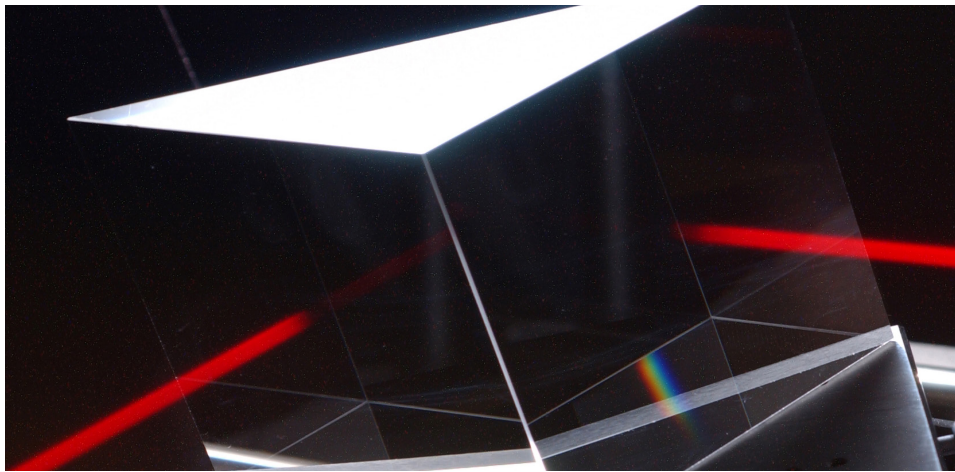




CORNING



Corning® Calcium Fluoride (CaF₂) - Code 9575

Fluoride Crystal Materials

Corning Specialty Materials is a premier supplier of fluoride crystal materials. With exceptional purity and quality, our crystal materials transmit at multiple wavelengths and can be used in a variety of applications. Corning also offers design engineering, fabricating, polishing and coating capabilities. With our capabilities to produce end-to-end optical solutions, let Corning be the supplier of choice for your most complex optical requirements.

Calcium Fluoride is uniquely suited for demanding optical applications from deep ultraviolet through the infrared. Being physically stable and chemically inert with superior hardness, Calcium Fluoride is the material of choice for microlithography and laser optics applications. Single crystal ingots are grown using Corning's proprietary highly purified material process, ensuring a consistent supply of high quality crystalline grades. A full range of geometries, from ingots to blanks, and finishes, including complex multi-faceted and highly polished parts, are available. Standard (111) orientation, as well as specifically oriented parts, are offered. Multiple material grades are available to match customer needs; Visible-Infrared, Ultraviolet, Excimer, Super Excimer, and Laser Durability. Low absorption coatings are customized to meet customer specifications, including coatings designed for enhanced laser durability in reflective, anti-reflective, and partially reflective applications.

Physical and Chemical Properties

General Properties

CAS#	7789-75-5
Molecular Weight	78.08 g/mol
Structure	Cubic, fluorite type, space group Fm $\bar{3}$ m, a ₀ = 5.462 Angstroms, z = 4
Density	3.18 g/cm ³ at 25 °C
Melting Point	1360 °C
Boiling Point	2451 °C
Solubility	0.0017 g/100 g H ₂ O at 20 °C

Mechanical and Elastic Properties

Young's Modulus (E)	75.8 GPa
Shear Modulus (G)	33.77 GPa
Bulk Modulus (K)	82.71 GPa
Elastic Compliance	(x10 ⁻² /GPa) S ₁₁ = 0.6867 S ₃₃ = 0.1451 S ₄₄ = 2.9764
Elastic Stiffness	(x10 ² GPa) C ₁₁ = 1.6420 C ₁₂ = 0.5300 C ₄₄ = 0.3370
Dielectric Constant	E ₀ = 6.76 at 1 MHz
Poisson Ratio	0.26
Hardness	158.3 Knoop for both [100] and [110] directions

Thermal Properties

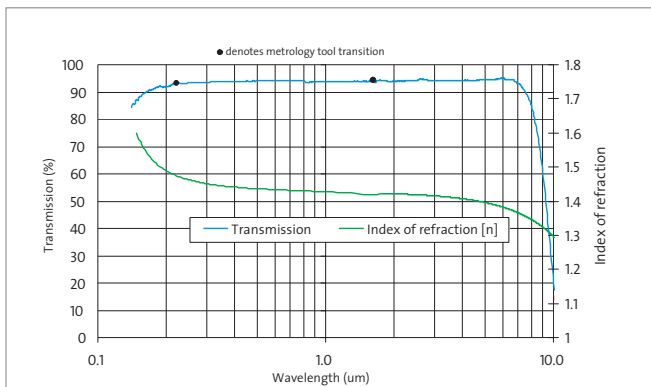
Absorption Coefficient (H→0):	$\Phi \leq 2 \times 10^{-3} / \text{cm}^{-1}$ @193 nm [E^{-0x}]
Non-linear (2-photon) absorption coefficient:	$\leq 2 \times 10^{-9} \text{ cm}^2 / \text{W}$ @193 nm
Debye Temperature	513 ± 2 K
Thermal Conductivity	9.71 [W/(m K)]

Linear Thermal Expansion Coefficient

T [°C]	T [K]	Coefficient [$\times 10^{-6} \text{ K}^{-1}$]
-180	93	6.7
-160	113	9.1
-140	133	11.1
-120	153	12.8
-100	173	14.1
-80	193	15.2
-60	213	16.2
-40	233	17.0
-20	253	17.7
0	273	18.3
20	293	18.7
40	313	19.1
60	333	19.4
80	353	19.7
100	373	20.0
120	393	20.4
140	413	20.8
160	433	21.3
180	453	21.7
200	473	22.2

Optical Properties

Transmission Range	0.12 μm to beyond 7.5 μm , depending on thickness
Energy Gap	10 eV
Restrahl Frequency	35 μm and 25 μm maxima
Reciprocal Dispersive Power	94
Photoelasticity	In the visible region the piezo coefficients are: 10^{-12} Pa $q_{11} = -0.038$ $q_{12} = 1.08$ ($q_{11} - q_{12}$) = -1.46 $q_{44} = 0.71$ At 10.6 μm ($q_{11} - q_{12}$) = -0.513
Optic Modes Transverse: Longitudinal:	257 cm^{-1} at 300 K and 267 cm^{-1} at 80 K 463 cm^{-1} at 300 K and 472 cm^{-1} at 80 K



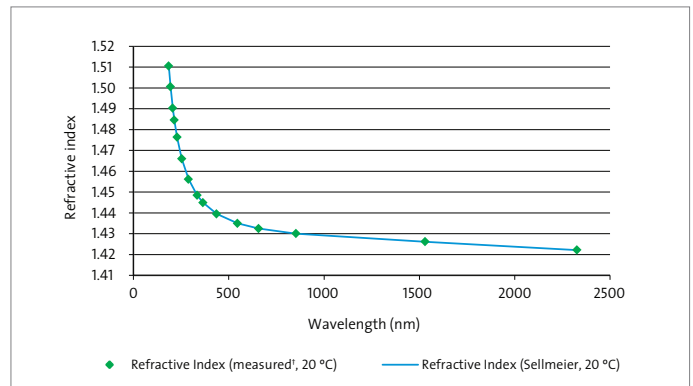
Sample transmission and index of refraction (7 mm thickness, uncorrected for surface effects)

CaF₂ Refractive Index

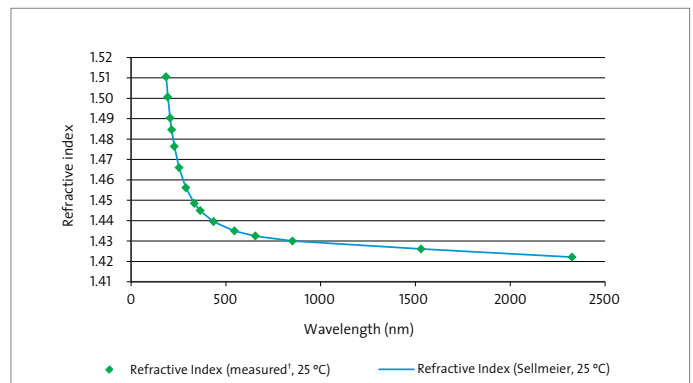
Refractive Index of CaF₂ in Nitrogen Gas (1013.25 hPa)

Symbol of Spectral line	Wavelength in Vacuum (nm)	Wavelength in Vacuum (μm)	Refractive Index (measured', 20 °C)	Refractive Index (Sellmeier, 20 °C)	Refractive Index (measured', 25 °C)	Refractive Index (Sellmeier, 25 °C)
	2326.05	2.326	1.422132	1.422133	1.422084	1.422085
	1530.00	1.530	1.426143	1.426141	1.426091	1.426090
[n ₁]	852.344	0.852	1.430042	1.430042	1.429990	1.429991
[n ₂]	656.454	0.656	1.432471	1.432472	1.432420	1.432421
[n ₃]	546.227	0.546	1.434945	1.434947	1.434897	1.434897
[n _g]	435.957	0.436	1.439480	1.439480	1.439433	1.439432
[n _i]	365.119	0.365	1.444900	1.444898	1.444852	1.444852
	334.244	0.334	1.448498	1.448498	1.448454	1.448453
	289.444	0.289	1.456183	1.456184	1.456141	1.456142
	253.728	0.254	1.465997	1.465996	1.465959	1.465958
	228.872	0.229	1.476372	1.476373	1.476339	1.476340
	214.506	0.215	1.484572	1.484573	1.484544	1.484544
	206.266	0.206	1.490325	1.490326	1.490300	1.490300
	194.227	0.194	1.500606	1.500605	1.500587	1.500585
	184.950	0.185	1.510562	1.510562	1.510546	1.510547

Measurement accuracy: ± 0.000005 estimated. (2326.05 nm–1530.00 nm)
 ± 0.000001 estimated. (852.344 nm–365.119 nm)
 ± 0.000003 estimated. (334.244 nm–206.266 nm)
 ± 0.000005 estimated. (194.227 nm–184.950 nm)



CaF₂ Refractive index (20 °C in Nitrogen, 1013.25 hPa, 36% RH)



CaF₂ Refractive index (25 °C in Nitrogen, 1013.25 hPa, 36% RH)

Sellmeier Dispersion Formula* (2326 nm-185 nm, 20 °C, 25 °C):

$$n^2-1 = A_1\lambda^2/(\lambda^2 - B_1) + A_2\lambda^2/(\lambda^2 - B_2) + A_3\lambda^2/(\lambda^2 - B_3) + A_4\lambda^2/(\lambda^2 - B_4)$$

Sellmeier Dispersion Coefficients (20 °C)		Sellmeier Dispersion Coefficients (25 °C)	
A ₁	4.430595147E-01	A ₁	4.463112200E-01
A ₂	4.454624348E-01	A ₂	4.408035972E-01
A ₃	1.502595301E-01	A ₃	1.515166998E-01
A ₄	8.859807728E+00	A ₄	8.853841319E+00
B ₁	1.733873966E-03	B ₁	1.752260093E-03
B ₂	7.939087382E-03	B ₂	7.970736905E-03
B ₃	1.234337898E-02	B ₃	1.231282897E-02
B ₄	2.751117861E+03	B ₄	2.751117881E+03

Temperature Coefficients of Refractive Index of CaF₂

Symbol of Spectral Line	Wavelength in Vacuum (nm)	dn/dT* (relative, N ₂) (1x10 ⁻⁶ /°C)
	2326.05	-9.6
	1530.00	-10.5
[n _d]	852.344	-10.3
[n _c]	656.454	-10.2
[n _e]	546.227	-9.7
[n _g]	435.957	-9.5
[n _i]	365.119	-9.6
	334.244	-8.9
	289.444	-8.4
	253.728	-7.6
	228.872	-6.6
	214.506	-5.7
	206.266	-5.2
	194.227	-3.9
	184.950	-3.2

*Measurement accuracy:
 <±-1.4x10⁻⁶/°C estimated. (2326.05 nm–1530.00 nm)
 <±-0.3x10⁻⁶/°C estimated. (852.344 nm–365.119 nm)
 <±-0.8x10⁻⁶/°C estimated. (334.244 nm–206.266 nm)
 <±-1.4x10⁻⁶/°C estimated. (194.227 nm–184.950 nm)

Polynomial Dispersion Formula* (2326 nm-185 nm):

$$dn/dT \text{ (relative, N}_2, 20\text{-}25 \text{ °C)} = (C_0 + C_1\lambda^2 + C_2\lambda^{-2} + C_3\lambda^{-4} + C_4\lambda^{-6}) \times 10^{-6}$$

Polynomial Dispersion Coefficients (20-25 °C)	
C ₀	-1.059200E+01
C ₁	1.543519E-01
C ₂	1.515306E-01
C ₃	2.230264E-03
C ₄	4.820581E-05

*Where λ=wavelength (μm); A₁-A₄, B₁-B₄, and C₀-C₄ are coefficients from the appropriate tables above

Available Grades and Additional Information

Corning® Calcium Fluoride Material is Classified in the Following General Grades:

- Laser Durability 193 nm *recommended for ArF*
- Super-Excimer 193 nm *recommended for ArF*
- Excimer 193 nm *recommended for KrF and ArF*
- Ultraviolet 200 nm – 400 nm
- Visible-Infrared 400 nm – 10.6 μm

Corning's crystal experts work actively with prospective customers to determine the most appropriate and cost effective solution for each application. Depending on the application of interest, some or all of the following attributes may be considered in the selection process:

Internal Transmittance	> 99.9% @ 193.3 nm
Stress Birefringence	<1 nm/cm (avg.), [111], measured at 546 nm
Bubbles/Inclusions	ISO 10110 - 1/1 x 0.02
Scratch Dig	To 10/5 available
Micro-roughness	To 2 Å available
Available Raw Material Diameters	1.75", 1.9", 2.4", and 4.1" (typical), others upon request.
Orientation	(111) ±2° typical, others upon request
Finish	Cleaved, saw cut, fine ground, polished, super-polished, enhanced super-polished
Coatings	Anti-reflective, highly reflective, partially reflective, low absorption, protective/enhanced durability, custom solutions upon request

Depending on customer requirements, Corning can provide solutions ranging from crystal blanks to complete turnkey optical packages. Corning can precisely manufacture a wide variety of laser optic components including: windows, prisms, mirrors, plano convex, plano concave, and hemispherical optics. With world-class coating engineering expertise, Corning can customize final optical performance to enhance transmission, reflectivity, and/or laser durability to customer specification in order to provide a comprehensive optical path solution.

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For more information about Corning's fluoride crystals and our world wide sales office locations please contact:

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www.Corning.com/specialtymaterials

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