Optoelectronics
(광전자공학)

Lecture 3. Optical properties of solids

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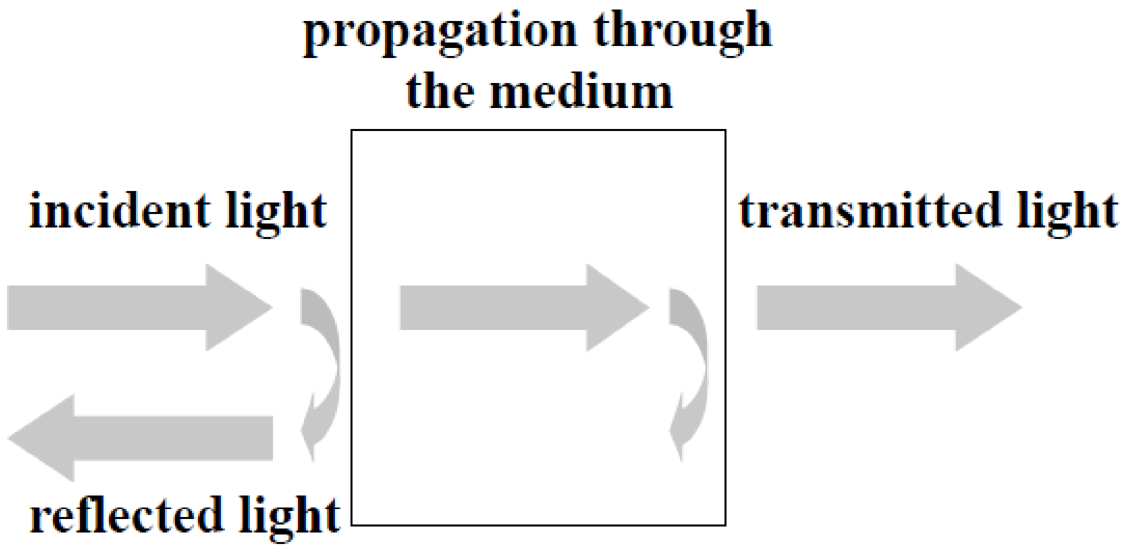
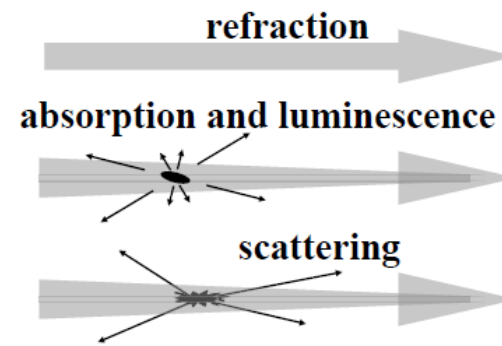
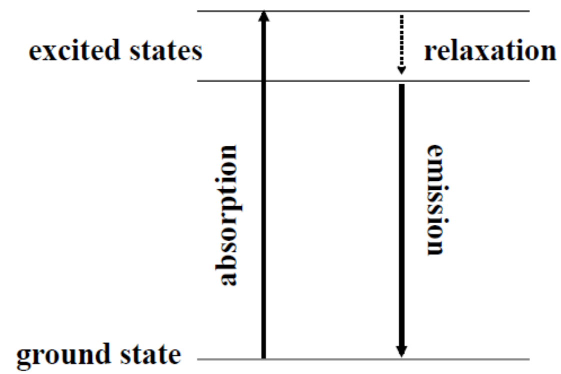
Optical coefficients





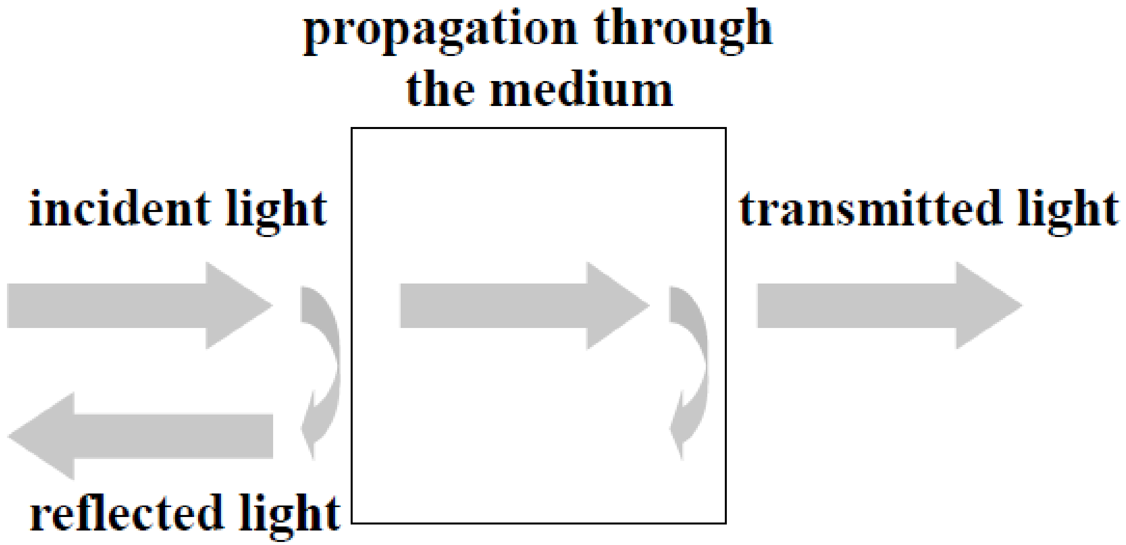
Luminescence



- Reflectivity = reflected / incident power
- Transmissivity = transmitted / incident power
- $T + R = 1$ if medium is transparent

- Luminescence comes out at lower frequency than absorption due to internal relaxation.
- The energy shift between absorption and luminescence is called the Stokes shift.

Optical coefficients

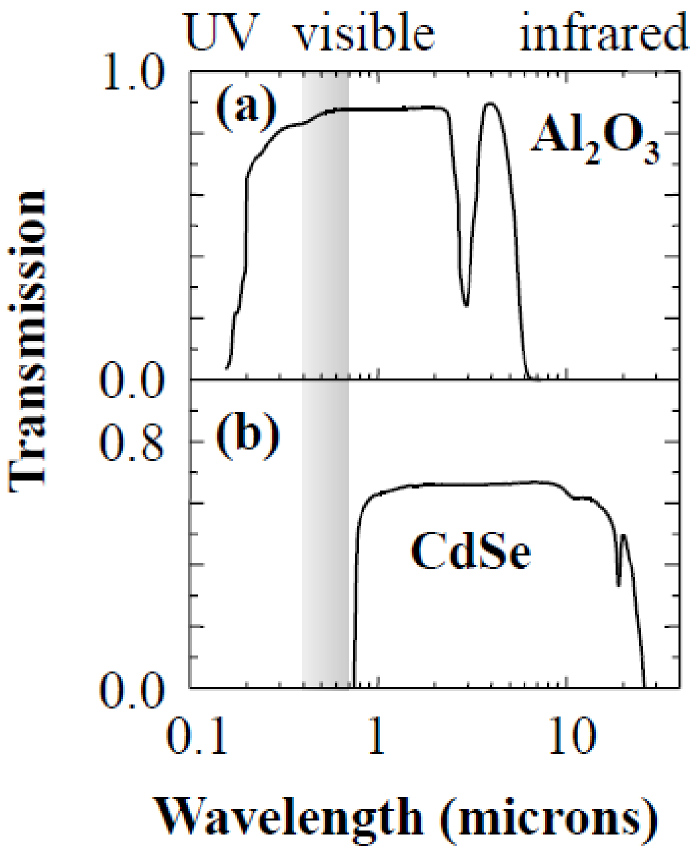


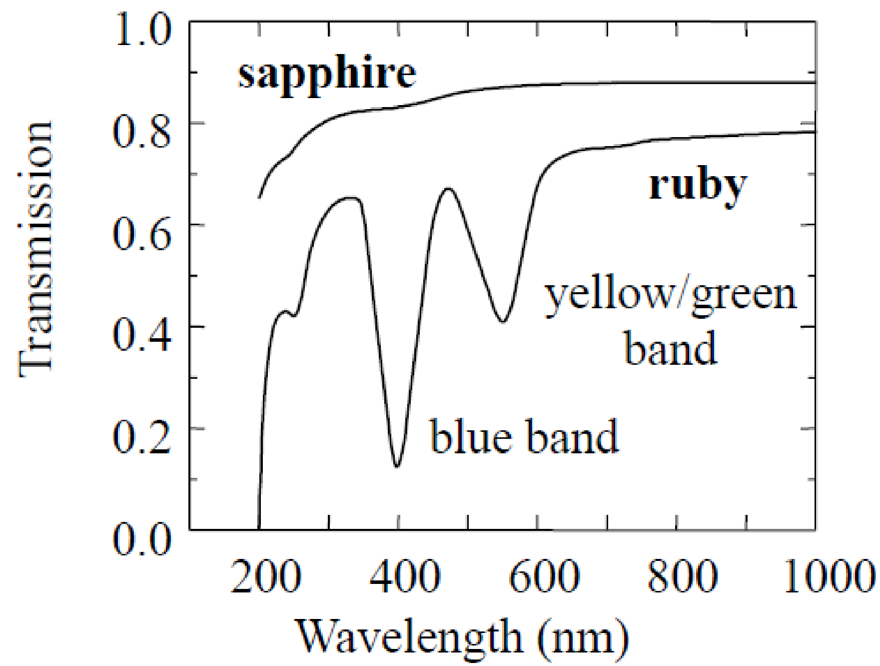
Optical coefficients

Complex refractive index

Complex refractive index

Insulators/semiconductors

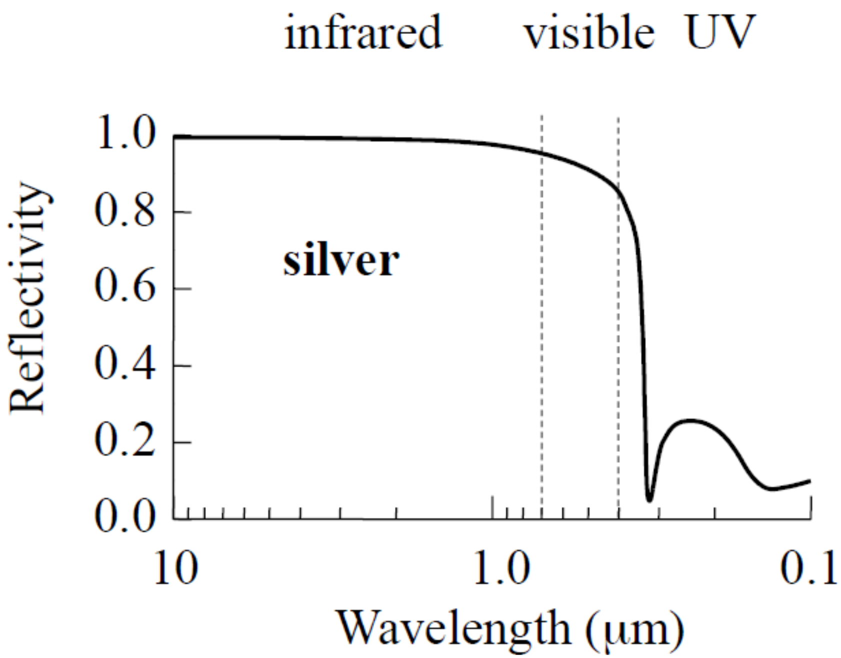


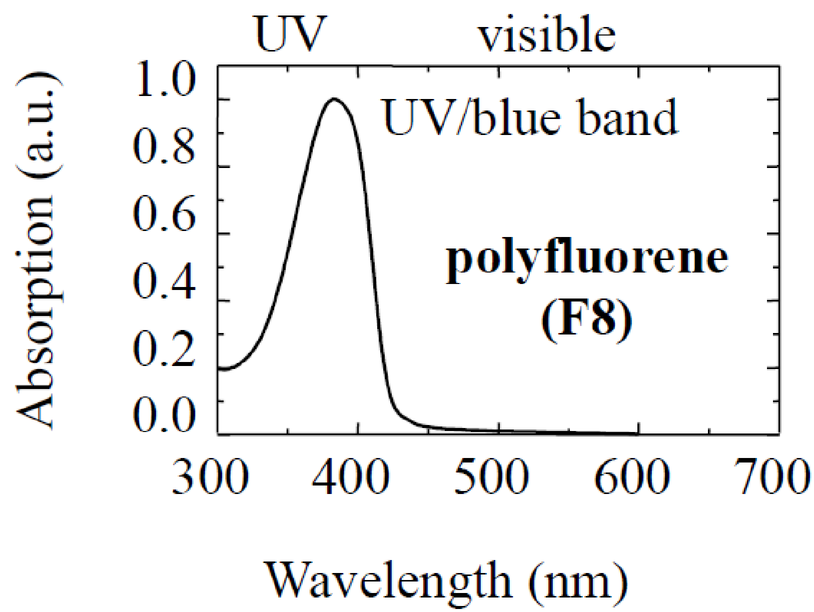


- Infrared absorption due to phonons
- UV/visible absorption due to bound electrons
- Position of fundamental absorption edge depends on the bandgap

- Cr3+ ions doped into sapphire absorb in the blue and yellow/green spectral regions, hence red colour

Metals/Organic materials

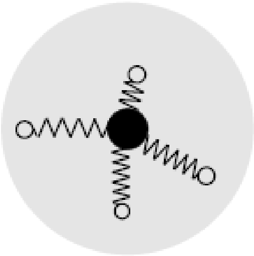




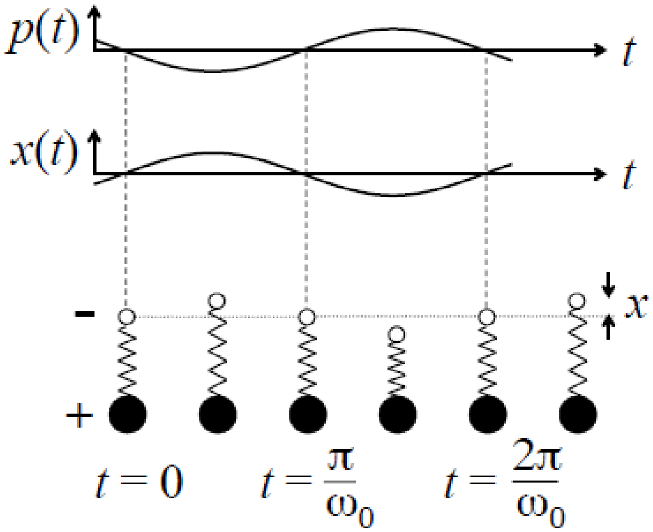
- Free electrons in the metal absorb
→ High reflectivity up to 'plasma frequency' in the UV

- Strong absorption in UV/visible spectral region due to electronic transitions
- Stokes-shifted emission across the visible spectral region

Dipole oscillators



Classical model of an atom. Electrons are bound to the nucleus by springs which determine the natural frequencies.



Dipole oscillators

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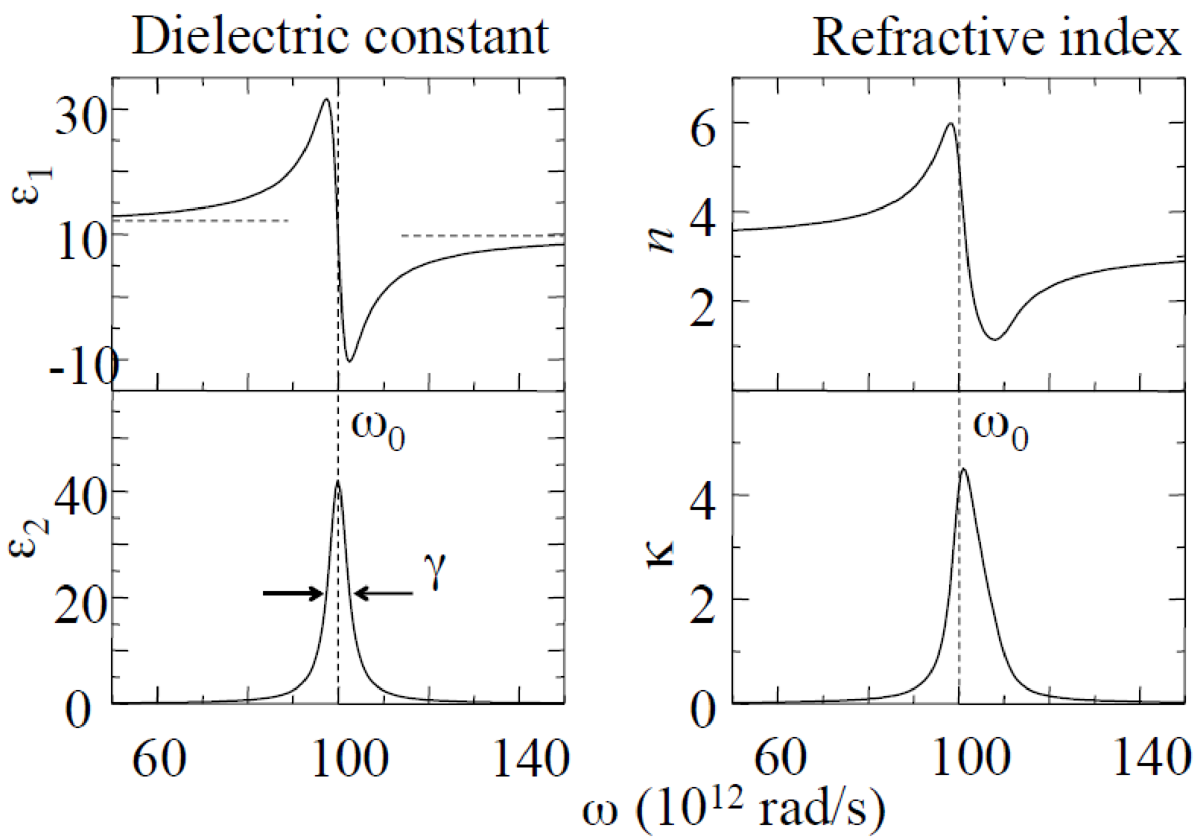


Lorentz oscillator with

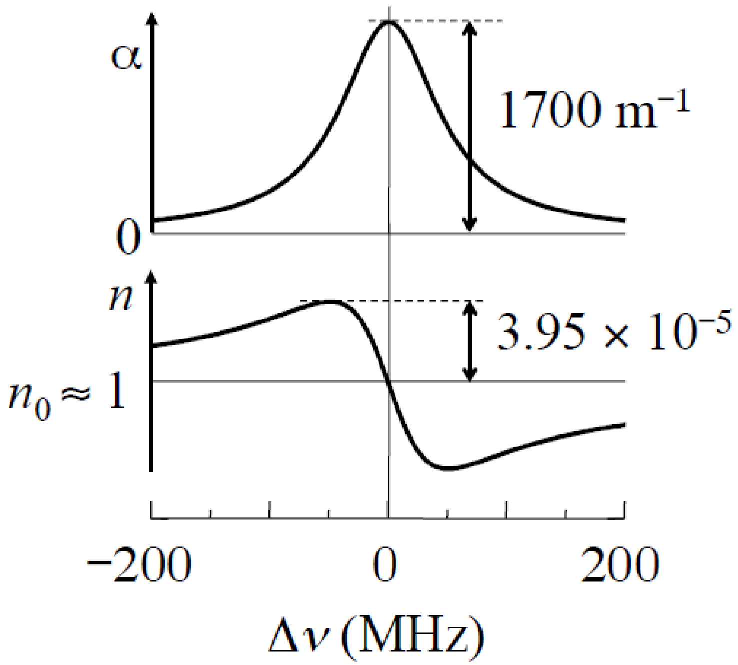
$\omega_0 = 10^{14}$ rad/s

$\gamma = 5\times10^{12}\ s^{-1}$

$\varepsilon_{st} = 12.1$

$\varepsilon_{\infty} = 10$

Atomic absorption line



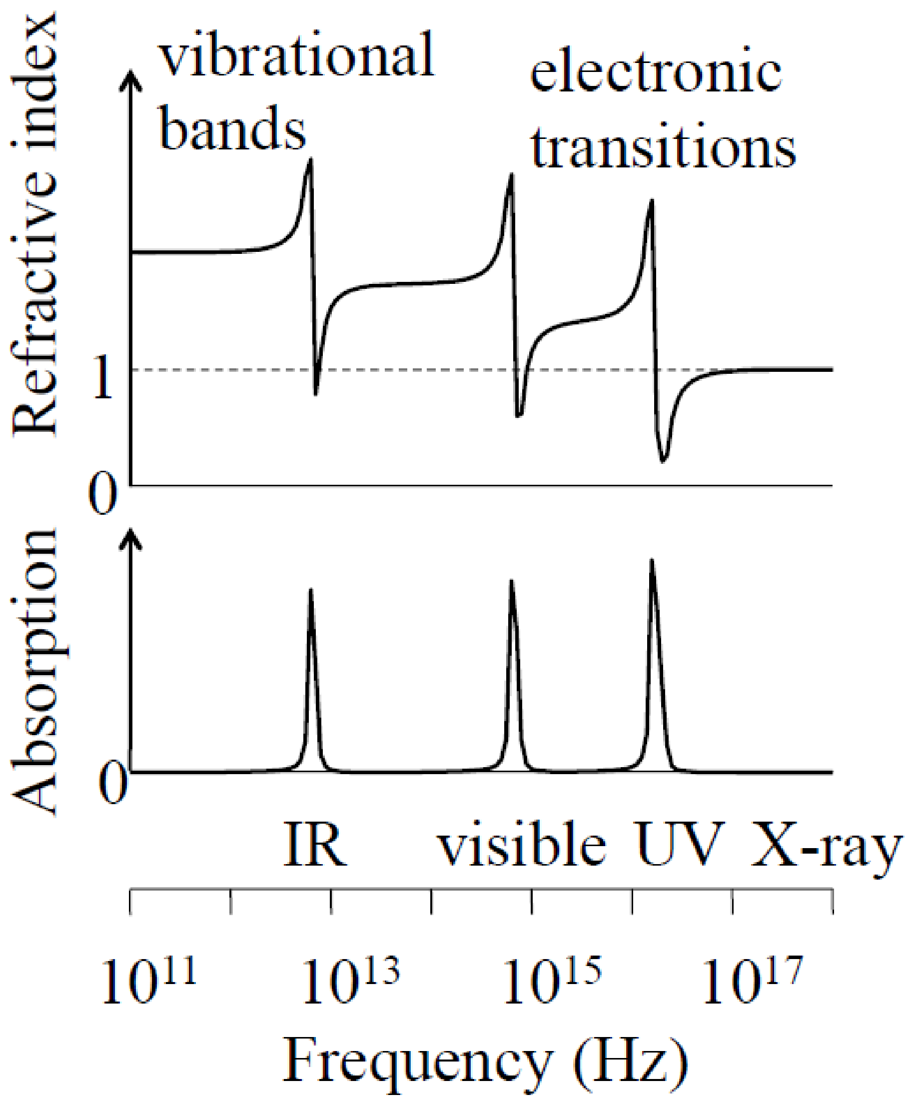
Lorentzian lineshape

$$\alpha(\omega) = \alpha_0 \frac{\gamma^2}{4\Delta\omega^2 + \gamma^2}$$

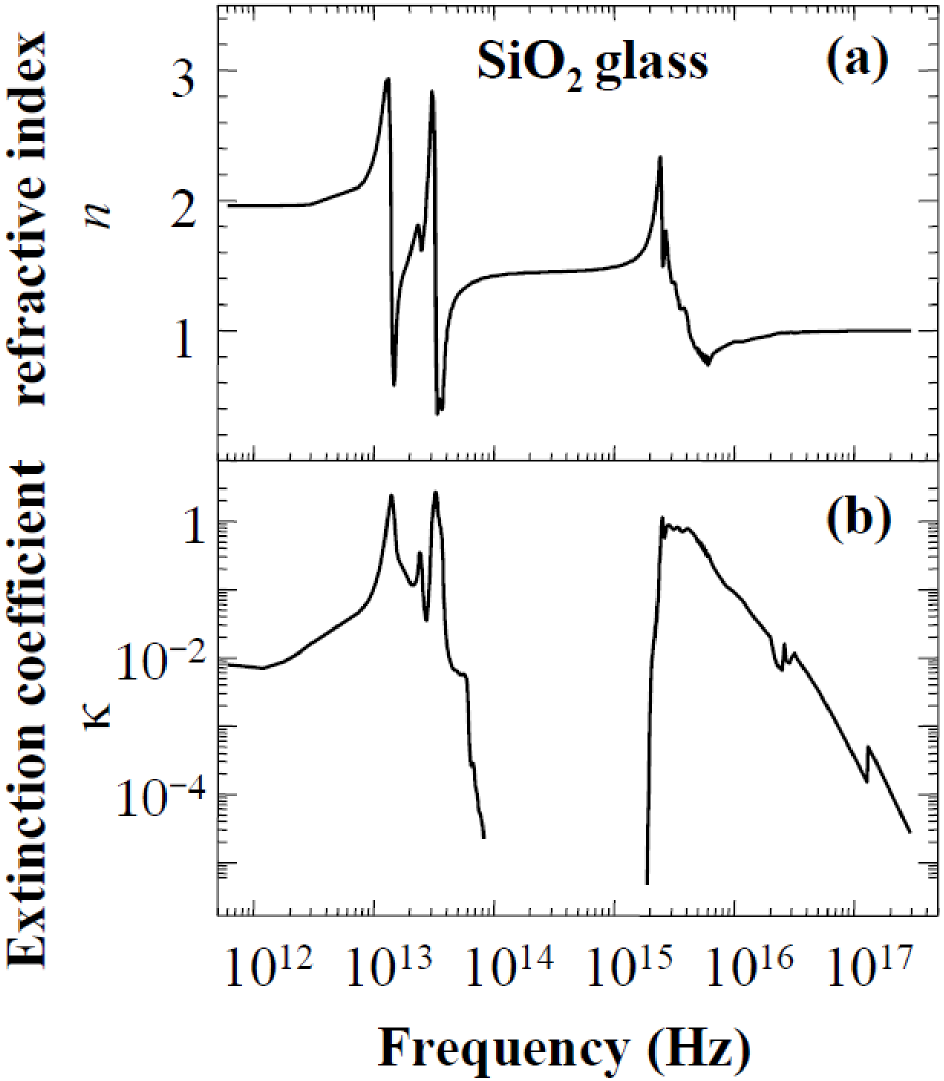
$$n(\omega) = n_0 - \Delta n \frac{4\gamma\Delta\omega}{4\Delta\omega^2 + \gamma^2}$$

$$\Delta\omega = \omega - \omega_0$$

Multiple resonances



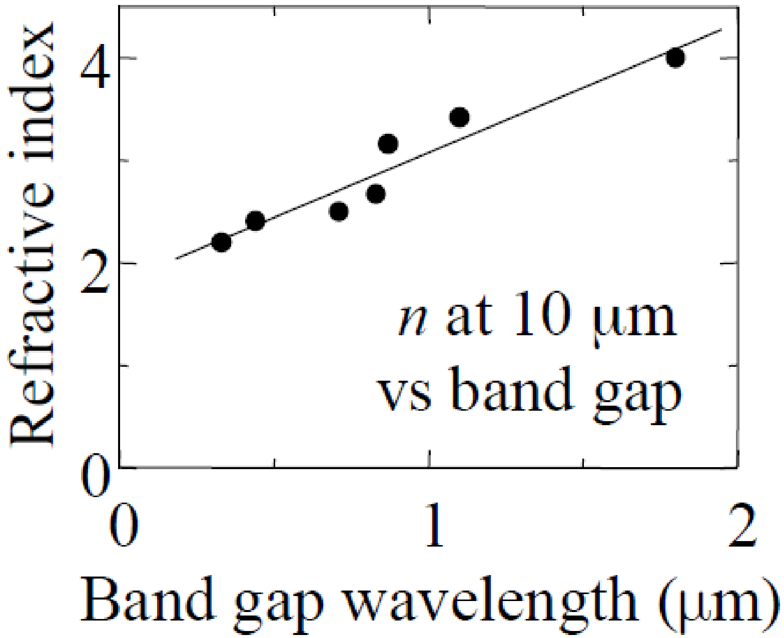
SiO_2 glass


SiO2 glass
(a)
(b)
refractive index
n
Extinction coefficient
κ
3
2
1
1
10−2
10−4
10^12 10^13 10^14 10^15 10^16 10^17
Frequency (Hz)

Kramers-Kronig relationships

$$n(\omega)-1=\frac{2}{\pi}\mathrm{P}\int_0^\infty \frac{\omega'\kappa(\omega')}{\omega'^2-\omega^2}\,\mathrm{d}\omega'$$

$$\kappa(\omega)=-\frac{2}{\pi\omega}\mathrm{P}\int_0^\infty \frac{\omega'^2\left[n(\omega')-1\right]}{\omega'^2-\omega^2}\,\mathrm{d}\omega'$$

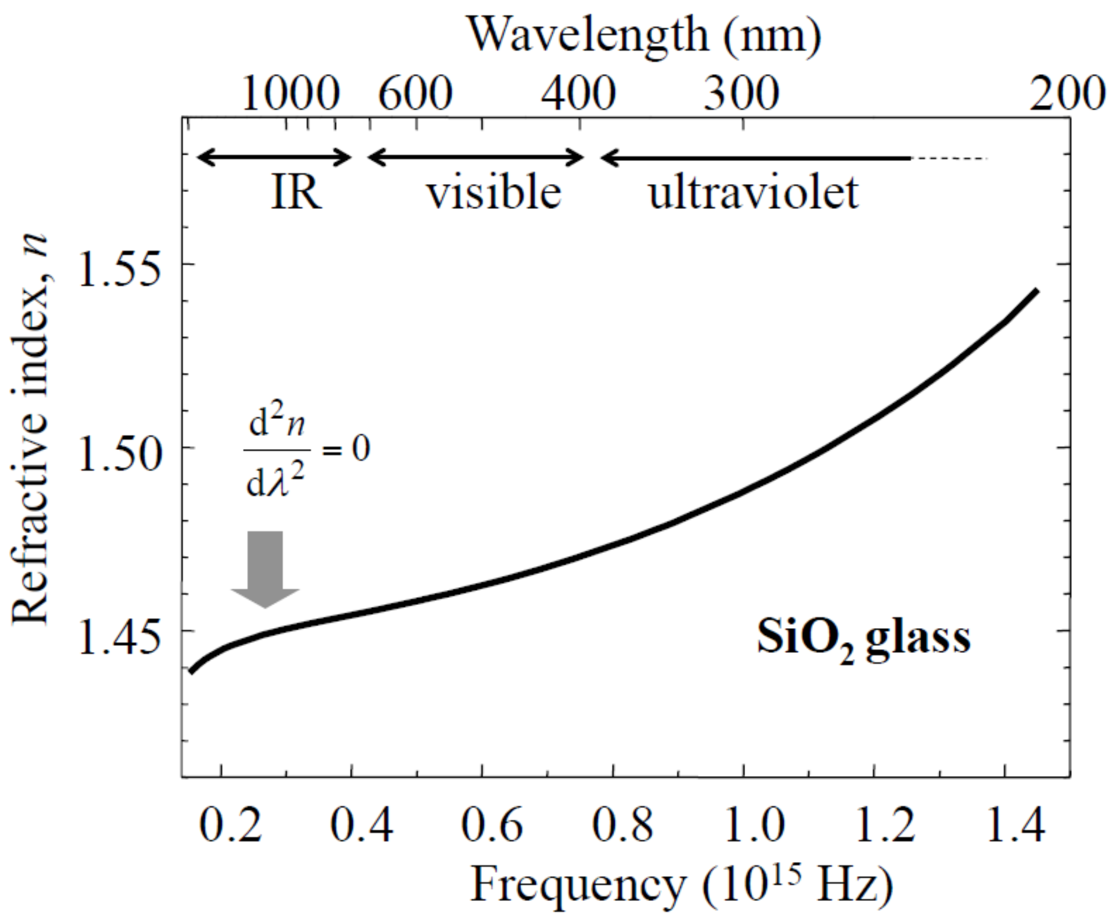


UV transmission of glass

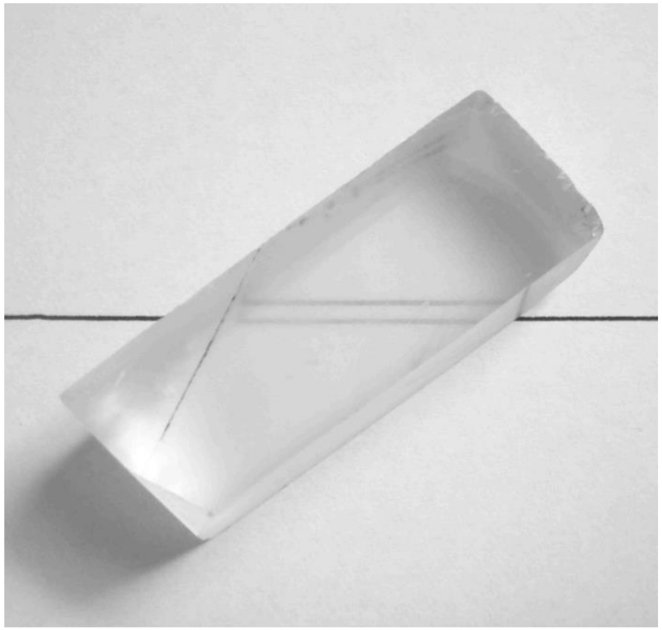
Table 1.4 Composition, refractive index and ultraviolet transmission of some common glasses. The letters after the names give the abbreviations used to identify the glass type. The composition figures are the percentage by mass. The refractive index is measured at 546.1 nm, and the transmission is for a 1 cm plate at 310 nm. (Data from Driscoll & (1978), and Lide (1996).)

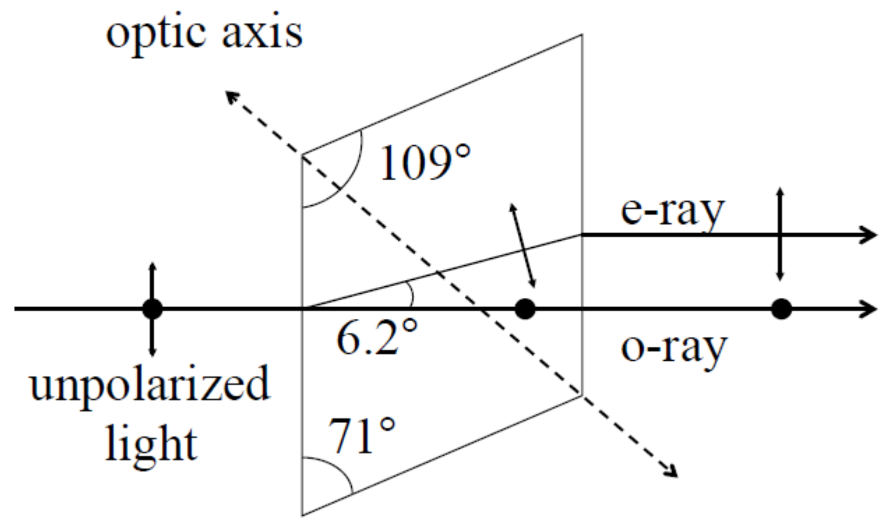
Name	$Si0_2$	B_2O_3	Al_20_3	Na_20	K_20	CaO	BaO	PbO	P_2O_5	n	T
Fused silica	100									1.460	0.91
Crown (K)	74			9	11	6				1.513	0.4
Borosilicate crown (BK)	70	10		8	8	1	3			1.519	0.35
Phosphate crown (PK)		3	10		12	5			70	1.527	0.46
Light flint (LF)	53			5	8			34		1.585	0.008
Flint (F)	47			2	7			44		1.607	–
Dense flint (SF)	33				5			62		1.746	–

Dispersion

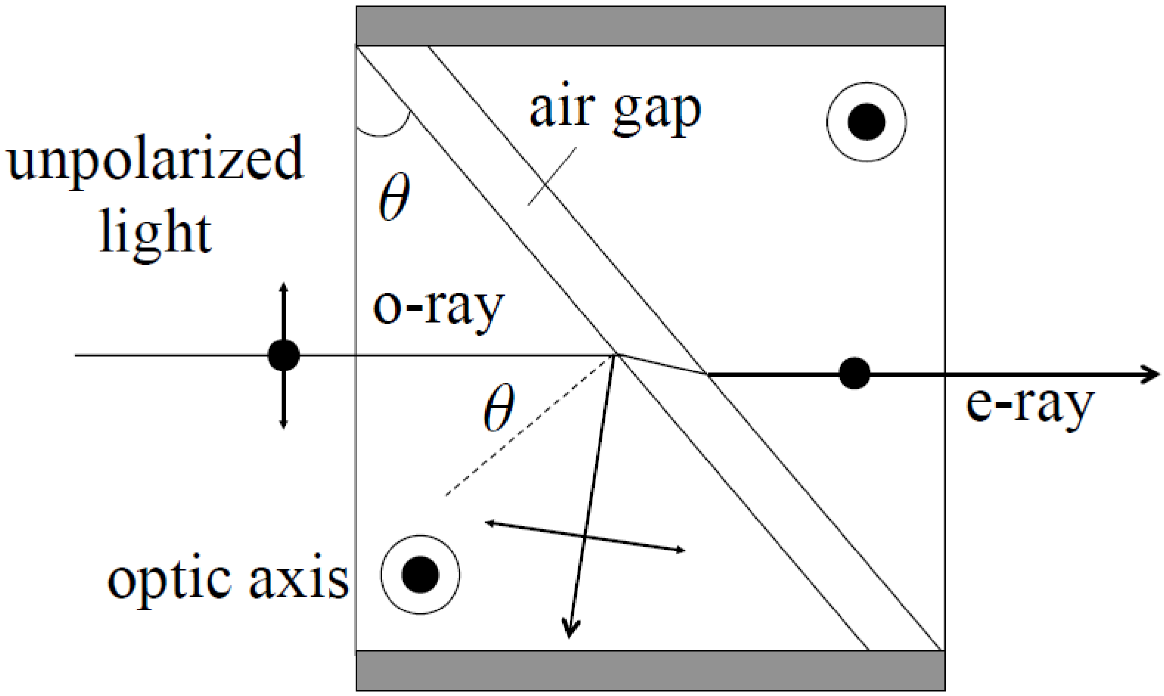

Wavelength (nm)
1000
600
400
300
200
IR
visible
ultraviolet
Refractive index, n
1.55
1.50
1.45
$\frac{d^2n}{d\lambda^2} = 0$
SiO_2 glass
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Frequency (10^{15} Hz)

Double refraction (Birefringence)





Polarizing beam splitters



Question or Comment?