Selection of Optimal Material

LASER COMPONENTS has a variety of laser optic substrates available. These substrates differ not only in form but also in the type of material. Not all materials are suited for every application. It is therefore necessary to be familiar with the properties of each material in order to find a fitting selection.

For optimal performance of a laser optic, the coating and substrate should also fit together. Not only the optical but also mechanical features of these substrates should be taken into consideration. The main focus of optical features is on the refractive index and on the spectral range in which the material transmits. Additional factors such as the hardness of a material, the thermal expansion, temperature stability, and laser resistance are also of importance.

Material Overview*

For applications in the visible and near IR ranges, BK7 have established themselves as standard glass. When used in the UV range and for very high power densities, synthetic quartz glass such as Suprasil®, Q1, C7980, and JGS1 have become standard.

Other common materials include Infrasil® and Suprasil® 300 for the IR range to approximately 3500 nm as well as sapphire, which excels in particular because of its hardness and a wide transparency from 250 nm to 5000 nm. For applications in which the lowest thermal expansion is of great importance, glass ceramics such as Zerodur® can be used.

The transmission ratio and refractive index of substrates are of particular interest in laser optics. The following overview lists the transmission range of common materials.

*) For a reference to the trademark ownership see appendix.

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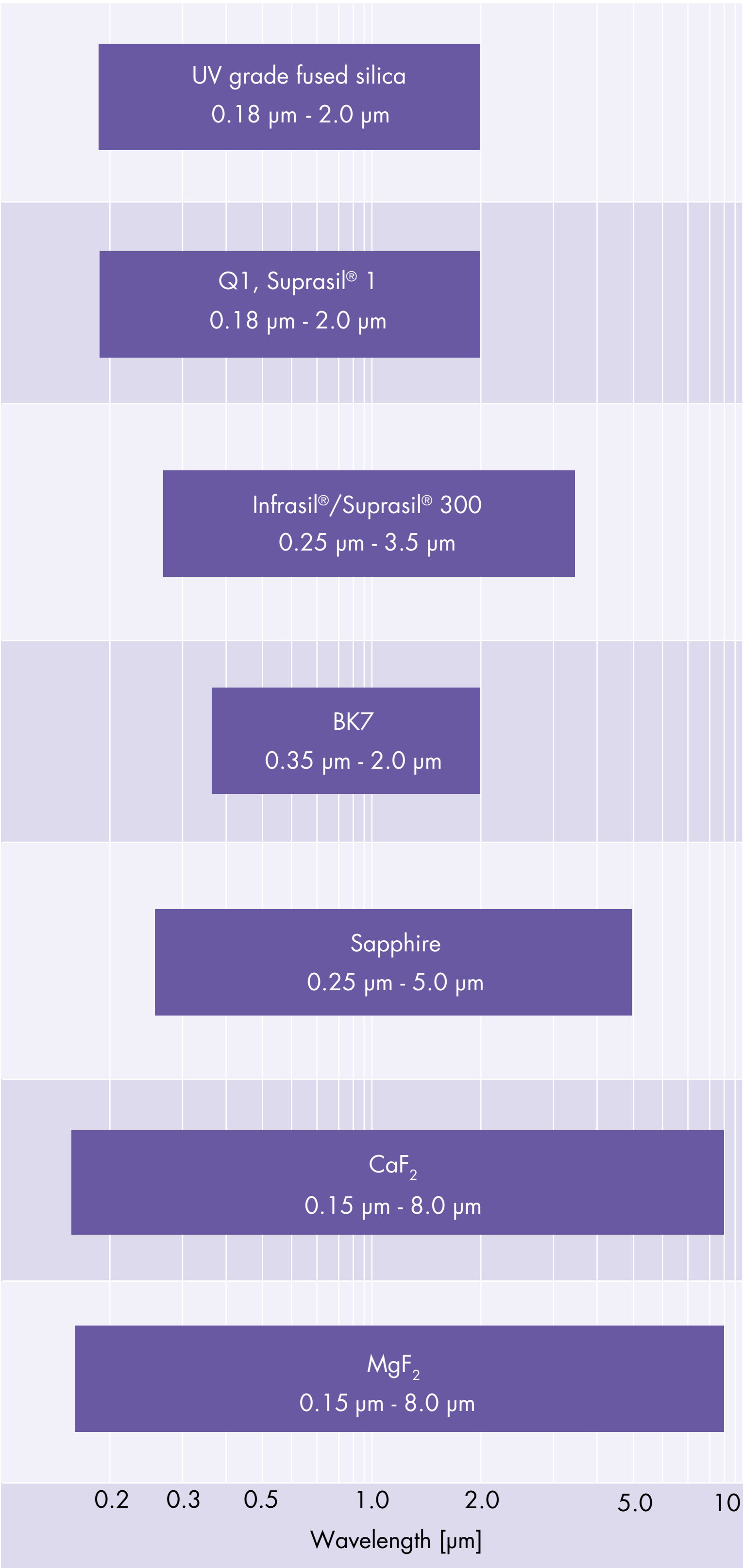
Typical Transmission Range



Description

UV grade fused silica

- Commonly used material for high power laser applications
- Good transmission values from the UV to NIR range
- High stability and low thermal expansion coefficient

Q1, Suprasil® 1

- Fused silica with high purity and excellent homogeneity
- Low metallic impurities, therefore high UV transmission & minimum fluorescence
- No polishing marks and streaks

Infrasil®/Suprasil® 300

- Fused silica for IR applications to 3500 nm
- Specially treated / manufactured fused silica with < 1 ppm OH contents
- No absorption effects at 2700 nm due to low OH content
- Reduced UV transmission (due to higher metallic contamination)

BK7

- Borosilicate crown glass
- Most commonly used material in laser optics
- Excellent quality at a low price
- Easy to process and to polish to high accuracy

Sapphire

- Synthetic, monocrystalline aluminium oxide
- Optically strongly anisotropic, shows birefringent effects
- Performance depends on orientation of optical axis
- High mechanical strength, chemical resistance and thermal stability

CaF_2

- Cubic single crystal
- Available in different quality levels (IR, UV, VUV-laser-grade)
- Popular choice for VUV and Excimer laser optics
- Very broad transmission range from UV to IR

MgF_2

- Tetragonal positive birefringent crystal
- Popular choice for VUV and Excimer laser optics
- Material shows birefringent effects
- Performance depends on orientation of optical axis

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Transmission Curves

In the following, we will introduce the transmission curves of the most commonly used materials. Not only is the transmission ratio of particular interest in laser optics, but the achievable polishing quality as well.
We can certainly request additional transmission curves from various glass manufacturers for you.

Nomenclature

The mentioning of BK7 always refers to N-BK7 or H-K9L. Fused silica generally refers to materials like Lithosil® Q0/Q1/Q2, Suprasil®, C7980, or JGS1.
Simply let us know if you only allow certain materials to be used in your application.

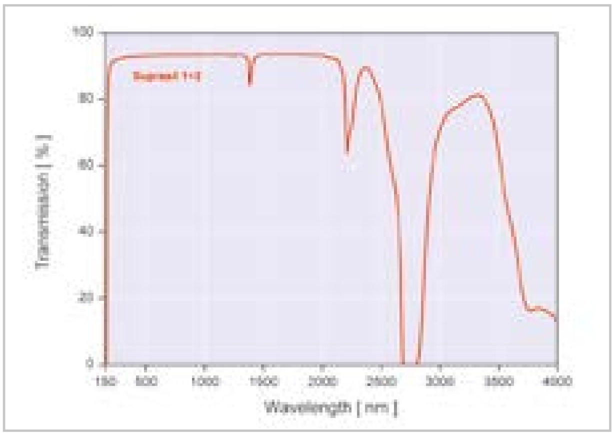
Synthetic Quartz – UV to NIR

Lithosil® Q0/Q1/Q2; Suprasil® 1, 2, 311, 312; HPFS® C7980; JGS1

Any synthetic, amorphous form of silicon oxide that is manufactured from a silicon tetrachloride base via flame hydrolysis is called synthetic quartz. Quartz glass is commonly used and exhibits good transmission values from the UV to NIR range.

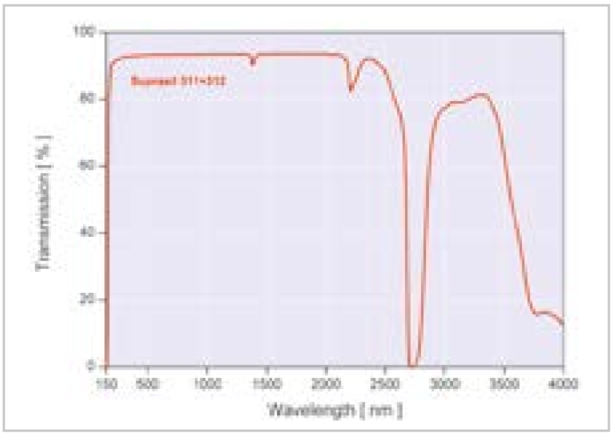
Many kinds of quartz glass that narrowly differ in transmission values and other parameters are available from various manufacturers. Examples include:
For applications in the UV range, the quartz brands Lithosil® Q0/Q1, Suprasil® 1 and 2, HPFS® Corning Code 7980 and JGS1 are comparable. LASER COMPONENTS primarily uses Lithosil® Q1, C7980, and JGS1 as standard material.

The brands Spectrosil® A and B and the glass types 1100 and 4100 from Dynasil come very close to the aforementioned quartz brands.



Suprasil® 1 + 2

Typical transmission of Suprasil® 1 and 2 including Fresnel reflection losses for 10 mm pass length.



Suprasil® 311 + 312

Typical transmission of Suprasil® 311 and 312 including Fresnel reflection losses for 10 mm pass length.

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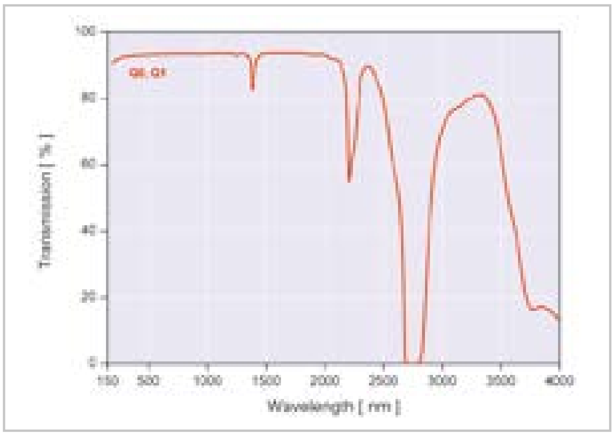
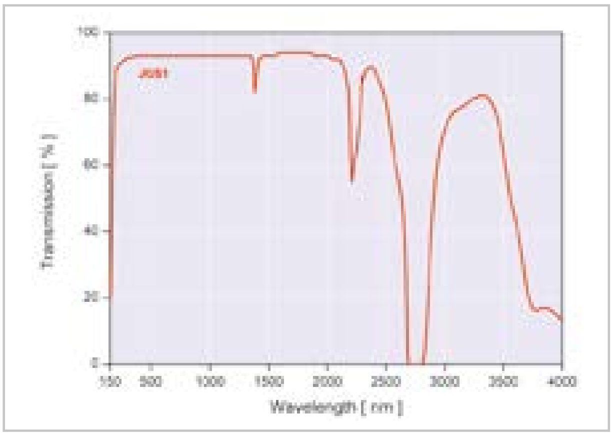


Schott Lithosil® Q0/Q1

Typical transmission of Lithosil® Q0/Q1 including Fresnel reflection losses for 10 mm pass length.



Fused Silica JGS1

Typical transmission of JGS1 including Fresnel reflection losses for 10 mm pass length.

Features

Some glasses, for example Lithosil® Q0, are homogenous and display the same refractive index in all three spatial directions. This model is particularly well suited for applications in multi-dimensional optics.

All aforementioned glasses are suited for conventional laser applications. When placing an order, you can, of course, request certain materials if they will influence your application. However, please be aware that this may increase the delivery time.

Synthetic Quartz – IR

Infrasil®, Suprasil® 300

Quartzes such as Infrasil® or Suprasil® 300 are used for applications in the IR range to about 3000 nm and to prevent absorption effects due to the OH water band at 2700 nm.

Infrasil® is a synthetic quartz that is manufactured by electrically melting high quality quartz crystals.

The metallic contamination in Infrasil® is a little bit higher than in Suprasil®. This results in a reduced UV transmission. On the other hand, the OH content is lower, which leads to a higher transmission in the IR range.

Suprasil® 300 is a highly pure synthetic quartz glass that is manufactured from $SiCl_4$ via flame hydrolysis. On account of an additional drying step, the OH content of the quartz glass is reduced to less than 1 ppm.

Therefore, Suprasil® 300 does not exhibit any absorption bands in the visible and infrared spectral ranges. As a result of the drying step, this material has a chlorine content of 1000 – 3000 ppm and a UV absorption slope shifted to longer wavelengths.

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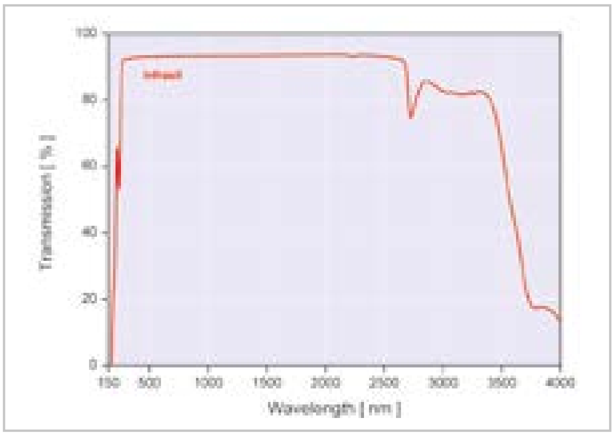
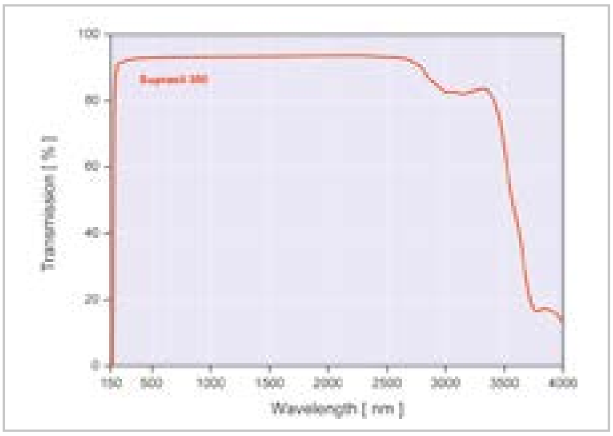


Infrasil®

Typical transmission of Infrasil® including Fresnel reflection losses for 10 mm pass length.



Suprasil® 300

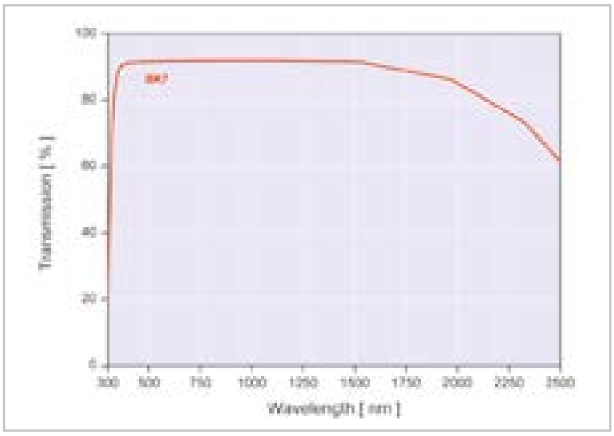
Typical transmission of Suprasil® 300 including Fresnel reflection losses for 10 mm pass length.

BK7

BK7 are borosilicate crown glasses with exceptional optical homogeneity. LASER COMPONENTS uses this glass when especially high demands of quality are put on the glass in both transmission and reflection.

BK7 is the most commonly used materials in laser optics. They feature the following:

- Excellent quality at a low price.
- Very good to process; easy to polish. The achievable polishing quality is suited for high power laser applications.
- Material can be used without exception in transmission in the wavelength range from 400 nm to 2000 nm.
- When used as HR mirror, this material can also be used outside of this wavelength range because the beam does not penetrate the material.



BK7

Typical transmission of BK7 including Fresnel reflection losses for 10 mm pass length.

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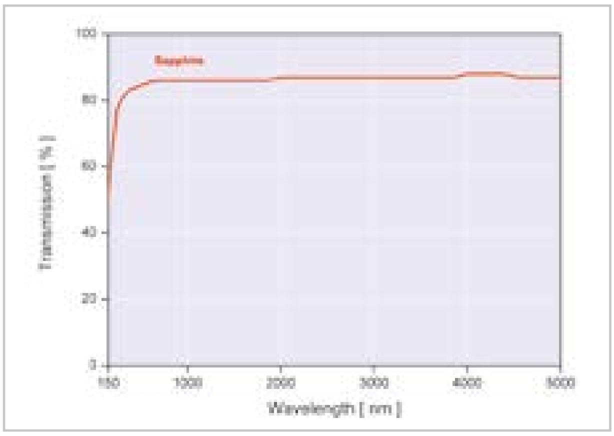
Sapphire

Sapphire is a synthetic, monocrystalline aluminum oxide. Because of its structure, it is optically strongly anisotropic. The exact optical features depend on the orientation of the crystallographic axis relative to the optical axis. LASER COMPONENTS uses a "random" orientation on a standard basis in sapphire. If you require a specific orientation, simply let us know when placing your order.

Sapphire has a breaking strength five times that of synthetic quartz and excellent transmission properties from the UV to the IR range at 5 μm.

Due to its hardness, however, the processing and polishing is much more extensive than for fused silica or BK7.



Sapphire

Typical transmission of Sapphire including Fresnel reflection losses for 10 mm pass length.

CaF_2

Synthetic calcium fluoride crystals CaF_2 offer a very broad spectral transmission range from approx. 150 nm to above 5 μm.

Calcium fluoride single crystals are required in microlithography for illumination and projection optics at 248 nm and 193 nm. The very high laser durability of CaF_2 makes it the first choice material for excimer laser optics. Calcium fluoride is, for the most part, resistant against aggressive excimer laser gases and can be used inside the cavity.

The material is also very common in the IR range due to the broad transmission range.

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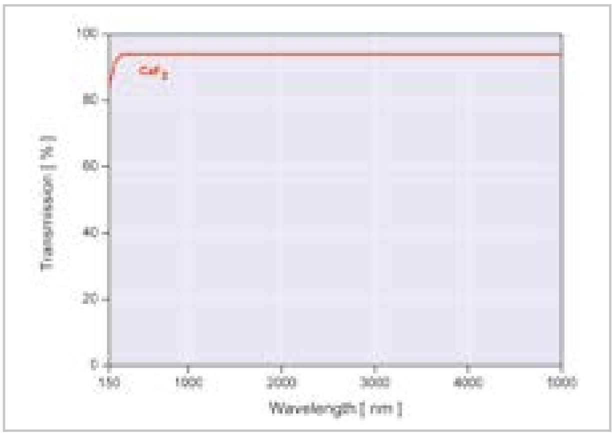
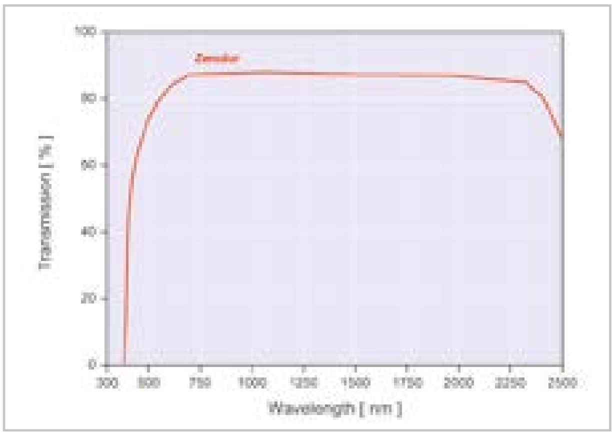


CaF_2

Typical transmission of CaF_2 including Fresnel reflection losses for 10 mm pass length.

Zerodur®

Zerodur® is a glass ceramic with a thermal expansion coefficient of almost zero. These substrates are used when a maximum insensitivity to temperature fluctuations is required. Zerodur® is recommended, for example, for use in interferometer mirrors.



Zerodur®

Typical transmission of Zerodur® including Fresnel reflection losses for 10 mm pass length.

Refractive Index

The refractive index of the material is primarily relevant when used as a lens. The following tables show the refractive indices of different common materials at various laser wavelengths.
For birefringent materials such as sapphire or MgF_2, the values of both the ordinary n_0 and the extraordinary refractive index n_e are given.

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Refractive Index of Some Materials for UV Wavelengths

Wavelength [nm]	Fused Silica n	Sapphire n_0	Sapphire n_e	CaF_2 n	MgF_2 n_0	MgF_2 n_e
193	1.561	1.929	1.917	1.502	1.428	1.441
213	1.535	1.889	1.878	1.485	1.416	1.429
222	1.527	1.875	1.865	1.480	1.412	1.425
226	1.523	1.870	1.860	1.478	1.410	1.424
244	1.511	1.851	1.841	1.470	1.404	1.417
248	1.509	1.847	1.837	1.468	1.403	1.416
257	1.504	1.840	1.830	1.465	1.401	1.414
266	1.500	1.833	1.824	1.462	1.399	1.412
280	1.494	1.824	1.815	1.458	1.396	1.409
308	1.486	1.811	1.802	1.453	1.392	1.404
325	1.482	1.805	1.796	1.450	1.390	1.402
337	1.479	1.801	1.792	1.448	1.389	1.401
351	1.477	1.797	1.788	1.446	1.387	1.400
355	1.476	1.796	1.787	1.446	1.387	1.399

Refractive Index of Some Materials for Vis and IR Wavelengths

Wavelength [nm]	Fused Silica n	Sapphire n_0	Sapphire n_e	CaF_2 n	BK7 n	SF6 n	SF10 n	SF11 n	SF14 n
400	1.470	1.787	1.778	1.442	1.531	1.867	1.778	1.845	1.819
442	1.466	1.780	1.772	1.439	1.526	1.844	1.760	1.822	1.797
458	1.465	1.778	1.770	1.438	1.525	1.838	1.754	1.816	1.791
488	1.463	1.775	1.767	1.437	1.522	1.827	1.746	1.806	1.782
515	1.462	1.773	1.765	1.436	1.520	1.820	1.740	1.799	1.775
532	1.461	1.772	1.764	1.435	1.519	1.816	1.737	1.795	1.771
633	1.457	1.766	1.758	1.433	1.515	1.799	1.723	1.779	1.756
670	1.456	1.764	1.756	1.432	1.514	1.795	1.720	1.775	1.752
694	1.455	1.763	1.755	1.432	1.513	1.792	1.718	1.772	1.750
755	1.454	1.761	1.753	1.431	1.512	1.787	1.714	1.768	1.746

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Refractive Index of Some Materials for Vis and IR Wavelengths

Wavelength [nm]	Fused Silica n	Sapphire n_0	Sapphire n_e	CaF_2 n	BK7 n	SF6 n	SF10 n	SF11 n	SF14 n
780	1.454	1.761	1.753	1.431	1.511	1.786	1.712	1.766	1.744
800	1.453	1.760	1.752	1.431	1.511	1.784	1.711	1.765	1.743
820	1.453	1.760	1.752	1.430	1.510	1.783	1.710	1.764	1.742
860	1.452	1.759	1.751	1.430	1.510	1.781	1.709	1.762	1.740
980	1.451	1.756	1.748	1.429	1.508	1.776	1.704	1.757	1.735
1047	1.450	1.755	1.747	1.429	1.507	1.774	1.703	1.755	1.733
1064	1.450	1.754	1.747	1.428	1.507	1.774	1.702	1.754	1.733
1320	1.447	1.750	1.742	1.427	1.503	1.768	1.697	1.749	1.728
1550	1.444	1.746	1.738	1.426	1.501	1.764	1.693	1.745	1.724
2010	1.438	1.737	1.730	1.424	1.494	1.758	1.687	1.738	1.717
2100	–	1.736	1.728	1.423	–	1.756	1.686	1.736	1.716
2300	–	1.731	1.723	1.422	–	1.753	1.682	1.733	1.712
2500	–	1.726	1.719	1.421	–	1.750	–	–	–
2700	–	1.721	1.713	1.420	–	–	–	–	–
2940	–	1.714	1.706	1.418	–	–	–	–	–
4000	–	1.675	1.668	1.410	–	–	–	–	–
5000	–	1.624	1.618	1.399	–	–	–	–	–

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Infrasil® and Suprasil® are registered trademarks of Heraeus Quarzglas GmbH & Co. KG.

Spectrosil® is a registered trademark of Compagnie de Saint-Gobain.

Zerodur® and Lithosil® are registered trademarks of SCHOTT AG.

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