

## Infrared Optical Material - CaF<sub>2</sub>

Calcium Fluoride is used for optical windows, lenses and prisms in the 0.15 μm - 9 μm (ultraviolet to infrared) regions. The low power absorption has made this material attached to wide use in high power laser optics. Polished surfaces are stable and will last several years under normal conditions. Due to its composition, CaF<sub>2</sub> has a much longer usable life-time than most materials operating in fluorine environments.

Calcium Fluoride, which is grown by vacuum Stockbarger technique, has a low refractive index, hence can be used without anti-reflection coating. Material for IR use is grown using naturally mined fluorite, in large quantities at relatively low cost.

Maximum available size: 380 mm Dia x 70 mm Thk

BASE PROPERTIES	
PARAMETER	VALUE
<b>OPTICAL</b>	
Transmission Range	0.13 to 10 microns
Refractive Index	1.39908 at 5 microns
Reflection Loss	5.4% at 5 microns (2 surfaces)
dN/dT	-10.6 x 10 <sup>-6</sup> e/°C
<b>PHYSICAL</b>	
Density	3.18 g/cm <sup>3</sup>
Melting Point	1360 °C
Thermal Conductivity	9.71 W/(m*K)
Thermal Expansion	18.85 x 10 <sup>-6</sup> e/°C
Hardness	Knoop 158.3 kg/mm <sup>2</sup> (100)
Specific Heat Capacity	854J/(kg K)
Dielectric Constant	6.76 at 1MHz
Young's Modulus (E)	75.8 GPa
Shear Modulus (G)	33.77 GPa
Bulk Modulus (K)	82.71 GPa
Elastic Coefficients	C <sub>11</sub> =164 MPa, C <sub>12</sub> =53 MPa, C <sub>44</sub> =33.7 MPa
Apparent Elastic Limit	36.54 MPa
Poisson Ratio	0.26
<b>CHEMICAL</b>	
Solubility	0.0017g/100g water at 20 °C
Molecular Weight	78.08
Class/Structure	Cubic (111) cleavage



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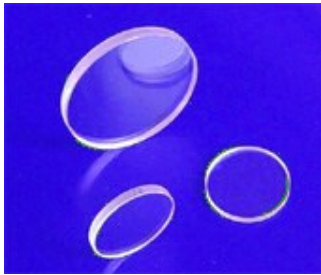
Introduction

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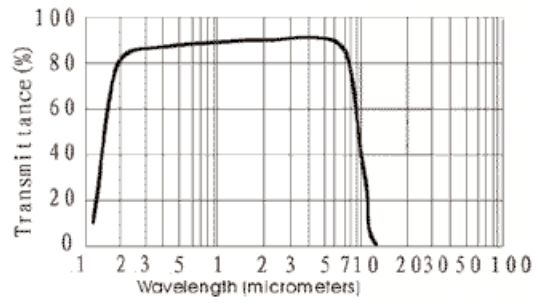
**REFRACTIVE INDEX**

<b>Wavelength, <math>\mu\text{m}</math></b>	0.19	0.21	0.25	0.33	0.41	0.88
<b>Refractive Index</b>	1.51	1.49	1.47	1.45	1.44	1.43
<b>Wavelength, <math>\mu\text{m}</math></b>	2.65	3.90	5.00	6.20	7.00	8.22
<b>Refractive Index</b>	1.42	1.41	1.40	1.38	1.36	1.34

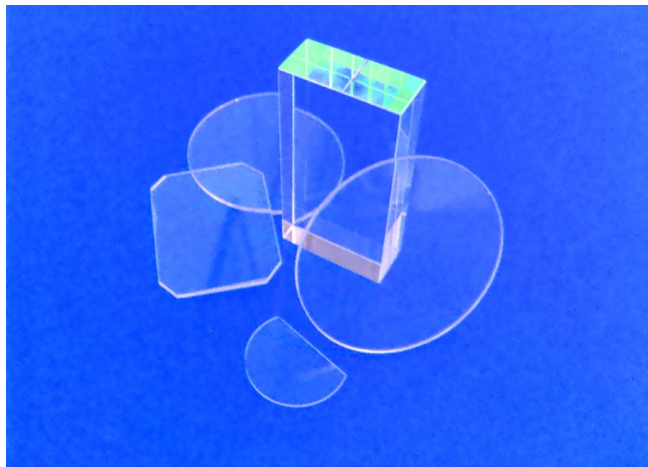
Optics for Medical  
Laser System



Calcium Fluoride (CaF<sub>2</sub>)



Optics for Spectroscopy  
Biomedical Application Laser



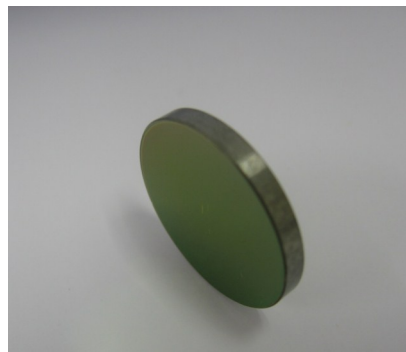
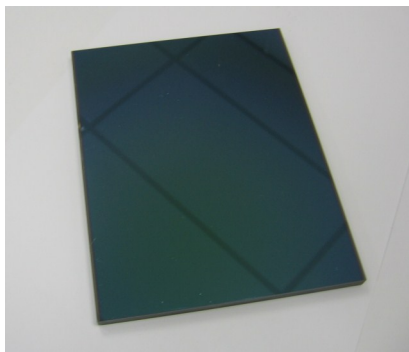
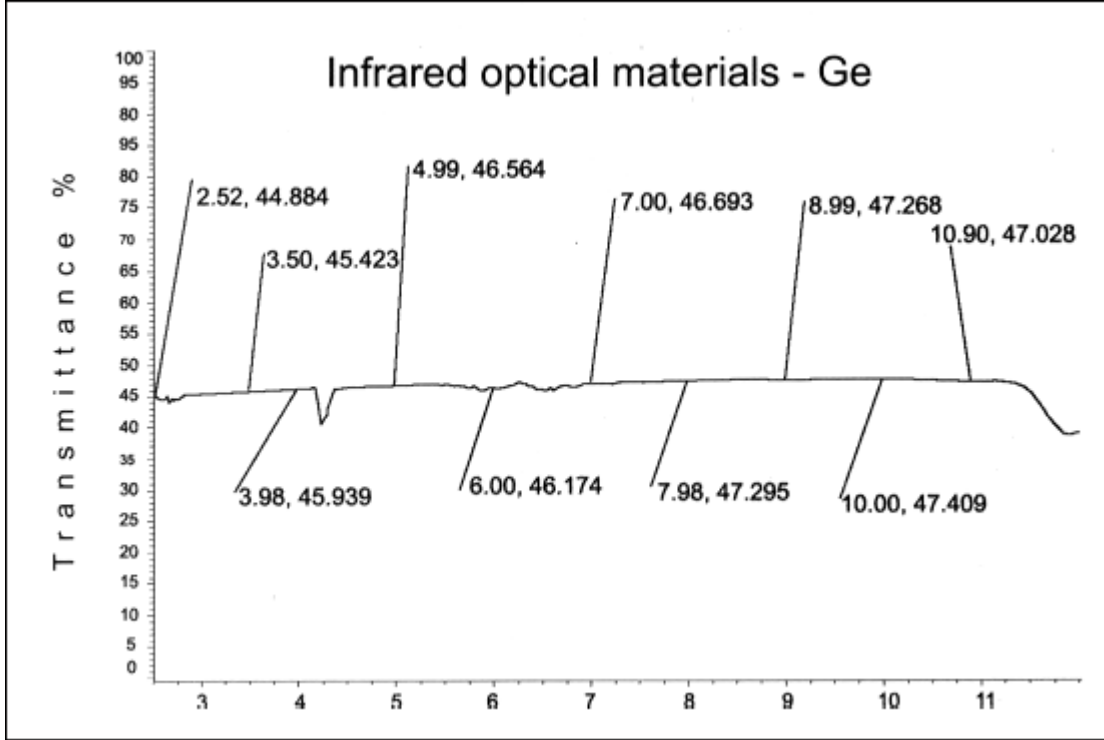
Optical Material

Laser Accessories Components

## Infrared Optical Material - Ge

Germanium is a versatile infrared material commonly used in imaging systems and instruments in the 2 to 12 microns spectral region. It is used as a substrate for lenses, windows, and output couplers for low power CW as well as pulsed TEA, CO2 lasers. Ge is non-hygroscopic and non-toxic has good thermal conductivity excellent surface hardness, and good strength.

Basic Properties:	Germanium (Ge)	Chalcogenide glass containing germanium (GG -1)	Chalcogenide glass containing germanium (GG -2)	Chalcogenide glass containing germanium (GG -3)
Transmission band(μm)	1.8-23	1-16	0.9-16	0.9-16
Uniformity index	$\frac{4.89 \times 10^{-5}}{(\phi 250\text{mm})}$	$\frac{1.1 \times 10^{-4}}{(\phi 100\text{mm})}$	$\frac{1.1 \times 10^{-4}}{(\phi 100\text{mm})}$	$\frac{1.1 \times 10^{-4}}{(\phi 100\text{mm})}$
Refractive index(10μm)	4.0032	2.6002	2.4976	2.4347
Temperature coefficient of the refractive index(10 <sup>-6</sup> /°C)	400	80	72	
Absorption(10μm.cm <sup>-1</sup> )	0.03	< 0.02	< 0.07	< 0.07
Hardness(kg/cm <sup>2</sup> )	800	150	170	<u>236 virkers</u>
Density(g/cm <sup>3</sup> )	5.323	4.67	4.40	4.36
Rupture Modulus (Mpa)	75	18.2	18.2	
Yang's modulus (Gpa)	103	21.8	22.1	18.6
Poisson's ratio	0.28	0.26	0.26	0.26
Melting point(°C)	937			
Thermal conductivity (Wcm-1k-1)	0.7	0.72	0.6	
Thermal expansion coefficient (X10 <sup>-6</sup> °C <sup>-1</sup> )	6.1	16	13	13.7
Specific Heat (Cal/g.k.)	0.074	0.066	0.07	
Permittivity	16			
Conductive models	N			
Resistivity (Ωcm)	5-40			
Maximum diameter (mm)	300	150	150	150

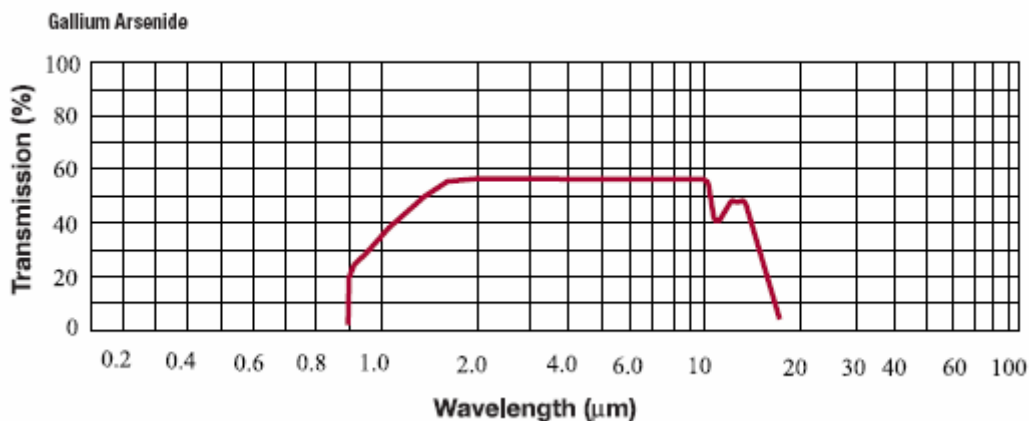


# Infrared Optical Material - GaAs

Semi-insulating GaAs provides an alternative to ZnSe in medium and high-power CW CO<sub>2</sub> laser systems for lenses and rear mirrors. GaAs is manufactured for semiconductor applications rather than optical applications, so careful material screening is vital in producing quality GaAs optics. GaAs optics are limited by crystal growth technology to diameters typically less than 10cm. the material is non-hygroscopic, safe to use in laboratory and field applications, and chemically stable except when contacted with strong acids.

### Basic Properties:

Specification	GaAs
Transmission Range (um)	1.0-22
Refractive Index@10um	3.277
Temperature Coefficient of Refractive Index, /°C	149 x 10 <sup>-6</sup>
Bulk Absorption Coefficient@10um / cm	<0.01
Melting Point, °C	1600
Hardness (Knoop), Kg/mm <sup>2</sup>	750
Density, g/cm <sup>3</sup>	5.37
Rupture Modulus, Mpa	13.8
Young's Modulus, Gpa	8.3
Fracture Toughness Mpam <sup>-1/2</sup>	0.31



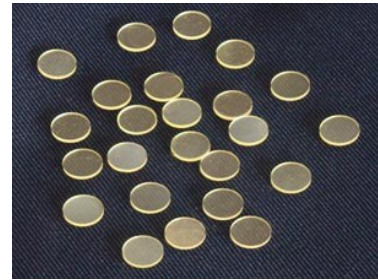
# Infrared Optical Material - LaF<sub>3</sub>/LiF

## — LaF<sub>3</sub> Crystalline Electrodes

LaF<sub>3</sub> is used for optical windows and lenses in the 0.2 μm - 10.5 μm regions.

### Physical properties:

Refractive Index	Nd=1.603, Ne=1.597
Melting point	1.493°C
Density	5.936g/cm <sup>3</sup>
Hardness, Mohs	4.5
Cleavage plane	[001]
Thermal expansion coefficient	11.9×10 <sup>-6</sup> /°C
Transmission range	-9μm
Thermal conductivity	51C/g.°C.CM.S
Size	Ø30-Ø50mm



LaF<sub>3</sub> Crystal

## — LiF Crystal

### Physical properties:

Refractive Index	Nd=1.394, n(5μ)=1.394
Melting point	884°C
Density	2.64g/cm <sup>3</sup>
Hardness, Mohs	3
Cleavage plane	[100]
Solubility in water	0.27g/100gH <sub>2</sub> O
Thermal expansion coefficient	3.195×10 <sup>-5</sup> /°C
Transmission range	0.11-6.5μm
Thermal conductivity	0.0249c/g.°C.cm.s.
Dispersion	Nf-Nc=0.00393
Diameter	<200mm



LiF

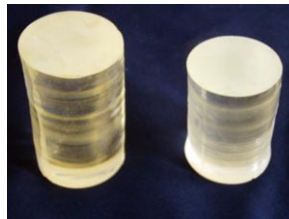


## Infrared Optical Material - LiNbO<sub>3</sub> Crystal

As one of the most important Functional Materials, Lithium Niobate Crystal is widely used as frequency doublers, switch, retarder, frequency multiplier, parametric oscillator.

### Physical properties:

Refractive Index	Ne=2.208, Nd=2.297, (λ=632.8nm)
Melting point	1250-1260°C
Density	4.64g/cm <sup>3</sup>
Hardness, Mohs	5-6
Extinction Ratio	1000:1
Dual graded-index	10-5/cm
Thermal expansion coefficient	A-axis a800°C=16.7×10-6/°C C-axis a600°C=2×10-6/°C
Dielectric constant	/ 84 / 29 / 43 / 28
Electromechanical Coupling Coefficient	Kt 0.20 K31 0.028



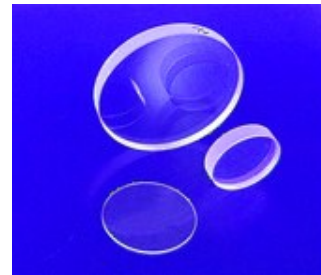
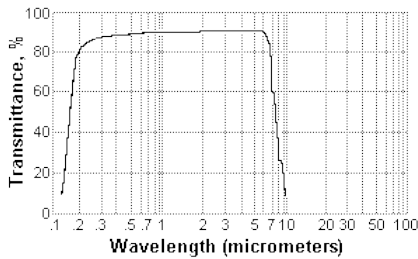
LiNbO<sub>3</sub> Crystal

### Specification:

Style	Diameter (mm)	Length (mm)	Remark
C801	20-25	50-80	Growth along the C-axis, used as optical components
A812	20-25	50-80	Growth along the A-axis, used as optical components
C801	30-60	50-100	Growth along the C-axis, used as Piezoelectric devices
C845	80-180	40-80	Growth along the C-axis, used as Piezoelectric devices
[104]847	80-180	40-80	Growth along the 104-axis, used as Piezoelectric devices

## Infrared Optical Material - MgF<sub>2</sub>

Magnesium fluoride is transparent over an extremely wide range of wavelengths. The effective transmission range is 0.11 μm - 7.5 μm (ultraviolet to infrared). Irradiation does not lead to color centers. Magnesium fluoride is a rugged, hard material which is resistant to thermal and mechanical shock. Considerable mechanical shock is needed to cause cleavage which is near perfect when it occurs. The natural form of MgF<sub>2</sub> is known as Sellaite. Magnesium fluoride is a positive birefringent crystal grown normally to 135 mm diameter by vacuum Stockbager technique, seeding along the C-axis. Thin layers of MgF<sub>2</sub> are frequently applied to the surfaces of optical elements as part of optical coatings such as anti-reflective coatings.



Magnesium Fluoride (MgF<sub>2</sub>)

### BASE PROPERTIES

#### PARAMETER

#### VALUE

#### OPTICAL

Transmission Range	0.11 to 7.5 microns
Refractive Index	N <sub>0</sub> =1.3836 N <sub>e</sub> =1.3957 at 0.405 microns
Reflection Loss	11.2% at 0.12 microns (2 surfaces)
dN/dT	+2.3 and +1.7 x 10 <sup>-6</sup> e/ °C at 0.4 microns

#### PHYSICAL

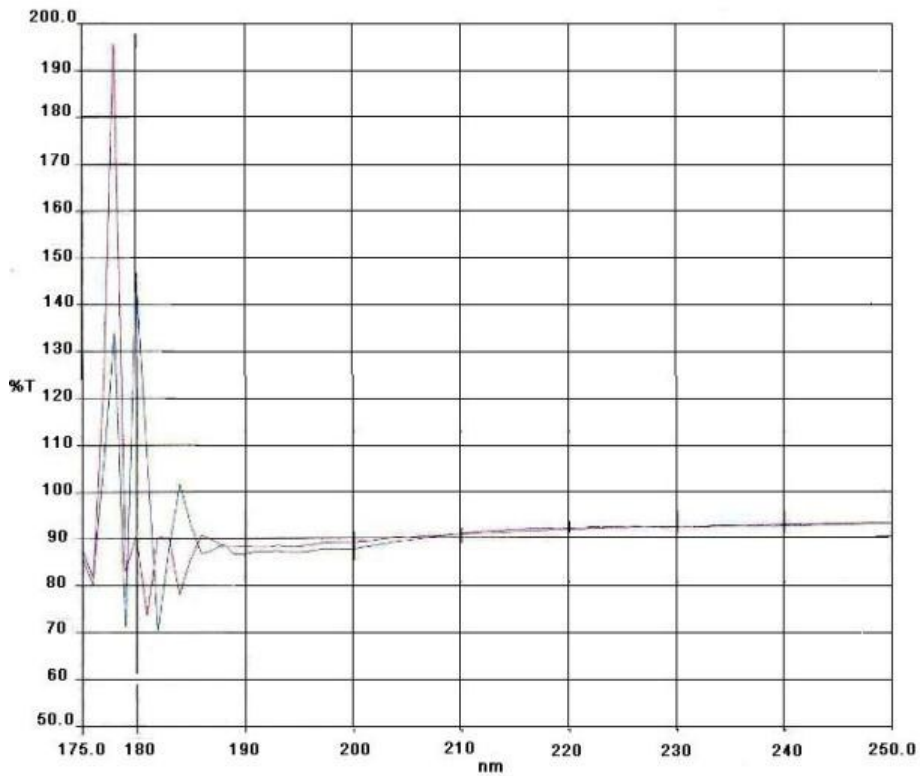
Density	3.177 g/cm <sup>3</sup>
Melting Point	1255 °C
Thermal Conductivity	0.3 W/(m K) at 27 °C
Thermal Expansion	13.7 and 8.48 x 10 <sup>-6</sup> e/ °C
Hardness	Knoop 415 kg/mm <sup>2</sup>
Specific Heat Capacity, cal/(g K)	
at 298 K	0.24
at 1700 K	0.362
Dielectric Constant	4.87 parallel and 5.45 perpendicular
Young's Modulus (E)	138.5 GPa
Shear Modulus (G)	54.66 GPa
Bulk Modulus (K)	101.32 GPa
Elastic Coefficients	C <sub>11</sub> =140.2 C <sub>12</sub> =89.5 C <sub>44</sub> =56.8 C <sub>33</sub> =204.7 C <sub>13</sub> =62.9 C <sub>66</sub> =95.7
Apparent Elastic Limit	49.64 MPa
Poisson Ratio	0.276

#### CHEMICAL

Solubility	<0.0002 g/100g water at 0 °C
Molecular Weight	62.32
Class/Structure	Tetragonal, can cleave on C-axis



REFRACTIVE INDEX					
<b>Wavelength, <math>\mu\text{m}</math></b>	0.20	0.23	0.27	0.34	0.56
<b>Refractive Index (ne)</b>	1.43	1.42	1.41	1.40	1.39
<b>Refractive Index (no)</b>	1.42	1.41	1.40	1.39	1.38



SCAN024.SP - 06-8-8  $\Phi$ 13x1  
SCAN023.SP - 06-8-8  $\Phi$  8x1



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Introduction

RONAR-SMITH® Laser Optics

Optics for Medical Laser System

# Infrared Optical Material - Sapphire

Sapphire initially refers to gem varieties of the mineral corundum, an aluminium oxide (Al<sub>2</sub>O<sub>3</sub>), when it is a color other than red. Nowadays, sapphire can be found naturally or manufactured in large crystal boules. Sapphire is highly transparent at wavelengths of 170 nm to 5.3 μm (ultraviolet to infrared), as well as being five times stronger than glass. This leads to use of synthetic sapphire windows in high pressure chambers for spectroscopy. The hardest of the oxide crystals, sapphire retains its high strength at high temperatures and has good thermal properties. It is well known for chemically resistant to common acids and alkali at temperatures up to 1000 °C as well as to HF below 300 °C. Maximum available size for windows, lenses and blanks: 100 mm Dia x 10 mm Thk and 100 mm Square x 10 mm Thk.

## BASE PROPERTIES

### PARAMETER | VALUE

#### OPTICAL

Transmission Range	0.17 to 5.5 microns
Refractive Index	1.75449 (o) 1.74663 (e) at 1.06 microns
Reflection Loss	14% at 1.06 microns (2 surfaces)
Absorption Coefficient	0.3 x 10 <sup>-3</sup> cm <sup>-1</sup> at 2.4μm
dN/dT	13.7 x 10 <sup>-6</sup> at 5.4μm
dN/dμ = 0	1.5μm

#### PHYSICAL

Density	3.97 g/cm <sup>3</sup>
Melting Point	2040°C
Thermal Conductivity	27.21 W/(m*K) at 300K
Thermal Expansion	5.6 (paral) & 5.0 (perp) x 10 <sup>-6</sup> e/K *
Hardness	Knoop 2000 with 2000g indenter
Specific Heat Capacity	419 J/(kg K)
Dielectric Constant	11.5 (paral) 9.4 (perp) at 1MHz
Young's Modulus (E)	335 GPa
Shear Modulus (G)	148.1 GPa
Bulk Modulus (K)	240 GPa
Elastic Coefficients	C11=496 C12=164 C13=115 C33=498 C44=148
Apparent Elastic Limit	275 MPa (40,000 psi)
Poisson Ratio	0.25

#### CHEMICAL

Solubility	98x10 <sup>-6</sup> g/100g water
Molecular Weight	101.96
Class/Structure	Trigonal (hex), R3c

Optics for Semiconductor Spectroscopy Biomedical Application Laser

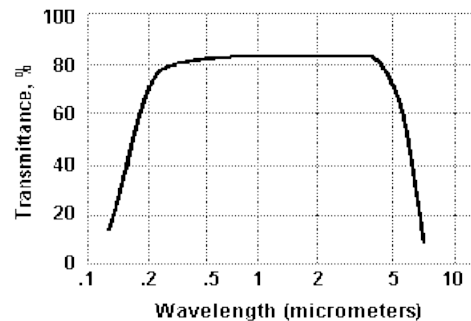
Optical Material

Laser Accessories Components

REFRACTIVE INDEX						
Wavelength, $\mu\text{m}$	0.308	0.325	0.337	0.351	0.355	0.442
Refractive Index (ne)	1.811	1.805	1.801	1.797	1.796	1.780
Refractive Index (no)	1.802	1.796	1.792	1.788	1.787	1.772
Wavelength, $\mu\text{m}$	0.458	0.488	0.55	0.532	0.590	0.633
Refractive Index (ne)	1.778	1.775	1.773	1.772	1.768	1.766
Refractive Index (no)	1.770	1.767	1.765	1.764	1.760	1.758
Wavelength, $\mu\text{m}$	0.670	0.694	0.775	0.780	0.800	0.820
Refractive Index (ne)	1.764	1.763	1.761	1.761	1.760	1.760
Refractive Index (no)	1.756	1.755	1.753	1.753	1.752	1.7528
Wavelength, $\mu\text{m}$	0.980	1.064	1.320	1.550	2.010	2.249
Refractive Index (ne)	1.756	1.754	1.750	1.746	1.737	1.732
Refractive Index (no)	1.748	1.747	1.742	1.738	1.729	1.724
Wavelength, $\mu\text{m}$	2.703	2.942	3.333	3.704	4.000	4.348
Refractive Index (ne)	1.719	1.712	1.701	1.687	1.674	1.658
Refractive Index (no)	1.711	1.704	1.693	1.699	1.666	1.65
Wavelength, $\mu\text{m}$	4.762	5.000	5.263			
Refractive Index (ne)	1.636	1.623	1.607			
Refractive Index (no)	1.628	1.615	1.599			



Sapphire



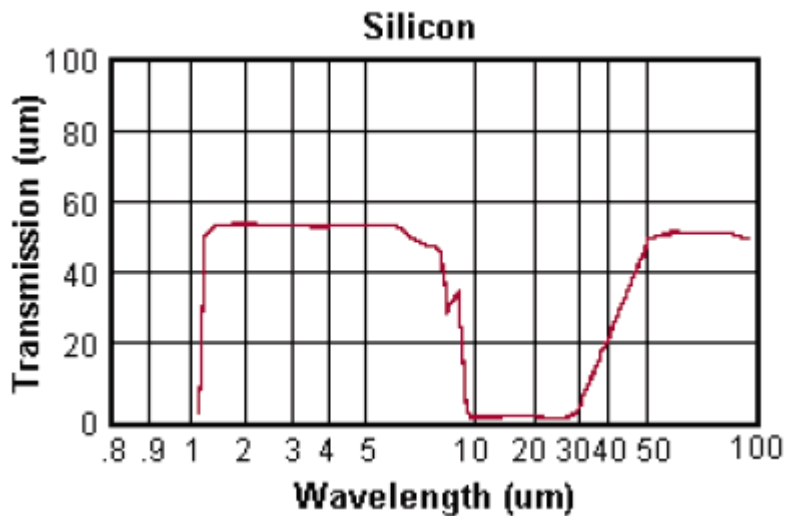
# Infrared Optical Material - Si

Si is used as the substrate for IR gold mirrors because it has an extremely large thermal conductivity and gold easily binds to the surface. It is highly durable, has low internal absorption and is commonly used at wavelength region from 1.2 to 6µm.

## Optical Properties

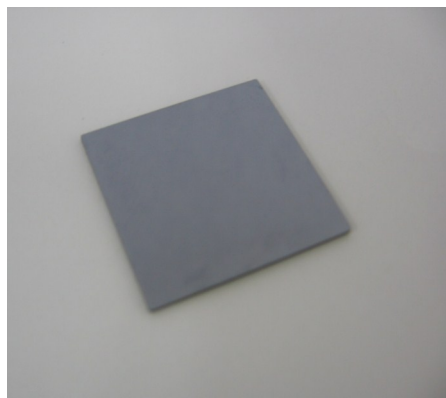
Transmission Range	1.2~8µm
Reflection Loss, for two surfaces at 5µm	46.2%
Reflection Index	See below

Wavelength (µm)	Refractive Index (n)	Wavelength (µm)	Refractive Index(n)
1.357	/	5.500	3.4213
1.3951	3.4975	6.000	3.4202
1.6606	3.4929	6.500	3.4195
1.8131	3.4608	7.000	3.4189
2.1526	3.4476	7.500	3.4186
2.3254	3.443	8.000	3.4184
3.000	3.432	8.500	3.4182
3.500	3.4284	10.00	3.4179
4.000	3.4257	10.50	3.4178
4.500	3.4236	11.04	3.4176
5.000	3.4223		



**Physical properties**

Density	2.33g/cm <sup>3</sup>
Hardness, Mohs	7
Dielectric Constant for 9.37 x 10 <sup>9</sup> Hz	13
Melting point, °C	1414
Thermal Conductivity, W/m·K at 313 K	163
Thermal Expansion, 1/K at 293 K	2.6x10 <sup>-6</sup>
Specific Heat Capacity, J (kg·°C)	712.8
Bandgap, eV	1.1
Knoop Hardness, kg/mm <sup>2</sup>	1100
Young's Modulus, Gpa	130.91
Shear Modulus, Gpa	79.92
Bulk Modulus, Gpa	101.97
Debye Temperature, K	640
Poisson's Ratio	0.28
<b>Chemical properties</b>	
Solubility in water	None
Molecular Weight	28.09





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Introduction

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Optics for Medical Laser System

Optics for Semiconductor Spectroscopy Biomedical Application Laser

Optical Material

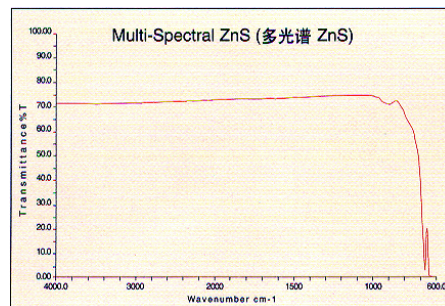
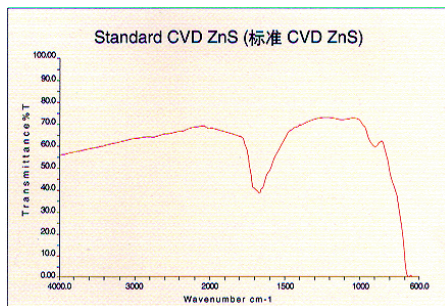
Laser Accessories Components

# Infrared Optical Material - ZnS

## Basic Properties:

Specification	Standard CVD ZnS	Multi-spectrum CVD ZnS
Transmission Range (um)	0.6-12.0	0.35-12.0
Refractive Index@10um	2.2002	2.2008
Temperature Coefficient of Refractive Index@10.6um	41 x 10 <sup>-6</sup> /°C	54 x 10 <sup>-6</sup> /°C
Bulk Absorption Coefficient@10um / cm	0.096	0.02
Melting Point, °C	1830	1830
Hardness (Knoop), Kg/mm <sup>2</sup>	210-230	160
Density, g/cm <sup>3</sup>	4.09	4.09
Rupture Modulus, Mpa	103.4	68
Young's Modulus, Gpa	74.5	74.5
Fracture Toughness Mpa <sup>-1/2</sup>	1.0	0.8

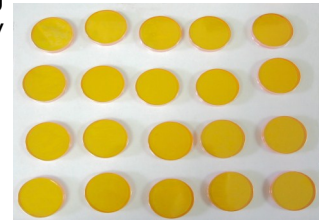
Wavelength (µm)	Index	Wavelength (µm)	Index	Wavelength (µm)	Index	Wavelength (µm)	Index
0.42	2.516	1.0	2.292	7.0	2.232	13.0	2.152
0.46	2.458	1.4	2.275	7.4	2.228	13.4	2.143
0.50	2.419	1.8	2.267	7.8	2.225	13.8	2.135
0.54	2.391	2.2	2.263	8.2	2.221	14.2	2.126
0.58	2.371	2.6	2.260	8.6	2.217	14.6	2.116
0.62	2.355	3.0	2.257	9.0	2.212	15.0	2.106
0.66	2.342	3.4	2.255	9.4	2.208	15.4	2.095
0.70	2.332	3.8	2.253	9.8	2.203	15.8	2.084
0.74	2.323	4.2	2.251	10.2	2.198	16.2	2.072
0.78	2.316	4.6	2.248	10.6	2.192	16.6	2.059
0.82	2.310	5.0	2.246	11.0	2.186	17.0	2.045
0.86	2.305	5.4	2.244	11.4	2.180	17.4	2.030
0.90	2.301	5.8	2.241	11.8	2.173	17.8	2.015
0.94	2.297	6.2	2.238	12.2	2.167	18.2	1.998
0.98	2.294	6.6	2.235	12.6	2.159	-	-





# Infrared Optical Material - ZnSe

ZnSe is a preferred material for lenses, windows, output couplers and beam expanders for its low absorption at infrared wavelengths and its visible transmission. ZnSe is non-hygroscopic and chemically stable, unless treated with strong acids. It's safe to use in most industrial field and laboratory environment.



**Basic Properties:**

Specification	ZnSe
Transmission Range (um)	0.5-22
Refractive Index@10um	2.4381
Temperature Coefficient of Refractive Index, /°C	61 x 10 <sup>-6</sup>
Bulk Absorption Coefficient@10um / cm	0.0004
Melting Point, °C	1520
Hardness (Knoop), Kg/mm <sup>2</sup>	112
Density, g/cm <sup>3</sup>	5.27
Rupture Modulus, Mpa	55.2
Young's Modulus, Gpa	67.2
Fracture Toughness Mpam <sup>-1/2</sup>	0.5

**CVD ZnSe**

