SQ Fused Silica

Grades and Subgrades

SQ is the result of several decades of experience in the development, manufacturing and qualifying of fused synthetic silica in Jena – all done in accordance with our clients' requirements and the market's material specifications.

SQ ultra-pure synthetic fused silica is our new offering to manufacturers of optics and photonic devices in fiber optics, semiconductor, display technologies, optical, and laser industries.

With SQ fused silica j-plasma provides advanced industries with inclusion and bubble free material showing best laser durability, refractive index homogeneity as well as stability under thermal conditions and stress. SQ fused silica is being offered in three qualities regarding its level of homogeneity and striation to serve high-end, mid and standard technical use in optical elements such as prisms, lenses, wafers or displays.

SQ fused silica shows a very good transmission from UV- to IR range.

SQ supports the design and make of specialty applications preforms as well as the parameter controlled drawing of high-performance optical fibers for use in advanced specialty and photonic devices.

Key quality features of the different grades are

- Inclusion / bubble free (eg. grades SQ0 + SQ1)
- Excellent UV transmittance
- Very low fluorescence
- High laser durability
- Low stress birefringence
- High refractive index homogeneity: additional 3D option
- Very low thermal expansion coefficient
- High temperature stability

SQ0 is characterized by its high three-dimensional optical homogeneity. Free of striations in any functional direction, it is recommended for high-end resolution requirements in optical elements such as prisms and lenses.

SQ1 exhibits high homogeneity and has no striations in the functional direction. Typical applications are optical elements such as lenses, windows, wafers, and optical fibers.

SQT is not specified concerning homogeneity, striae and striations. This grade is recommended for technical applications.

Grades and Subgrades of SQ

Grades are:

- SQ0
- SQ1
- SQT

Subgrade:

- SQ-E (Excimer grade fused silica – available as SQ1 or SQ0):
  - Excellent transmission at 193 nm / 248 nm
  - Lowest level of laser induced fluorescence (LIF)
- SQ0-E193 / SQ1-E193 (ArF Excimer grade)
- SQ0-E248 / SQ1-E248 (KrF Excimer grade)

Ordering Information

To order SQ please call, fax or email us and specify the following parameters:

Rod Type:	SQ0; SQ1; SQT
Excimer grade	E193; E248
Rod Diameter:	mm
Rod Length:	mm
Rod Quantity:	kg
Other:	desired ship date, special requests

All j-plasma products are subject to j-plasma's ongoing process and quality improvement programs ensuring excellent performance and high reliability. We reserve the right to make changes to the above specification without notice.

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Officially registered facility according to EWG No. 1221/2009

For further information about our SQ rods and other j-plasma products and services, please contact us:

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Optical Properties

Bubbles, Inclusions, Homogeneity, and Stress Birefringence

Grade	Bubbles and Inclusions[4]		Homogeneity Data		Stress Birefringence
	according to ISO 10110-3	max. Diameter [mm]	local inhomogeneities striae and striations[1] according to ISO 10110-4	refractive index change Δn[2) 3)] in functional directions [ppm = $1*10^{-6}$]	standard[3] [nm/cm]
SQ0	1/ 1 x 0.063	0.07	2/- ; 5 all directions	standard: PV ≤ 40 ppm	≤ 5
SQ1	1/ 1 x 0.063	0.07	2/- ; 5 functional directions		≤ 5
SQT	not defined	0.5	not specified	on request	≤ 10

[1] Shadow method, polarizer and interferometer are used for striae and striation detection

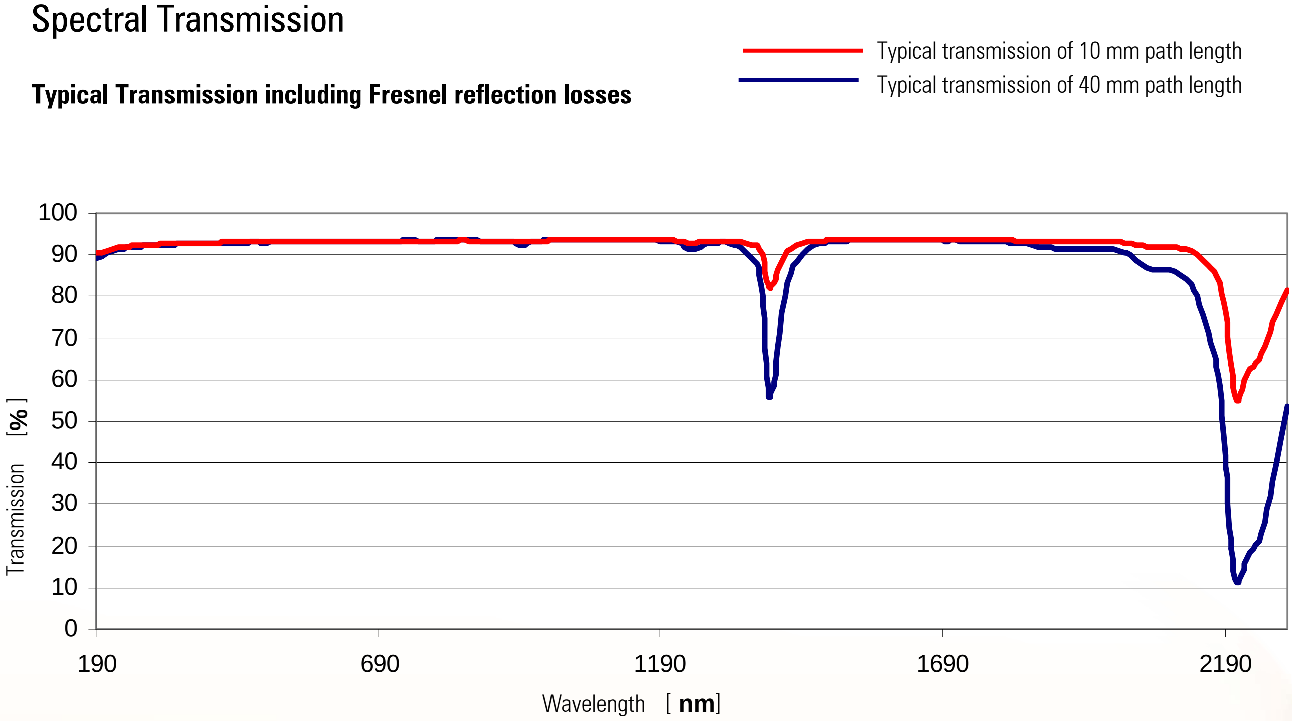
[2] Homogeneity Δn is tested interferometrically (5% outer edge exclusion).

[3] Lower values with respect to size and processing available on request.

[4] Bubbles and inclusions < 0.05 mm in diameter are not considered in these cases.

Spectral Transmission

Typical Transmission including Fresnel reflection losses



Grade	Internal Transmittance [%] per 10 mm sample thickness			OH Content	Other Contaminants
	λ=193 nm	λ=248 nm	λ=300 nm	[ppm]	[ppm]
SQ0	≥ 98.0	≥ 99.5	≥ 99.9	Appr. 1200	≤ 0.05
SQ1	≥ 98.0	≥ 99.5	≥ 99.9	Appr. 1200	≤ 0.05
SQT	-	≥ 95.0	≥ 99.9	800-1400	≤ 0.6
SQ-E193	≥ 99.3	≥ 99.8	≥ 99.9	Appr. 1200	≤ 0.05
SQ-E248	≥ 99.0	≥ 99.8	≥ 99.9	Appr. 1200	≤ 0.05

- All grades show an internal transmittance ≥ 99.9 % in the wavelength range of 300…900 nm.
- All grades show a hydrogen content of appr. 1 $*10^{18}$ Mol. / cm^3 H_2

Refraction Properties of SQ

Refractive Indices n (at 20 °C, nitrogen atmosphere, 1013 hPa)			Variation over Temperature
	λ_{vac} [nm]	n	$\Delta n/\Delta T$ [10^{-6}/K]
n_{2325}	2325.59	1.43290	-
n_{1970}	1970.56	1.43849	-
n_{1530}	1530	1.44424	-
n_{1060}	1060	1.44965	-
n_t	1014.25	1.45021	9.6
n_s	852.35	1.45243	9.7
n_r	706.71	1.45511	9.8
n_C	656.45	1.45633	9.9
$n_{C'}$	644.03	1.45667	9.9
$n_{He\text{-}Ne}$	632.98	1.45698	9.9
n_D	589.46	1.45837	10.0
n_d	587.73	1.45843	10.0
n_e	546.23	1.46004	10.1
n_F	486.27	1.46309	10.3
$n_{F'}$	480.13	1.46347	10.3
n_g	435.96	1.46666	10.5
n_h	404.77	1.46958	10.8
n_i	365.12	1.47450	11.2
n_{334}	334.24	1.47973	11.6
n_{312}	312.66	1.48446	12.1
n_{296}	296.82	1.48870	12.5
n_{280}	280.43	1.49401	13.0
n_{248}	248.35	1.50837	14.5
n_{194}	194.23	1.55887	20.1
n_{193}	193.37	1.56022	20.3

All refractive indices are interpolated from values measured under dry nitrogen; λ_{vac} = vacuum wavelength. Tolerances of refractive indices: $\pm 2.0 \cdot 10^{-5}$

Abbe Numbers		
$n_d = 1.45843$	$\nu_d = 67.83$	$n_F - n_C = 0.00676$
$n_e = 1.46004$	$\nu_d = 67.68$	$n_{F'} - n_{C'} = 0.00680$

Relative Partial Dispersion	
$P_{s,t}$	0.3287
$P_{C,s}$	0.5770
$P_{d,C}$	0.3102
$P_{e,d}$	0.2388
$P_{g,F}$	0.5277
$P_{i,h}$	0.7283

Deviation of Relative Partial Dispersions from "Normal Line"	
$\Delta P_{C,t}$	0.0390
$\Delta P_{C,s}$	0.0159
$\Delta P_{F,e}$	-0.0017
$\Delta P_{g,F}$	-0.0020
$\Delta P_{i,g}$	0.0054

Sellmeier Dispersion Formula for Refractive Indices			
$n^2-1 = B_1 \lambda^2/(\lambda^2-C_1) + B_2 \lambda^2/(\lambda^2-C_2) + B_3 \lambda^2/(\lambda^2-C_3)$ with λ in μm			
Constants of Sellmeier Dispersion Formula for λ_{vac} and n			
B_1	$6.694226 \cdot 10^{-1}$	C_1	$4.480112 \cdot 10^{-3}$
B_2	$4.345839 \cdot 10^{-1}$	C_2	$1.328470 \cdot 10^{-2}$
B_3	$8.716947 \cdot 10^{-1}$	C_3	$9.534148 \cdot 10^{1}$

Valid for $0.184\ \mu m < \lambda < 2.326\ \mu m$ (20 °C; 1013 hPa); $n = n(N_2)$; $\lambda = \lambda_{vac}$

Refractive Index Variation over Temperature Change:
$\Delta n/\Delta T\ (18 - 28\ °C) = t_0 + t_1 \cdot \lambda^{-2} + t_2 \cdot \lambda^{-4} + t_3 \cdot \lambda^{-6}$

Formula for dn_{abs}/dT:

$$\frac{dn_{abs}(\lambda,T)}{dT} = \frac{n^2(\lambda,T_0)-1}{2 \cdot n(\lambda,T_0)} \cdot \left(D_0 + 2 \cdot D_1 \cdot \Delta T + 3 \cdot D_2 \cdot \Delta T^2 + \frac{E_0 + 2 \cdot E_1 \cdot \Delta T}{\lambda^2 - \lambda_{TK}^2} \right)$$

with $T_0 = 20\ °C$

Constants of formula for $\Delta n/\Delta T$ in Nitrogen[1]	
t_0	$9.4 \cdot 10^{-0}$
t_1	$1.7 \cdot 10^{-1}$
t_2	$8.7 \cdot 10^{-2}$
t_3	$3.1 \cdot 10^{-4}$
-	-
-	-

Constants of formula for dn_{abs}/dT in Vacuum[2]	
D_0	$2.06 \cdot 10^{-5}$
D_1	$2.51 \cdot 10^{-8}$
D_2	$-2.47 \cdot 10^{-11}$
E_0	$3.12 \cdot 10^{-7}$
E_1	$4.22 \cdot 10^{-10}$
λ_{TK} [μm]	0.16

[1]Valid for $0.184\ \mu m < \lambda < 1.014\ \mu m$ and for $+18\ °C \le T \le +28\ °C$

[2]Valid for $0.365\ \mu m < \lambda < 1.060\ \mu m$ and for $-100\ °C \le T \le +140\ °C$

Differential Temperature Coefficients of the Refractive Index[1]						
	$\Delta n_{rel}/\Delta T$ [10^{-6}/K][2]			$\Delta n_{abs}/\Delta T$ [10^{-6}/K][3]		
λ_{vac} [nm]	1060.0	546.23	365.12	1060.0	546.23	365.12
-40/-20 [°C]	8.9	9.4	10.2	6.9	7.3	8.1
+20/+40 [°C]	9.4	9.9	10.9	8.1	8.6	9.6
+60/+80 [°C]	9.8	10.4	11.5	8.8	9.4	10.4

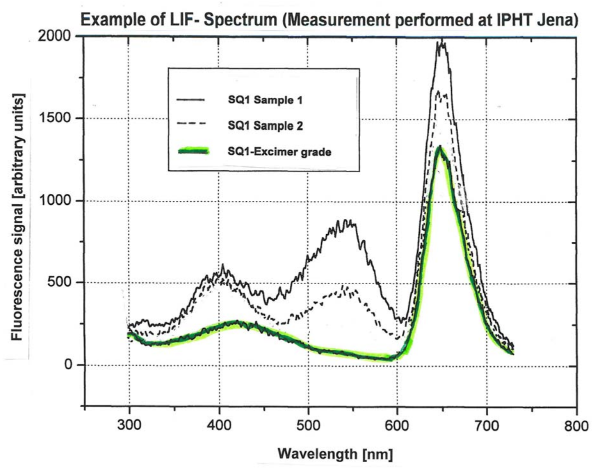
[1]Valid for 365 nm $< \lambda <$ 1060 nm and for $-100\ °C \le T \le +140\ °C$

[2]Relative to nitrogen

[3]Relative to vacuum

Fluorescence

- Excimer grade Fused Silica is qualified by the LIF-measurement equipment (IPHT Jena).
- Best compatibility of every sample by routine LIF-measurements to a calibration standard.
- Irradiation parameter to LIF-qualification:
  - Laser wavelength 193 nm
  - Energy density 210 mJ / cm^2
  - Repetition rate 10 Hz



Red fluorescence: sensitive criteria for NBOHC (Non Bridging Oxygen Hole Center). Low level is characteristic for a hight Hydrogen content.
Blue fluorescence: sensitive criteria for ODC (Oxygen Deficiency Centers)

Thermal Properties		Unit
Strain point T_{10} $^{14.5}$	980	°C
Annealing point T_{10} $^{13.0}$	1080	°C
Softening point T_{10} $^{7.6}$	1600	°C
Max working temperatures Continuously Short-term	 930 1180	 °C °C
Mean specific heat Cp (20°C-100°C)	0.79	J/g·K
Heat conductivity λ (32°C)	1.31	W/(m·K)
Linear thermal expansion coefficient		
α (25°C-100°C)	0.5	10^{-6}/K
α (25°C-200°C)	0.52	10^{-6}/K
α (25°C-300°C)	0.55	10^{-6}/K
α (25°C-600°C)	0.51	10^{-6}/K

Electrical Properties	
Dielectric constant ε_r	3.8 ± 0.2
Dielectric loss angle φ (25°C/1MHz)	$89.92° \pm 0.03°$
tan δ (δ=90° - φ) (25°C/1MHz)	$(14 \pm 5) \cdot 10^{-4}$
Electrical resistivity (25°C) [$\Omega \cdot$ cm]	$1.15 \cdot 10^{18}$

Chemical Behavior of Polished Surfaces Climatic Resistance Class		
(ISO/WD 13384)	CR	1
Acid Resistance Class (ISO 8424)	SR	1.0
Alkali Resistance Class (ISO 10629)	AR	1.0
Phosphate Resistance Class (ISO 9689)	PR	1.0
Stain Resistance Class	FR	0

Typical Trace Contaminants [ppm]	
Trace Elements	SQ0/ SQ1
Al	≤ 0.05
Na	≤ 0.02
Ca	≤ 0.02
K	≤ 0.01
Fe	≤ 0.005
Ti	≤ 0.01
Cu	≤ 0.005
Cr	≤ 0.005
Mn	≤ 0.005

Mechanical Properties		Unit
Young's modulus (25°C)	72	GPa
Shear modulus	31	GPa
Compressive strength	1250	N/mm^2
Bending strength	80-100	N/mm^2
Poisson's ratio μ	0.17	
Knoop HK 0.1/20	580	
Mohs	5-6	
Density ρ	2.2	g/cm^3
Stress optical coefficient	$3.4 \cdot 10^{-12}$	1/Pa
Longitudinal ultrasonic velocity	5940	m/s
Transversal ultrasonic velocity	3770	m/s
Internal damping (25°C-500°C)	$2.0 \cdot 10^{-5}$	