

## Quartz Glass for Optics Data and Properties

# Quartz Glass for Optics Data and Properties



= 3D material, optically isotropic.

In quartz glass, the homogeneity is typically specified in one direction only. Heraeus manufactures quartz glass grades, which are controlled and specified in all 3 directions regarding striae, homogeneity and stress induced birefringence, for the most demanding applications. These materials are identified by the 3D symbol.

❶ For raw formed ingots the bubble specification is valid for the area defined by the minimum diameter tolerance. For machined parts it is defined as 100% of the material.

- ❷ Bubbles or inclusions  $\leq 0.08$  mm diameter are not counted. Tighter specification for bubbles and inclusions down to  $\leq 10\mu\text{m}$  is possible on request.
- ❸ For non-spherical bubbles the maximum dimension is used.
- ❹ The  $\Delta n$  value is the maximum permissible lateral variation in refractive index (measured by interferometer at 632.8 nm after subtraction of tilt and offset) over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot.

Grade	Bubbles and Inclusions <sup>❶ ❷</sup>			Homogeneity <sup>❸</sup>	
	The bubble grade is given for every 100 cm <sup>3</sup> . Quartzglass from Heraeus is free of inclusions.			$\Delta n$ -value <sup>❹</sup>	
	DIN 58927	DIN ISO 10110 <sup>❸</sup>	Total cross-sections (in mm <sup>2</sup> ) of all bubbles (TBCS value)	Striae class as <sup>❹</sup> per DIN ISO 10110 (per 30 mm thickness)	PV value <sup>❸</sup> (Peak-to-Valley)
Suprasil® 311	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 3 \cdot 10^{-6}$
Suprasil® 312	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 313	0	1/1*0.08	$\leq 0.015$	2 / -,5	n. sp. <sup>❸</sup>
Suprasil® 3001	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3002	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® 300	0	1/1*0.08	$\leq 0.015$	acc. MIL	n. sp.
Suprasil® 3301	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 2 \cdot 10^{-6}$
Suprasil® 3302	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 3 \cdot 10^{-6}$
Suprasil® 1	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade A	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade B	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® CG	0	1/1*0.08	$\leq 0.015$	acc. MIL	$\leq 30 \cdot 10^{-6}$
Suprasil® 1 ArF / KrF	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 ArF / KrF	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 5 \cdot 10^{-6}$
Spectrosil® 2000	0	1/1*0.08	$\leq 0.015$	2 / -,5	$\leq 10 \cdot 10^{-6}$
Infrasil® 301	0	1/1*0.16	$\leq 0.03$	2 / -,5	$\leq 5 \cdot 10^{-6}$
Infrasil® 302	0..1	1/1*0.35	$\leq 0.1$	2 / -,5	$\leq 6 \cdot 10^{-6}$
HOQ® 310	2...3	1/1*0.63 $\leq 6$ kg 1/2*1.0 $> 6$ kg	0.5	n. sp.	n. sp.

Synthetic Fused Silica

Natural Quartz<sup>❸</sup>

n. sp. = not specified

= 3D material, optically isotropic

The maximum test diameter is 430 mm. Larger pieces are measured using overlapping interferograms.

- ⑥ Does not apply to drawn rods.
- ⑥ Lower values available on request.
- ⑦ The residual strain values refer to the measured phase difference per cm light path. The residual strain value is specified over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot.
- ⑥ Typically less than 10·10<sup>-6</sup>.
- ⑥ The chemical composition, and therefore, the optical properties of natural quartz can vary.

### Refractive index

at 20°C and 1 bar

The given values are interpolated from measured values. More accurate data available upon request.

In contrast to other optical glasses, quartz glass shows very little difference in refractive index from melt to melt.

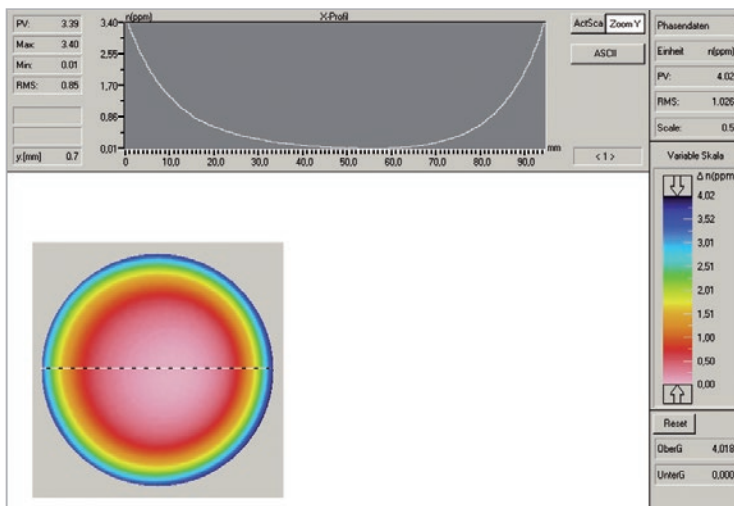
Residual Strain nm/cm <sup>⑥</sup>	Fluorescence	OH-Content
	Excitation by Hg-Lamp@ λ= 254 nm and UG 5-filter; Lamp-power: 8W; Detection: adapted eye	ppm (µg/g)
≤ 5	free	≤ 300
≤ 5	free	≤ 300
≤ 5	free	≤ 300
≤ 6	slight blue	≤ 1
≤ 6	slight blue	≤ 1
≤ 5	slight blue	≤ 1
≤ 2	free	≤ 20
≤ 3	free	≤ 20
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 20	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	blue-violet	≤ 8
≤ 5	blue-violet	≤ 8
≤ 10	blue-violet	ca. 30

Wavelength nm	Suprasil®- family	Suprasil® 3001/3002/300	Infrasil® / HQ®
ArF	190	1,5657	-
	193,4	1,5601	-
	200	1,5505	-
	202,54	-	1,5473
	220	1,5285	-
	232,94	-	1,5287
	240	1,5133	-
	248,4	1,5083	-
KrF	260	1,5024	-
	266	1,4997	-
	274,87	1,4961	-
	280	1,4942	-
	300	1,4878	-
	308	1,4856	-
	320	1,4827	-
	325	1,4816	-
	337	1,4792	-
	340	1,4787	-
	360	1,4753	-
	365,48	1,4745	1,4748
	380	1,4725	1,4728
	400	1,4701	1,4704
	404,65	1,4696	1,4699
	435,83	1,4667	1,4670
	441,6	1,4662	1,4665
	447,1	1,4658	1,4661
	486,13	1,4631	1,4634
	488	1,4630	1,4633
	514,5	1,4616	1,4619
	532	1,4607	1,4610
	546,07	1,4601	1,4604
	587,56	1,4585	1,4588
	632,8	1,4570	1,4573
	656,27	1,4564	1,4567
	694,3	1,4554	1,4557
	752,5	1,4542	1,4545
	800	1,4533	1,4536
	850	1,4525	1,4528
	900	1,4518	1,4520
	905	1,4517	1,4518
	1000	1,4504	1,4507
	1064	1,4496	1,4499
	1153	1,4486	1,4489
	1200	1,4481	1,4483
	1319	1,4467	1,4470
	1400	1,4458	1,4461
	1600	1,4434	1,4437
	1800	1,4409	-
	2000	1,4381	-
	2200	1,4350	-
	2400	1,4316	-
	2600	1,4279	-
	2800	1,4238	-
	3000	1,4193	-
	3200	1,4143	-
	3400	1,4088	-

# Optical Homogeneity and Stress Induced Birefringence

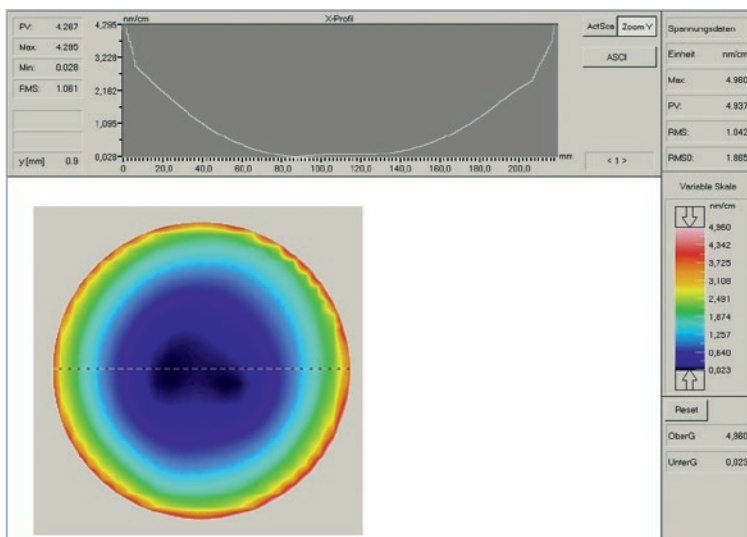
The false colour diagram below shows the typical two-dimensional refraction-index distribution. The interferogram belongs to a circular blank.

The sectional view along the diameter shows the refraction-index distribution across the blank. One can clearly see the very low value in the center of the plate and the rise close to the edge.



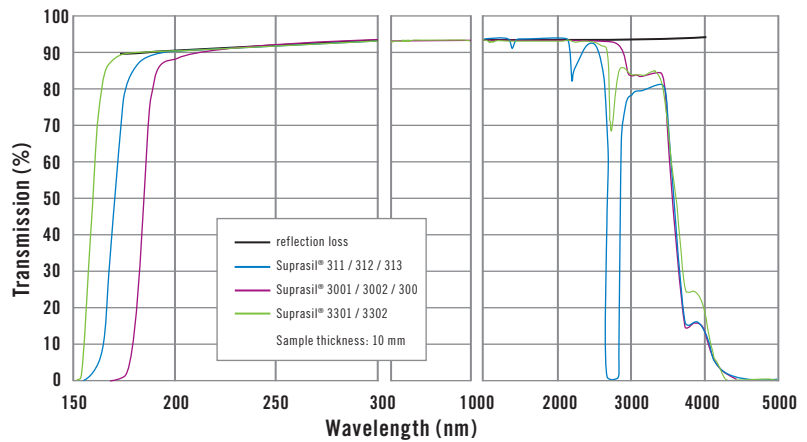
The false colour diagram below shows the typical two-dimensional birefringence distribution.

The sectional view along the diameter shows the birefringence distribution across the plate. One can clearly see the very low value in the center of the plate and the rise close to the edge.

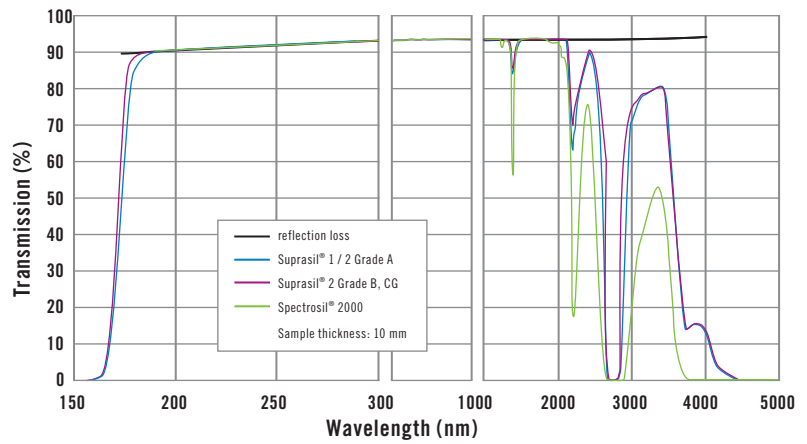


Typical transmission including Fresnel reflection losses  $(1-R)^2$

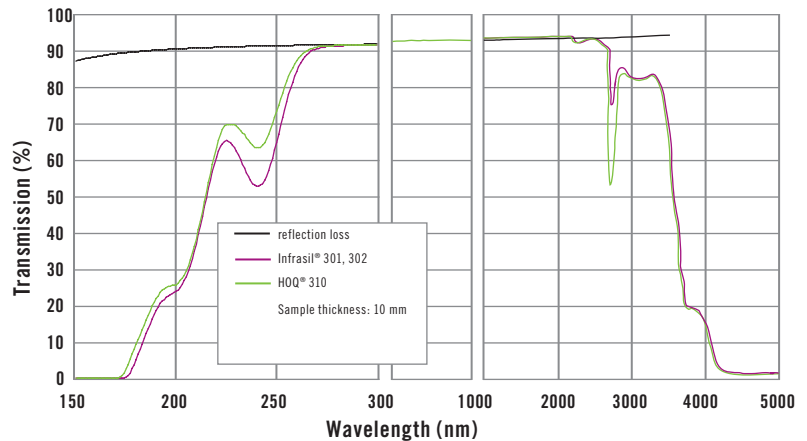
Suprasil® 311, 312, 313  
 Suprasil® 3001, 3002, 300  
 Suprasil® 3301, 3302



Suprasil® 1, 1 ArF / KrF  
 Suprasil® 2 Grade A, 2 ArF / KrF  
 Suprasil® 2 Grade B, Suprasil® CG  
 Spectrosil® 2000



HQ® 310  
 Infrasil® 301, 302



The uppermost curves in the transmission graphs indicate the calculated Fresnel reflection losses for two uncoated surfaces.

Please find our transmission calculator online at [www.herae.us/transmission-calculator](http://www.herae.us/transmission-calculator)

# Technical Properties

## Internal transmission (%)

Values of pure transmissions of a 10 mm thick sample for selected UV-Wavelengths.

Wavelength nm	Suprasil® ArF/ KrF - specified -	Suprasil®- family - typical -
193,4	≥ 99,30	98,50
248,4	≥ 99,80	99,50
266	99,90	99,90

## Relative temperature coefficients of the refractive index in 10<sup>-6</sup> K<sup>-1</sup>

Wave-length nm	Suprasil®-family, Spectrosil®		Infrasil® / HOQ®	
	0...20°C	20...40°C	0...20°C	20...40°C
237,8	14,6	14,9	15,2	15,3
365	11	11,2	11,5	11,6
546,1	9,9	10,1	10,6	10,7
587,6	9,8	10,0	10,5	10,6
643,8	9,6	9,8	10,4	10,5

## Abbe constant

$v_d = \frac{n_d - 1}{n_f - n_c}$	67,8 ± 0,5
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## Birefringence constant @ 633 nm

$\frac{\text{nm}}{\text{cm} \cdot \text{bar}}$	3,54 ± 0,05	3,61 ± 0,05
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## Refraction index dispersion

Dispersion constants (Sellmeier)

	Suprasil®-family, Spectrosil®	Infrasil® / HOQ®
B1	4,73115591 · 10 <sup>-1</sup>	4,76523070 · 10 <sup>-1</sup>
B2	6,31038719 · 10 <sup>-1</sup>	6,27786368 · 10 <sup>-1</sup>
B3	9,06404498 · 10 <sup>-1</sup>	8,72274404 · 10 <sup>-1</sup>
C1	1,29957170 · 10 <sup>-2</sup>	2,84888095 · 10 <sup>-3</sup>
C2	4,12809220 · 10 <sup>-3</sup>	1,18369052 · 10 <sup>-2</sup>
C3	9,87685322 · 10 <sup>1</sup>	9,56856012 · 10 <sup>1</sup>

## Sellmeier Equation:

$$n^2 - 1 = B_1 \lambda^2 / (\lambda^2 - C_1) + B_2 \lambda^2 / (\lambda^2 - C_2) + B_3 \lambda^2 / (\lambda^2 - C_3)$$

Wavelength  $\lambda$  in  $\mu\text{m}$  at 20°C

## Typical trace impurities in quartz glass

Impurities	Suprasil®-family, Spectrosil® ppm	Infrasil® / HOQ® ppm
Al = aluminium	≤ 0,010	20
Ca = calcium	≤ 0,015	1
Cr = chrome	≤ 0,001	0,1
Cu = copper	≤ 0,003	0,1
Fe = iron	≤ 0,005	0,8
K = potassium	≤ 0,010	0,8
Li = lithium	≤ 0,001	1
Mg = magnesium	≤ 0,005	0,1
Na = sodium	≤ 0,010	1
Ti = titanium	≤ 0,005	1

Mechanical data		Suprasil®-family, Spectrosil® Infrasil® / HOQ®
Density	g/cm <sup>3</sup>	2,20
Mohs-hardness		5,5.....6,5
Micro-hardness	N/mm <sup>2</sup>	8600.....9800
Knoop-hardness	N/mm <sup>2</sup>	5800.....6200
Modulus of elasticity (at 20°C)	N/mm <sup>2</sup>	7,0 · 10 <sup>4</sup>
Modulus of torsion	N/mm <sup>2</sup>	3 · 10 <sup>4</sup>
Poisson's ratio		0,17
Compressive strength	N/mm <sup>2</sup>	1150
Tensile strength	N/mm <sup>2</sup>	50
Bending strength	N/mm <sup>2</sup>	67
Torsional strength	N/mm <sup>2</sup>	30
Sound velocity	m/s	5720

Electrical data		
<b>Resistivity in Ω·m</b>		
20°C	10 <sup>16</sup>	
400°C	10 <sup>8</sup>	
800°C	6,3 · 10 <sup>4</sup>	
1200°C	1,3 · 10 <sup>3</sup>	
<b>Dielectric strength in kV/mm (Layer thickness ≥ 5 mm)</b>		
20°C	40...50	
500°C	4...5	
<b>Dielectric loss angle (tg δ)</b>		
1kHz	0,0005	
1...1000MHz	< 0,001	
3 · 10 <sup>4</sup> MHz	0,0004	
<b>Dielectric constant (ε)</b>		
20°C	0...1 MHz	3,7
23°C	0...1000 MHz	3,80
23°C	3 · 10 <sup>4</sup> MHz	3,81

Thermal data		Suprasil®- Family, Spectrosil®	Infrasil®/ HOQ®
Softening temperature	°C	~ 1600	~ 1730
Annealing temperature	°C	~ 1120	~ 1180
strain temperature	°C	~ 1025	~ 1075
<b>Max. working temperature</b>			
continuous	°C	~ 950	~ 1150
short-term	°C	~ 1200	~ 1300
<b>Mean specific heat J/kg·K</b>			
	0...100°C	772	
	0...500°C	964	
	0...900°C	1052	
<b>Heat conductivity W/m·K</b>			
	20°C	1,38	
	100°C	1,46	
	200°C	1,55	
	300°C	1,67	
	400°C	1,84	
	950°C	2,68	
<b>Mean thermal expansion coefficient K<sup>-1</sup></b>			
	-160...0°C	0	
	-50...0°C	2,7 · 10 <sup>-7</sup>	
	0...100°C	5,1 · 10 <sup>-7</sup>	
	0...200°C	5,8 · 10 <sup>-7</sup>	
	0...300°C	5,9 · 10 <sup>-7</sup>	
	0...600°C	5,4 · 10 <sup>-7</sup>	
	0...900°C	4,8 · 10 <sup>-7</sup>	

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