

Quartz Glass for Optics Data and Properties

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= 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.

● 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.

- Bubbles or inclusions ≤ 0.08 mm diameter are not counted. For Suprasil® 311/312 and Suprasil® 3001/3002 a specification for bubbles and inclusions of $\leq 10\mu\text{m}$ is possible on request.
- For non-spherical bubbles the diameter is averaged.
- The Δn 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 ^{1 2}			Homogeneity ⁵	
	The bubble grade is given for every 100 cm ³ . Quartzglass from Heraeus is free of inclusions.			Δn -value ⁴	
	DIN 58927	DIN ISO 10110 ³	Total cross-sections (in mm ²) of all bubbles (TBCS value)	Striae class as ⁴ per DIN ISO 10110 (per 30 mm thickness)	PV value (Peak-to-Valley)
Suprasil® 311	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 3 \cdot 10^{-6}$
Suprasil® 312	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3001	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3002	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® 300	0	1/1*0.08	≤ 0.015	acc. MIL	n. sp.
Suprasil® 1	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade A	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade B	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® C6	0	1/1*0.08	≤ 0.015	acc. MIL	$\leq 30 \cdot 10^{-6}$
Suprasil® 1 ArF / KrF	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 ArF / KrF	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Spectrosil® 2000	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Homosil® 101	0	1/2*0.10	≤ 0.03	2 / -,5	$\leq 3 \cdot 10^{-6}$
Herasil® 102	0	1/1*0.20	≤ 0.1	2 / -,5	$\leq 4 \cdot 10^{-6}$
Infrasil® 301	0	1/1*0.16	≤ 0.03	2 / -,5	$\leq 5 \cdot 10^{-6}$
Infrasil® 302	0..1	1/1*0.35	≤ 0.1	2 / -,5	$\leq 6 \cdot 10^{-6}$
HQ® 310	2...3	1/1*0.63 ≤ 6 kg 1/2*1.0 > 6 kg	0.5	n. sp.	n. sp.

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

- ⑤ 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 edge zone is defined as the outer 10% (for raw formed ingots and rods, the edge zone is defined as the outer 15%) of diameter or side-length.

n. sp. = not specified

PV values by special request	Residual Strain ^⑦		Fluorescence	OH-Content
	in the center nm/cm	at the edges nm/cm	Excitation by Hg-Lamp@ λ = 254 nm and UG 5-filter; Lamp-power: 8W, Detection : adapted eye	ppm (µg/g)
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	ca. 200
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	ca. 200
≤ 1 · 10 ⁻⁶	≤ 6	5...15	slight blue	≤ 1
≤ 1 · 10 ⁻⁶	≤ 6	5...15	slight blue	≤ 1
-	≤ 5	5...15	slight blue	≤ 1
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	400...1200
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	≤ 1000
-	≤ 5	5...15	free	≤ 1000
-	≤ 20	n. sp.	free	400...1200
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	400...1200
≤ 1 · 10 ⁻⁶	≤ 5	5...15	free	400...1200
≤ 3 · 10 ⁻⁶	≤ 5	5...15	free	≤ 1200
≤ 1 · 10 ⁻⁶	≤ 5	5...15	blue-violet	ca. 150
≤ 1 · 10 ⁻⁶	≤ 5	5...15	blue-violet	ca. 150
≤ 2 · 10 ⁻⁶	≤ 5	5...15	blue-violet	≤ 8 ^⑤
≤ 3 · 10 ⁻⁶	≤ 5	5...15	blue-violet	≤ 8 ^⑤
-	≤ 10	10...20	blue-violet	ca. 30

Refractive index

at 20°C and 1 bar

The given values are interpolated from measured values having an accuracy of ± 3 · 10⁻⁵.

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

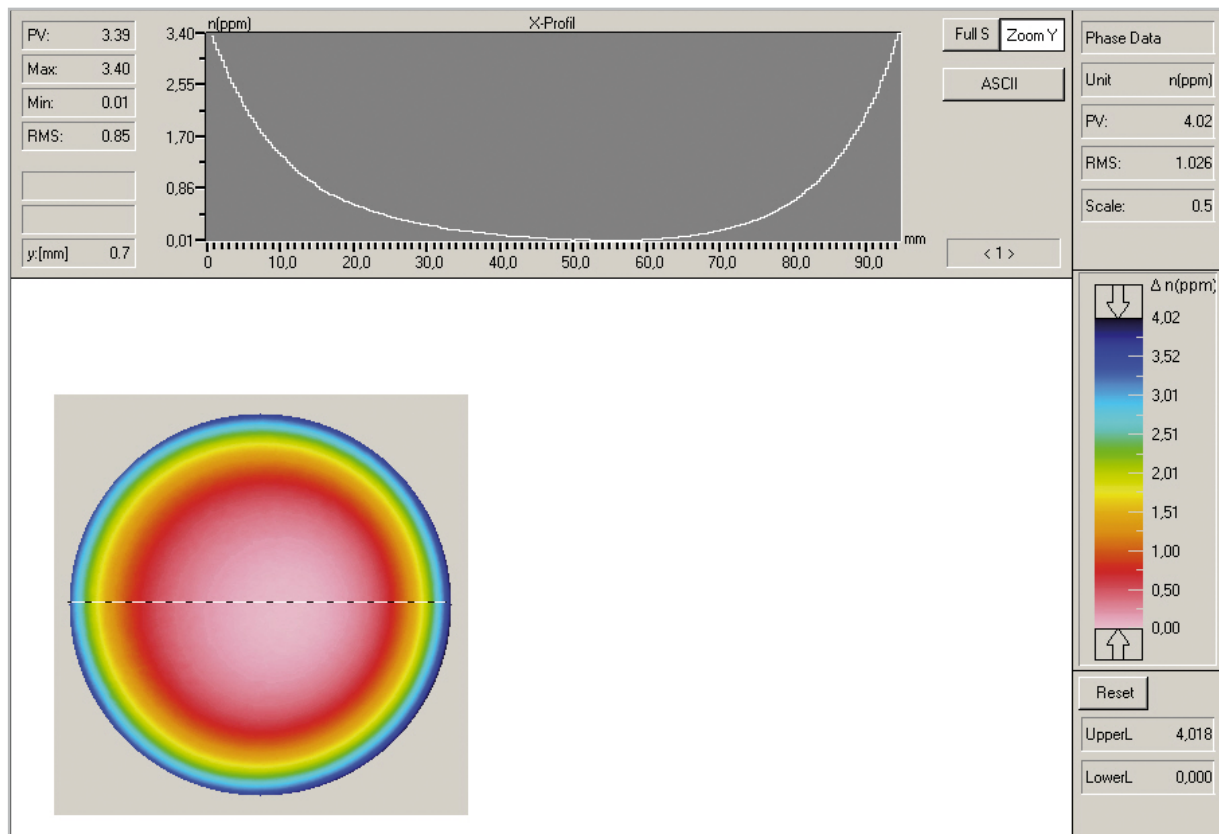
*without Suprasil® 3001, 3002, 300

Wavelength nm	Suprasil-family	Homosil / Herasil / Infrasil / HQQ
ArF	190	1,56572
	193,4	1,56013
	200	1,55051
	202,54	-
	220	1,52845
	232,94	1,51834
	240	1,51334
KrF	248,4	1,50833
	260	1,50239
4 x Nd:YAG	266	1,49968
	274,87	1,49607
	280	1,49416
	300	1,48779
XeCl	308	1,48564
	320	1,48274
HeCd	325	1,48164
N2	337	1,47921
	340	1,47865
	360	1,47529
(ni)	365,48	1,47447
	380	1,47248
	400	1,47012
(nh)	404,65	1,46962
(ng)	435,83	1,46669
HeCd	441,6	1,46622
Kr	447,1	1,46578
(nF)	486,13	1,46313
Ar	488	1,46301
Ar	514,5	1,46156
2 x Nd:YAG	532	1,46071
(ne)	546,07	1,46008
(nd)	587,56	1,45846
HeNe	632,8	1,45702
(nc)	656,27	1,45637
Ruby	694,3	1,45542
Kr	752,5	1,45419
	800	1,45332
	850	1,45250
	900	1,45175
GaAs	905	1,45168
	1000	1,45042
Nd:YAG	1064	1,44963
HeNe	1153	1,44859
	1200	1,44805
Nd:YAG	1319	1,44670
	1400	1,44578
	1600	1,44342
	1800	1,44087
	2000	1,43809
	2200	1,43501
	2400	1,43163
	2600	1,42789
	2800	1,42377
	3000	1,41925
	3200	1,41427
	3400	1,40881

Optical Homogeneity

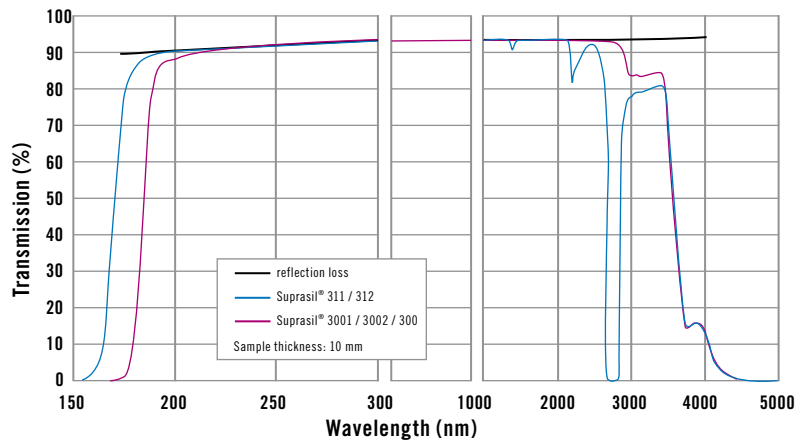
The false colour interferogram below shows the typical two-dimensional refraction-index distribution. The interferogram belongs to a circular blank.

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.

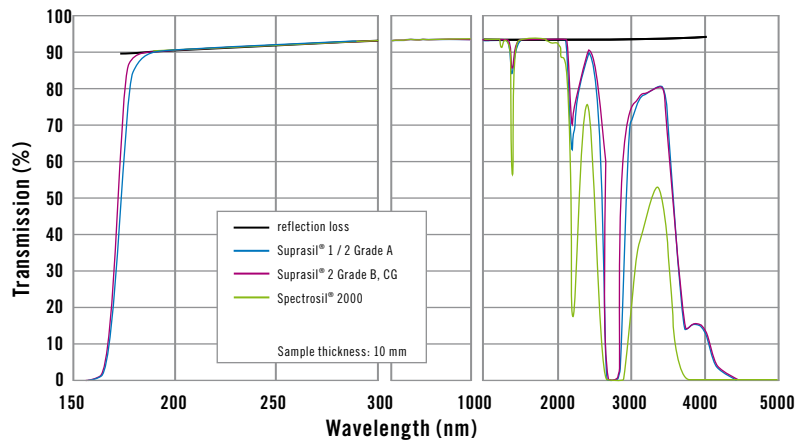


Measured transmission including Fresnel reflection losses $(1-R)^2$

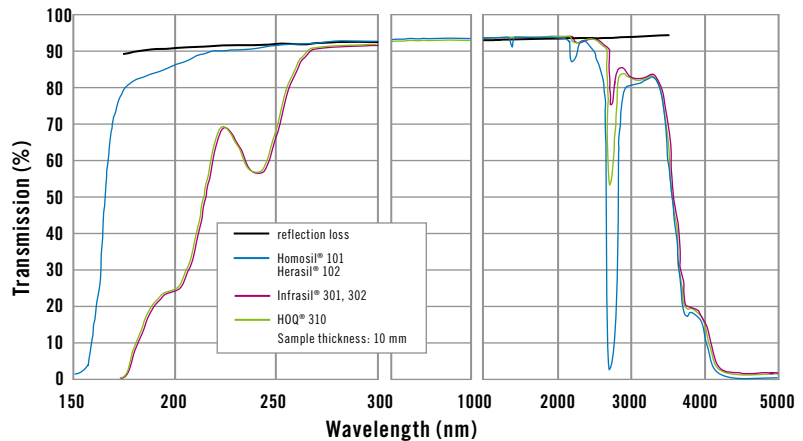
Suprasil® 311, 312
 Suprasil® 3001, 3002, 300



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



Homosil® 101
 Herasil® 102
 HOQ® 310
 Infrasil® 301, 302



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

Technical Properties

Internal transmission (%)

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

Wavelength nm	Suprasil® ArF/ KrF	Suprasil®- family	Homosil® 101 Herasil® 102
	- specified -	- typical -	
193,4	≥ 99,30	98,50	92,00
248,4	≥ 99,80	99,50	98,00
266	99,90	99,90	99,50

Relative temperature coefficients of the refractive index in 10⁻⁶ K⁻¹

Wave-length nm	Suprasil®-family, Spectrosil®		Homosil® / Herasil® / 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

$$v_d = \frac{n_d - 1}{n_f - n_c} \quad 67,8 \pm 0,5$$

Birefringence constant @ 633 nm

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

Refraction index dispersion

Dispersion constants (Sellmeier)

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

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 λ in μm at 20°C

Typical trace impurities in quartz glass

Impurities	Suprasil®- family, Spectrosil® ppm	Herasil® 102 / Homosil® 101 ppm	Infrasil® / HOQ® ppm
Al = aluminium	≤ 0,010	10	20
Ca = calcium	≤ 0,015	1	1
Cr = chrome	≤ 0,001	0,1	0,1
Cu = copper	≤ 0,003	0,1	0,1
Fe = iron	≤ 0,005	0,2	0,8
K = potassium	≤ 0,010	0,1	0,8
Li = lithium	≤ 0,001	1	1
Mg = magnesium	≤ 0,005	0,1	0,1
Na = sodium	≤ 0,010	1	1
Ti = titanium	≤ 0,005	0,1	1

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

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

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

Germany

**Heraeus Quarzglas GmbH
& Co. KG**

Optics

Quarzstr. 8, 63450 Hanau
Phone +49 (6181) 35-62 85
Fax +49 (6181) 35-62 70
sales.hqs.optics.de@
heraeus.com

USA

Heraeus Quartz America, LLC.
Optics

100 Heraeus Blvd.
30518 Buford, Georgia
Phone +1 (678) 714-4350
Fax +1 (678) 714-4355
sales.hqs.optics.us@
heraeus.com

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China

**Heraeus ShinEtsu Quartz
(China) Inc.**

QianJiang Tower, 20th Floor,
Room A, No. 971 Dongfang Road
200122 Shanghai
Phone +86 (21) 68672266-809
Fax +86 (21) 68751434
sales.hqs.optics.cn@heraeus.com

UK

Heraeus Quarzglas UK

4 Tannery House
Tannery Lane
Send, Woking
Surrey GU23 7EF
Phone +44 (1483) 213323
Fax +44 (1483) 213329
sales.hqs.optics.uk@heraeus.com

Korea

YOUNG SHIN QUARTZ CO.,Ltd.

149, Hoechuk-ri
Mansung-myon, Chinchon-kun
Chungbuk Province, 365-830
Phone +82-43-535-2338
Fax +82-43-535-2337
ykkim@ysq.co.kr
www.ysq.co.kr

www.optics.heraeus-quarzglas.com