ ultra broadband thin film polarizers provide efficient extinction over a wide wavelength range. The polarizing coating is deposited on ultrathin fused silica plates in order to minimize the GDD of the component. Since the plates are mounted such that the lateral displacement of the beam is perfectly compensated, the polarizer can be inserted and rotated without causing any beam displacement.

Special features

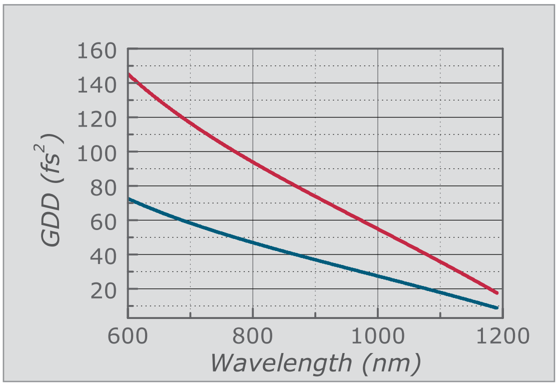
- Efficient extinction over a large bandwidth
- Small GDD upon transmission

Applications

- Polarization cleaning for sub-7 fs pulses at 800 nm
- Neutral attenuation for sub-7 fs pulses at 800 nm



Typical transmittance vs. wavelength of the thin film polarizers OA512, OA513 for p-polarized light (blue) and s-polarized light (red).



GDD vs. wavelength of the thin film polarizers OA512 (blue) and OA513 (red).

Order code	OA513	OA512
Type	dielectric thin film multilayer polarizer	
Extinction ratio	better than 2×10^{-2} in the wavelength range 600 nm - 900 nm	
Insertion loss	< 3 %	
Substrate material	fused silica	
Free aperture	19 mm	10 mm
Total thickness	2.6 mm	1.3 mm
Mount	black anodized Al | length 160 mm outer diameter 25 mm	black anodized Al | length 82 mm outer diameter 12 mm

Ultra broadband thin film polarizers for sub-30 fs pulses | 800 nm

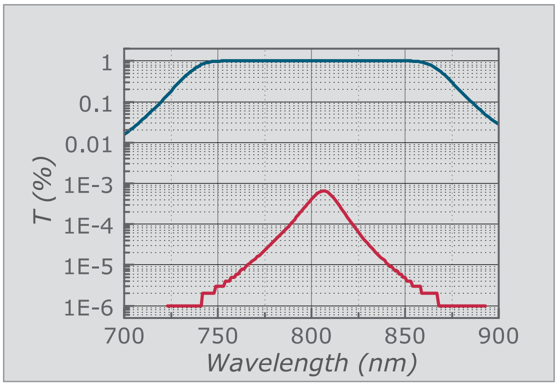
An extinction ratio of more than two orders of magnitude can be achieved with a single plate thin film polarizer over a bandwidth supporting sub-30 fs pulses at 800 nm. Since both sides of the polarizing plate are coated only the transmitted beam can be used.

Special features

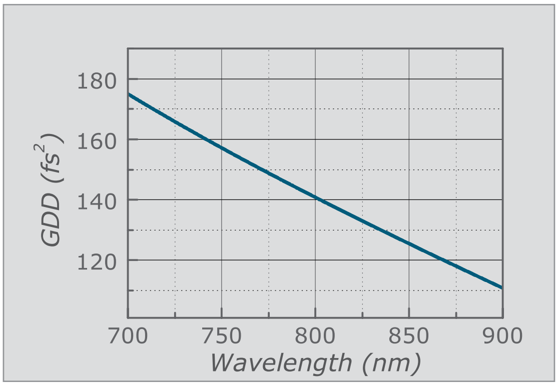
- Efficient extinction
- Moderate GDD upon transmission

Applications

- Polarization cleaning for sub-30 fs pulses at 800 nm
- Neutral attenuation for sub-30 fs pulses at 800 nm



Typical transmittance vs. wavelength of the thin film polarizers OA542 for p-polarized light (blue) and s-polarized light (red).



GDD vs. wavelength of the thin film polarizer OA542.

Order code	OA542
Type	dielectric thin-film multilayer polarizer
Extinction ratio	better than 10^{-2} in the wavelength range 750 nm - 850 nm AOI = 72°
Insertion loss	< 3 %
Substrate material	fused silica
Dimensions	80 mm x 25 mm x 3 mm
Free aperture	23 mm
Total thickness	3.9 mm (at the nominal AOI)
Wedge angle	0.1°

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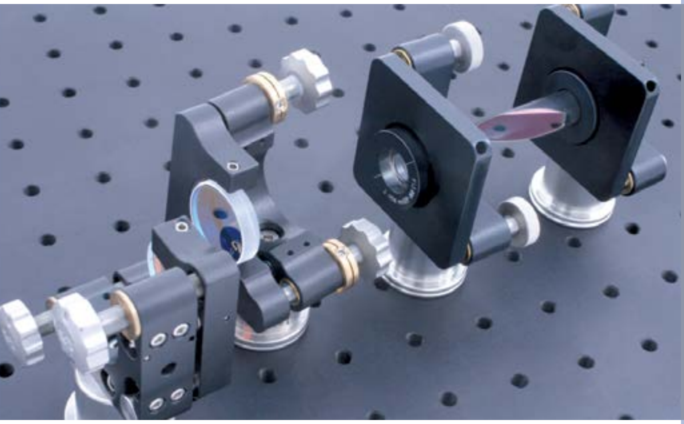


Dispersion compensated neutral attenuators

Applications

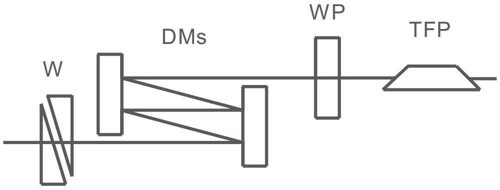
Power tuning of sub-10 fs pulses

Special features

Preserve the spectral shape and pulse duration

High dynamic range

Neutral attenuation



Schematic representation of a dispersion compensated neutral attenuator (W = wedges, DMs = dispersive mirrors, WP = waveplate, TFP = thin film polarizer).

For several applications including nonlinear microscopy and material processing accurate control of the laser power is essential. Employing these neutral attenuation kits the laser power can be finely adjusted in a wide range without affecting the duration and shape of pulses as short as less than 10 fs.

The dispersion compensated neutral attenuators are individually tested in our labs and supplied with a measured interferometric autocorrelation trace.

Dispersion compensated neutral attenuators

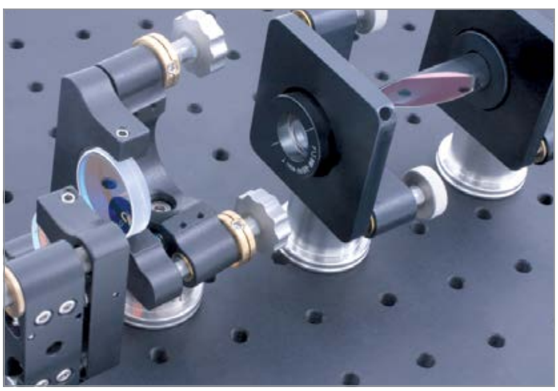
For several applications including nonlinear microscopy and material processing accurate control of the laser power is essential. Employing these neutral attenuation kits the laser power can be finely adjusted in a wide range without affecting the duration and shape of pulses as short as less than 10 fs. The dispersion compensated neutral attenuators are individually tested in our labs and supplied with a measured interferometric autocorrelation trace.

Special features

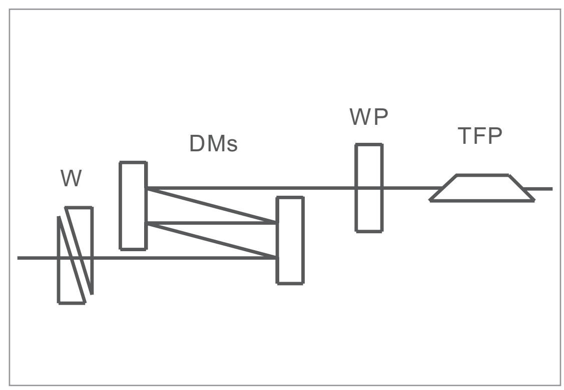
- Preserves the spectral shape and pulse duration
- High dynamic range
- Neutral attenuation

Applications

- Power tuning of sub-10 fs pulses



Dispersion compensated neutral attenuators.



Schematic representation of a dispersion compensated neutral attenuator (W = wedges, DMs = dispersive mirrors, WP = waveplate, TFP = thin film polarizer).

Order code	OA332	OA331
Description	Set consisting of:	Set consisting of:
	1 pc. ultra broadband achromatic waveplate OA232	1 pc. ultra broadband achromatic waveplate OA228
	1 pc. dispersive mirror compressor (2 mirrors)	1 pc. dispersive mirror compressor (2 mirrors)
	1 pc. thin film polarizer OA512	1 pc. thin film polarizer OA513
Laboratory test	measured interferometric autocorrelation supplied	
Wavelength range	650 nm - 950 nm	
Maximum optical density	1.7 (for linearly polarized light)	
Supported pulse duration	< 10 fs	
Insertion loss	5 %	
Free aperture	10 mm	19 mm
Optomechanical parts	mounts and posts are not included | can be supplied upon request	
Installation	not included | can be supplied upon request	

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Frequency doubling crystals

Applications

Second harmonic generation with sub-20 fs 800 nm pulses

Special features

Ultra thin crystals

Broadband phase matching

The BBO (Beta Barium Borate) crystals are phase-matched for frequency doubling of pulses centered at 800 nm. The reduced crystal thickness enhances the phase-matching bandwidth enabling the frequency conversion of sub-20 fs pulses.

Frequency doubling crystals

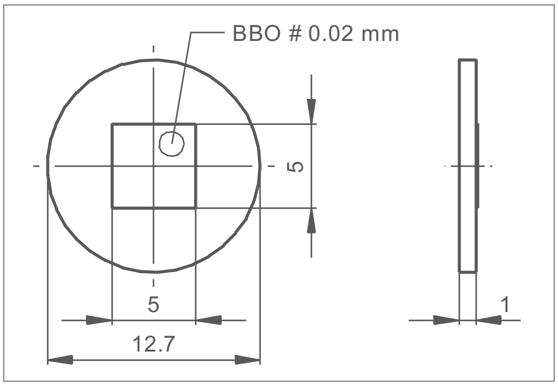
The BBO (Beta Barium Borate) crystals are phase matched for frequency doubling of pulses centered at 800 nm. The reduced crystal thickness enhances the phase-matching bandwidth enabling the frequency conversion of sub-20 fs pulses. The crystals are attached to thin fused fused silica substrates ensuring mechanical stability.

Special features

- Ultra thin crystals
- Broadband phase matching

Applications

- Second harmonic generation with sub-20 fs 800 nm pulses



Technical drawing of a BBO frequency doubling crystal.

Order code	FO030	OA218
Type	BBO with anti-fog protection coating	
Phase matching	SHG at 800 nm (theta = 28.5° | phi = 90°)	
Crystal dimensions	5 mm x 5 mm x 0.02 mm	5 mm x 5 mm x 0.01 mm
Substrate material	fused silica	
Substrate diameter	0.5 ''	
Substrate thickness	1 mm	
Substrate coating	none	

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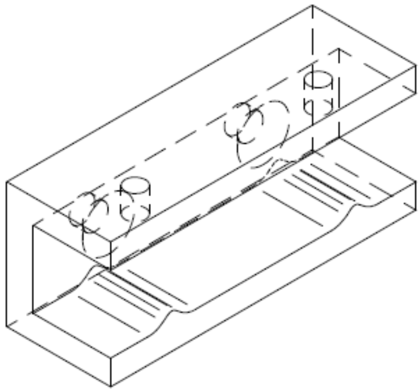


Optomechanical adapters

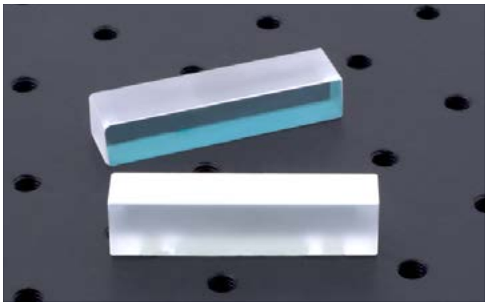
Applications

Mounting of non-standard optical components

Special features

Compatible with standard mirror mounts

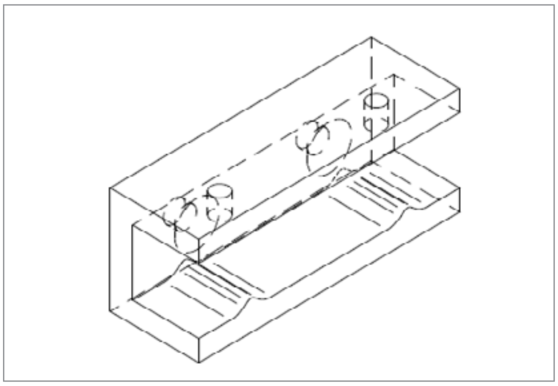
Minimum free aperture loss



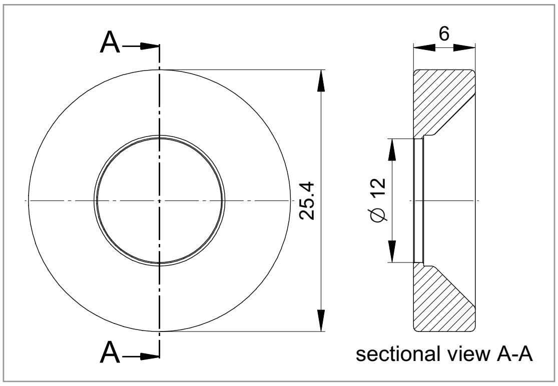
Rectangular dispersive mirrors (GSM201, GSM205, GSM206) can be attached to commercially avail¬able platform mounts by means of the adapter OM063.

Femtosecond laser applications often require components with non-standard dimensions, that do not fit into readily available mounts. We have designed a set of adapters that enables mounting these parts in standard mirror holders without compromising flatness and with minimum loss of free aperture. Whenever beam splitters are ordered with an adapter they will be supplied glued onto the adapter unless explicitely requested otherwise in your order.

Optomechanical adapters

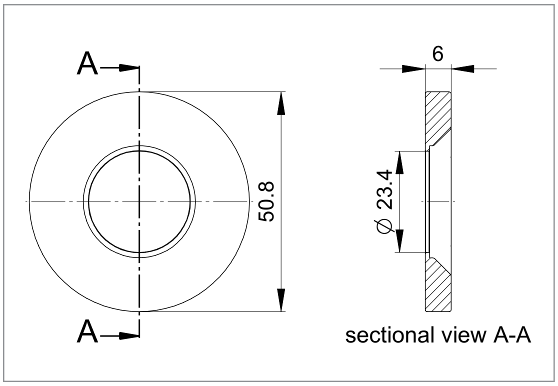


Adapter OM063

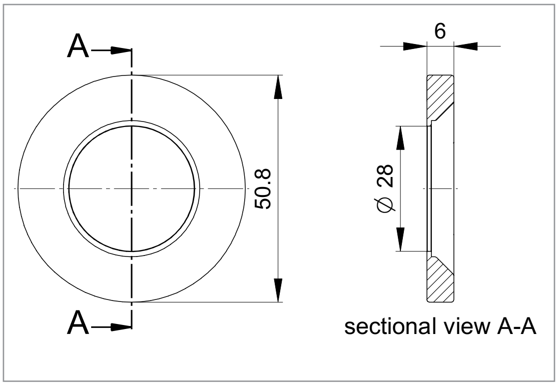


Adapter OM312

Order code	OM063	OM312
Type	mount adapter for 10 mm x 50 mm x 12.7 mm mirrors	mount adapter for 0.5 " beam splitters or windows
Compatibility	fits on New Focus 9806 platform mounts	fits in any standard 1" mirror mount
Thickness	NA	6 mm
Free aperture	NA	12 mm
Material	black anodized Aluminium	black anodized Aluminium



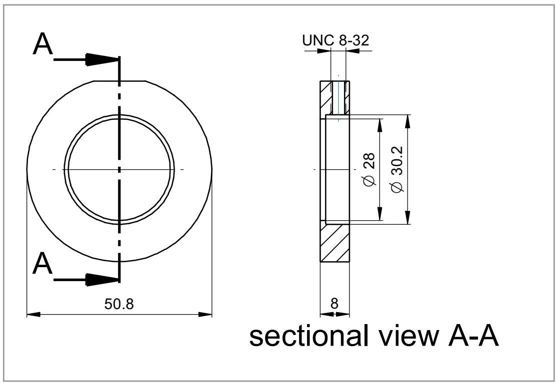
Adapter OM314



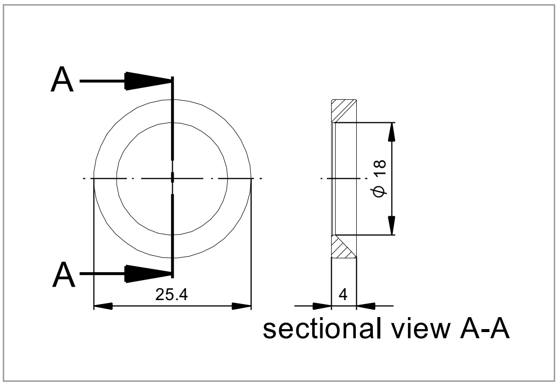
Adapter OM315

Order code	OM314	OM315
Type	mount adapter for 1 " beam splitters or windows	mount adapter for 30 mm beam splitters or windows
Compatibility	fits in any standard 2 " mirror mount	fits in any standard 2 " mirror mount
Thickness	6 mm	6 mm
Free apterure	23.4 mm	28 mm
Material	black anodized Aluminium	black anodized Aluminium

Optomechanical adapter



Adapter OM316



Adapter FM102

Order code	OM316	FM102
Type	mount adapter for 30 mm waveplates OA230, OA228	mount adapter for 1 " beam splitters or windows
Compatibility	fits in any standard 2 " mirror mount	fits in any standard 1 " mirror mount
Thickness	6 mm	4 mm
Free aperture	28 mm	18 mm
Material	black anodized Aluminium	black burnished steel

Index

Index

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