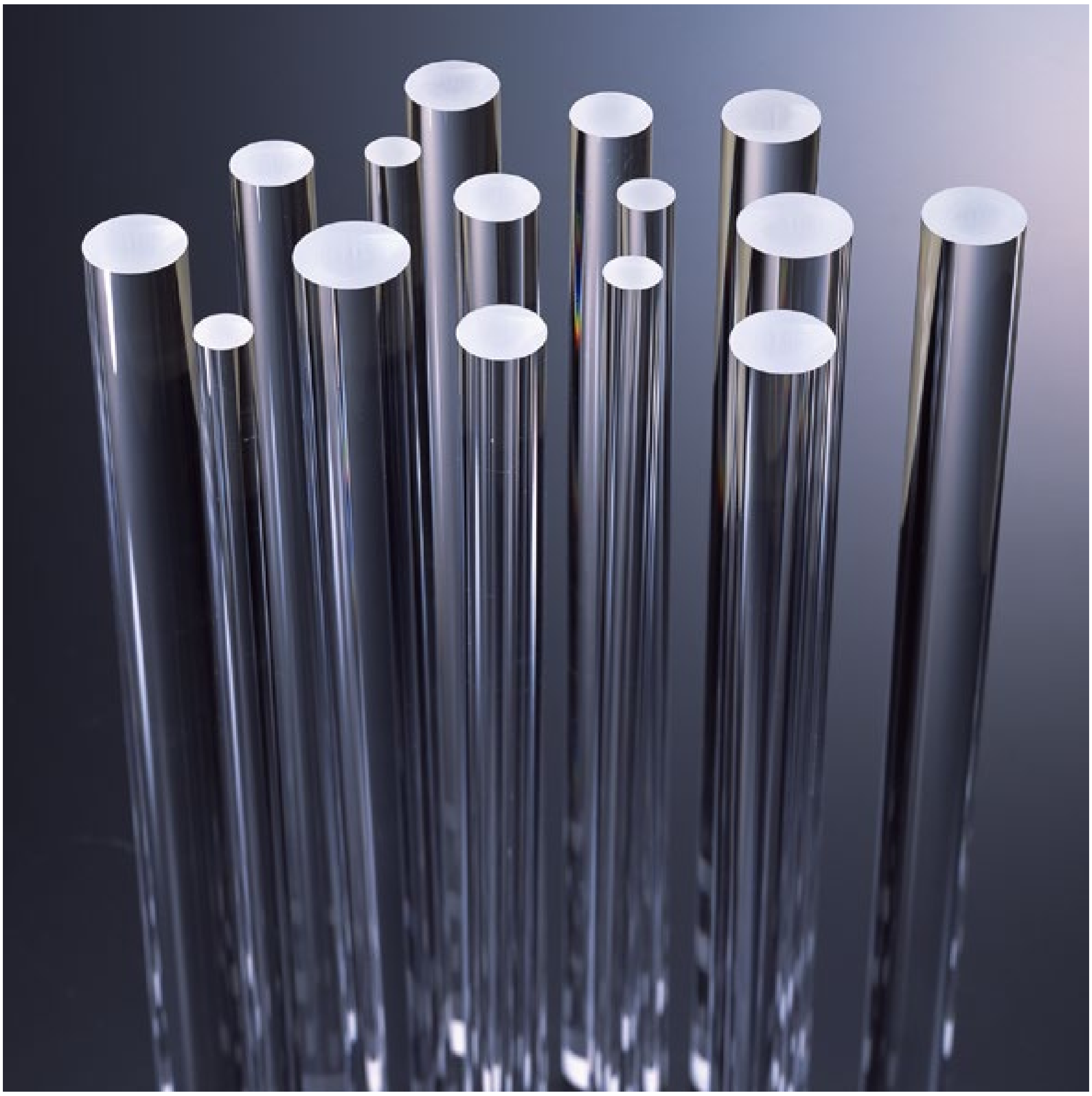
Heraeus Quarzglas GmbH Co.KG

Fluosil Preform

Shin-Etsu Quartz Products Co., Ltd. imports and sells the Fluosil® brand of specialty fiber-use quartz preform—employed in UV laser and IR laser transmissions, etc.—made by the German company, Heraeus Quartzglas GmbH & Co,KG. Fluosil products can be customized to meet each application, including UV or IR transmissions, spectroscopy and high power transmissions, and the desired key preform characteristics such as cladding thickness, numerical aperture (NA), and core material properties, etc., can be arranged.



Product characteristics

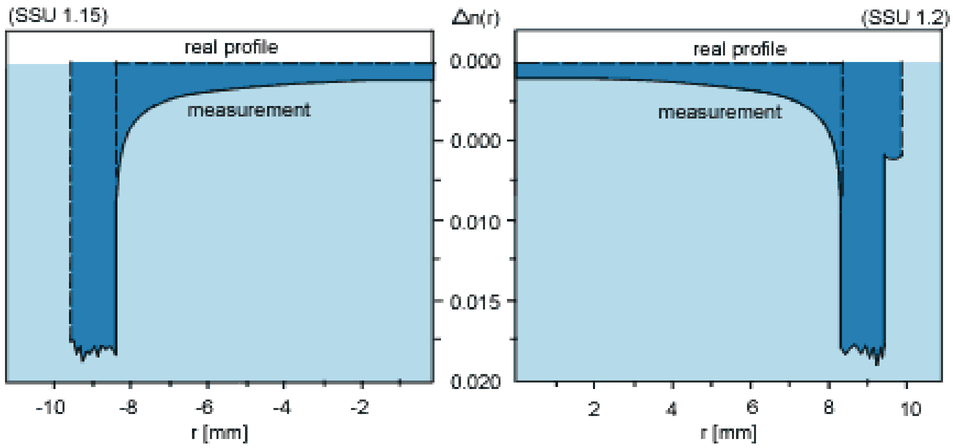
The optical performance of silica/silica fibers is mainly controlled by a number of preform attributes including the spectral attenuation (which is principally determined by the core material), the cladding thickness and the numerical aperture. The methods to determine these preform attributes are described below.

Methods to determine preform attributes

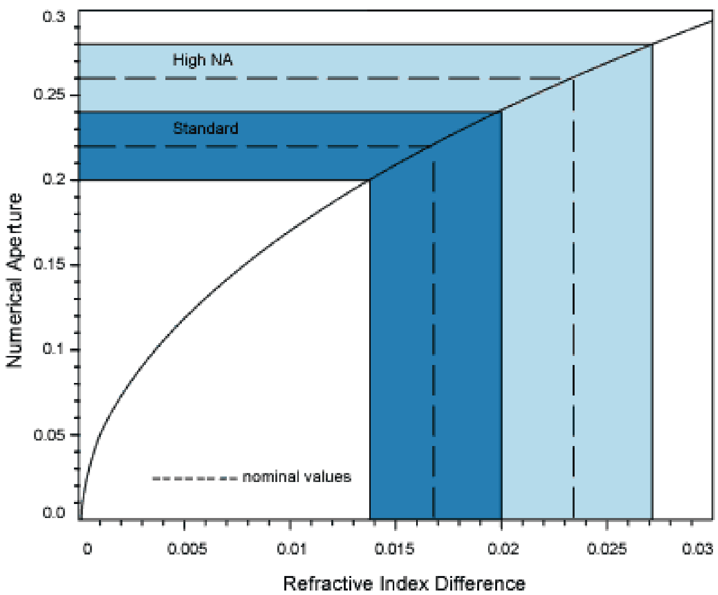
1. Refractive Index Profiles

The refractive index profiles are measured with commercially available equipment (P102, York Technology Ltd.). Special modifications, as well as corrections, were implemented in order to provide high measurement accuracy even for preforms with step profiles as steep as those of Fluosil, products. Special emphasis was put on absolute accuracy as well as long term consistency of the measurements. Therefore an excellent Fluosil, preform was selected as the reference standard for regular instrument calibration. The absolute value of the refractive index difference of a fiber drawn from that preform was determined precisely by interferometry at the National Physical Laboratory, UK. The results are documented in an official measurement certificate and are in very good agreement with those obtained via the Heraeus standard procedure (for details see technical note: "Determination of refractive index Differences of Fluosil preforms"). To determine the ratio of outer diameter to core diameter, called Cladding to Core Diameter Ratio (CCDR) from the index profiles, diameter corrections were calculated from ray tracing methods.

■ **Typical profiles of two different preform types SSU1.15 (left side) and SSS1.2 (right side)**



■ **Relation of refractive index difference to calculated NA together with the standard NA and High NA specifications**



Standard: $0.014 \leq \Delta n \leq 0.020$ NA = 0.22 ± 0.02

High NA: $0.020 \leq \Delta n \leq 0.027$ NA = 0.26 ± 0.02

Calculation of refractive index difference $\Delta n = n_{core} - n_{clad}$

The refractive index differences between core (n_{core} = 1.4571) and inner cladding region (n_{clad}) define the numerical aperture NA of the optical fiber via the relation:

$$NA = \sqrt{n^2_{core} - n^2_{clad}}$$

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2. Visual Preform Quality

All preforms are inspected under collimated light in a dark room for visual defects such as open or closed bubbles, inclusions, or scratches. None of these are permissible except for a limited number of very small closed bubbles below a specific dimension. Their size is judged by comparison to a reference sample.

3. Spectral Attenuation

To determine the spectral attenuation, fiber samples of every preform batch are investigated by the cut-back method. The attenuation as well as solarization behavior and radiation resistance of fibers are principally determined by the preform core material.

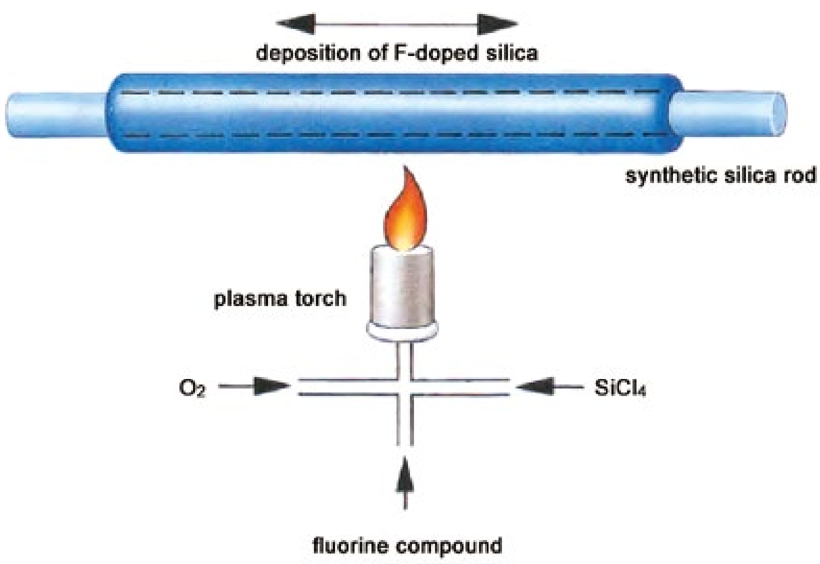
4. Physical Material Characteristics

	Core	Cladding	Unit
Refractive Index@633 nm	1.4571	1.440	—
Refractive Index@1,064 nm	1.4498	1.433	—
Transformation Temperature	1,050	750	°C
Fluorine Content	0	4.0	wt %
Thermal Expansion Coefficient (20 to 400°C)	9	2.5	10^{-7}/k
Density	2.203	2.180	g/cm^3
Elasticity Modulus	7.25 x 10^{10}	n.d.	N/m^2

Production Method

Preforms are manufactured by the Plasma Outside Deposition (POD), process. Rods of extremely pure synthetic fused silica are coated with fluorine doped silica layers to obtain preforms with step-like refractive index profiles. Plasma torches prepare the reaction compounds from $SiCl_4$, O_2, and a fluorine containing gas. Strong thermal gradients combined with the high temperature plasma lead to chemical deposition conditions, which allow very high fluorine concentrations to be incorporated in the fused silica network. Refractive index differences of 0.027 corresponding to numerical apertures (NA) in excess of 0.28 have been realized with undoped core rods. This is a unique feature of the Fluosil process technology.

A Fluosil preform is manufactured as a large ingot which is pulled and cut to yield rods suitable for fiber drawing. These rods constitute a batch and are an important unit in quality control.



Product Guide

The optical performance of silica/silica fibers is mainly controlled by a number of preform attributes including the spectral attenuation (which is principally determined by the core material), the cladding thickness and the numerical aperture. The effect of these characteristics and the Fluosil, product code are described below.

1. Product Code

ex: S S U 1.1 H / 25 mm

● **Meaning**

- 25 mm: denotes the diameter: 15, 20, 25, 30 and 35 mm are available, others on request
- H: denotes the NA: blank for standard NA, H for High NA, L for low NA
- 1.1: denotes the CCDR: Cladding / Core Diameter Ratio's from 1.04 up to 1.4 are available, other values upon request!
- U: denotes the cladding profile type: U: uniformly doped, S: double clad
- S (second): denotes the core material: S: high OH, W: low OH, L, etc.
- S (first): step index preform

2. Numerical Aperture (NA)

The refractive index difference of a step-index fiber defines the numerical aperture (NA) of the fiber. The acceptance-cone half angle (θ) is defined as follows.
Where n_{core} and n_{clad} denote the refractive indices of the core and cladding material. The value of n_{clad} is defined by the fluorine concentration.

$$\sin\theta = NA = \sqrt{n^2_{core} - n^2_{clad}}$$

3. Available numerical apertures

- 0.22 ± 0.02 standard NA (undoped core material)
- 0.26 ± 0.02 high NA (undoped core material)
- Low NA values on request
- In choosing the optimum NA for a certain application, considerations include the geometry of coupling light into and out of the fiber, as well as sensitivity to bend losses. If fibers undergo strong bending, the angle of total reflection can be exceeded by the light traveling in the fiber at the point of the strongest bending. To minimize these losses, a larger radius of curvature, a higher NA and shorter wavelengths are desirable.

4. Cladding to Core Diameter Ratio (CCDR)

The guided light in an optical fiber is totally reflected at the core/cladding interface. At every reflection a small amount of the light intensity penetrates into the cladding (evanescent field). In the case of a thin cladding, the evanescent field can reach the outer diameter of the fiber. This will result in excessive attenuation of the guided wave. For a typical fiber with a NA of 0.22, the rule of the thumb is that the cladding thickness should be at least ten times the longest wavelength of interest. As an example, assume that the longest wavelength of interest is 1000 nm and the core diameter is 200 microns. The CCDR should be 1.1 because this will give a cladding thickness of 10 microns.

5. Preforms available

- CCDR in the range 1.04 to 1.4 other values upon request!
- Preforms with CCDR ≦ 1.15 generally have a single highly doped cladding layer (U-Type, e.g. SSU1.1 or SWU1.1). For larger CCDR values a double cladding structure is offered as an option. It consists of an inner cladding layer identical to the above for distances between 1.00 and 1.15 times the core radius and an outer one which is only slightly fluorine doped (S-Type, e.g. SSS1.2, SWS1.4)
- As a further option all preforms can be overcladded with pure silica tubes to realize larger CCDR values with double cladding structure, where the outer cladding has the refractive index of undoped silica (e.g. SWS2.5/SWU1.4 where an SWU1.4 preform is overcladded with a pure silica tube to a final CCDR of 2.5).

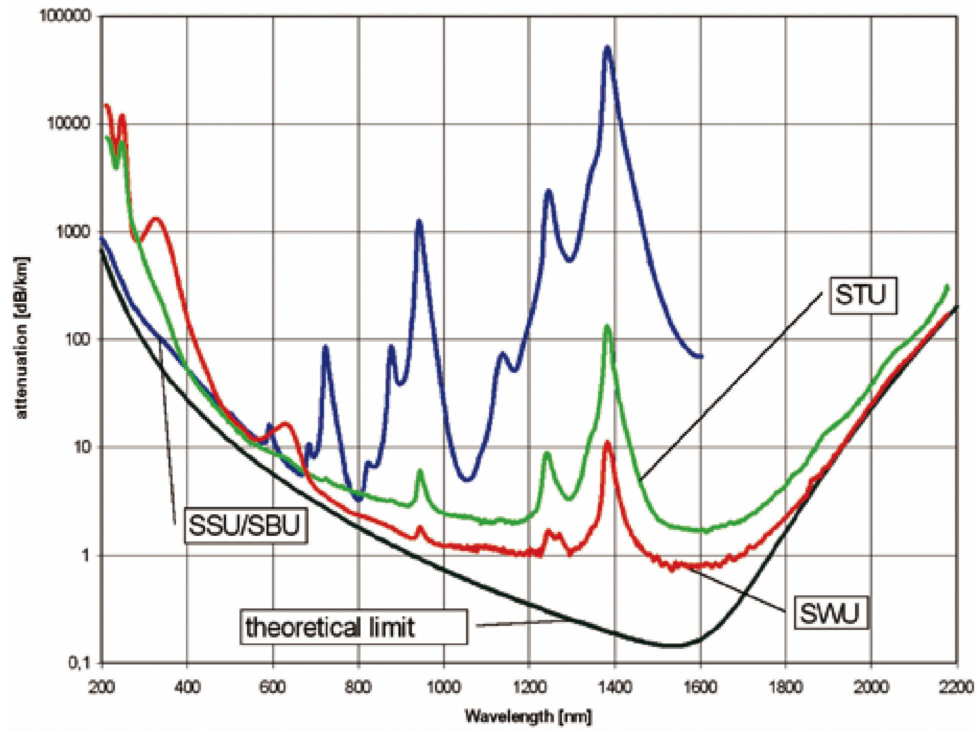
6. Core Materials

The transmission of an optical fiber is determined primarily by the properties of the core material. When attenuation of pure silica is plotted versus wavelength, the theoretical limit is a V-shaped curve with a minimum at 1550 nm.

Although state of the art synthetic silica is used as core material for Fluosil preforms, the theoretical limit can't be reached over the whole spectral range!

Therefore the optimum core material is selected depending on the wavelength range of interest. A high OH core material is used for UV transmission and a low OH core material is used for IR transmission. In addition to the initial transmission, the UV solarization and the radiation resistance of the fibers are also determined by the core material.

■Spectral attenuation of Fluosil fibers with different core material together with the theoretical limit in pure silica.



	Preform type	Wavelength range [nm]	Features
High OH	SSU	190-550 670, 800, 1030	● Excellent transmission in UV ● High radiation resistance to gamma irradiation at 800 nm ● SBU: Low deep-UV solarization ● Low solarization at 308 nm
	SBU		
	SXU		
Low OH	SWU	550-2100	● OH content < 0.7 ppm ● Excellent Transmission in VIS / NIR / MIR ● High power laser transmission ● Spectroscopy
	STU	350-2100	● Broad range Spectroscopy

■Product inquiries

https://www.sqp.co.jp/e/

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