5. Mirrors

Mirror is one of the basic elements in optical systems, used for partial or full reflection of the optical beam. It can be used for creating both real and imaginary pictures of an objects, which can be reversed or upright, magnified or diminished or unchanged in size as compared to the object. In some special cases, it is better to replace lenses with mirrors in the optical system.

Shape of mirrors: Plane mirrors
Spherical mirrors

Mirror substrates: B270, N-BK7, Zerodur, Pyrex, Fused Silica, Borofloat, Copper, Silicon, etc.

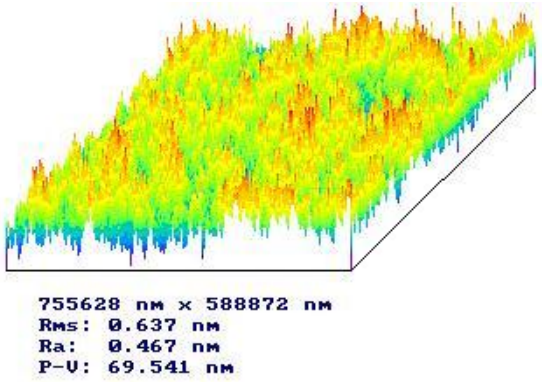
Mirror coatings: metallic (optional with protection overcoating), dielectric.

The optical function of the mirror describes its geometrical shape, and kind of mirror coating.

The choice of material for mirror substrates is also described by its function. When B270 or N-BK7 are commonly used for mirror substrates working in room temperature, Zerodur or quartz glass are recommended for all these performances where changes in the mirror caused by temperature fluctuations must be taken into account. High energy lasers require mirrors of copper.

Substrate	Thermal expansion coefficient	Temperature range
B270	$9,5 \cdot 10^{-6}$ / K	20 ÷ 300°C
N-BK7	$8,3 \cdot 10^{-6}$ / K	20 ÷ 300°C
Zerodur	$0,05 \cdot 10^{-6}$ / K	20 ÷ 300°C
Fused Silica	$0,6 \cdot 10^{-6}$ / K	0 ÷ 300°C
Borofloat	$3,25 \cdot 10^{-6}$ / K	0 ÷ 300°C
Silicon	$3,7 \cdot 10^{-6}$ / K	0 ÷ 300°C
Copper	$16,5 \cdot 10^{-6}$ / K	20 °C

We produce mirrors and mirror substrates with nanometric Surface Form Accuracy and subnano-roughness.

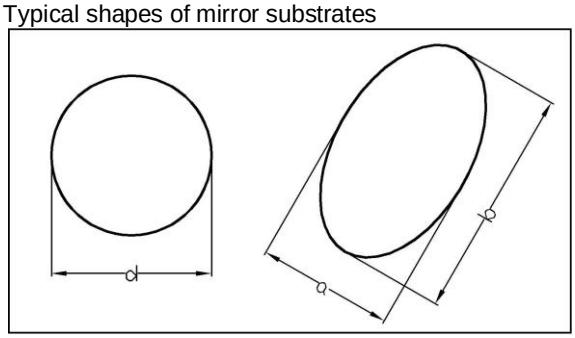


5.1. Plane mirrors

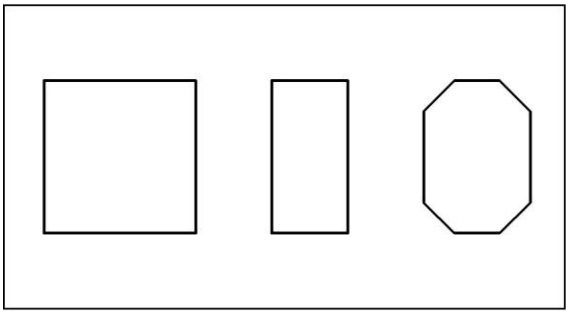
Flat mirrors are used in optical system as unfocal elements. May serve as to create imaginary or real picture, equal and placed symmetrically to object.

Sets of plane mirrors are widely used for multiple reflection of the optical beam to optimize tightness of optical system.

Typical shapes of mirror substrates



Round and elliptical



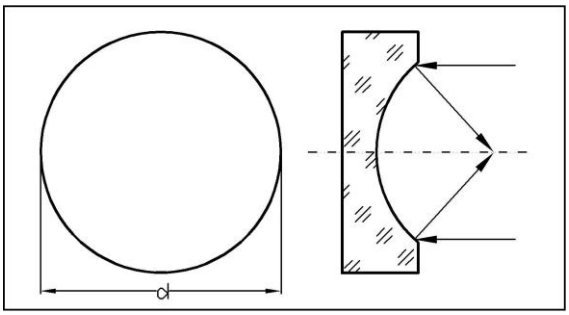
Square and rectangular

Technical specification-plane mirrors	
	Standard
Substrate material	on request
Size	4 mm ÷ 200 mm
Size tolerance	–0,1 mm ÷ –0,3 mm
Clear aperture	90%
Thickness tolerance	± 0,1 mm
Flatness (633 nm)	1 λ per inch
Surface finish (scratches - digs)	60 – 40
Coatings	on request
Mounting	on request

According to customer specification, we can deliver non-standard plane mirrors with significantly higher optical parameters: 10-5; λ/10 (633 nm), for example.

5.2. Spherical mirrors

In optical systems spherical mirrors can play a role similar to that of focusing lenses. Active surface of such a mirror is part of sphere. There are spherical mirrors concave (focusing) with the inner surface of sphere, and convex – where mirror surface is the outer surface of sphere.
Depending of radius of curvature of concave mirror and distance from object to mirror surface, it is created the picture – real or imaginary, reversible or simple, decreased, increased or equal to object.
Convex spherical mirror independently of its radius of curvature and distance to object, creates imaginary, decreased and simple picture.



Technical specification – spherical mirrors	
	Standard
Material	on request
Range of sizes	5 mm ÷ 150 mm
Size tolerance	–0,1 mm ÷ –0,3 mm
Clear aperture	90%
Thickness tolerance	± 0,1 mm
Focal length range	10 mm ÷ 2000 mm
Focal length tolerance	± 1%
Radius tolerance	± 1%
Centering error	3 ÷ 10 arcmin
Surface accuracy (633 nm)	λ/4
Surface finish (scratches - digs)	60 – 40
Coatings	on request
Mounting	on request

According to customer specification, we can deliver non-standard spherical mirrors with significantly higher optical parameters: 10-5; λ/10 (633 nm), for example.

5.3. Mirror coatings

5.3.1. Metallic mirror coatings

The reflection properties of metallic coatings little depend on wavelength, polarization state and angle of incidence. Materials used for metallic mirror coatings are aluminum, silver and gold. According to the kind of metal and wavelength range, the reflection level is from 85% to 98%. Because of significant absorption level of metallic layers, such kind of mirrors cannot be used in systems where high light power density is present.

Coatings made of evaporated metals are chemically sensitive and can function as oxidizers. Therefore they are given an additional coat of SiO_2 or MgF_2 as protection layer, due to the wavelength range demanded. For UV and VIS there is used MgF_2 and for VIS and NIR it is used SiO_2. For laboratory use there can be also produced aluminum mirrors without protection.

Gold mirrors can be also made with or without protection layer.

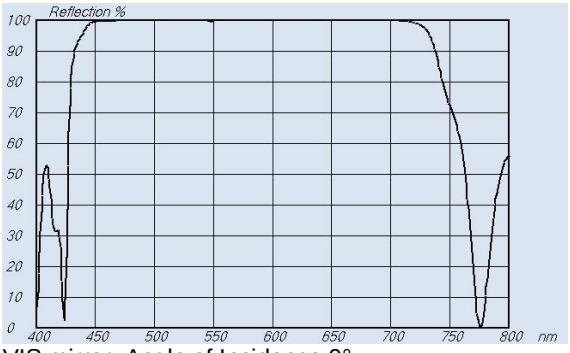
Technical specification – metallic coatings	
Spectral range	**Standard coatings**
UV	Aluminum (optional MgF_2 – protection)
VIS, NIR	Aluminum, Silver (optional SiO_2 or Y_2O_3 – protection)
IR, FIR	Gold (optional with Y_2O_3 – protection)

5.3.2. Dielectric mirror coatings

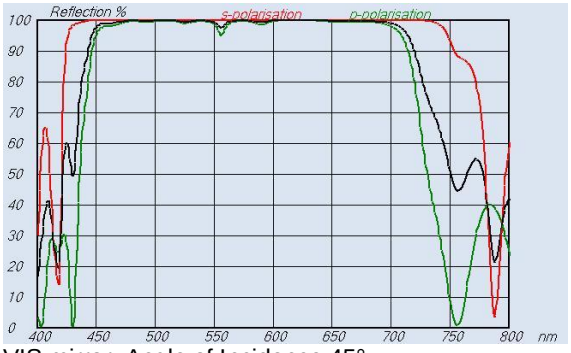
In comparison to metallic coatings they have higher reflection coefficient, better mechanical durability and they are laser radiation resistant. What is more, dielectrics do not phase shift the E vector orientation. But one should remember that the kind of coating is selected according to the demanded wavelength range and that the high reflection effect as well as other properties of the mirror depend on the angle of incidence and state of polarization.

Dielectric coated mirrors can be designed as single wavelength (laser line mirrors) or broadband ones. It is also possible to realize some special requirements for other spectral ranges.

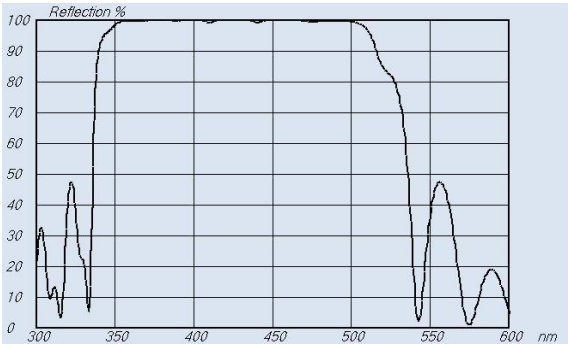
Technical specification – dielectric coatings		
Spectral range	**Wavelengths**	**Reflection**
Angle of Incidence: 0°		
UV	248 ÷ 300 nm	> 98,0%
	300 ÷ 400 nm	> 99,5%
VIS	400 ÷ 800 nm	> 99,7%
NIR	800 ÷ 1600 nm	> 99,7%
Angle of Incidence: 45°		
UV	248 ÷ 300 nm	> 97,0%
	300 ÷ 400 nm	> 98,5%
VIS	400 ÷ 800 nm	> 99,0%
NIR	800 ÷ 1600 nm	> 99,0%



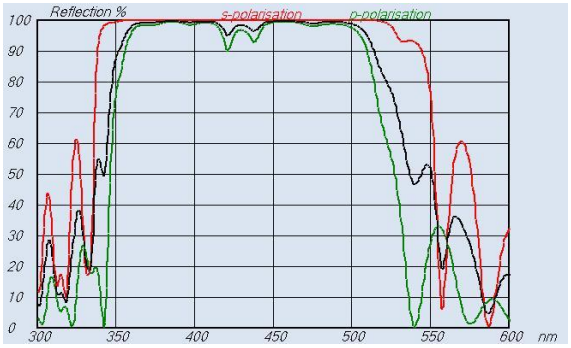
VIS mirror, Angle of Incidence 0°



VIS mirror, Angle of Incidence 45°



UV mirror, Angle of Incidence 0°



UV mirror, Angle of Incidence 45°