Technical Note:
Optical Materials

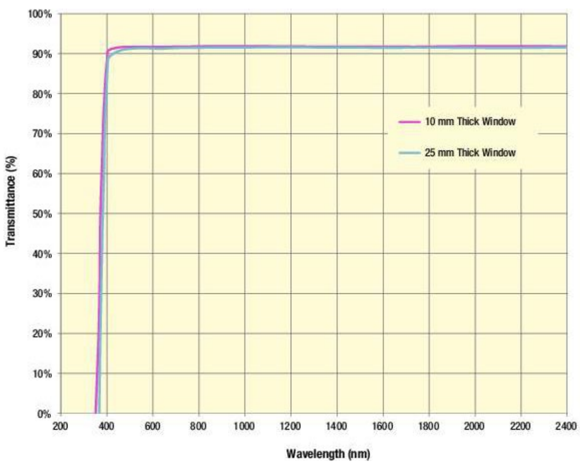
Newport offers a wide variety of spherical and aspherical lenses made from BK 7, UV grade fused silica, Infrared grade Calcium Fluoride (CaF_2), Magnesium Fluoride (MgF_2), AMTR and Zinc Selenide materials. For applications in the visible and infrared up to about 2.1 µm, BK 7 offers excellent performance at a good value. In the ultraviolet down to 195 nm, UV fused silica is a good choice. UV fused silica also has excellent transmission in the visible and infrared up to about 2.1 µm, better homogeneity, and a lower coefficient of thermal expansion than BK 7. CaF_2 and MgF_2 are excellent choices for deep UV or infrared applications—for custom applications, Newport can provide quotes on a build-to-print basis.

For common optical materials, this technical note offers specifications for important basic parameters such as index of refraction, transmission across various wavelength ranges, reflectance, Abbe Number, coefficient of thermal expansion, conductivity, heat capacity, density, Knoop hardness, and Young's modulus.

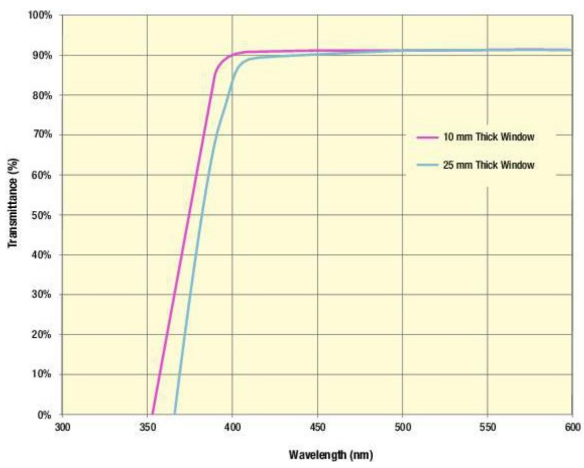
Also see Optical Material Properties, for additional information.

BK 7

BK 7 is one of the most common borosilicate crown glasses used for visible and near infrared optics. Its high homogeneity, low bubble and inclusion content, and straightforward manufacturability make it a good choice for transmissive optics. BK7 is also relatively hard and shows good scratch resistance. The transmission range for BK 7 is 380–2100 nm. It is not recommended for temperature sensitive applications, such as precision mirrors.



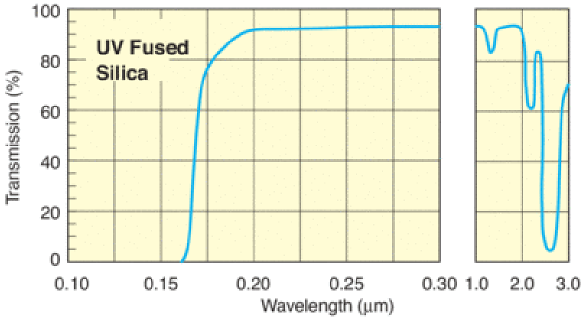
N-BK7 transmittance (%) vs. wavelength (nm) with 4% reflection from both sides



N-BK7 transmittance (%) in the UV vs. wavelength (nm) with 4% reflection from both sides

UV Grade Fused Silica

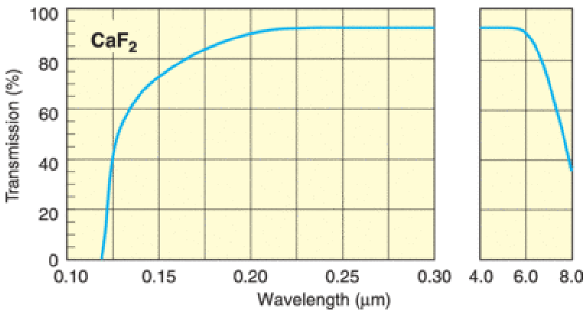
UV Grade Fused Silica is synthetic amorphous silicon dioxide of extremely high purity. This non-crystalline, colorless silica glass combines a very low thermal expansion coefficient with good optical qualities, and excellent transmittance in the ultraviolet region down to 195 nm. Transmission and homogeneity exceed those of crystalline quartz without the problems of orientation and temperature instability inherent in the crystalline form. Fused silica is ideally used with high-energy lasers due to its high energy damage threshold. UV fused silica also has excellent transmission in the visible and infrared region up to approximately 2.1 µm, and a low content of inclusions with high refractive index homogeneity. Fused silica is used for both transmissive and reflective optics, especially where high laser damage threshold is required.



CaF_2

Calcium Fluoride is a cubic single crystal material grown using the vacuum Stockbarger Technique with good vacuum UV to infrared transmission. CaF_2 has a wide spectral range and is an excellent choice for deep UV to infrared applications because of its non-birefringent properties. CaF_2 has a transmission above 90% between 0.25 and 7µm, and is commonly used for excimer laser optics due to its low absorption and high damage threshold. Material for IR use is grown using naturally mined fluorite, at much lower cost. CaF_2 has very poor thermal properties with its high coefficient of thermal expansion, and should be avoided in high operating temperature environment. Calcium fluoride can be used without an Anti-Reflection coating due to its low index of refraction.

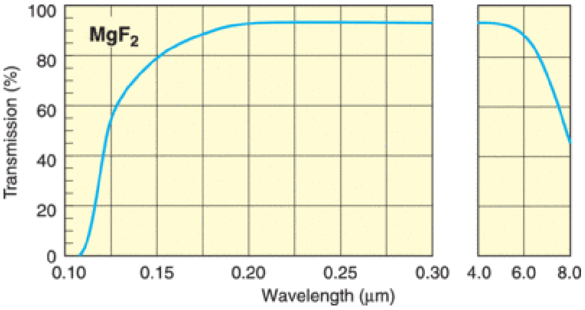
Note that this material is mildly hydroscopic. If used under normal operating conditions, no pitting is expected. However, it is not recommended for water immersion applications.



MgF_2

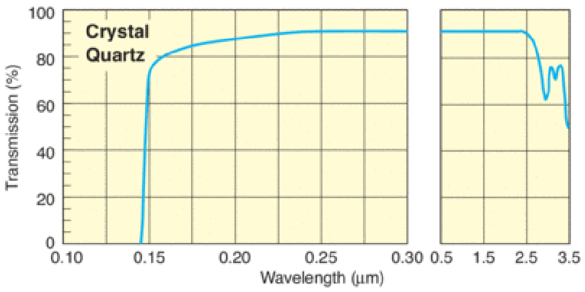
Magnesium Fluoride is a positive birefringent crystal grown using the vacuum Stockbarger Technique with good vacuum UV to infrared transmission. It is typically oriented with the c axis parallel to the optical axis to reduce birefringent effects. MgF_2 is another excellent choice for deep UV to infrared regions, with good transmission range from 0.15 µm to 6.5 µm, and its proven use in fluorine environments make it ideal for lenses, windows, and polarizers for Excimer lasers. MgF_2 is resistant to the thermal and mechanical shock, and has higher energy damage threshold. MgF_2 is one of the lowest index infrared materials, which usually doesn’t require anti-reflection coating. MgF_2 is extremely durable compared to other materials which are transparent from the UV to the IR spectrum. MgF_2 is an ideal choice for many biological and military imaging applications that require wide broadband laser pulses.

Note that this material is mildly hydroscopic. If used under normal operating conditions, no pitting is expected. However, it is not recommended for water immersion applications.



Crystal Quartz

Crystal Quartz is a positive uniaxial birefringent single crystal grown using a hydrothermal process. It has good transmission from the vacuum UV to the near infrared. Due to its birefringent nature, crystal quartz is commonly used for wave plates.



Borofloat®

Borofloat® is a borosilicate glass with a low coefficient of thermal expansion. It is mainly used for non-transmissive optics, such as mirrors, due to its low homogeneity and high bubble content.

Zerodur®

Zerodur® is a glass ceramic material that has a coefficient of thermal expansion approaching zero, as well as excellent homogeneity of this coefficient throughout the entire piece. This makes Zerodur ideal for mirror substrates where extreme thermal stability is required. Zerodur should not be used for transmissive optics due to inclusions in the material.

ZnSe

Zinc selenide is a chemically vapor deposited material commonly used in thermal imaging and medical systems. ZnSe is an excellent choice for IR lens with its broad wavelength range (600nm- 16 µm). ZnSe has a high index of refraction which normally requires an anti-reflection coating to achieve high transmission. ZnSe is relatively soft with low scratch resistance thus not recommended for use in harsh environment. Extra caution is required during cleaning, handling, and mounting. ZnSe is the best choice for optics used in high power CO_2 laser systems due to its low absorption coefficient and high resistance to thermal shock

Properties of Optical Materials

Material	Abbe Number v_d	Coefficient of Thermal Expansion (10-6/°C)	Conductivity (W/m°C)	Heat Capacity (J/gm°C)	Density at 25°C (gm/cm3)	Knoop Hardness (kg/mm2)	Young's Modulus (GPa)
BK 7	64.17	7.1	1.114	0.858	2.51	610	81.5
SF 2	33.85	8.4	0.735	0.498	3.86	410	55

UV Fused Silica	67.8	0.52	1.38	0.75	2.202	600	73
CaF_2	94.96	18.85	9.71	0.85	3.18	158	75.8
MgF_2	106.18	13.7 || to c axis 8.48 ⊥ to c axis	21 || to c axis 30 to ⊥ c axis	1.024	3.177	415	138.5
Crystal Quartz	69.87	7.1 to || c axis 13.2 ⊥ to c axis	10.4 || to c axis 6.2 ⊥ to c axis	0.74	2.649	740	97 || to c axis 76.5 ⊥ to c axis
Borofloat®	65.41	3.25	1.2	0.83	2.2	480	64
Zerodur®	56.09	0 ± 0.1	1.46	0.80	2.53	620	90.3
ZnSe	84.45	7.6	18.0	0.399	5.27	105	70

Common Optical Material Properties

Material	Transmission Range	Cost	Features
BK 7	380–2100 nm	Low	High transmission for visible to near infrared applications, the most common optical glass
UV Fused Silica (UVFS)	195–2100 nm	Moderate	Excellent homogeneity and low thermal expansion, high laser damage resistance
CaF_2	170–8000 nm	High	High transmission for deep UV to infrared applications
MgF_2	150–6500 nm	High	Birefringent material, excellent for use in the deep UV to infrared
ZnSe	600–16000 nm	High	Excellent choice for IR lens due to its broad wavelength range. Perfect candidate to use with high power infrared laser due to its low absorption coefficient.

Index of Refraction

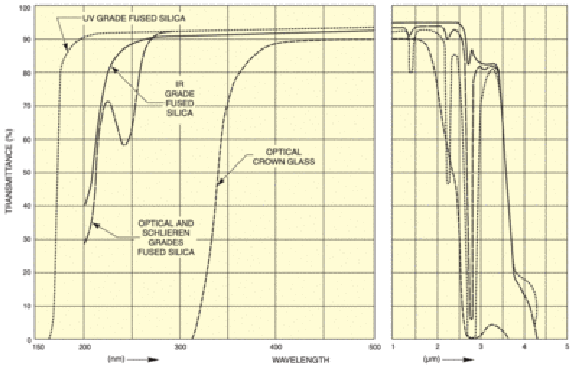
Wavelength (nm)	Source	BK 7	SF 2	UV Fused Silica	CaF_2	MgF_2 n_o	MgF_2 n_e	Crystal Quartz n_o	Crystal Quartz n_e
193	ArF excimer laser	1.65528	1.52127	1.56077	1.50153	1.42767	1.44127	1.66091	1.67455
244	Ar-Ion laser	1.58265	1.98102	1.51086	1.46957	1.40447	1.41735	1.60439	1.61562
248	KrF excimer	1.57957	1.93639	1.50855	1.46803	1.40334	1.41618	1.60175	1.61289
257	Ar-Ion laser	1.57336	1.86967	1.50383	1.46488	1.40102	1.41377	1.59637	1.60731
266	Nd:YAG laser	1.56796	1.82737	1.49968	1.46209	1.39896	1.41164	1.59164	1.60242
308	XeCl excimer laser	1.55006	1.73604	1.48564	1.45255	1.39188	1.40429	1.57556	1.58577
325	HeCd laser	1.54505	1.71771	1.48164	1.44981	1.38983	1.40216	1.57097	1.58102
337.1	N_2 laser	1.54202	1.70749	1.47919	1.44813	1.38858	1.40085	1.56817	1.57812
351	XeF excimer laser	1.53896	1.69778	1.47672	1.44642	1.38730	1.39952	1.56533	1.57518
351.1	Ar-Ion laser	1.53894	1.69771	1.47671	1.44641	1.38729	1.39951	1.56531	1.57516
354.7	Nd:YAG laser	1.53821	1.69548	1.47612	1.44601	1.38699	1.39920	1.56463	1.57446
	Ar-Ion								

363.8	laser	1.53649	1.69029	1.47472	1.44504	1.38626	1.39844	1.56302	1.57279
404.7	Mercury arc, h line	1.53023	1.67263	1.46961	1.44151	1.38360	1.39567	1.55714	1.56670
416	Kr-Ion laser	1.52885	1.66893	1.46847	1.44072	1.38301	1.39505	1.55583	1.56535
435.8	Mercury arc,g line	1.52669	1.66331	1.46670	1.43949	1.38207	1.39408	1.55379	1.56323
441.6	HeCd laser	1.52611	1.66184	1.46622	1.43916	1.38183	1.39382	1.55324	1.56266
457.9	Ar-Ion laser	1.52461	1.65807	1.46498	1.43830	1.38118	1.39314	1.55181	1.56119
465.8	Ar-Ion laser	1.52395	1.65641	1.46443	1.43792	1.38088	1.39284	1.55118	1.56053
472.7	Ar-Ion laser	1.52339	1.65505	1.46397	1.43760	1.38064	1.39258	1.55065	1.55998
476.5	Ar-Ion laser	1.52309	1.65432	1.46372	1.43744	1.38051	1.39245	1.55036	1.55969
480	Cadmium arc, F’ line	1.52283	1.65367	1.46350	1.43728	1.38040	1.39233	1.55011	1.55943
486.1	Hydrogen arc, F line	1.52238	1.65258	1.46313	1.43703	1.38020	1.39212	1.54968	1.55898
488	Ar-Ion laser	1.52224	1.65225	1.46301	1.43695	1.38014	1.39206	1.54955	1.55885
496.5	Ar-Ion laser	1.52165	1.65083	1.46252	1.43661	1.37988	1.39179	1.54898	1.55826
501.7	Ar-Ion laser	1.52130	1.65000	1.46223	1.43641	1.37973	1.39163	1.54865	1.55792
510.6	Cu vapor laser	1.52073	1.64865	1.46176	1.43609	1.37948	1.39137	1.54810	1.55735
514.5	Ar-Ion laser	1.52049	1.64808	1.46156	1.43595	1.37937	1.39126	1.54787	1.55711
532	Nd:YAG laser	1.51947	1.64570	1.46071	1.43537	1.37892	1.39079	1.54689	1.55610
543.5	HeNe laser	1.51886	1.64427	1.46019	1.43502	1.37865	1.39051	1.54630	1.55549
546.1	Mercury arc, e line	1.51872	1.64397	1.46008	1.43494	1.37859	1.39044	1.54617	1.55535
578.2	Cu vaport laser	1.51720	1.64053	1.45880	1.43408	1.37792	1.38974	1.54470	1.55383
587.6	Helium arc, d line	1.51680	1.63963	1.45846	1.43385	1.37774	1.38956	1.54431	1.55343
589.3	Sodium arc, D line	1.51673	1.63947	1.45840	1.43381	1.37771	1.38952	1.54424	1.55336
594.1	HeNe laser	1.51653	1.63904	1.45824	1.43370	1.37762	1.38943	1.54405	1.55316
611.9	HeNe laser	1.51584	1.63752	1.45765	1.43331	1.37732	1.38911	1.54337	1.55247
628	Ruby laser	1.51526	1.63626	1.45716	1.43298	1.37706	1.38884	1.54281	1.55188
632.8	HeNe laser	1.51509	1.63590	1.45702	1.43289	1.37698	1.38876	1.54264	1.55171
635	Laser diode	1.51501	1.63574	1.45695	1.43284	1.37695	1.38873	1.54257	1.55164
643.8	Cadmium arc, C' line	1.51472	1.63512	1.45671	1.43268	1.37682	1.38859	1.54228	1.55134

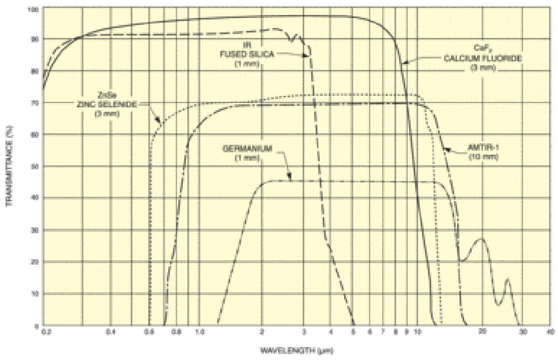
647.1	Kr-Ion laser	1.51461	1.63489	1.45661	1.43262	1.37677	1.38854	1.54218	1.55123
650	Laser diode	1.51452	1.63469	1.45653	1.43257	1.37673	1.38850	1.54209	1.55114
656.3	Hydrogen arc, C line	1.51432	1.63427	1.45637	1.43246	1.37664	1.38840	1.54189	1.55093
670	Laser diode	1.51391	1.63340	1.45601	1.43223	1.37646	1.38821	1.54148	1.55051
676.4	Kr-Ion laser	1.51372	1.63301	1.45585	1.43212	1.37637	1.38812	1.54130	1.55032
694.3	Ruby laser	1.51322	1.63198	1.45542	1.43185	1.37615	1.38789	1.54080	1.54981
750	Laser diode	1.51184	1.62922	1.45424	1.43109	1.37553	1.38724	1.53943	1.54839
780	Laser diode	1.51118	1.62796	1.45367	1.43074	1.37524	1.38693	1.53878	1.54771
830	Laser diode	1.51020	1.62613	1.45282	1.43023	1.37480	1.38647	1.53779	1.54668
850	Laser diode	1.50984	1.62548	1.45250	1.43004	1.37464	1.38630	1.53742	1.54630
852.1	Cesium arc, s line	1.50980	1.62541	1.45247	1.43002	1.37462	1.38628	1.53739	1.54626
905	Laser diode	1.50892	1.62387	1.45168	1.42957	1.37422	1.38586	1.53648	1.54532
980	Laser diode	1.50779	1.62202	1.45067	1.42902	1.37371	1.38533	1.53531	1.54409
1014	Mercury arc, t line	1.50731	1.62128	1.45024	1.42879	1.37350	1.38510	1.53481	1.54357
1053	Nd:YLF laser	1.50678	1.62049	1.44976	1.42854	1.37326	1.38485	1.53425	1.54299
1060	Nd:Glass laser	1.50669	1.62035	1.44968	1.42850	1.37322	1.38480	1.53415	1.54288
1064	Nd:YAG laser	1.50663	1.62028	1.44963	1.42848	1.37319	1.38478	1.53410	1.54282
1300	Laser diode	1.50370	1.61644	1.44692	1.42721	1.37188	1.38338	1.53094	1.53950
1320	Nd:YAG laser	1.50346	1.61616	1.44669	1.42711	1.37177	1.38327	1.53068	1.53922
1550	Laser diode	1.50065	1.61312	1.44402	1.42602	1.37052	1.38194	1.52761	1.53596
1970.1	Mercury arc	1.49495	1.60780	1.43852	1.42401	1.36803	1.37928	1.52138	1.52932
2100	Ho:YAG laser	1.49296	1.60608	1.43659	1.42334	1.36718	1.37837	1.51924	1.52703
2325.4	Mercury arc	1.48921	1.60291	1.43293	1.42212	1.36559	1.37667	1.51524	1.52277
2940	Er:YAG laser	1.47670	1.59273	1.42065	1.41827	1.36051	1.37123	1.50246	1.50908

Transmittance of Optical Materials

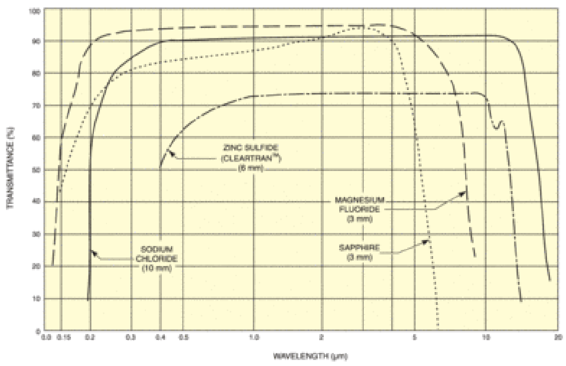
These graphs compare the transmission of standard optical materials. The transmission values listed here are equivalent to "external transmittance" and takes into consideration the reflectances you get from uncoated optical elements.



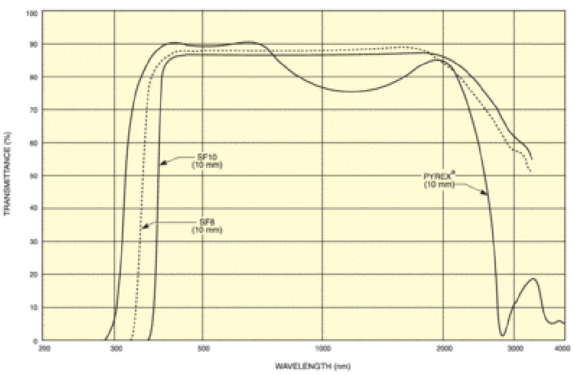
Transmission of 10 mm thick fused silica of different grades, and crown glass windows.



Transmittance of IR optical materials.



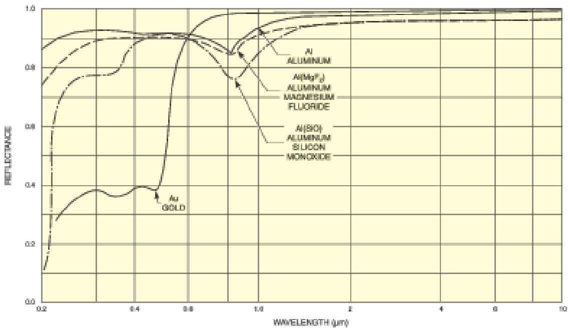
Transmittance of UV-IR materials.



Transmittance of VIS-NIR materials.

Reflectance of Optical Materials

All metal reflectors deteriorate slowly in polluted atmosphere. Cumulative exposure to intense ultraviolet radiation also affects performance; overheating of the reflective surface will destroy the reflector.



Typical near normal incidence reflectance of freshly deposited Al, $AlMgF_2$, AlSiO, and Au.

The $AlMgF_2$ coating has been optimized for performance in the near UV.

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