4. Antireflection coatings

Antireflection coatings decrease reflection losses from the active surface of optical element. It means that they increase transmission of such optical elements as lenses, prisms or windows, which is very important for designs using more than a few components. Using antireflection coating becomes especially important in the case of optical elements made of material with high refraction index. Optical properties of antireflection coating depend on wavelength, angle of incidence and state of polarization.

For light with normal incidence, the reflection index R from the border of two media (one surface of glass in air) is as follows:

$$R = \left(\frac{n_{glass} - n_{air}}{n_{glass} + n_{air}} \right)^2$$

This equation can be applied as approximated for angle of incidence up to 50^{o}.

Surface reflectance depends on the difference in refractive indices for air and glass (or other optical material). Light reflected from one uncoated surface of optical element made of different materials is presented in the table below:

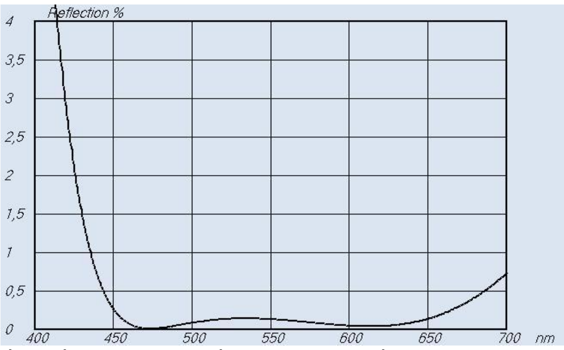
	n (589,3 nm)	Reflexion
N-BK7	1,517	4,2%
N-BaK4	1,569	4,9%
N-SF11	1,784	7,9%
Quarzglas	1,459	3,5%
	n (4200 nm)	
Si	3,424	29,9%
Ge	4,022	36,2%
ZnSe	2,195	14,0%
CaF_2	1,407	2,86%

Antireflection coatings consist of one or more dielectric layers. The kind of materials and thickness of layers used depend on the kind of substrate, wavelength range, properties of incident light and customer requirements.

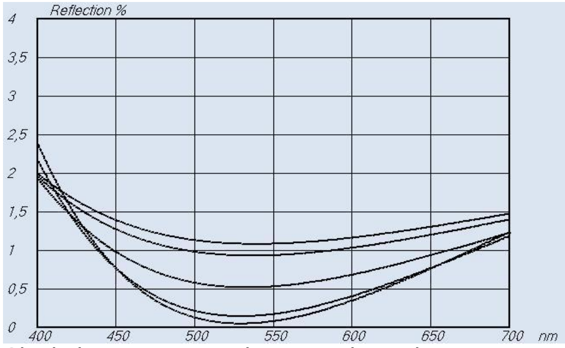
Basically there are two kinds of antireflection coatings: one wavelength and broadband (multi-wavelength). The first one (also called “V”-type) is strongly optimized for one wavelength and recommended for laser optics. The very special item of this kind is two-wavelength coating (e.g. YAG 532/1064 nm).

Technical specification – Antireflection coatings.		
Antireflection coating	Wavelength/Substrate	Typical rest reflection
Single-layer	MgF_2, UV, VIS or NIR optimized	
V-type AR coating (one wavelength optimized)	240 nm ÷ 450 nm on Quartz glass	R < 0,25 %
	450 nm ÷ 1200 nm on optical glass	R < 0,2 %
	900 nm ÷ 6000 nm on Si and Ge	R < 0,3 %
	10,6 µm on ZnSe	R < 0,2 %
Double V-type AR coating(two wavelengths optimized)	400 nm & 800 nm	R < 0,25 %
	532 nm & 1064 nm	R < 0,25 %
	780 nm & 1064 nm	R < 0,25 %
Broadband basic AR coating	300 nm ÷ 1500 nm on Quartz glass and optical glass with range λ1 - λ2 : λ2 = 1,5•λ1 (for example 440 nm ÷ 660 nm)	R (average) < 0,4 %
Broadband wide AR coating	450 ÷ 1500 nm on optical glass with range λ1 - λ2 : λ2 = 2•λ1 (for example 450 nm ÷ 900 nm)	R (average) < 0,5 %
Broadband very wide AR coating	500 nm ÷ 1100 nm on optical glass with range (500 nm ÷ 1100 nm)	R (average) < 0,6 %
Broadband AR coating on Si	3,0 µm ÷ 5,5 µm on Silicon	R (average) < 1,5 %

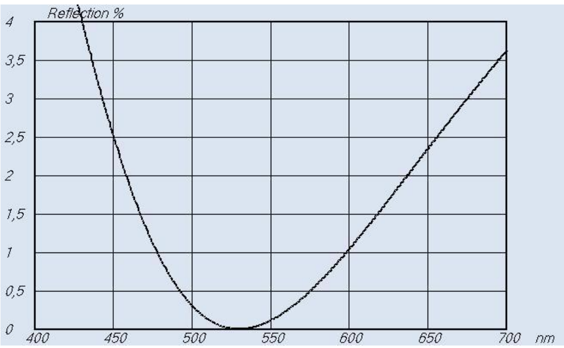
Examples of typical AR-coatings



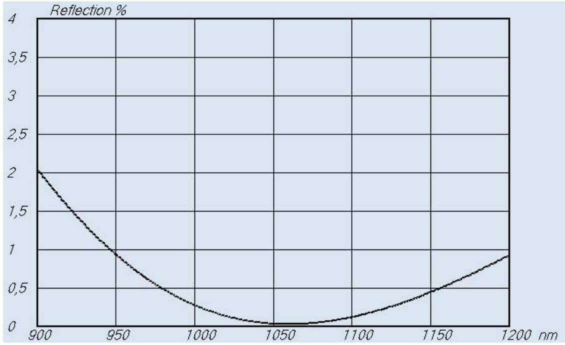
three layers AR coating on N-BK7 glass



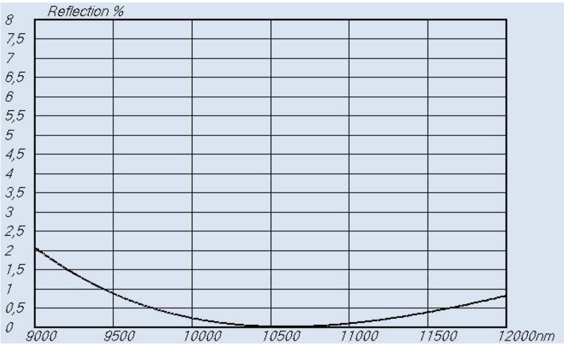
Single layer MgF_2 coating on various glasses



V-type AR coating for 532nm

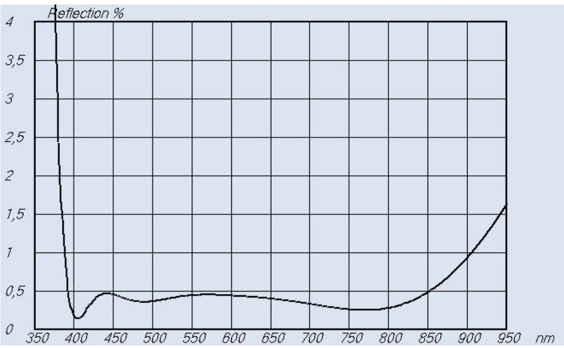


V-type AR coating for 1064nm

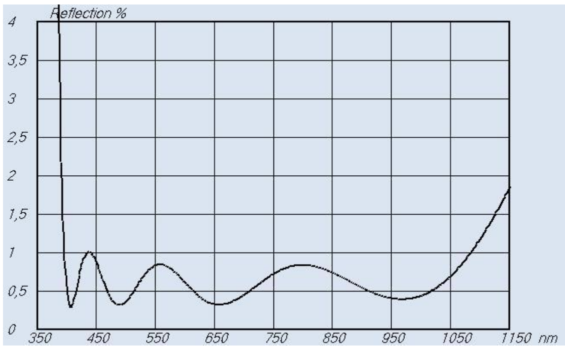


V-type AR coating for 10,6 µm

Double V-type AR coating for 532 nm and 1064nm



Broadband basic AR coating for VIS



Very wide AR coating for VIS and NIR