Heraeus

Suprasil® and Infrasil® – Material Grades for the Infrared Spectrum

Operation @946 nm @1064 nm @1319 nm

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The growing need for Infrared Optics especially in high power laser applications, e. g. for material processing, requires special fused silica with the combination of ultra low absorption and optical performance.

Wavelength of Interest

946 nm: Typical Laser Diode wavelength, used for pumping and material processing.
1040 nm, 1064 nm, 1080 nm: Nd-doped Lasers, material processing.
1319 nm: Nd-doped Lasers, medical applications.

Suitable Quartz glass

Suprasil® 3001, 3002, 300 is the best choice for infrared region.
Suprasil® 311, 312 very good for 1064 nm.
Infrasil® 301, 302 is suited for the infrared, especially for longer wavelengths.

Material	Wavelength	Remark	Application	Performance
Suprasil® 3001	200 nm – 3500 nm	Lowest absorption	Highest quality optics	Outstanding
Suprasil® 3002	200 nm – 3500 nm	Lowest absorption	Highest quality 2D optics	Outstanding
Suprasil® 300	200 nm – 3500 nm	Lowest absorption	Windows, lenses with medium need for homogeneity	Outstanding
Suprasil® 311	190 nm – 1100 nm	Very low absorption @ 1064 nm	3D applications, e. g. high grade prisms	Excellent
Suprasil® 312	190 nm – 1100 nm	Very low absorption @ 1064 nm	2D applications, e. g. lenses, windows	Excellent
Infrasil® 301	270 nm – 3500 nm	High cost efficiency	3D applications, e. g. high grade prisms	Very Good
Infrasil® 302	270 nm – 3500 nm	High cost efficiency	2D applications, e. g. lenses or windows	Very Good

Suprasil® 3001, 3002 and 300

Suprasil® 3001, 3002 and 300 are high purity synthetic fused silica materials manufactured by flame hydrolysis. They combine excellent physical properties with outstanding optical characteristics from the UV to the near IR. During the manufacturing process an intermediate drying step reduces the OH content of the Suprasil® 300x to below 1 ppm. A chlorine content of 1000 ppm – 3000 ppm is material inherent and results in a slight shift of the UV-absorption edge to the longer wavelength region.

The Suprasil® 300x family of materials has the combination of ultra low total metal impurities (< 1 ppm) and low OH (< 1 ppm) that result in no absorption bands from the visible to the IR spectral region. This property makes this material family the ideal choice for any low absorption application in the near-IR.

Infrasil® 301 and 302

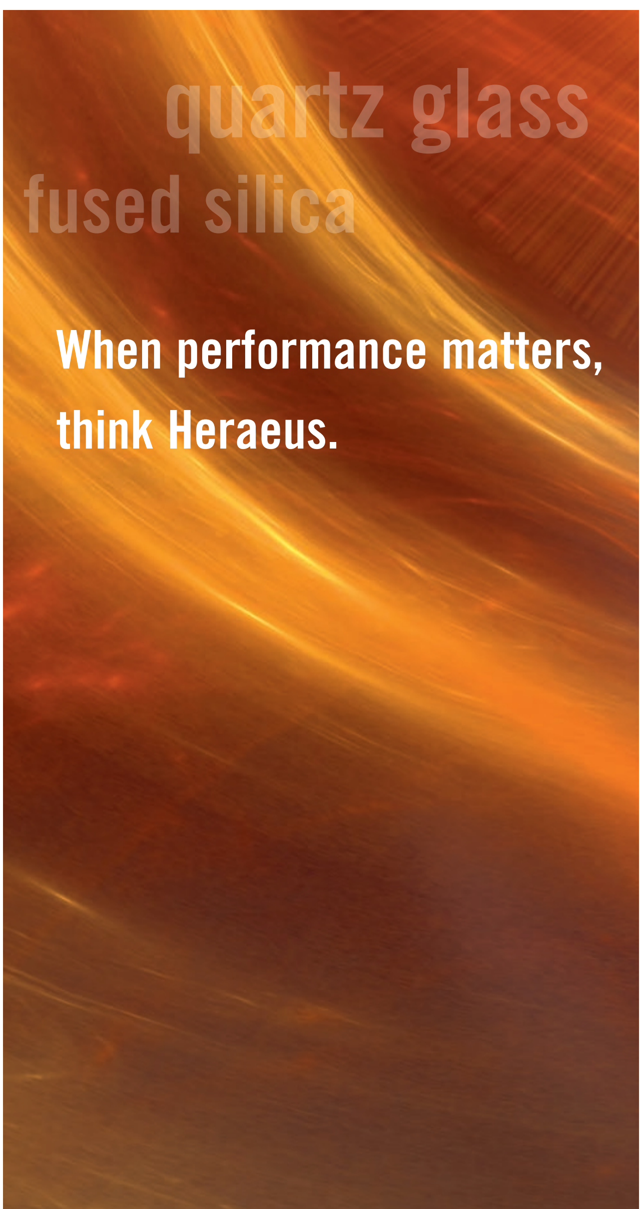
Infrasil® 301 and 302 are optical quartz glass grades manufactured by fusion of natural quartz crystals in an electrically heated furnace. They combine excellent physical properties with very good optical characteristics especially in the IR and the visible wavelength range. The index homogeneity is controlled and specified either in one direction (the direction of use or functional direction) or even in all three directions.

Attenuation

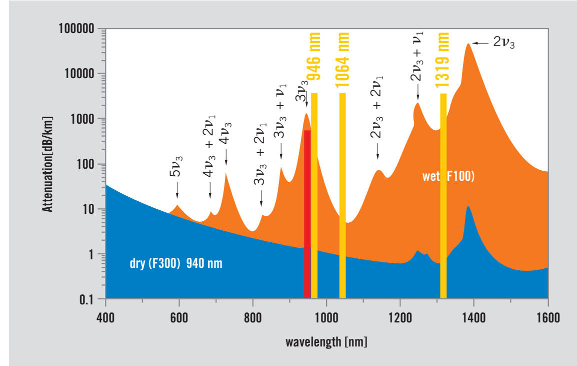
The graphic on the right hand side on top shows the absorption of fused silica due to OH – molecular vibrational or rotational excitation. Key laser lines, in yellow, show the relative position of laser lines with respect to the NIR OH absorption bands. The red line shows the OH absorption band @ 940 nm.

Synthetic fused silica with low OH content is the preferred choice for the three laser wavelengths! The bulk absorption can be calculated: x dB/km => x * 2.3 ppm/cm.

This calculated value gives a rough estimate of the order of magnitude of the absorption.
Example: The attenuation @ 940 nm = 2 dB/km
=> Absorption ~ 4.6 ppm/cm

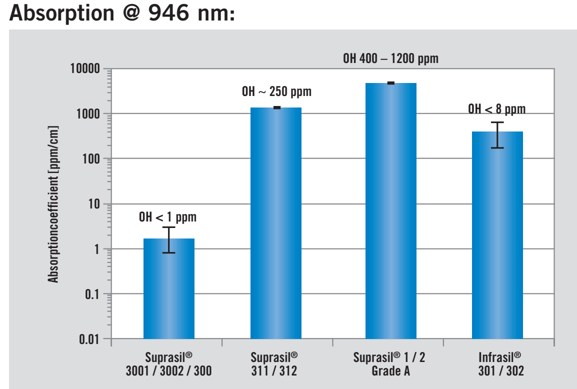


Attenuation:



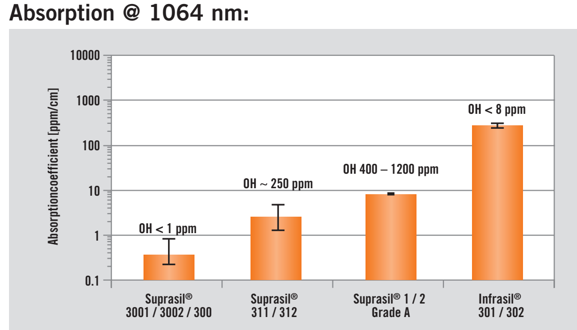
Source: O.Humbach et al., J. Non Crystalline Solids, 203 (1996)

Absorption @ 946 nm:



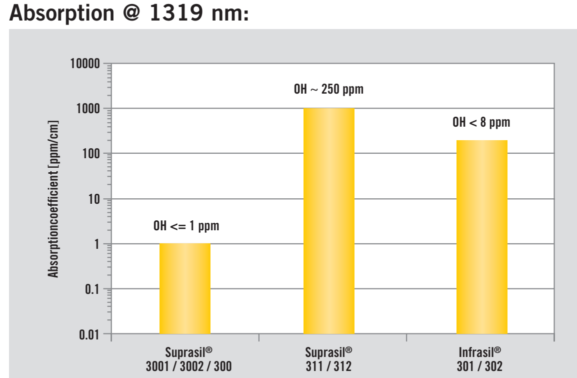
Data by measurements from: Dr. Mühlig, Institut für Photonische Technologien (IPHT) , Jena

Absorption @ 1064 nm:



Data by measurements from:
Dr. Kondilenko, Ginzton Lab, Stanford University, USA, Dr. Pinard, Laboratoire des Matériaux Avancés, Lyon, France, Dr. Mühlig, Institut für Photonische Technologien (IPHT), Jena, Priv. Communications

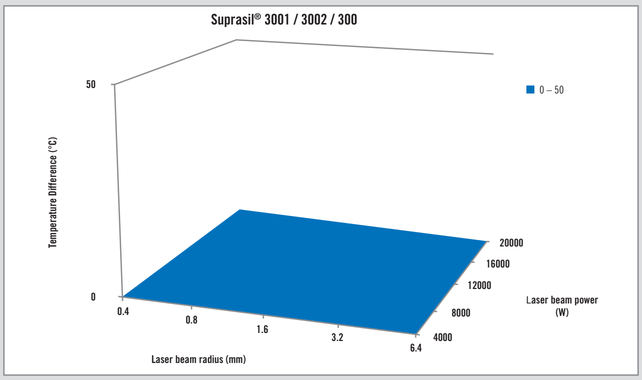
Absorption @ 1319 nm:



Data by measurements from: Dr. Kondilenko, Ginzton Lab, Stanford University, USA

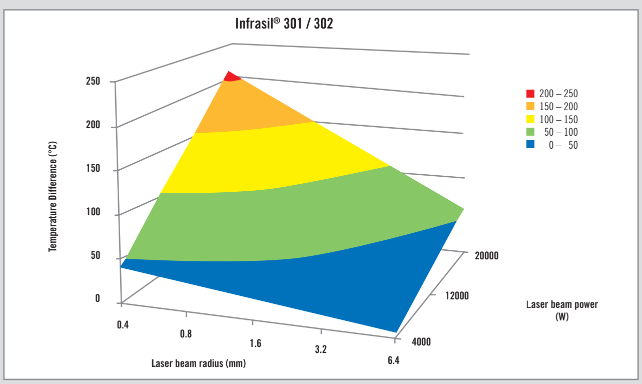
Absorption @ 946 nm:

- Absorption can lead to an increase in temperature
- Absorption also depends on laser beam irradiated area (or beam size).
- The following graphics show a simulation based on
  - Steady-state diffusion equation with bulk and surface heat sources.
  - Convective cooling with a heat transfer coefficient of 10 W/(m^2*K) and ambient temperature of 25°C.



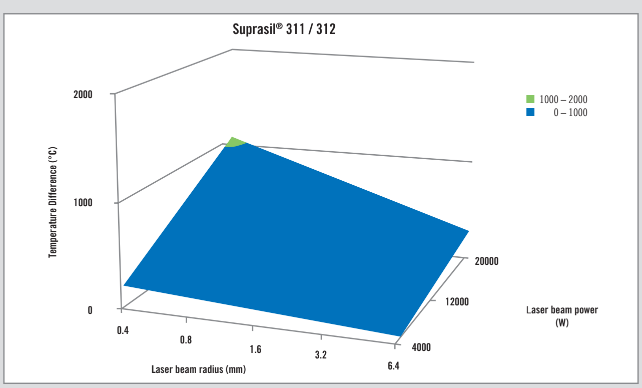
Suprasil® 3001 / 3002 / 300

- The simulation shows only a negligible increase in temperature due to bulk absorption
- Even laser powers up to 20 kW show an extremely low temperature increase due to bulk absorption.



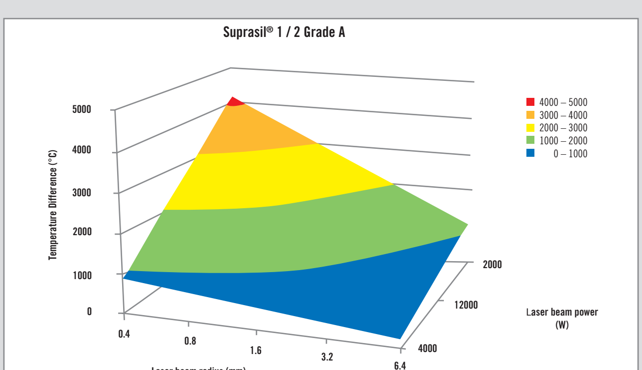
Infrasil® 301 / 302

- For a given input power, decreasing the laser beam size increases the power density (W/sq.cm) resulting in more absorption and a higher temperature rise.
- The temperature rises with a decrease in the laser beam size.
- The temperature rises with an increase in laser pow
- This is due to the bulk absorption of the material Infrasil®
- The maximum temperature is slightly above 200°C for 20 kW and a laser beam radius of 0.4 mm.



Suprasil® 311 / 312

- The simulation shows an increase in temperature due to bulk absorption for rising laser powers.
- An increase in temperature can be seen for decreasing laser beam sizes.
- For laser powers up to 20 kW and a laser beam size radius of 0.4 mm the simulation shows a temperature increase to over 1000°C due to bulk absorption.

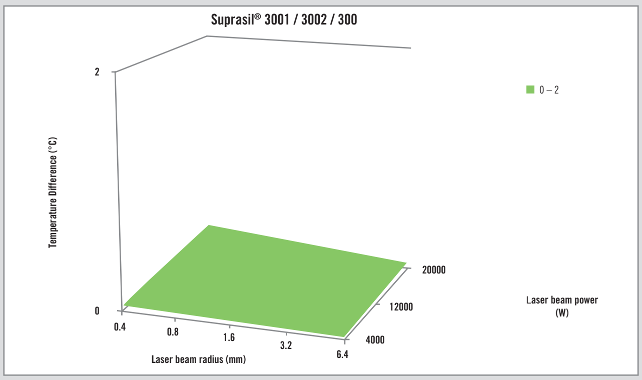


Suprasil® 1 / 2 Grade A

- The temperature dependence on beam size and laser power is clearly visible and up to ~5x to ~20x higher than Suprasil® 311 / 312 (OH ~250) and Infrasil (OH < 8 ppm) respectively. In this case absorption and temperature rise is dominated by OH content.
- The temperature rises with a decrease in the laser beam size.
- The temperature rises with an increase in laser power.
- Temperatures above 1700°C are not realistic and failure in coating and or the optic substrate would occur before this.

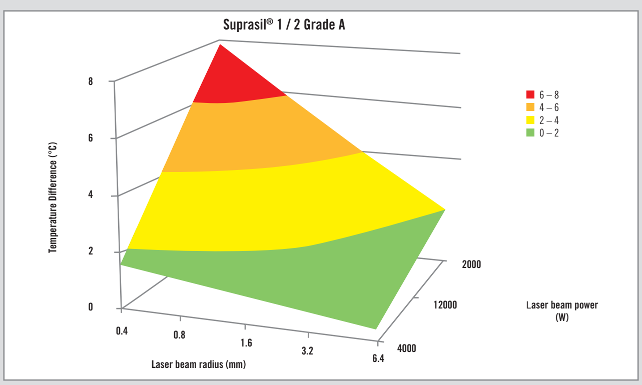
Absorption @ 1064 nm:

- Absorption @ 1064 nm is dependent on both impurity level & OH content.
- Absorption also depends on laser beam irradiated area (or beam size).
- The following graphics show a simulation based on
  - Steady-state diffusion equation with bulk and surface heat sources.
  - Convective cooling with a heat transfer coefficient of 10 W/(m^2*K) and ambient temperature of 25°C.



Suprasil® 3001 / 3002 / 300

- The simulation shows a negligible increase in temperature due to bulk absorption.
- Even laser powers up to 20 kW show an extremely low temperature increase due to bulk absorption.

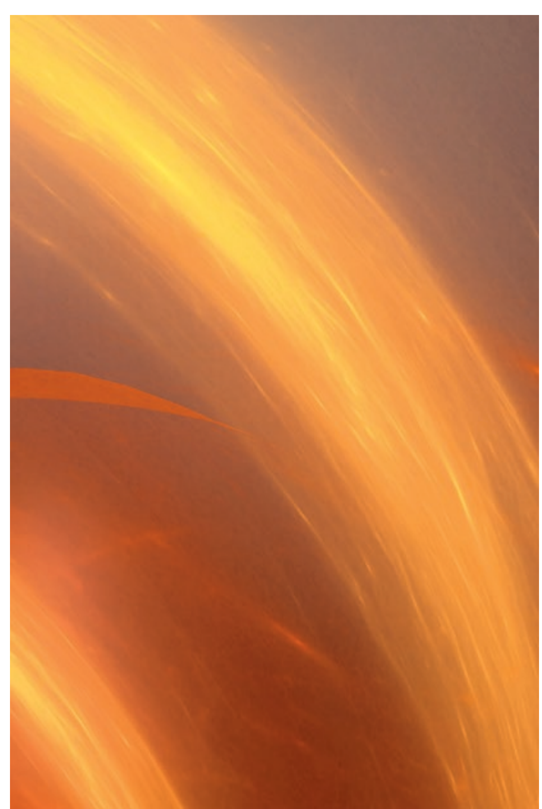


Suprasil® 1 / 2 Grade A

- The temperature dependence on beam size and laser power is visible.
- The temperature rises with a decrease in the laser beam size.
- The temperature rises with an increase in laser power.
- The maximum temperature is around 8°C for 20 kW and a laser beam size of 0.4 mm.
- The OH content of Suprasil® 1 has only a very small contribution to the bulk absorption @ 1064 nm.

Summary

- **OH absorption bands strongly influence performance. Impurity level also plays a role, depending on laser line proximity to key OH absorption lines.**
- **Low OH grades show lower absorption in the IR.**
- **High OH content may lead to lens heating and changes to the index homogeneity and aberrations to the transmitted wave front.**
- **Suprasil® 3001, 3002, 300 is the best choice for infrared applications where performance must be optimized.**
- **Infrasil® 301, 302 is a suitable alternative for applications requiring combined very good NIR performance and economy.**



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