Coatings

Reflection and transmission properties of optical components can be selectively modified, enhanced or suppressed by applying specialized coatings to the optical surfaces. TYDEX offers a wide selection of optical coatings covering a wide spectral range starting from the deep ultraviolet (DUV, 193nm) and extending to far infrared (FIR, 20µm). TYDEX coatings are applied using resistant evaporation and electron beam (e-beam) deposition methods with machines such as the Balzers BAK-760 (Lichtenstein) and VU-1A (Belarus). Technology of electron beam deposition with ion cleaning of optical surface and ion assistance during the process at vacuum machine VU-2MI (Belarus) is also used.

I. ANTI-REFLECTION (AR) COATINGS

AR coatings increase the transmittance through an element by reducing the naturally occurring Fresnel reflection losses always present at any interface separating different indices of refraction. AR coatings are most often applied to lenses, windows, prisms, and rods. TYDEX supplies the following types of AR coatings: single layer MgF_2 coating, V-type single wavelength coating, broadband anti-reflection (BBAR) coating, dual- and triple-band coating, V-type infrared single wavelength coating, broadband infrared coating, and dual band infrared coating.

1. Single Layer MgF_2 Coating

Perhaps the simplest, most common and least expensive anti-reflective coating consists of a single layer of Magnesium Fluoride (MgF_2). Because MgF_2 has a very low refractive index (approx. 1.38 at 550 nm), it follows that a single "quarter-wave-thick" layer deposited upon typical optical glasses (with typical refractive indices ranging from 1.45 to 1.85) has attractive broad-band anti-reflective properties. The single layer MgF_2 coating will reduce a Fresnel reflection loss from typically 4% (uncoated) to less than 1% (coated). MgF_2 coatings can also be optimized for a specific wavelength. For example, in the case of a MgF_2 coating designed to reduce Fresnel reflections across the wide band of 400-700nm, the coating will usually show the least losses at the center wavelength 550nm. Naturally, if Fresnel losses need to be reduced down to the level of 0.5% or less, then the multi-layer coating options, described below, should be used.

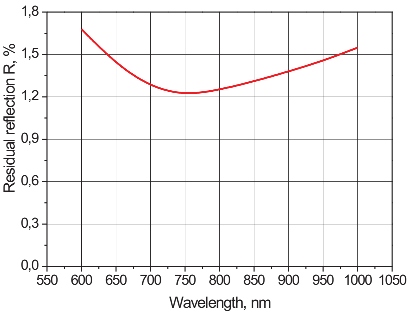

Fig. I-1 Single layer MgF2 AR coating at 600-1000 nm, AOI=0°.

Wavelength range, nm	Residual reflection per surface, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
400-700	<=2.0	0	2
600-1000	<=2.0	0	2

2. V-type Single Wavelength AR Coating

V-type AR multi-layer coatings generate extremely low Fresnel losses for a particular wavelength, usually generated by lasers. The designation "V" derives from the shape of the residual reflectance curve, which is characterized by a steep V-shape (as opposed to a single layer MgF_2, which looks more like a very shallow "U"). TYDEX' standard reflection loss per surface for a V-coating is less than 0.25%. Performance as good as <=0.1% per surface is available on request.

Wavelength range, nm	Standard residual reflection per surface, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
248	<0.25	0	2
266	<0.25	0	2
308	<0.25	0	3
337	<0.25	0	3
355	<0.25	0	3
488	<0.25	0	4
532	<0.25	0	4
633	<0.25	0	4
670	<0.25	0	4
780	<0.25	0	4
1064	<0.25	0	4
1310	<0.25	0	4
1550	<0.25	0	4
2100	<0.3	0	4

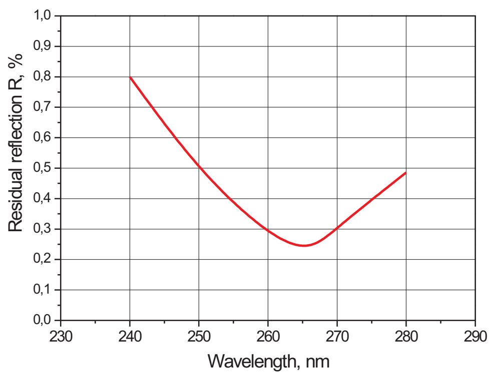

Fig. I-2-1 AR coating at 266 nm, AOI = 0°.

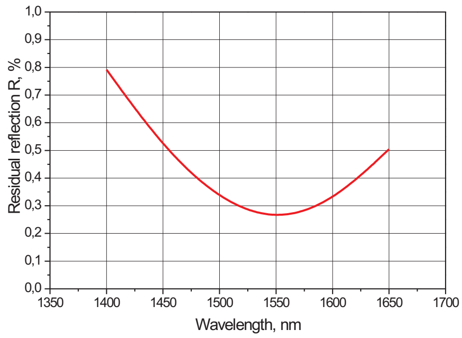

Figure I-2-2. AR coating at 1550 nm, AOI = 0°.

3. Broadband AR Coating

BBAR coating utilizes multiple layers usually consisting of alternating layers of two materials with different refractive indices, which provides much better performance over a wide wavelength range comparing to single layer AR coating.

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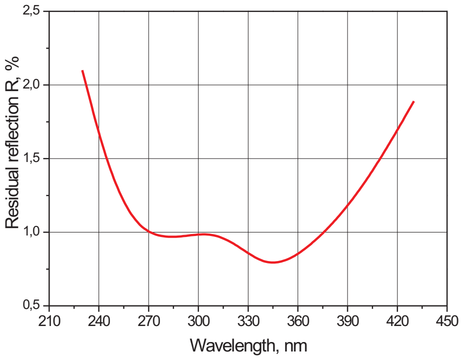

Fig. I-3-1 AR coating at 250-420 nm, AOI = 0°.

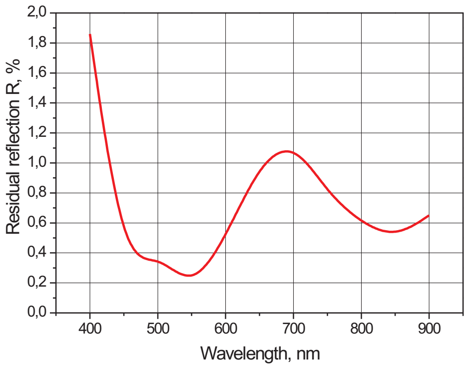

Fig. I-3-2 AR coating at 425-675 nm, AOI = 0°.

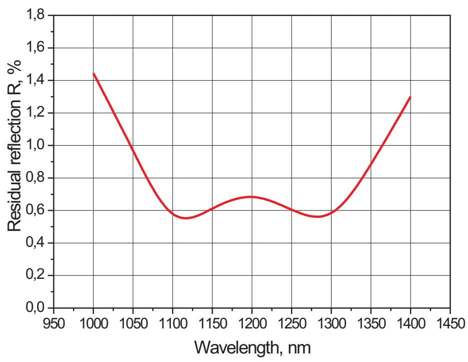

Fig. I-3-3.AR coating at 1000-1400 nm, AOI = 0°.

Wavelength range, nm	Average reflection per surface, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
250-420	<=1.4	0	2
425-675	<=0.45	0	3
400-700	<=0.5	0	3
400-900	<=1.0	0	3
600-900	<=0.5	0	4
700-1100	<=0.5	0	4
1000-1400	<=0.7	0	4
1500-1800	<=0.6	0	3

4. Dual- and triple-band AR Coating

Dual-band AR multi-layer coatings are required when an optical component has to simultaneously exhibit extremely high transmission at two different wavelengths.

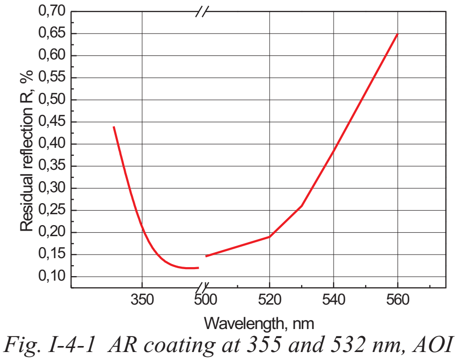

Fig. I-4-1 AR coating at 355 and 532 nm, AOI = 0°.

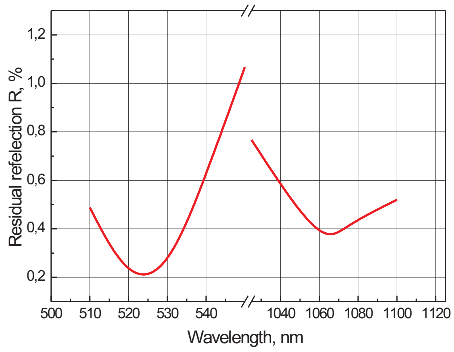

Fig. I-4-2 AR coating at 532 and 1064 nm, AOI = 0°.

Wavelength, nm	Maxl residual reflection, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
266 & 355	<=1.4	0	3
266 & 532	<=0.45	0	3
355 & 532	<=0.25 & <=0.5, respectively	0	4
400 & 800	<=0.5	0	4
532 & 1064	<=0.5	0	5
355 & 532 & 1064	<=0.5 at each wavelength	0	4

Similarly, triple-band AR coatings optimize an optic's transmission simultaneously at three different wavelengths. A common application is for YAG lasers where the fundamental wavelength, second harmonic, and third harmonic must all pass through the same optic with high efficiency.

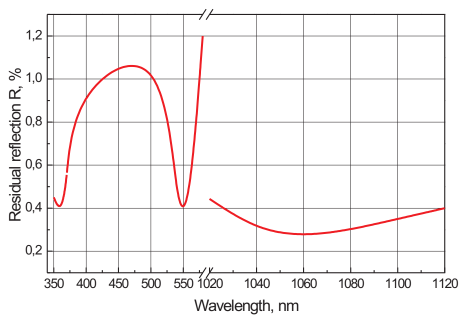

Fig. I-4-3. AR coating at 355, 532, and 1064 nm, AOI = 0°.

5. V-type infrared single wavelength AR coating

Although TYDEX can deliver single-wavelength AR coatings at nearly any infrared wavelength, the most requested wavelength is the 10.6μm CO_2 laser, the workhorse of the industrial laser industry. TYDEX offers low-loss performance, down to 0.25%, which is suitable for use in focusing lenses and windows used in relatively low-power industrial CO_2 lasers.

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Coatings

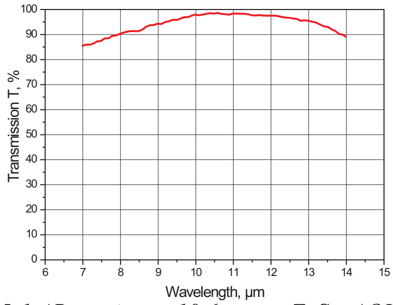

Fig. I-5-1 AR coating at 10.6 µm on ZnSe, AOI = 0°.

Wavelength, nm	Max. residual reflection, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
ZnSe/10.6	<=0.5	0	1
GaAs/10.6	<=0.5	0	No data

6. Broadband Infrared AR Coating

We offer a very wide range of broad-band coatings for infrared applications such as thermal imaging in the popular 3-5µm and 7-14µm bands, which can be deposited upon a very wide variety of substrates. TYDEX broad-band infrared AR coatings are also widely used in FTIR spectroscopy applications. Below mentioned transmission values are given for complete window with thickness 2.0 mm. Damage thresholds for these coatings are not listed below because the vast majority of applications do not involve high intensities.

Substrate/Wave-length range, µm	Average transmission for complete window, %	AOI, deg
ZnSe/3-12	>95	0
ZnSe/7-14	>97	0
Ge/7-14	>97	0
Ge/3-5 & 8-12	>96	0
Ge/2-20	>95	0
Si/2-6	>91	0
Si/3-5	>93	0

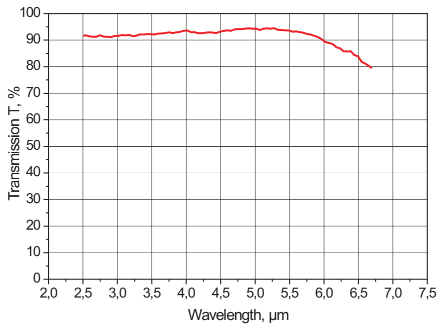

Fig. I-6-1 AR coating at 2-6 µm on Si, AOI = 0°.

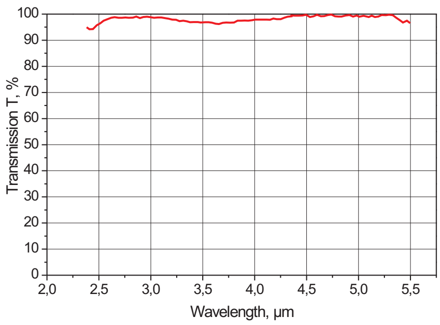

Fig. I-6-2 AR coating at 3-5 µm on ZnSe, AOI = 0°.

7. Dual Band Infrared AR Coating

Very common for industrial CO2 laser applications is the use of visible laser light traveling along the same optical path as the infrared beam, usually for beam aiming purposes. For this application and especially since the Fresnel losses from uncoated ZnSe are extremely high, a coating that is transmissive both for a visible laser and the CO2 laser is highly advantageous. TYDEX' standard coatings for this application are specified below.

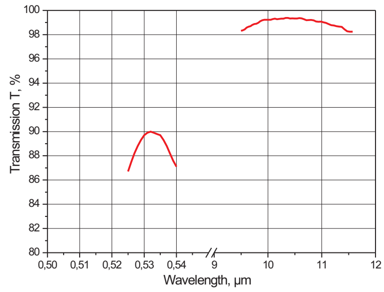

Fig. I-7-1 AR coating for 532 nm and 10.6 µm on ZnSe, AOI=0°.

Substrate/ Wavelengths, µm	Max. residual reflection, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
ZnSe/0.532 & 10.6	<0.5	0	1
ZnSe/0.633 & 10.6	<0.5	0	1

II. HIGH-REFLECTION (HR) DIELECTRIC MIRROR COATINGS

HR mirror coatings consist of layers of dielectric materials (i.e. not metals, which are used in mirrors for consumer goods) and are designed to achieve the highest possible reflectance, usually at specific wavelengths. Although engineered for best performance at normal (0) or 45 degrees angles-of-incidence, these coatings can be tailored for most any angle.

1. Laser Line HR Coating

This type of multilayer dielectric coatings is often employed in laser applications where low scattering is important. Typical reflectivity value for S-polarization is greater than 99.5% and P-polarization greater than 99%.

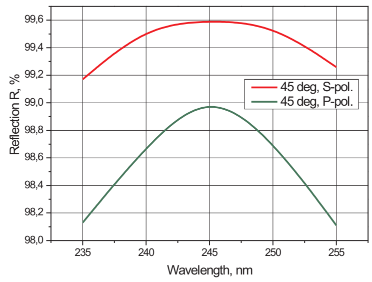

Fig. II-1-1 HR coating at 248 nm for S- and P-polarization, AOI=45°.

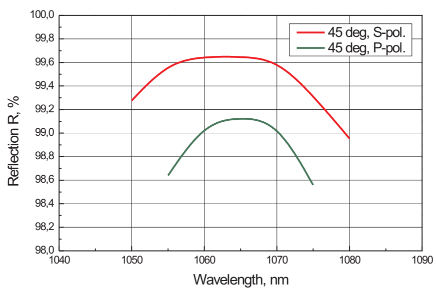

Fig. II-1-2 HR coating at 1064 nm for S- and P-polarization, AOI = 45°.

Wavelength nm	Reflection %	AOI, deg	Polarization	Damage threshold, J/cm2, 10 ns pulse
248	>=99.5	0,45	S	2
	>=99.0	45	P, UNP	
266	>=99.5	0,45	S	2
	>=99.0	45	P, UNP	
308	>=99.5	0, 45	S	2
	>=99.0	45	P, UNP	
337	>=99.5	0,45	S	2.5
	>=99.0	45	P, UNP	
355	>=99.5	0,45	S	2.5
	>=99.0	45	P, UNP	
532	>=99.5	0,45	S	3.5
	>=99.0	45	P, UNP	
633	>=99.5	0,45	S	4
	>=99.0	45	P, UNP	
1064	>=99.5	0,45	S	5
	>=99.0	45	P, UNP	
1550	>=99.5	0,45	S	3
	>=99.0	45	P, UNP	
2100	>=99.0	0,45	S	2.5
	>=98.5	45	P, UNP	
10600	>=99.0	0	S, P, UNP	1 kW/cm^2, CW mode

UNP = unpolarized

2. Dual-wavelength HR Coating

We have achieved considerable success in making dual-wavelength high-reflectors. Because YAG laser technology is very advanced in Russia, we are able to deliver very impressive YAG (and related) optics. TYDEX dual-band mirrors for 1064nm and 532nm have proven to be just as good as those produced at the top US and European companies, at considerably lower cost. This impressive performance is achieved using highly resourceful Tydex coating engineers who have pushed e-beam technology to its limits.

Wavelength, nm	Min reflection, %	AOI, deg	Polari-zation	Damage threshold, J/cm^2, 10 ns pulse
355 & 532	>=99.0 and >=99.5 respectively	0	any	3
532 & 1064	>=99.5 at each wavelength	0	any	4

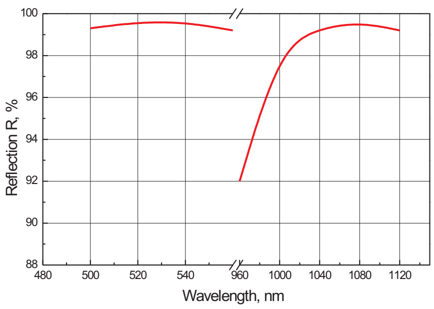

Fig. II-2-1 Reflectivity vs. wavelength for HR coating R>99.0% at 355 nm and R>99.5% at 532 nm, AOI=0 °.

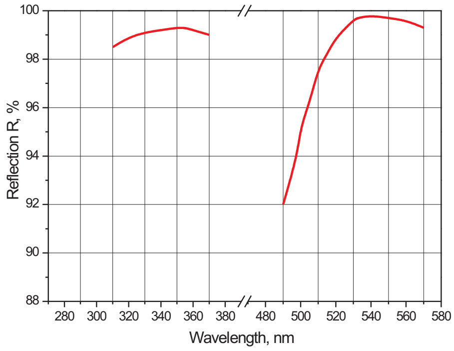

Fig. II-2-2 Reflectivity vs. wavelength for HR (R>99.5%) coating at 532 nm and 1064 nm, AOI = 0°.

3. Broadband HR coatings

Although broadband HR coatings can be metallic or dielectric, the dielectric versions are specified here. See section VI for metallic coatings.

Wavelength range, nm	Average reflection, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
260-340	>=99.0	0,45	2
350-450	>=99.0	0,45	2
700-900	>=99.0	0,45	4
900-1100	>=99.0	0,45	4

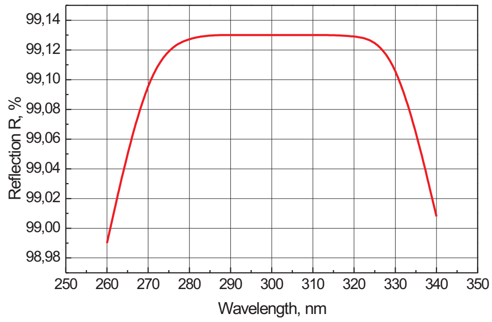

Fig. II-3-1 HR coating at 260-340 nm, AOI = 0°.

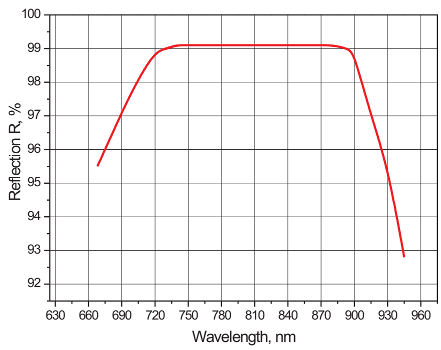

Fig. II-3-2 HR coating at 700-900 nm, AOI = 0°.

III. PARTIAL REFLECTING (PR) DIELECTRIC COATINGS

These multilayer dielectric coatings perform specialized beam-splitting functions. Probably the most demanding application is in laser cavity output couplers.

1. Laser line PR coatings

The PR coatings on a laser cavity output coupling mirrors allow the maximum amount of laser light to escape the laser cavity while simultaneously retaining enough light inside the laser cavity to sustain lasing.

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One of the critical aspects of the PR coating is the precision allowable tolerance on the PR splitting ratio. For example, an engineer may design a laser cavity requiring an output coupler with a 40% transmission and 60% reflection. However, the coating can be fabricated with a standard manufacturing tolerance of ±4%. That means that the delivered production parts may have a PR splitting ratio ranging from 36%T/64%R to 44%T/56%R. The standard tolerances listed in the table below can be tightened-up, of course, at extra cost.

Standard reflectance at chosen wavelength:

10% ±2%	40% ±4%	80% ±3%	99% ±0.5%
15% ±2%	50% ±5%	90% ±3%	
20% ±3%	60% ±4%	95% ±2%	
30% ±3%	70% ±4%	98% ±1%	

Wavelength, nm	AOI, deg	Damage threshold, J/cm^2,10 ns pulse
248	0, 45	2
266	0, 45	2
308	0, 45	2
337	0, 45	2.5
355	0, 45	2.5
532	0, 45	3.5
633	0, 45	4
1064	0, 45	5
1550	0, 45	3
10600	0	1 kW/cm^2, CW mode

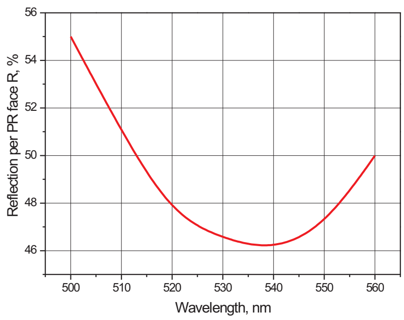

Fig. III-1-1 PR coating R=(50 ±5)% at 532 nm, AOI = 0°.

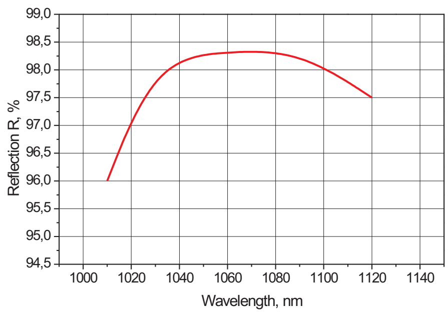

Fig III-1-2 PR coating R=(98 ±1)% at 1064 nm, AOI = 0°.

2. Broadband partial reflective coatings

Similarly, PR coatings are available for broad-band applications. A typical application is a beam-splitter used in visible imaging systems, where the light from an image may be split 70/30, with 70% of the light going to the viewer's eye, and the remaining 30% going to a video camera.

Wavelength range, nm	Absolute reflection, %	AOI, deg	Damage threshold, J/cm2, 10 ns pulse
470-520	70 ±4	0, 45	3.5
700-900	92 ±4	0, 45	4.5
1500-1800	80 ±4	0, 45	3

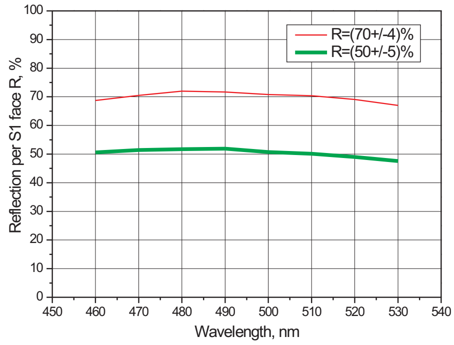

Figure III-2-1. PR coating at 470-520 nm for S- and P-polarization, AOI=45°.

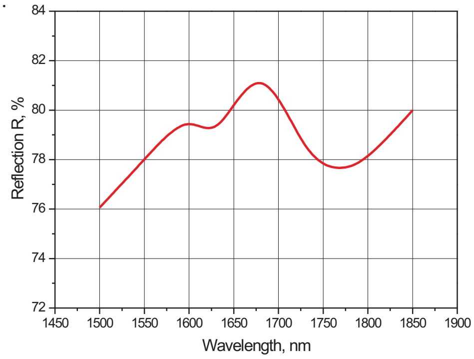

Figure III-2-2 PR coating R=(80 +/-4)% at 1500-1800 nm, AOI = 0°.

IV. WAVELENGTH SEPARATING/COMBINING COATINGS

Very often it is necessary to separate a laser's harmonics from its fundamental wavelength, or to combine dissimilar wavelengths so that they will travel along the same optical path. These specialized functions are performed using engineered multi-layer coatings, resulting in optical elements called beam separators and beam combiners, respectively.

Wavelength R/T, nm	Minimal reflection, %	Minimal transmission, %	AOI, deg	Damage threshold, J/cm^2, 10 ns pulse
532/1064	99	93	0, 45	3
355/532 & 1064	99	90 and 92, respectively	0, 45	3
800/400	99	90	0, 45	3
1064/808	99	93	0, 45	3

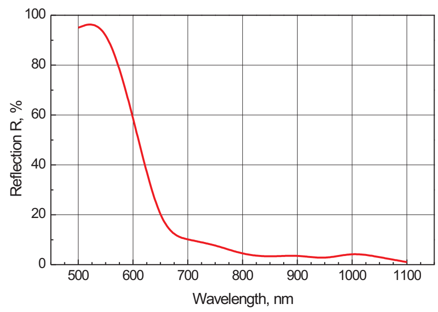

Figure IV-1. HR coating at 532 nm and HT coating at 1064 nm, AOI = 45°, unpolarized radiation.

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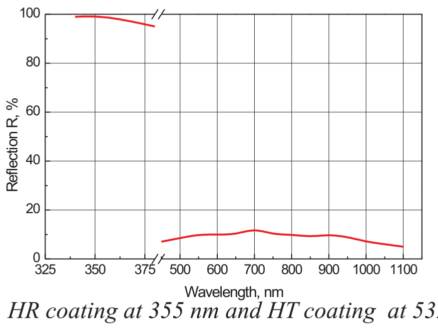

Figure IV-2. HR coating at 355 nm and HT coating at 532 and 1064 nm, AOI = 0°.

V. HOT/COLD MIRRORS

So-called "hot" mirrors will reflect infrared light while transmitting visible light. Visa versa, a "cold" mirror reflects visible light while transmitting infrared. Hot or cold mirrors are often employed in projection systems to reduce the heat of the visible beam.

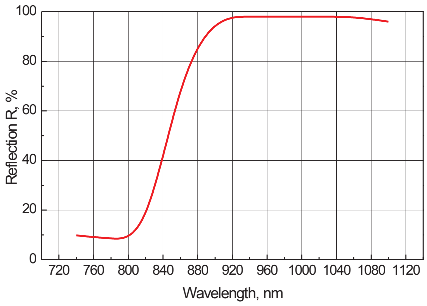

Figure V-1. HT coating at 740-820 nm and HR coating at 900-1100 nm, AOI = 0°.

Type	Wavelength R/T, nm	Average reflection, %	Average transmission, %	AOI, deg	Damage threshold, J/cm^2,10 ns pulse
Hot	900-1100/ 740-820	98	90	0, 45	3
Hot	700-1050/ 400-630	98	85	0, 45	3
Cold	420-650/ 750-1130	98	85	0, 45	3

VI. METALLIC COATINGS

Metallic coatings are used in applications requiring a high degree of reflection over a very wide wavelength range. The reflectivity of metallic coatings varies less as a function of the beam's polarization and angle of incidence than that does for dielectric coatings, but metallic coatings tend to be more lossy.

Aluminum coatings are widely used because of that metal's excellent reflectance over practically the entire optical spectrum, including from UV out to infrared. In addition, Aluminum is the only metal used in DUV mirror coatings.

1. Protected Aluminum coating

The Aluminum is overcoated with a single additional dielectric layer that protects the delicate metal layer from oxidation and scratches.

Wavelength range, μm	Average reflection, %	Damage threshold, J/cm^2, 50 ns pulse
0.2-5	>90	1

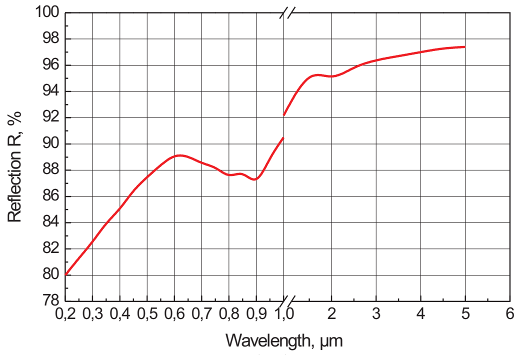

Figure VI-1. Protected Al coating at 0.2-5 μm

2. Enhanced Aluminum coating

The Aluminum is overcoated with multiple dielectric layers, boosting the reflectivity of the metallic coating within a desired wavelength sub-range.

Type	Wavelength range, nm	Average reflection, %	Damage threshold, J/cm^2, 50 ns pulse
UV enhanced	250-600	>85	1
VIS enhanced	400-700	>92	1

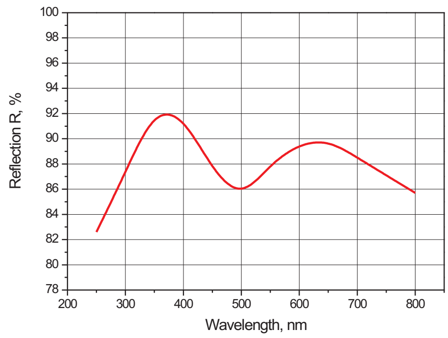

Figure VI-2-1. UV enhanced Al coating.

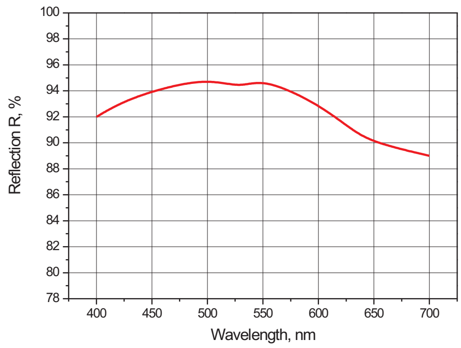

Figure VI-2-2. VIS enhanced Al coating.

Silver is preferred for visible to near-infrared wavelengths. Silver coatings show a higher damage threshold than Aluminum coatings. Silver is also routinely protected and/or enhanced by the addition of dielectric layers.

3. Protected Silver coating

Wavelength range, μm	Average reflection, %	Damage threshold, J/cm^2, 50 ns pulse
0.4-10	>95	2-3
0.532 & 0.633 and 10.6	>97 at 0.4-0.7 >= 99.0 at 10.6	2-3

Coatings

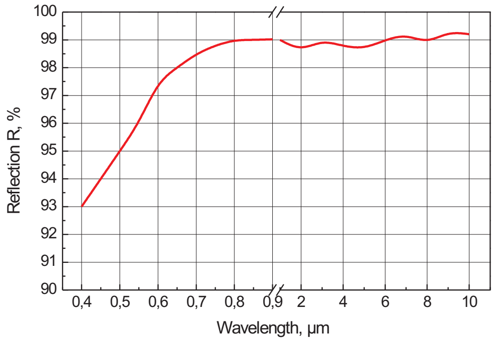

Figure VI-3. Protected Ag coating at 0.4-10 µm.

4. Enhanced Silver coating

Type	Wavelength range, nm	Average reflection, %	Damage threshold, J/cm^2, 50 ns pulse
VIS enhanced	400-700	>97	2-3
NIR enhanced	700-900	>97	2-3

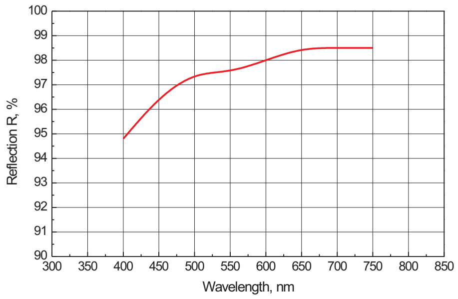

Figure VI-4-1. Enhanced Ag coating at 400-700 nm.

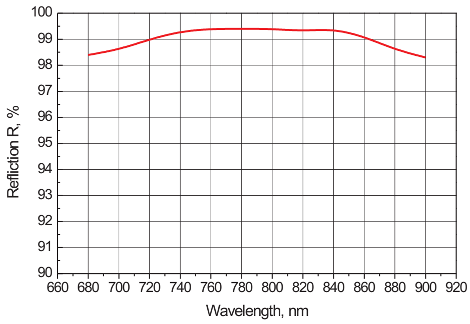

Figure VI-4-2. Enhanced Ag coating at 700-900 nm.

Gold coatings are used primarily for near-, mid- and far-infrared wavelengths. Gold starts to have attractive reflective properties at around 600nm and above.

5. Bare Gold coating

Bare gold is soft and very easily scratched, but the absence of protective layers eliminates it unwanted interference effects which can be detrimental to spectroscopic instruments operating over a very wide wavelength range. Like Aluminum and Silver, Gold is also routinely protected and/or enhanced by the addition of dielectric layers. Note however that a bare gold coating has a slightly better average reflectivity than a protected gold coating.

Wavelength range, µm	Average reflection, %	Damage threshold, J/cm^2, 50 ns pulse
0.6-10	>98	2-3

6. Protected Gold coating

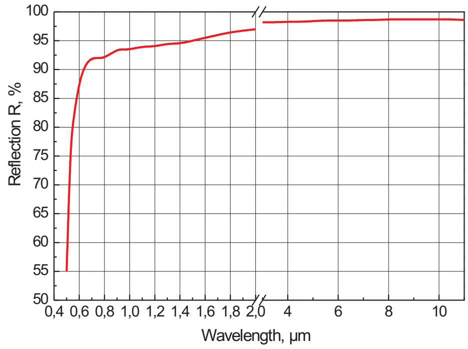

Figure VI-6. Protected Gold coating.

7. Enhanced Gold Coating

Wavelength range, µm	Average reflection, %	Damage threshold
0.532&0.633 and 10.6	>70 at 0.532 >85 at 0.633 >=99.2 at 10.6	1 J/cm^2, 10 ns pulse 1 J/cm^2, 10 ns pulse 2 kW/cm^2, CW mode

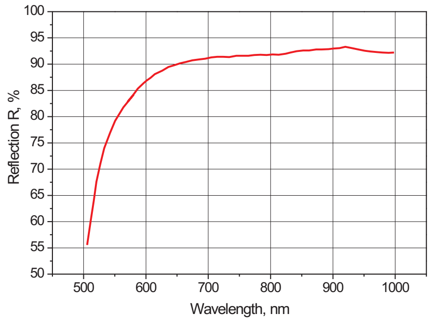

Figure VI-7-1. Enhanced Gold coating at 532 nm.

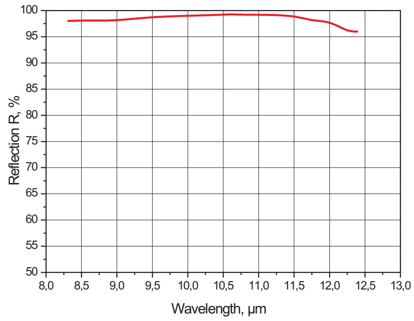

Figure VI-7-2. Enhanced Gold coating at 10.6 µm.

The following plot summarizes the performance of the different types of metallic coatings that have been discussed above.

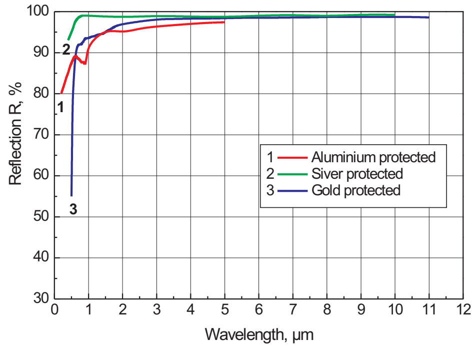

Figure VI-7-3. Comparative figure for metallic coatings.

VII. HARD CARBON COATING (DLC: "DIAMOND-LIKE COATING")

DLC is perhaps the world's most rugged optical coating, offering uncanny resistance to abrasion, salts, acids, alkalis, and oil. Most commonly applied to Silicon and Germanium windows deployed on military vehicles and outdoor thermal cameras, DLC protects the outer optical surfaces from high velocity airborne particles, seawater, engine fuel and oils, high humidity, improper handling, etc. A single layer of hard carbon, deposited using highly specialized coating methods, offers an attractive combination of highly protective properties coupled with good anti-reflective performance. DLC adheres extremely well to Germanium and Silicon.

Throughout the infrared wavelength region in which it is employed, DLC exhibits moderate absorption and scattering. With a refractive index of approximately 2.0, DLC delivers good BBAR performance on both Ge and Si. DLC, because it consists of a single layer, is optimized for a specific wavelength region (most commonly the 3-5µm and 8-14µm bands) by adjusting the layer thickness during the coating process.

Table VII-1 Transmission of Silicon window (thickness 2mm). Side 1: standard BBAR infrared coating optimized for lowest reflective loss at 3-5µm. Side 2: DLC layer also optimized at 3-5µm.

Wavelength µm	Transmission %	Wavelength µm	Transmission %	Wavelength µm	Transmission %
3.00	87,07	3.68	96,29	4.36	96,70
3.04	88,06	3.72	96,52	4.40	96,65
3.08	88,81	3.76	96,70	4.44	96,59
3.12	89,41	3.80	96,84	4.48	96,52
3.16	89,94	3.84	96,94	4.52	96,45
3.20	90,46	3.88	97,00	4.56	96,36
3.24	90,98	3.92	97,03	4.60	96,25
3.28	91,52	3.96	97,04	4.64	96,12
3.32	92,08	4.00	97,03	4.68	95,97
3.36	92,64	4.04	97,01	4.72	95,80
3.40	93,21	4.08	96,98	4.76	95,60
3.44	93,77	4.12	96,94	4.80	95,37
3.48	94,30	4.16	96,90	4.84	95,11
3.52	94,80	4.20	96,87	4.88	94,82
3.56	95,25	4.24	96,82	4.92	94,50
3.60	95,65	4.28	96,78	4.96	94,15
3.64	96,00	4.32	96,74	5.00	93,76

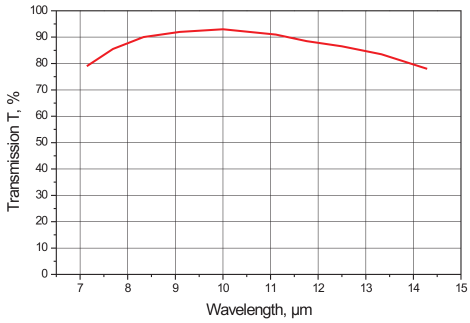

Figure VII-1. DLC+BBAR coating at Ge window 2 mm.

DLC CHARACTERISTICS

Chemical properties	
Composition	Carbon, hydrogen
Structure	Mixture of sp3 (tetrahedral diamond type) and sp2 (trigonal graphitic) and amorphous carbon
Reactivity	Generally inert to acids, alkalis, solvents, salts, water, and other reagents at ambient temperature

Physical properties	
Density	1.8-2.1 g/cm3
Thermal conductivity	10 W/cm × K
Thermal expansion coefficient	9×10^{-6}/°C
Electrical resistance	Several MOhm × cm
Dielectric constant	About 4-11
Adhesion	> 5000 psi std. pull strength
Permeability	Barrier to hydrogen and other gases
Optical properties	
Optical transparency	From NIR to FIR (see table VII-2)
Refractive index	1.85 - 2.0 (see table VII-2)
Layer thickness	Depends on operating wavelength (e.g. at 10.6 µm DLC layer thickness is 1.4 µm)
Surface roughness	Depends on chosen substrate
Stresses	Not measurable
Other properties	
Deposition temperature	10° C approximately
Operating temperature range	-60° C to +400° C
Biocompatibility	Maintains cell integrity, no inflammatory response
Durability performance	Resistant to adhesions, severe abrasion and mechanical strikes, high humidity, high and low temperature influence, thermal shock, salt spray fog, salt solubility, water solubility and resistance to atmospheric precipitation, dust and sand impact, resistance to some acids, resistance to oil and diesel fuel as per the following standards (where applicable): MIL-C-675C, MIL-STD-810

Table VII-2. DLC refractive index and absorption coefficient vs wavelength.

Wavelength, µm	Refractive index, n	Coefficient of absorption, α, cm^{-1}
0.4	2.05	0.28
0.5	2.04	0.22
0.6	2.02	0.14
0.7	2.01	0.08
0.8	2.0	0.04
0.9	1.99	0.03
1.0	1.98	0.027
1.1	1.97	0.026
1.2	1.965	0.025
2.0	1.95	0.025
3.0	1.945	0.025
4.0	1.943	0.025
5.0	1.941	0.025
6.0	1.94	0.025
7.0	1.938	0.025
8.0	1.935	0.024
9.0	1.933	0.024
10.0	1.931	0.024
11.0	1.93	0.023
12.0	1.93	0.023
13.0	1.93	0.023
14.0	1.93	0.023

Please note as a rule we do not offer coating service only but together with optical components produced at our facility. So please ask for the coated components you need.

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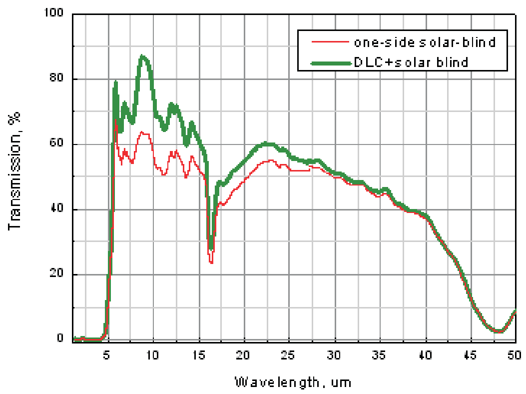
VIII. SOLAR-BLIND COATING

As a fusion of last R&D works Tydex offers complicated coating which allows to transmitt effectively infrared radiation over very wide range and simultaneously to eliminate solar shortwave emission. It is so called solar-blind coating.

The cut-off wavelength is controlled with high accuracy.

Tydex offers this coating deposited on Si substrates. Special grade of the used silicon allows to minimize absorption at working wavelength range.

Depending on the application we introduce items with one-side solar-blind coating (fig. 1) as well as with DLC applied ouside (fig. 2).



Specification

Coating sandwich	**Wavelength range 6-15 µm**	**Wavelength range 18-40 µm**
DLC+Si substrate +solar_blind	Taverage>=70% Tpeak= 85-90% Tmin= 60%	Taverage>=50% Tpeak= 55-60% Tmin= 35-40%
Si substrate +solar_blind (without DLC)	Taverage>=55% Tpeak= 60-70% Tmin= 50%	Taverage>=45% Tpeak= 50-55% Tmin= 35-40%
Additional specification to both coating sandwiches		
Working temperature range	-40 deg. C… +80 deg. C	
Humidity	Relatively high, up to 90-95%	
Cut-off wavelength (to be specified additionally)	4.5 +/- 0.3 µm	
T peak (not more than 2 peaks) at the range before cut-off	<=0.4% (in the range 1-4.5 µm)	
The range where transmission exceeds 20%	Up to 45 µm	

Similar solar-blind coatings are widely used in pyrgeometers (devices for measuring an effective atmospheric infrared radiation spectrum that extends approximately from 4.5um to 100um).

Tydex optics with solar-blind coating were suscesfully tested and certified in the Physical-Meteorological Observatory at Davos (Switzerland).