Quartz Glass for Optics
Data and Properties

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3D = 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 ⁄ 0.08 mm diameter are not counted. For synthetic fused silica a specification for bubbles and inclusions of ≤ 10µm is possible on request.

❸ For non-spherical bubbles the diameter is averaged.

❹ 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 ❶❷			Homogeneity ❺	
	The bubble grade is given for every 100 cm³. Quartzglass from Heraeus is free of inclusions.			Δn-value ❹	
	DIN 58927	DIN ISO 10110 ❸	Total cross-sections (in mm²) of all bubbles (TBCS value)	Striae class as ❹ per DIN ISO 10110	PV value (Peak-to-Valley)
Suprasil® 1 3D	0	1/ 1*0.10	≤ 0.03	2 / -;5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade A	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade B	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 10 \cdot 10^{-6}$
Suprasil® Standard	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 30 \cdot 10^{-6}$
Suprasil® 1 ArF / KrF * 3D	0	1/ 1*0.10	≤ 0.03	2 / -;5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 ArF / KrF *	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 5 \cdot 10^{-6}$
Suprasil® 311 3D	0	1/ 1*0.10	≤ 0.03	2 / -;5	$\leq 3 \cdot 10^{-6}$
Suprasil® 312	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3001 3D	0	1/ 1*0.10	≤ 0.03	2 / -;5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3002	0	1/ 1*0.16	≤ 0.03	2 / -;5	$\leq 5 \cdot 10^{-6}$
Suprasil® 300	0	1/ 1*0.16	≤ 0.03	n. sp.	n. sp.
Homosil® 101 3D	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	$\leq 4 \cdot 10^{-6}$
Herasil® 3	2...3	1/ 2*0.5	≤ 0.4	n. sp.	$\leq 10 \cdot 10^{-6}$
Infrasil® 301 3D	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	$\leq 6 \cdot 10^{-6}$
Infrasil® 303	1	1/ 2*0.35	≤ 0.25	2 / -;5	$\leq 10 \cdot 10^{-6}$
HOQ 310	2...3	1/ 1*0.63 ≤ 6 kg 1/ 2*1.0 > 6 kg	≤ 0.5	n. sp.	n. sp.

* Suprasil® 1, 2 ArF / KrF are especially optimized for excimer laser applications. Please ask for our "Application Note".

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

❺ Does not apply to drawn rods.

❻ Lower values available on request.

❼ 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

	Residual Strain ❼		Fluorescence	OH-Content
PV values by special request	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)
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	≤ 1000
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	≤ 1000
-	≤ 5	5...15	free	≤ 1000
-	≤ 20	n. sp.	free	400...1000
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	≤ 1200
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	≤ 1200
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	ca. 200
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	free	ca. 200
$\leq 1 \cdot 10^{-6}$	≤ 6	5...15	slight blue	≤ 1
$\leq 1 \cdot 10^{-6}$	≤ 6	5...15	slight blue	≤ 1
-	≤ 5	5...15	slight blue	≤ 1
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	blue-violet	ca. 150
$\leq 1 \cdot 10^{-6}$	≤ 5	5...15	blue-violet	ca. 150
-	≤ 10	10...15	blue-violet	ca. 150
$\leq 2 \cdot 10^{-6}$	≤ 5	5...15	blue-violet	≤ 8 ❻
$\leq 3 \cdot 10^{-6}$	≤ 5	5...15	blue-violet	≤ 8 ❻
-	≤ 10	10...20	blue-violet	≤ 8 ❻
-	≤ 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 $\pm 3 \cdot 10^{-5}$.

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

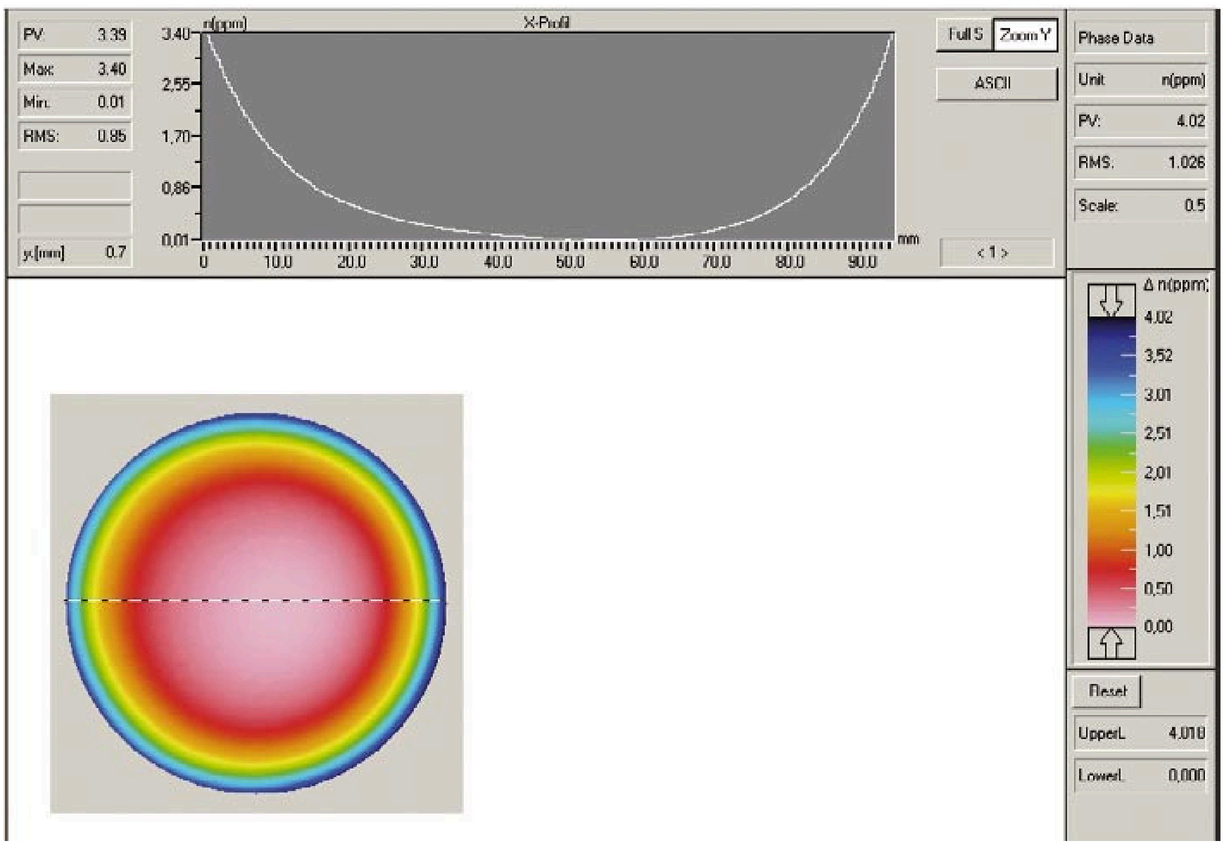
*without Suprasil 3001, 3002, 300

Wavelength nm		Suprasil-family	Homosil / Herasil / Infrasil / HOQ
	190	1,56572	-
ArF	193,4	1,56013	-
	200	1,55051	-
	202,54	-	1,54729
	220	1,52845	1,5287
	232,94	-	1,51834
	240	1,51334	1,51359
KrF	248,4	1,50833	-
	260	1,50239	1,50264
4 x Nd:YAG	266	1,49968	1,49993
	274,87	1,49607	1,49634
	280	1,49416	1,49439
	300	1,48779	1,48800
XeCl	308	1,48564	1,48583
	320	1,48274	1,48292
HeCd	325	1,48164	1,48182
N2	337	1,47921	1,47938
	340	1,47865	1,47881
	360	1,47529	1,47544
(ni)	365,48	1,47447	1,47462
	380	1,47248	1,47262
	400	1,47012	1,47025
(nh)	404,65	1,46962	1,46975
(ng)	435,83	1,46669	1,46681
HeCd	441,6	1,46622	1,46634
Kr	447,1	1,46578	1,46591
(nF)	486,13	1,46313	1,46324
Ar	488	1,46301	1,46313
Ar	514,5	1,46156	1,46166
2 x Nd:YAG	532	1,46071	1,46081
(ne)	546,07	1,46008	1,46018
(nd)	587,56	1,45846	1,45856
HeNe	632,8	1,45702	1,45711
(nc)	656,27	1,45637	1,45646
Ruby	694,3	1,45542	1,45552
Kr	752,5	1,45419	1,45428
	800	1,45332	1,45341
	850	1,45250	1,45259
	900	1,45175	1,45185
GaAs	905	1,45168	1,45177
	1000	1,45042	1,45051
Nd:YAG	1064	1,44963	1,44972
HeNe	1153	1,44859	1,44868
	1200	1,44805	1,44815
Nd:YAG	1319	1,44670	1,44680
	1400	1,44578	1,44589
	1600	1,44342	1,44353
	1800	1,44087	1,44099
	2000	1,43809	1,43821
	2200	1,43501	1,43515
	2400	1,43163	1,43177
	2600	1,42789	1,42804
	2800	1,42377	1,42393
	3000	1,41925	1,41941
	3200	1,41427	1,41444
	3400	1,40881	1,40897

Optical Homogeneity

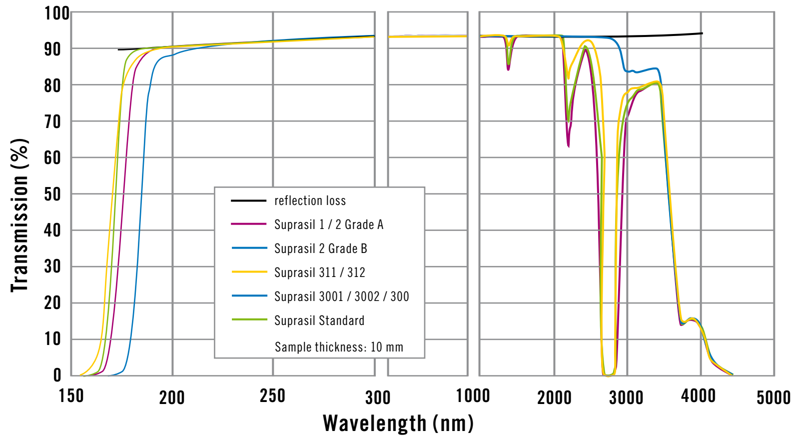
The false colour interferogram below shows the typical two-dimensional refraction-index distribution. The interferogram belongs to a circular blank.

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.

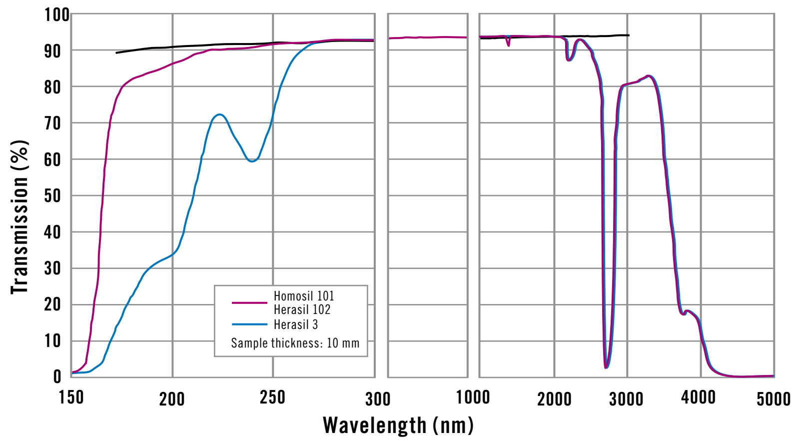


Measured transmission including Fresnel reflection losses $(1\text{-}R)^2$

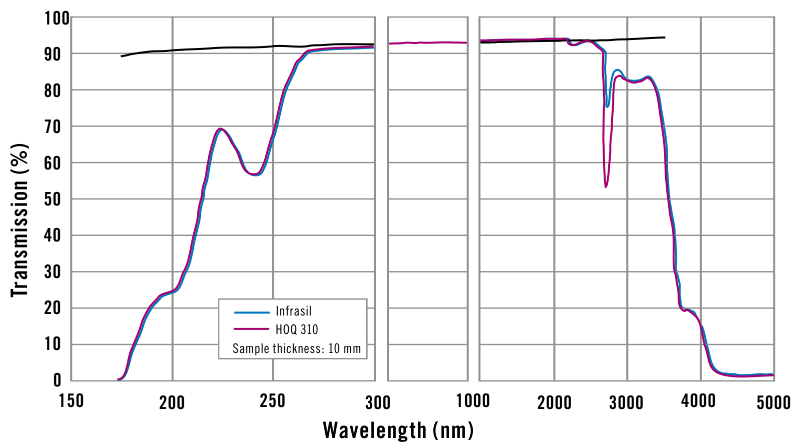
Suprasil® 1, 1 ArF / KrF
Suprasil® 2 Grade A, 2 ArF / KrF
Suprasil® 2 Grade B
Suprasil® 311, 312
Suprasil® 3001, 3002, 300
Suprasil® Standard



Homosil® 101
Herasil® 102,
Herasil® 3



HOQ 310
Infrasil® 301, 302, 303



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 - specified -	Suprasil-family - typical -	Homosil 101 Herasil 102
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	Suprasil-family		Homosil / Herasil / Infrasil / HOQ	
nm	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

$\nu_d = \frac{n_d - 1}{n_F - n_c}$	67,8 ± 0,5

Birefringence constant @ 633 nm

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

Refraction index dispersion

Dispersion constants (Sellmeier)

	Suprasil-family	Homosil / Herasil / Infrasil / HOQ
B1	$4{,}73115591 \cdot 10^{-1}$	$4{,}76523070 \cdot 10^{-1}$
B2	$6{,}31038719 \cdot 10^{-1}$	$6{,}27786368 \cdot 10^{-1}$
B3	$9{,}06404498 \cdot 10^{-1}$	$8{,}72274404 \cdot 10^{-1}$
C1	$1{,}29957170 \cdot 10^{-2}$	$2{,}84888095 \cdot 10^{-3}$
C2	$4{,}12809220 \cdot 10^{-3}$	$1{,}18369052 \cdot 10^{-2}$
C3	$9{,}87685322 \cdot 10^{1}$	$9{,}56856012 \cdot 10^{1}$

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 ppm	Herasil 102 / Homosil 101 ppm	Herasil 3 / 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 Homosil / Herasil / Infrasil / HOQ
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	$7{,}0 \cdot 10^4$
Modulus of torsion	N/mm^2	$3 \cdot 10^4$
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 $\Omega \cdot$m		
20°C		10^{16}
400°C		10^8
800°C		$6{,}3 \cdot 10^4$
1200°C		$1{,}3 \cdot 10^3$
Dielectric strength in kV/mm (Layer thickness $\geq$ 5 mm)		
20°C		40...50
500°C		4...5
Dielectric loss angle (tg δ)		
1kHz		0,0005
1...1000MHz		< 0,001
$3 \cdot 10^4$MHz		0,0004
Dielectric constant (ε)		
20°C	0...1 MHz	3,7
23°C	0...1000 MHz	3,80
23°C	$3 \cdot 10^4$ MHz	3,81

Thermal data		Suprasil-Family	Homosil/ Herasil/ Infrasil/ HOQ
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 termal expansion coefficient K^{-1}			
-160...0°C		0	
-50...0°C		$2{,}7 \cdot 10^{-7}$	
0...100°C		$5{,}1 \cdot 10^{-7}$	
0...200°C		$5{,}8 \cdot 10^{-7}$	
0...300°C		$5{,}9 \cdot 10^{-7}$	
0...600°C		$5{,}4 \cdot 10^{-7}$	
0...900°C		$4{,}8 \cdot 10^{-7}$	

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