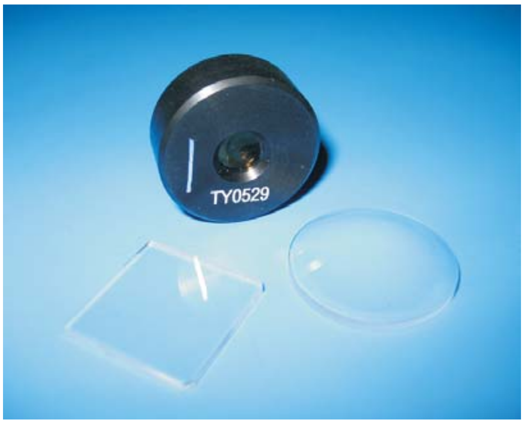
Synthetic crystal quartz



Crystal quartz is grown by hydrothermal synthesis method in autoclaves using specially prepared and initially oriented plates called orientation seeds. Growing run normally takes about one year and is managed so accurately and precisely to have stable temperature and pressure at around 340^{0}C and 1000 atm accordingly. Directions of crystallographic axes of as-grown crystals are defined by initial orientation of seeds. The crystals can be grown on one side of the seeds or simultaneously from their both sides depending on requirements to material quality and application.

Crystal quartz is anisotropic monoaxial crystal and has trigonal crystal structure. It has skeleton type and consists of silica-oxygen tetrahedrons located spirally (with right and left twisting) to the main axis of the crystal. Depending on this right-hand and left-hand modifications of the material are emphasized. Piezoelectric and pyroelectric properties of synthetic crystal quartz are caused by absence of both plane and centre of symmetry.

Crystal quartz is characterized by low stress birefringence and highest refractive index' homogeneity. Optical transmission of the material covers 0.15 - 4.35 µm range.

Due to the following peculiarities crystal quartz is widely utilized in electronics, optoelectronics, radio- and instrument- engineering, in production of precision optical components for lasers as polarizing and spectral optics:

- high internal crystalline perfection and optical homogeneity;
- relatively high hardness which itself ensures pretty good machining of the material as well as durability of the working surfaces during the operation;
- high chemical resistance to environment;
- insolubility in water and other solvents;
- low thermal coefficient of linear expansion;
- good dielectric properties in wide temperature range and frequency bands as well as in strong electrical fields;
- wide range of optical transparency;
- stability to intensive laser radiation including UV.

It should be specially emphasized that these peculiarities together with excellent DUV transmission make crystal quartz the unique material for production of optical components for various instruments, equipment and complex integrated systems operating in UV spectral range. Good optical transmission of the material over 100 µm wavelengths allows to effectively utilize it at THz diapason as well.

To get more detailed information on above applications please have a look at the following chapters:

Components for DUV-photolithography;

Thz materials and components.

PHYSICAL PROPERTIES

Density, g/cm^3	2.65
Melting point, ^{o}C	1467
Thermal conductivity, W/(m x K) (T = 25^{o}C)	10.7 (parallel to axis Z) 6.2 (perpendicular to axis Z)
Thermal coefficient of linear expansion at temperature range 0-25^{o}C, C^{-1}	7.1 x 10^{-6} (parallel to axis Z) 13.2 x 10^{-6} (perpendicular to axis Z)
Hardness (Mohs)	7
Specific heat capacity, J/(kg x K) (T = 25^{o}C)	710
Dielectric constant at 30 MHz	4.34 (parallel to axis Z) 4.27 (perpendicular to axis Z)
Young's modulus (E), GPa	97.2 (parallel to axis Z) 76.5 (perpendicular to axis Z)
Shear modulus (G), GPa	31.14
Bulk modulus (K), GPa	36.4
Chemical stability	insoluble in water
Elastic coefficients	C11=87 C12=7 C44=58 C13=13 C14=18 C33=106

Quartz refractive index vs wavelength

, µm	n_0	n_e	, µm	n_0	n_e	, µm	n_0	n_e
0.185	1.676	1.690	0.243	1.605	1.617	0.589	1.544	1.553
0.194	1.660	1.673	0.263	1.593	1.604	1.083	1.534	1.543
0.204	1.643	1.656	0.291	1.581	1.591	1.800	1.524	1.532
0.219	1.625	1.637	0.340	1.567	1.577	2.500	1.512	1.520
0.231	1.614	1.626	0.405	1.557	1.567	3.000	1.500	1.507

Typical transmission curves of the material are shown at Figures 1 and 2.

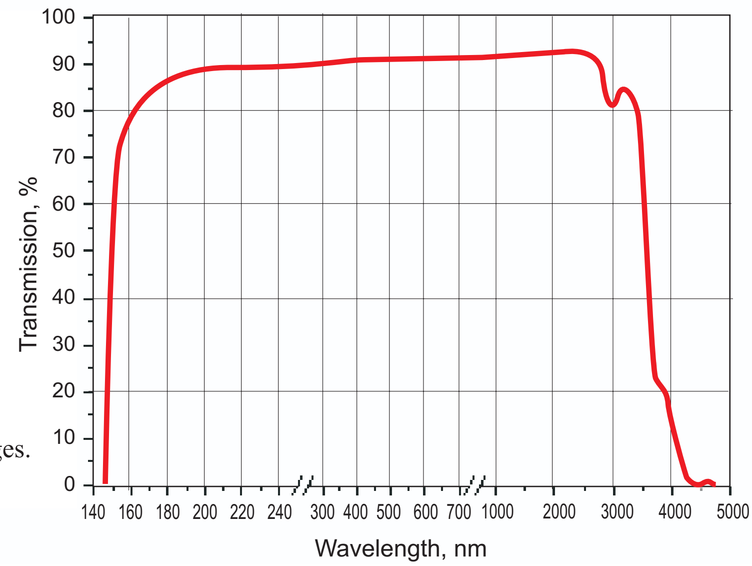


Figure 1. Transmission in UV-, Visible- and IR- ranges.
Sample thickness is 8.6 mm.

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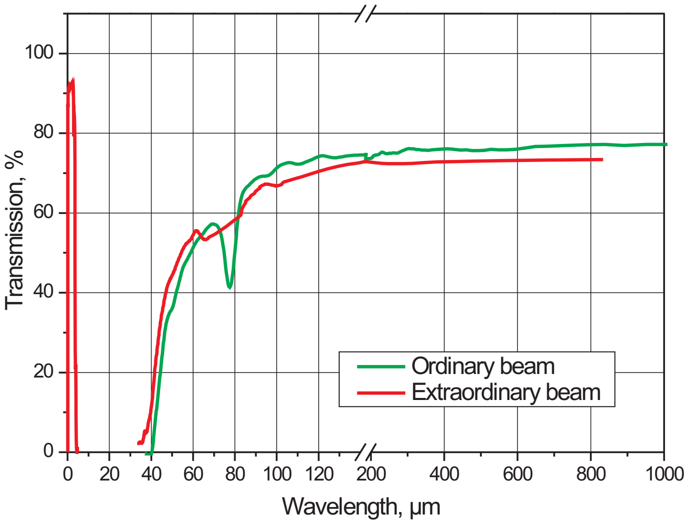

Figure. 2. Transmission in THz diapason.
Sample thickness is 1.0 mm.

Tydex does not specialize in production of components for electronics and X-ray, and depending on application we mainly introduce 2 grades of crystal quartz. Both are effectively used for production of optical components:

- Precision optical grade crystal quartz;
- Crystal quartz of standard optical grade.

Description of these grades is given below.

Precision optical grade crystal quartz

This grade is used for production of high power laser optics and precision polarizing optics such as waveplates and polarization rotators. For these applications most important parameters are the following: refractive index homogeneity, bubbleness category, UV stability, high transmission at DUV range (very important for the purposes of DUV-photolithography), purity and polarization uniformity of the material. To achieve the highest quality this material is grown on one side of the seed through special mask with very slow growth speed. Growth direction is Z-axis (so called Z-cut material).

Main material parameters are as follows:

- Twinnings, striaes, microbubbles including their conglomerates; inclusions and cracks are not allowed;
- Polarization uniformity: no visible variations during inspection between crossed polarizers;
- Homogeneity of refractive index:
  - category 1 (extra): $n < 3 \times 10^{-6}$ (TWD <= /10 per inch of crystal length);
  - category 2 (standard): $n < 3 \times 10^{-5}$ (TWD <= 1 per inch of crystal length);
- Etch channels, cm^{-2}: <= 30 typically;
- Absorption coefficient:
  - class A: <= 0.01 cm^{-1} at 190 nm, <= 0.03 cm^{-1} at 2800 nm;
  - class A1: <= 0.025 cm^{-1} at 190 nm, >= 0.045 cm^{-1} at 2800 nm;

  (these two separate inspection wavelengths are selected due to UV (190 nm) absorption is stipulated by impurity in the material, while IR (2800 nm) one occurs through OH-content).

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Available sizes of Z-cut ingots within discussed precision optical grade of the material (both right-hand and left-hand modifications) are the following: X >= 100 mm, Y >= 150 mm and Z - to 35 mm.
Synthetic crystal quartz with improved UV stability and with better DUV-performance can be grown upon special request.

Crystal quartz of standard optical grade

This grade is used for non-critical applications like optical filters, windows, prisms, and lenses. Usually it is specified by means of IR absorption at 3.585 µm (or by means of Q-value). This material is also grown on one side of the seed through special mask. Growth directions here are Z-axis and X-axis (X-cut material).

Other material parameters are as follows:

- Twinnings, striaes, microbubbles including their conglomerates, and cracks are not allowed;
- Inclusions: no inclusions visible with naked eye;
- Depending on IR absorption coefficient at 3.585 µm there are the following classes of the material:
  - class A: <= 0.05 cm^{-1} at 3.585 µm (Q >= 2.4 x 10^6 at 5 MHz);
  - class B: <= 0.07 cm^{-1} at 3.585 µm (Q >= 1.8 x 10^6 at 5 MHz);
  - class C: <= 0.10 cm^{-1} at 3.585 µm (Q >= 1.5 x 10^6 at 5 MHz);

Available sizes of the ingots within discussed standard optical grade of the material (both right-hand and left-hand modifications) are the following:
Z-cut material: X >= 100 mm, Y >= 150 mm, and Z to 35 mm;
X-cut material: X - to 30 mm, Y >= 100 mm, and Z >= 125 mm.

Please pay attention that this article is only for your information. We do not supply synthetic crystal quartz in ingots as well as semi-finished products. Our standard products are finished (polished, coated) parts.

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