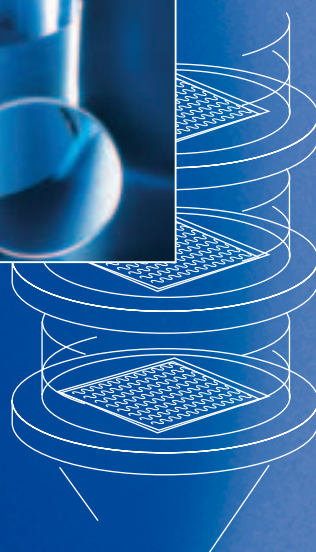


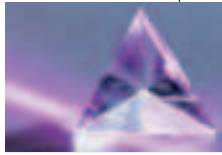
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Calcium Fluoride

VUV/DUV/UV, VIS & IR applications



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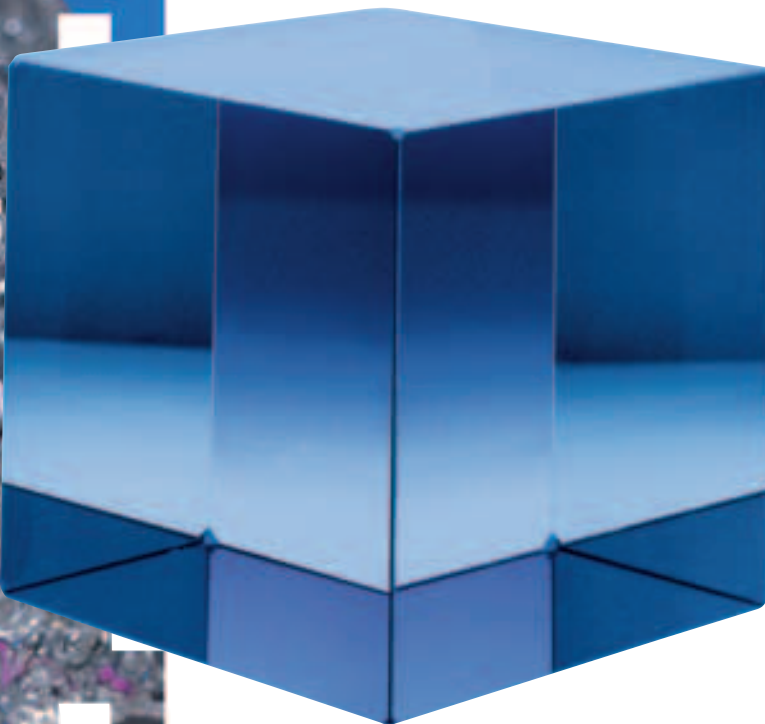


SCHOTT Lithotec Calcium Fluoride

Calcium fluoride single crystals, grown from high purity raw materials, are required for illumination and projection optics in 248 and 193 nm **microlithography technologies**. SCHOTT Lithotec's expertise allows fabrication of CaF_2 blanks in diameters up to 350 mm and with a thickness exceeding 100 mm and highest transmission down to 157 nm.

Key quality features are:

- Excellent UV transmittance
- High laser durability
- Low stress birefringence
- High refractive index homogeneity

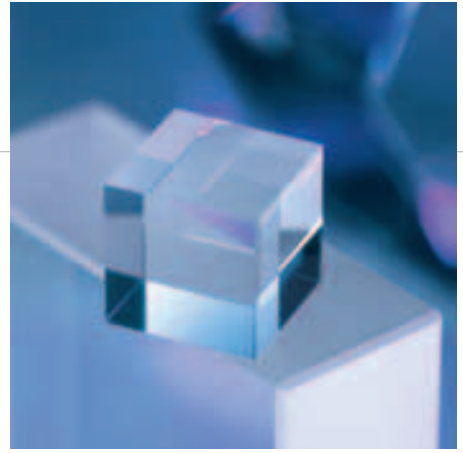


The very high laser durability of CaF_2 makes it the first choice material for litho **excimer laser optics, beam deliveries**, and for all excimer wavelengths in a wide range of other applications.

Synthetic calcium fluoride crystals complete the application range of **optical materials** from VUV to IR with a very good transmission ranging from 130 nm to 9 μm . Advantages in optical performance can be achieved with calcium fluoride in chromatically corrected optical systems in astronomy, photography, HDTV zoom lenses, as well as in microscopy. Further applications are sensors (especially in IR spectrum), spectrometers and medical lasers.

SCHOTT Lithotec offers CaF_2 components and blanks with different crystal orientations ($\langle 111 \rangle$, $\langle 100 \rangle$, random or others on request) along with different surface qualities (raw, cut, ground or polished), depending on the individual requirements.





Fields of Application

IC Litho: Manufacturing Tools

Typical Dimensions:	<i>up to 350 mm diameter, 80 mm thickness</i>		
Wavelength:	248 nm	193 nm	157 nm
Internal Transmittance per 10 mm sample thickness [%]	> 99.8	> 99.7	> 99.4
Refractive Index Homogeneity PV @ 633 nm [ppm]	1 ... 15 (depending on diameter)		
Stress Birefringence PV @ 633 nm [nm/cm] *	1 ... 20		
Bubbles, Inclusions (ISO 10110-3)	1/1 x 0.063 (typical)		

IC Litho: Excimer Laser & Beam Delivery Systems

Typical dimensions: disks - up to 100 mm diameter / 30 mm thickness; prisms - up to 100 mm edge length	
Characteristic Parameters:	See table above: Litho Manufacturing Tools
Laser Durability: SCHOTT Lithotec offers material with a laser durability up to highest requirements which is categorized by an internal classification method. In addition to volume characteristics, laser durability is also dependent on surface quality (with increasing laser energies) and on the laser operating conditions.	
Laser Durability Classification:	LD-A: Superior LD-C: Advanced LD-B: High LD-D: Standard
A qualified long-term laser durability is provided by each of these classes adapted to the individual application requirements. Please define application wavelength, energy density, repetition rate, pulse length and pulse number.	
Laser Damage Threshold @ 193 nm	~7 J/cm ² (effects: surface defects, ablation)

Non-Litho: Laser & Imaging Optics

Typical Dimensions:	100 mm diameter, 30 mm thickness
Max. dimensions:	up to 350 mm diameter, 80 mm thickness
Available Grades	UV grade / 193 - 400 nm VIS grade / 400 - 780 nm IR grade / 0.78 - 6.00 μm
Internal Transmittance per 10 mm sample thickness [%]	> 99.0
Refractive Index Homogeneity PV @ 633 nm [ppm]	3 ... 20
Stress Birefringence PV @ 633 nm [nm/cm] *	1 ... 50
Bubbles, Inclusions (ISO 10110-3)	1/1 x 0.10 (typical)

*) For single crystalline material; smallest value referring to <111> orientation. Polycrystalline material is also available.



For other specifications and individual requirements regarding dimensions, material and surface quality please contact our sales department.
See also: Request for Quotation (advice for download on page No. 7)



Properties of Calcium Fluoride



Optical Properties

Refractive Indices $n(N_2)$ (at 22°C, nitrogen atmosphere, 1013 hPa)		
	$\lambda_{vac}[nm]$	n^*
n_{2325}	2325.59	1.42212
n_{1970}	1970.56	1.42401
n_{1530}	1530.00	1.42612
n_{1060}	1060.00	1.42851
n_t	1014.25	1.42879
n_s	852.35	1.43002
n_r	706.71	1.43166
n_C	656.45	1.43245
$n_{C'}$	644.03	1.43267
n_{He-Ne}	632.98	1.43288
n_D	589.46	1.43380
n_d	587.73	1.43384
n_e	546.23	1.43493
n_F	486.27	1.43701
$n_{F'}$	480.13	1.43726
n_g	435.96	1.43946
n_h	404.77	1.44148
n_i	365.12	1.44488
n_{334}	334.24	1.44848
n_{312}	312.66	1.45173
n_{296}	296.82	1.45463
n_{280}	280.43	1.45824
n_{248}	248.35	1.46791
n_{194}	194.23	1.50060
n_{193}	193.37	1.50143
n_{184}	184.95	1.51055
$n_{157^{**}}$	157.63	1.55927

*) Tolerances of refractive indices: $\pm 2 \cdot 10^{-5}$
 **) Measurement at NIST on 08-01-00
 All refractive indices are interpolated from values measured under dry nitrogen;
 λ_{vac} = vacuum wavelength.

Relative Partial Dispersion	
$P_{s,t}$	0.2698
$P_{C,s}$	0.5333
$P_{d,C}$	0.3046
$P_{e,d}$	0.2388
$P_{g,F}$	0.5389
$P_{i,h}$	0.7462

Deviation of Relative Partial Dispersions from "Normal Line"	
$\Delta P_{C,t}$	-0.1935
$\Delta P_{C,s}$	-0.0915
$\Delta P_{F,e}$	0.0183
$\Delta P_{g,F}$	0.0552
$\Delta P_{i,g}$	0.2636

$n_d = 1.43384$	$v_d = 95.23$	$n_F - n_C = 0.00456$
$n_e = 1.43493$	$v_e = 94.69$	$n_{F'} - n_{C'} = 0.00459$

Constants of formula for dn_{abs}/dT in vacuum	
D_0	$-3.18 \cdot 10^{-5}$
D_1	$-2.31 \cdot 10^{-8}$
D_2	$4.13 \cdot 10^{-11}$
E_0	$3.35 \cdot 10^{-7}$
E_1	$1.91 \cdot 10^{-10}$
$\lambda_{TK} [\mu m]$	0.192

valid for $365 \text{ nm} < \lambda < 1014 \text{ nm}$ and for $-100^\circ\text{C} \leq T \leq +140^\circ\text{C}$

wavelength [nm]	Temperature coefficients of the refractive index					
	$\Delta n_{rel}/\Delta T [10^{-6}/K]^*$			$\Delta n_{abs}/\Delta T [10^{-6}/K]**$		
1060.0	546.23	365.12	1060.0	546.23	365.12	
-40/-20 [°C]	-8.6	-8.3	-7.7	-10.5	-10.3	-9.7
+20/+40 [°C]	-10.4	-10.1	-9.5	-11.6	-11.4	-10.8
+60/+80 [°C]	-11.2	-11.0	-10.3	-12.2	-12.0	-11.3

*) relative to nitrogen
 **) relative to vacuum

Constants of Sellmeier Dispersion Formula for λ_{vac} and $n(N_2)$	
B_1	$6.188140 \cdot 10^{-1}$
B_2	$4.198937 \cdot 10^{-1}$
B_3	3.426299
C_1	$2.759866 \cdot 10^{-3}$
C_2	$1.061251 \cdot 10^{-2}$
C_3	$1.068123 \cdot 10^3$

Sellmeier Dispersion Formula (according to SCHOTT Technical Information TIE29 Literature link: 9)	
$n^2 - 1 = B_1 \lambda^2 / (\lambda^2 - C_1) + B_2 \lambda^2 / (\lambda^2 - C_2) + B_3 \lambda^2 / (\lambda^2 - C_3)$ with λ in μm	

valid for $184 \text{ nm} < \lambda < 2326 \text{ nm}$ (22°C; 1013 hPa); $n = n(N_2)$; $\lambda = \lambda_{vac}$

Additional Properties

Chemical/Electrical Properties	
Solubility in water [g/l] 20°C	0.016
Crystal type	single crystal, synthetic
Crystal structure	cubic; CaF ₂ type structure
Cleavage planes	(111)
Lattice constant [nm]	0.546342

Thermal Properties	
Melting point [°C]	1420
Mean specific heat C _p (20°–100°C) [J/(kg · K)]	854
Heat conductivity λ (20°C) [W/(m · K)]	9.71
Linear thermal Expansion coefficient	
α (20°C ; 300°C) [10 ⁻⁶ /K]	21.28
α (-30°C ; 70°C) [10 ⁻⁶ /K]	18.41

Chemical Behavior of Polished Surfaces		
Climatic Resistance Class (ISO/WD 13384)	CR	1
Acid Resistance Class (ISO 8424)	SR	4.5
Alkali Resistance Class (ISO 10629)	AR	2.3
Phosphate Resistance Class (ISO 9689)	PR	1.3
Stain Resistance Class	FR	0

Mechanical Properties	
Young's Modulus (25°C) [GPa]	75.8
Shear Modulus (25°C) [GPa]	33.77
Compressive Strength [GPa]	83.8
Poisson's Ratio μ	0.26
Knoop Hardness (ISO 9385) HK	158.3
Mohs Hardness	4.0
Density ρ [g/cm ³]	3.18
Grindability (ISO 12844) HG	6

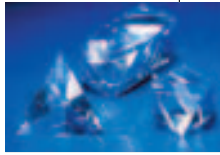
Stress-Optical Coefficients (q ₁₁ -q ₁₂) and q ₄₄ measured at NIST**		
λ (nm)	CaF ₂	
	(q ₁₁ -q ₁₂) (10 ⁻¹² Pa ⁻¹)	q ₄₄ (10 ⁻¹² Pa ⁻¹)
637.8*	-1.46 ± 0.01	0.71 ± 0.01
546.4	-1.53 ± 0.02	0.75 ± 0.01
436.0	-1.55 ± 0.02	0.74 ± 0.01
365.1	-1.57 ± 0.02	0.74 ± 0.01
253.7	-1.66 ± 0.02	0.73 ± 0.01
193.1	-1.77 ± 0.02	0.66 ± 0.01
156.1	-1.91 ± 0.05	0.45 ± 0.01
157.63 (linear int.)	-1.90	0.46

*) all values related to (111) direction

**) Lit. 2

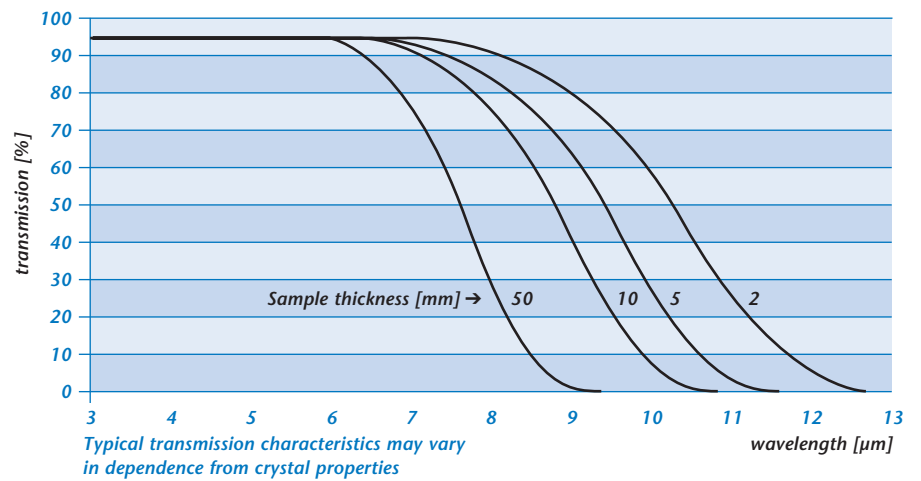
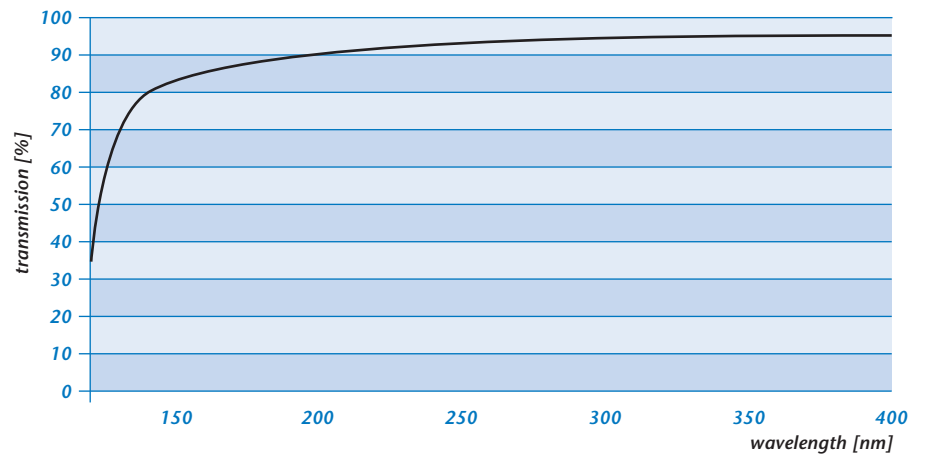
For further technical information please see Lit. 1, 9, 10





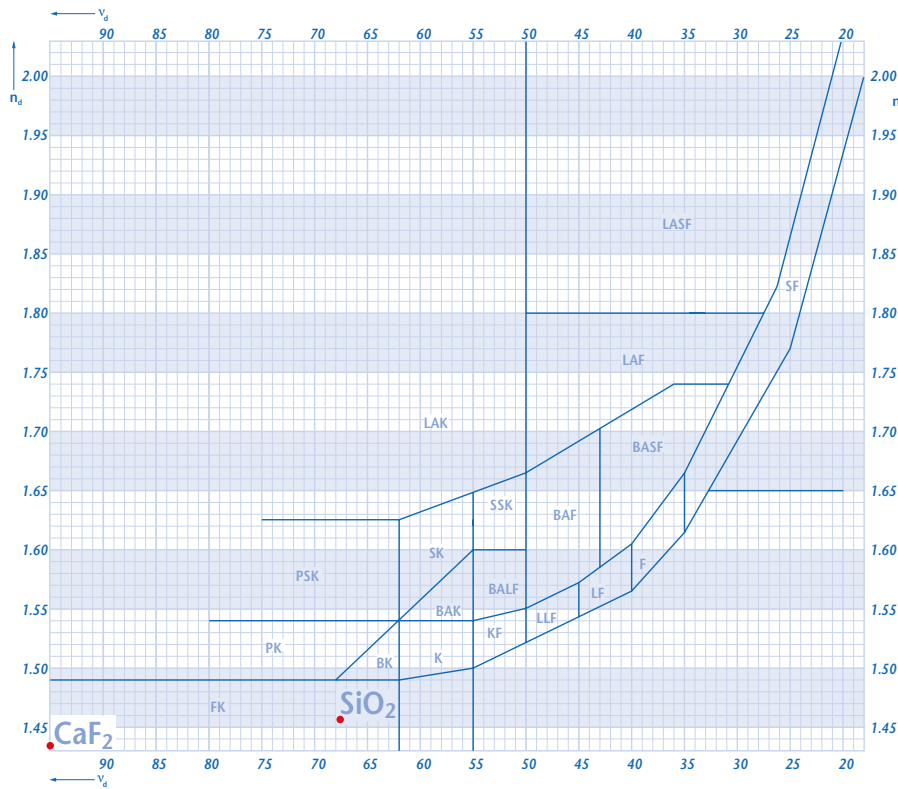
Spectral Transmission

The very broad spectral transmission range of calcium fluoride from 130 nm to 9 μm (depending on sample thickness) makes it suitable for various applications in the ultraviolet, visible and infrared spectrum.





Abbe Diagram



The following downloads are available at:
<http://www.schott.com/lithotec>
http://www.schott.com/optics_devices

- Request for Quotation (RfQ)
- Advice for Material Handling
- Material Safety Data Sheet (MSDS)
- RoHS Statement (Restriction of Hazardous Substances)
- ISO 9001 Certificate
- Optical Glass: Description of Properties
- Technical Data Sheets (ASCII, Zemax Format)
- Abbe Diagram

SCHOTT Lithotec
 is certified according to ISO 9001.

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 6. L. Parthier, G. Grabosch, U. Natura, M. Letz, K. Knapp, *"ArF Immersion Lithography – a new challenge for CaF₂ quality"*, SPIE Microlithography, Santa Clara, 2005
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 10. SCHOTT Technical Information, *"Optical Glass – Description of Properties"*, Optical glass catalog information, Download: www.schott.com/optics_devices/english/download/
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