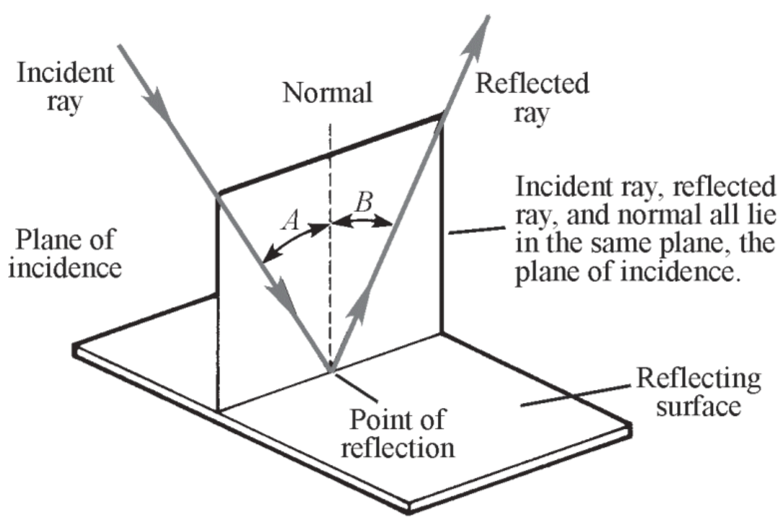
Design and Documentation of Optics and Circuits for Medical Equipment

“Mathematical and software research in a nutshell”

Photons;

E = Energy of photon in joules (J) v = Frequency in hertz (Hz) h = Planck’s constant = 6.625 10–34 joule-seconds. (This famous constant was identified by the German physicist Max Planck in 1900, during his attempt to explain the spectral distribution of black-body radiation. His work introduced the concept of a “quantum of action,” involving the constant h. The “quantum of action” led eventually to the idea of a photon.)

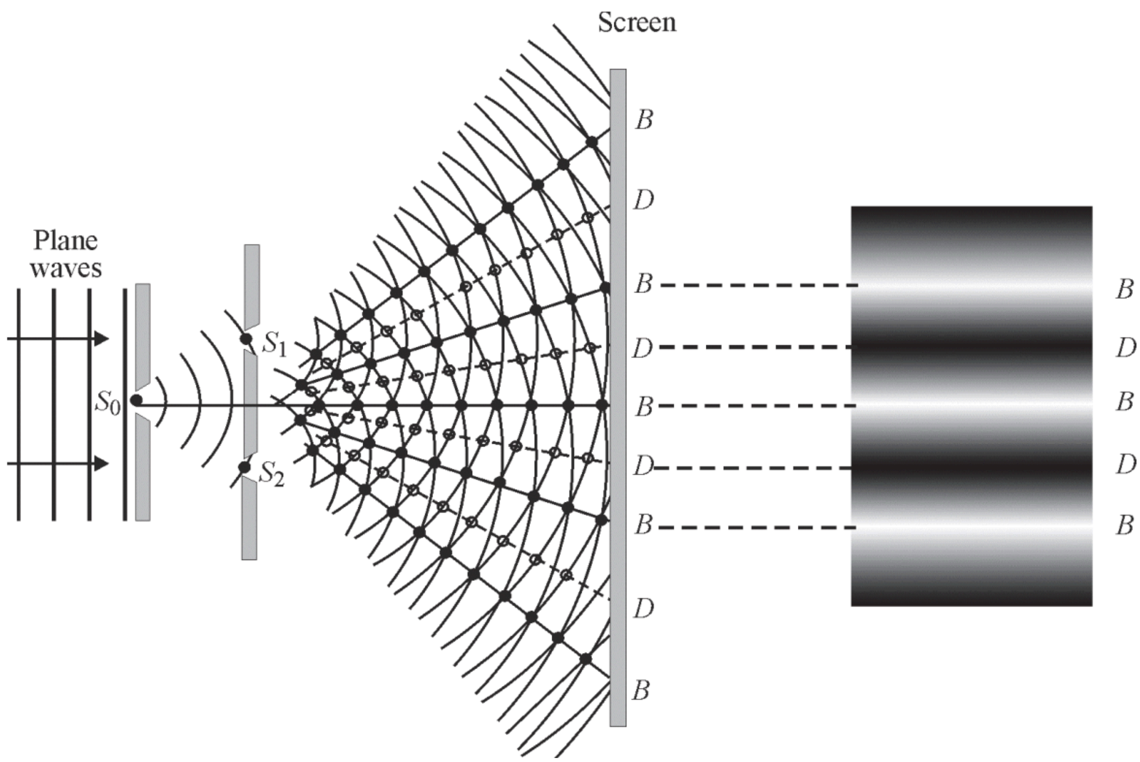
E = Energy of photon in joules c = Speed of light in a vacuum (m/s) = Wavelength of light in meters h = Planck’s constant = 6.625 10–34 joule-seconds



n1 = index of refraction of medium 1
n2 = index of refraction of medium 2
1 = angle of incidence (and reflection)
2 = angle of refraction

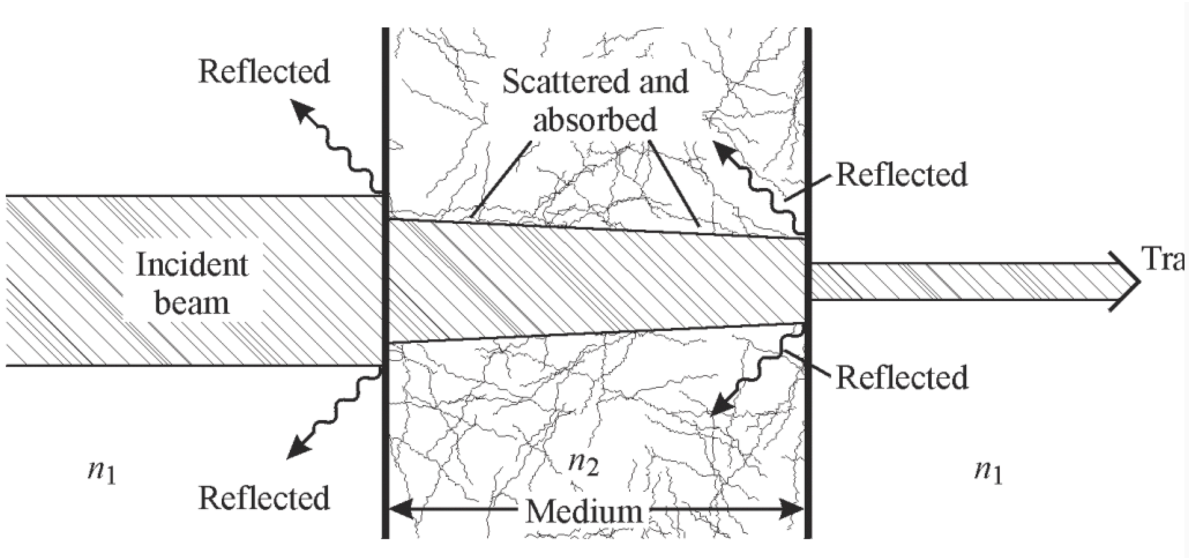
Table 1-2. Indexes of Refraction for Various Materials at 589 nm Substance n;

Substance n Air 1.0003 Polystyrene 1.49 Diamond 2.42 Quartz (fused) 1.46 Gallium Arsenide (semiconductor) 3.40 Water 1.33 Glass (crown) 1.52 Ice 1.31 Zircon 1.92 Germanium 4.1 Glass (flint) 1.66 Silicon 3.5

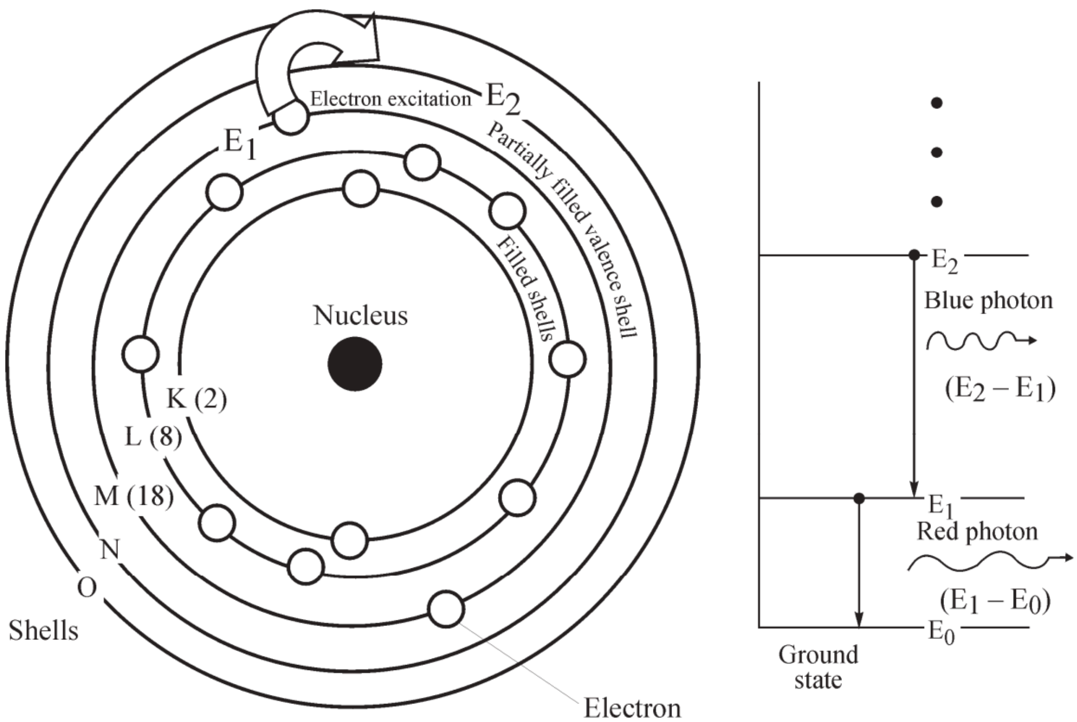


Light waves emanating from slits **S1** and **S2** are in phase and of the same wavelength. The light waves moving outwardly from S1 and S2 overlap and reinforce each other along lines with solid dots; they cancel each other along lines with unfilled dots. On the screen, alternate regions of bright **(B)** and dark **(D)** make up the interference fringes.

Example figure about the topic of the light beam depicts the energy contained within it. As the beam passes through a medium, its physical width stays constant, but as illustrated in the figure its energy content decreases as photons leave it through reflection, absorption, and scattering interactions.

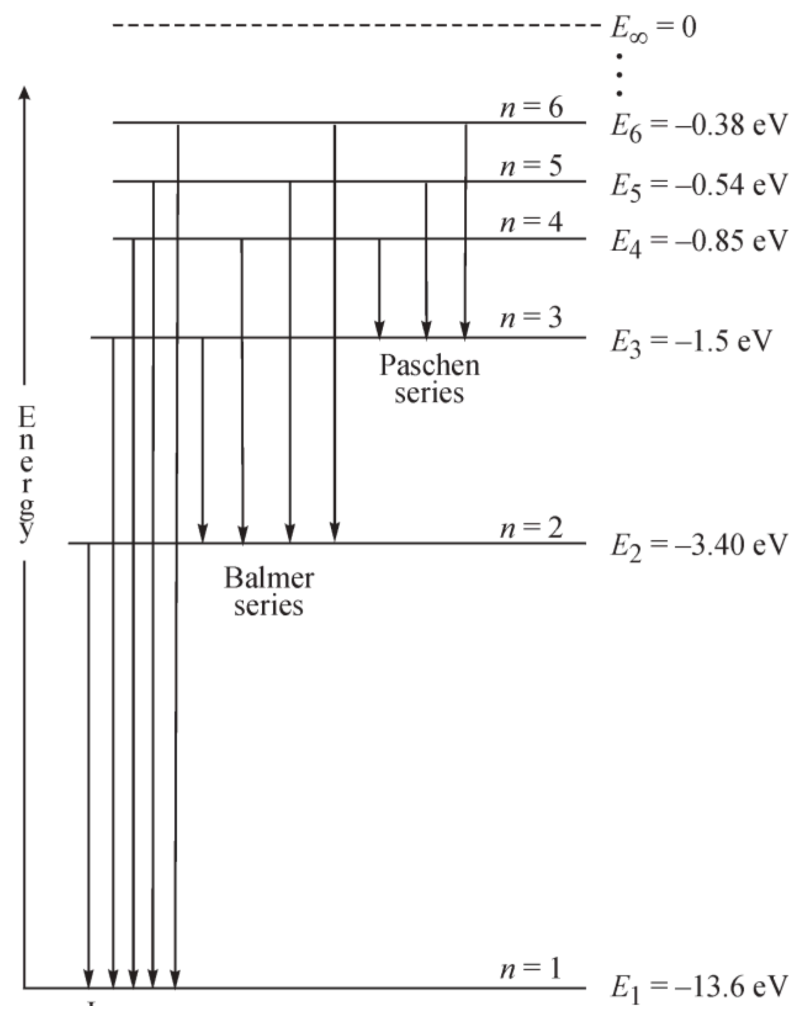


An atom is the smallest unit that retains the characteristics of a chemical element. It consists of a positive nucleus surrounded by negative electrons arranged in distinct energy shells designated K through O and the general example to check for a circuit of any medical device design with electrons and ions;



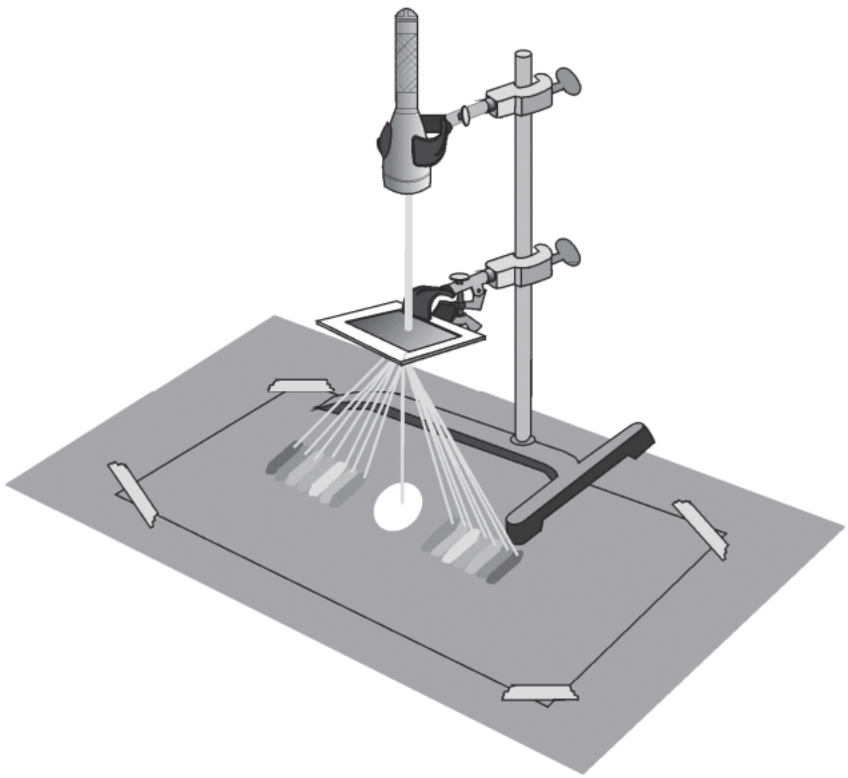
Ephoton E E 3 1 51 – –1. eV – (–13.6 eV) =12.09 eV

The atom can also absorb photons. This happens when the energy of a photon exactly matches the difference between two electron energy levels. For example, a hydrogen atom in the ground state can absorb a photon whose energy is 12.09 eV. The electron in the atom will then move from energy level E1 to energy level E3.

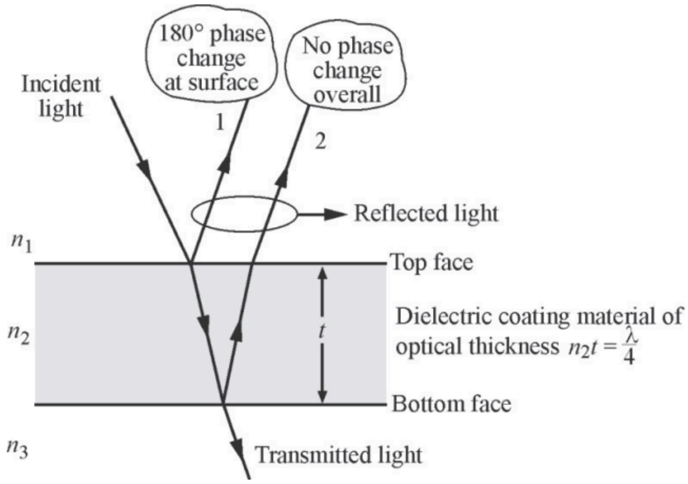


Radiation & SQL registers with Java;

Record the effectiveness of each brand in blocking UV radiation. Write a laboratory report to document your test, including your data and findings, and internet search results. In the document, your manager wants you to include an explanation of UVA, UVB, and UVC radiation and to document the damage these bands of UV radiation cause to the eye if proper protection is not provided by sunglasses.

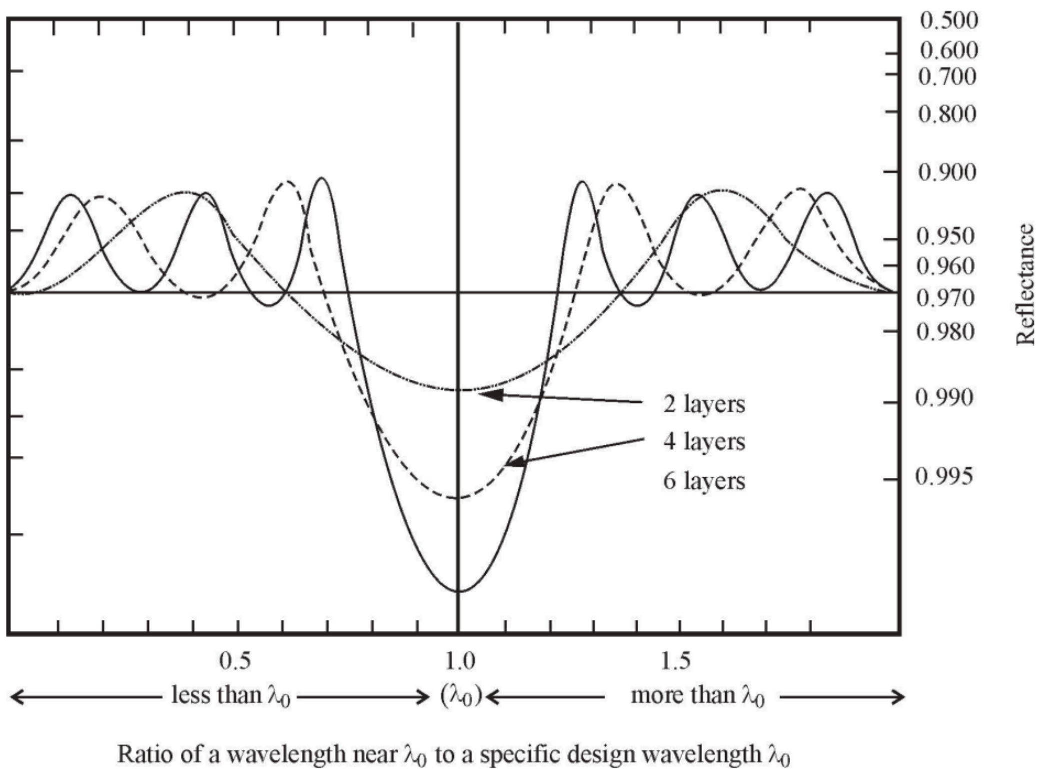


t = thickness of coat n = refractive index of coat = wavelength of light incident on the coat For a wavelength of 550 nm and refractive index of 1.4, Equation 2-9 yields for the minimum thickness t, t = -9 550 × 10 m 4 × 1.4 = 98.2 nm



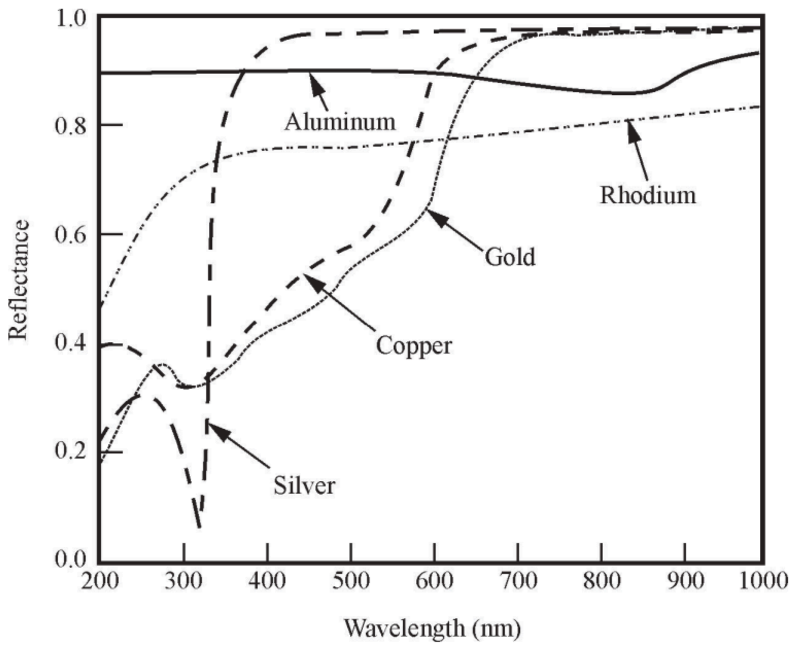
Partial reflectors can be used in the preparation of filters. However, the wavelength range of dielectric coatings is limited. Multi-layer coatings are always preferable since with them it is possible to increase the reflectivity by many orders. The process for coating multilayer high-reflecting elements is exactly the same as the one for anti-reflection coating.

Example of a wavelengths specifications for circuit FPGA design;



Ratio of a wavelength near λ_0 to a specific design wavelength λ_0

Metallic coatings can produce highly reflective, broadband, specular reflectors. Metallic films can be deposited on polished substrates. Some substances like aluminum can be directly coated on glass. For substances like gold, an intermediate layer such as chrome has to be used. It is better not to use very thick coatings since they tend to scatter light more.



Material Chemical formula Transparent region (m) Refractive index Density g/cc

Remarks ***Aluminum oxide Al2O3*** *0.2–9 1.65–1.60 3.6 Used in UV and mirror protection Chromium oxide Cr2O3 0.6–5 2.2 5.2 Very hard; resistant to acids* ***Hafnium dioxide HfO2*** *0.25–11 2.09–1.95 9.7 UV multilayers;*

high damage threshold ***Indium oxide In2O3*** *0.4–9 2.05 7.2 Hard, used for mirror protection Silicon monoxide SiO 0.45–7 1.9–1.83 2.0 Protection for Al and Ag mirrors*

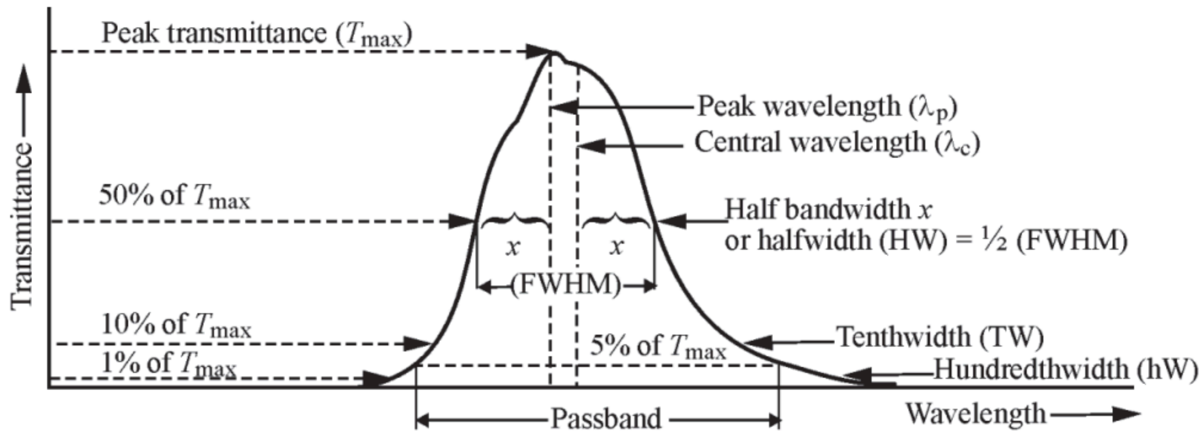
Titanium dioxide TiO2 *0.45–11 2.5–2.25 4.7 Durable, multilayer protection coatings, high tensile strength Zirconium dioxide ZrO2 0.3–11 2.3–2.0 5 Visible multilayer coatings;*

hard film Aluminum fluoride *AlF3 0.2–12 1.36–1.30 2.9 AR coatings in UV to IR range Cerium fluoride CeF3 0.2–14 1.35 2.6*

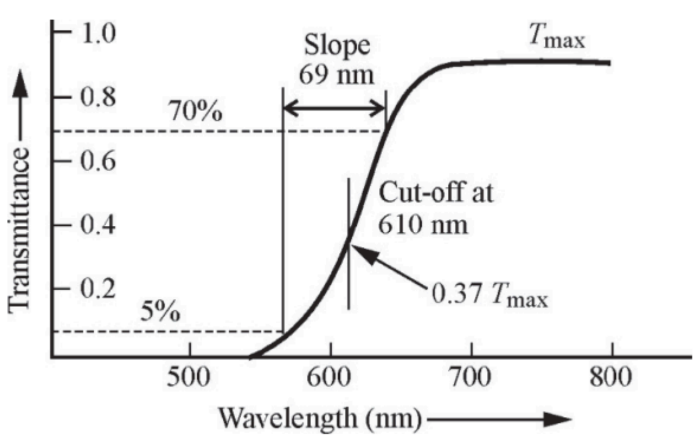
Water resistant Magnesium fluoride MgF2 0.15–6 1.42–1.36 301 AR coatings Yttrium fluoride YF3 0.25–11 1.45–1.3 8.0 IR multilayer coatings; high damage threshold Cadmium telluride CdTe 0.9–25 2.65 6.0 soft IR multilayer coatings Lead telluride PbTe 3.5–80 5–10 8.1 Far IR multilayer coatings Zinc selenide ZnSe 0.6–16 2.6–2.35 5.2 IR multiplayer coatings Zinc sulfide ZnS 0.4–14 2.5–2.15 3.8 IR multilayer

Broadband filters;

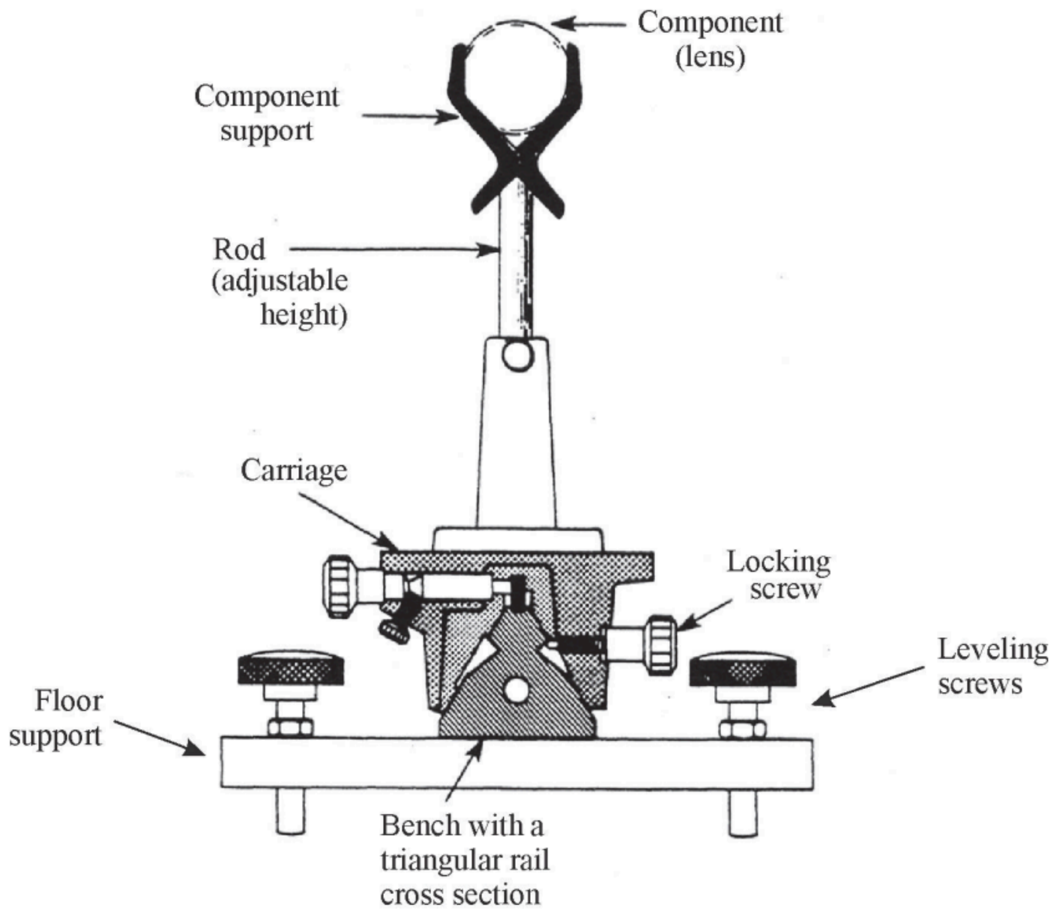
1. Peak transmission **(Tmax)** occurs at the desired wavelengths.
2. Full width at half maximum **(FWHM)** is the wavelength span between two points whose transmission is at half the value of Tmax.
3. Pass-band is the wavelength span between two points on the curve where the transmission is 5% of peak value. 4. Rejection ratio is more applicable to narrow-band filters and is the ratio of the Tmax and the transmittance outside the band.



There are two types of these filters: (a) the short-wave pass filters and (b) the long-wave pass filter. A long-wave pass filter is shown in Figure 2-13. The cut-off wavelength is not exactly "abrupt" and somewhat slopes down. The wavelength at 37% of Tmax is generally considered as the cut-off wavelength. The sharpness of the "cut off" is the wavelength difference between the 5% and 70% transmission points.

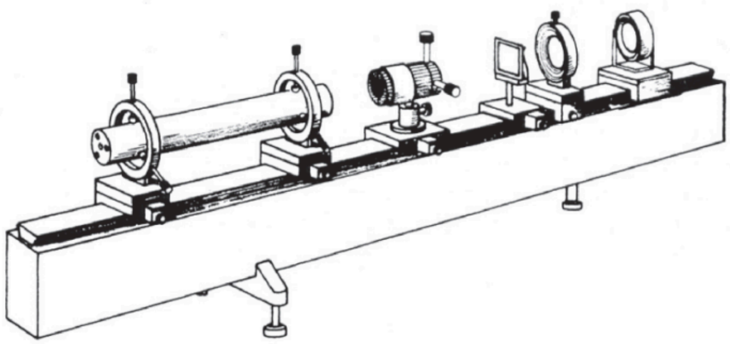


An optical bench or optical rail is a long stable base on which optical components can be mounted. This rail can have different cross-sectional shapes so that mounts with a reverse geometrical configuration can be positioned and moved along the rail. Optical components such as lenses, mirrors, filters and detectors can be mounted on movable carriages. Component supports are attached to rods with adjustable heights.

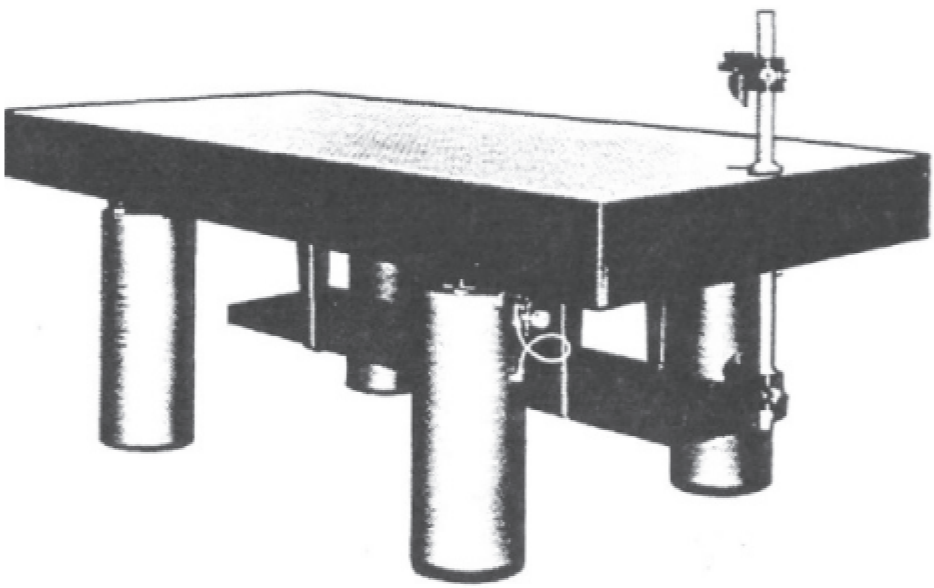


Flat-bed optical bench—A flat-bed bench is used when maximum stability is required for the optical system. Flat beds are made either out of high-grade stainless steel or granite. The rail has a dovetail cross-section along which carriers can be moved and fixed at desired positions. This type of bench is quite heavy and very stable.

Flat-bed optical bench example;



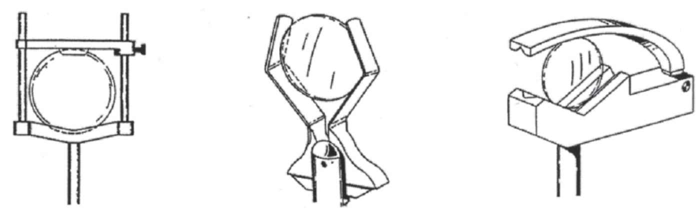
Optical tables are used instead of bench rails when optical elements must be aligned along more than one axis and when vibration isolation is required. A typical example where such an optical table is used is in a holographic set-up. Optical tables of different sizes, both with and without legs, are available.



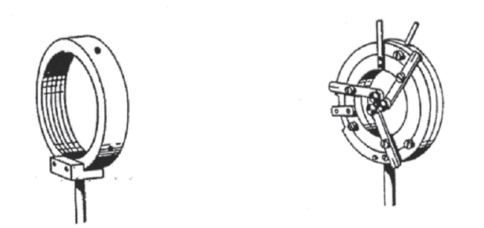
When **external vibrations** need to be completely eliminated, optical tables with pneumatic isolation legs are used. Vibrations that reach the optical table are generally of a low frequency (<30 Hz) and are due to the motion of the laboratory floor—generally from people walking nearby. The pneumatic legs are designed to have a vibration frequency far less than 30 Hz so that no vibrations are transferred to the table.

Components(Grid)

The sliding-grip lens holder has a V-groove in which the lens can rest and the movable horizontal bar can be fixed with a side screw. Thus ,a lens can be held between the V-groove and the horizontal bar. This support is mounted on a cylindrical rod that can be moved vertically to fix the lens at any height. In the spring grip lens holder, the lens is held in the jaws of a double "V" spring. The lens is positioned between the two jaws.

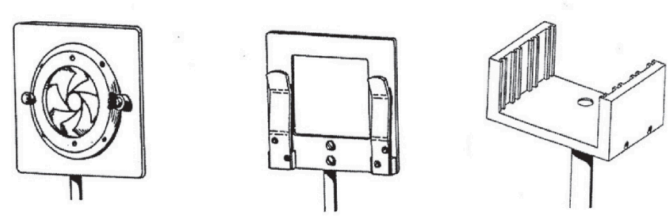


(a) Sliding grip (b) Spring grip (c) Swing arm

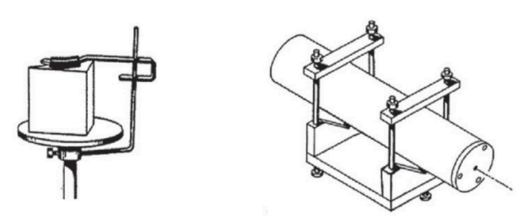


(d) Threaded ring (e) Self-centering

Most of these mounts can be combined with one-, two-, and three-dimensional movable positioners for finer adjustment of the optical element.



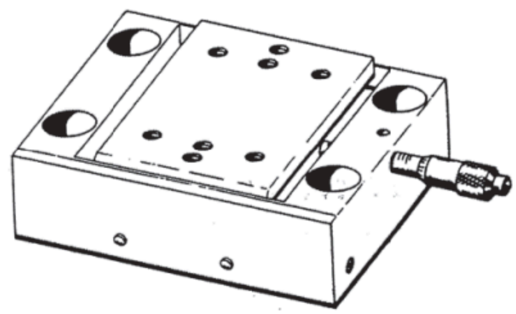
(a) Iris diaphragm (b) Filter holder (c) Filter holder



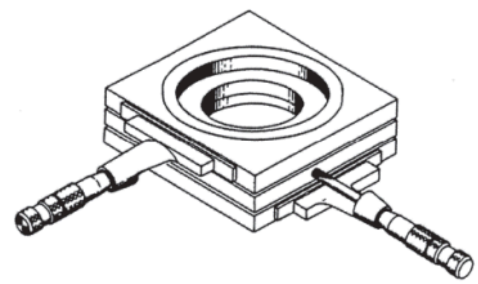
(d) Prism holder (e) Laser holder

Translation tables

Translation tables provide adjustable motion in one or two dimensions. These can be combined with other devices to produce either a three-dimensional motion or a combination of linear and rotational motions.



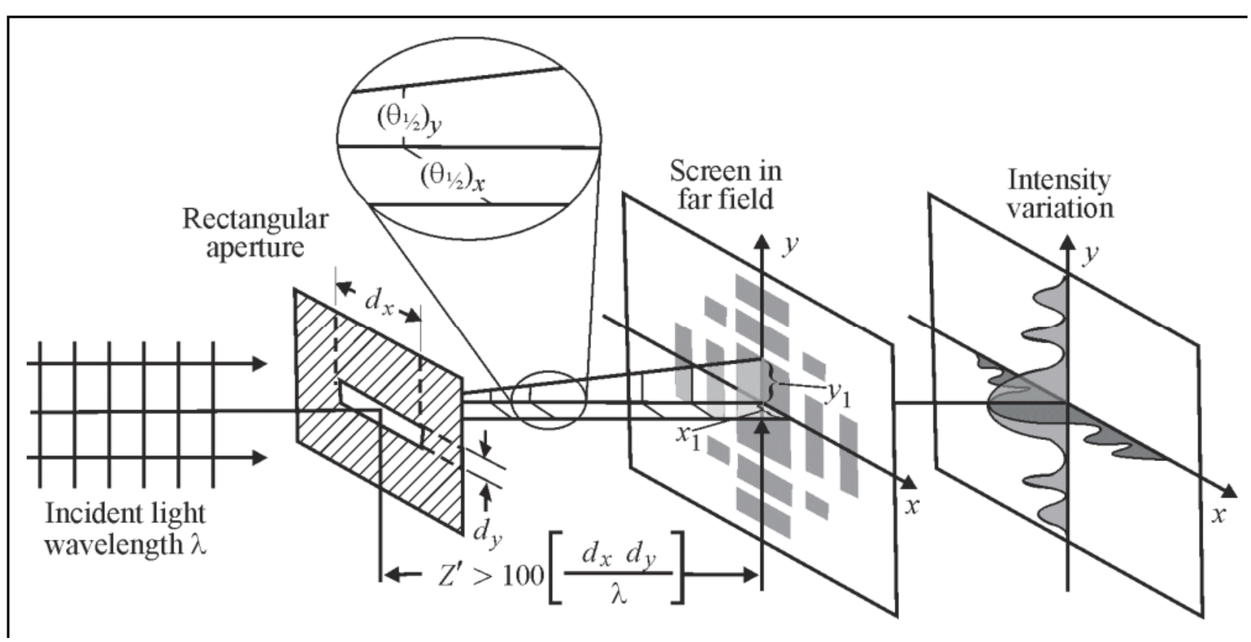
(a) Linear translator



(b) Two-dimensional translator

This micrometer can be attached to a slow motion motor to provide smooth and slow linear motion. Motion in two axes can also be accomplished by stacking two linear translators above and perpendicular to each other.

Variables = wavelength of light, D = diameter of pinhole, and Z = pinhole-to-screen distance

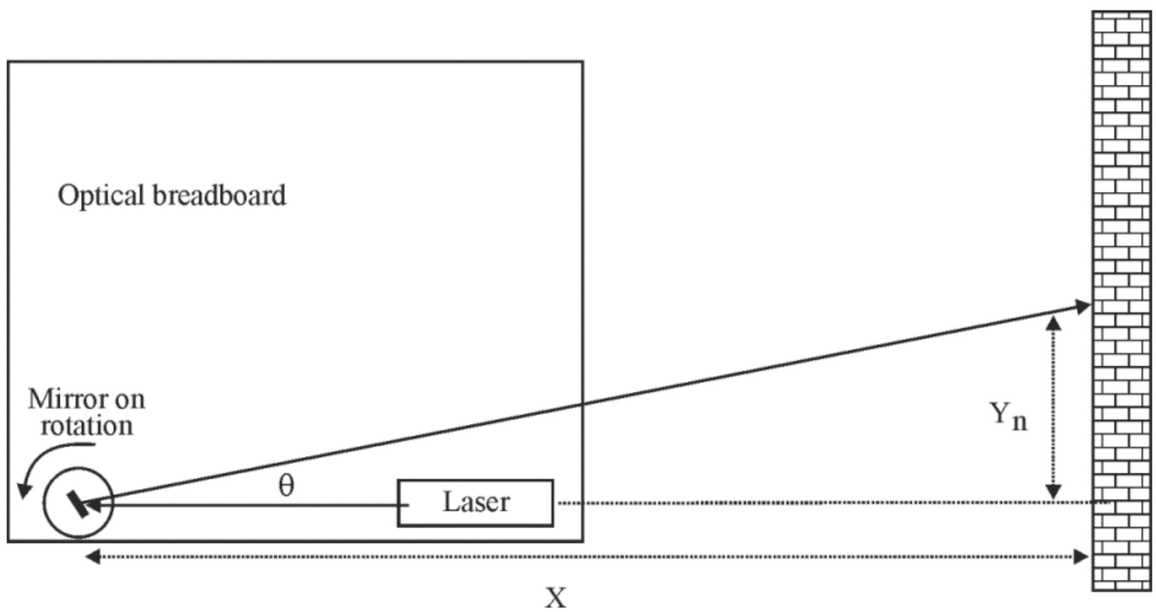


Equipment

(most from Newport Kit: OEK-STD) –25 mm Diverging Lens 1 LCA on a post 1 LCA on adjustable base 2 BSA Assemblies +50.2 mm Converging Lens +75.6 mm Converging lens Filter Holder and Clothespins 1 mm tall transparent arrow slide

LASERS;

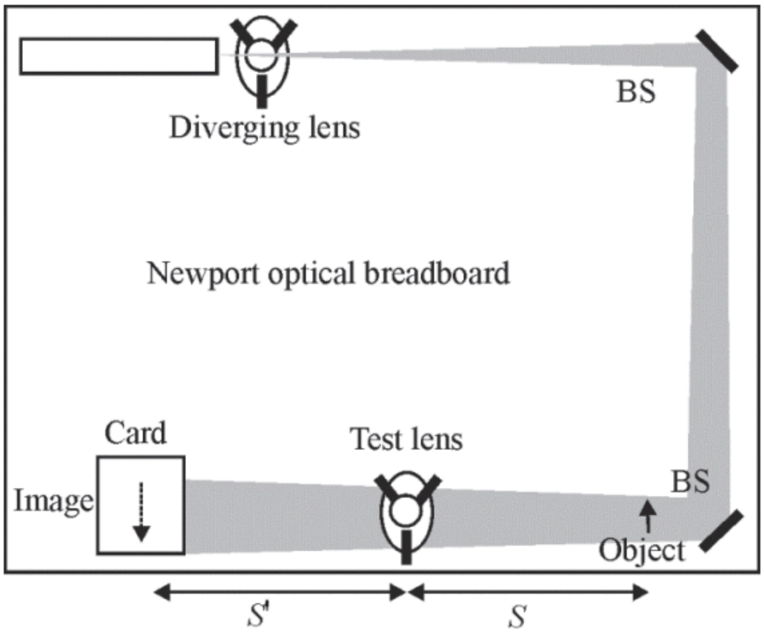
Procedure 1. The optical breadboard should be located on a table near a wall. Tape a sheet of paper on the wall at the same height you plan to set your laser. 2. Mount the He-Ne laser as described by your instructor and place it at the rear of the breadboard. 3. Mount a Beam Steering Assembly (BSA-I) onto a Rotation Stage (RSA-IT). The Rotation Stage should be attached to the table with screws. The BSA-I should be located so that the incident laser beam is perpendicular to the wall as shown in the Figure;



Variables to code with python;

```
Angle of Rotation X Yn Deviation Angle (Degrees) Error
(Degrees) (m) (m) Measured Expected (%)
.
```

Procedure 1. Install your Laser and two BSA assemblies. Insert the diverging lens as close to the laser as possible.



Variables for software design;

```
 s Y f s' y' s'predicted %Error y'predicted %Error
(mm) (mm) (mm) (mm) (mm) (mm) (mm)
100 10 50.2 150 10 50.2 200 10 50.2 100 10 75.6 150 10 75.6 200 10
75.6
```

Manual tests

Your main areas of responsibility during prototype testing are to:
1. Assist with obtaining parts and building the prototype.
2. Test the prototype.
3. Collect data on prototype performance.
4. Perform root-cause failure analysis on any prototype failures. 5. Document and report the results of the prototype run.

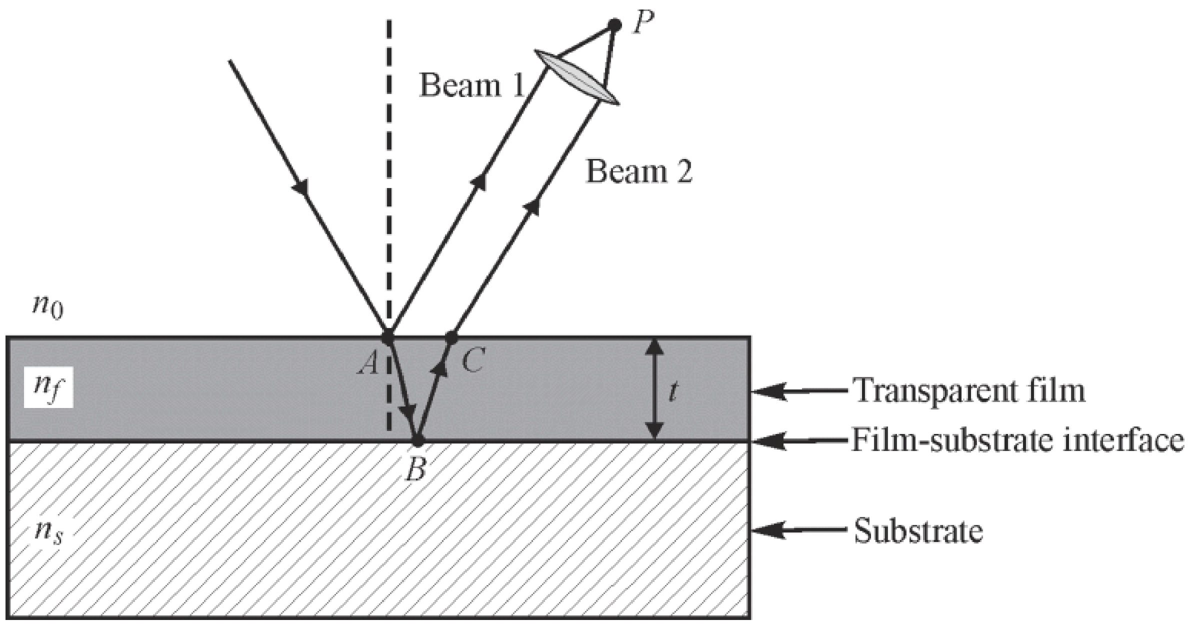
Variables for testing (mm)

```
Type Data Parameter Data Lens Type Converging Lens Lens Focal
Length 40 mm Aperture to Film Distance 60 mm Aperture to Lens
Distance 10 mm
```

Other wavelength variables for materials equipments design

IAV = intensity of light along screen at position y
E0 = amplitude of light wave from S1 or S2
d = distance from the plane of the double slit to the plane of the screen
a = slit separation = wavelength of monochromatic light from either S1 or S2 y = distance above (or below) the central bright fringe on the screen

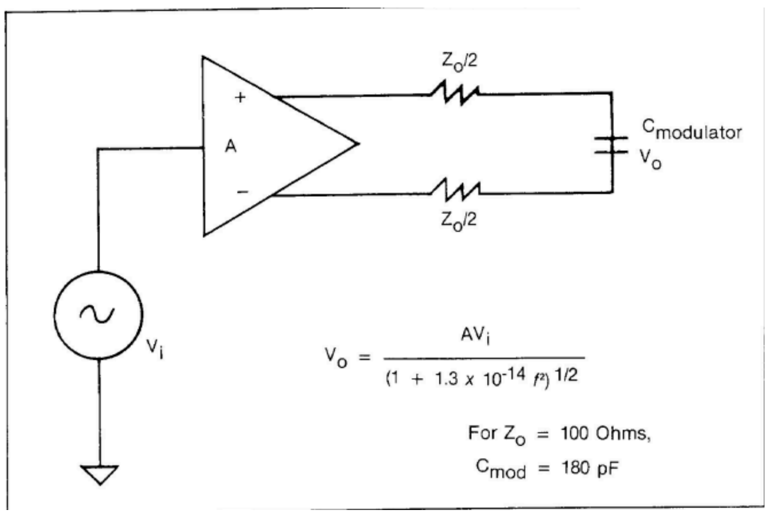
Single-film interference—The geometry for thin-film interference is shown in Figure 5-10. We assume that the light strikes the film—of thickness t and refractive index nf —at near-normal (perpendicular) incidence. In addition, we take into account the following established facts: A light wave traveling from a medium of lower refractive index to a medium of higher refractive index automatically undergoes a phase change of (180) upon reflection. A light wave traveling from a medium of higher index to one of lower index undergoes no phase change upon reflection. (We state this without proof.) The wavelength of light n in a medium of refractive index n is given by n = 0/n, where 0 is the wavelength in a vacuum or, approximately, in air.



Generally, the initial medium is air, so that n0 = 1. The beam incident on the film surface at point A divides into reflected and refracted portions. The refracted beam reflects again at the film-substrate interface at point B and exits the film at point C, in the same direction as the beam reflected at point A.

Mathematical description for wavelength paths; If the additional path length (AB + BC) which beam 2 travels is equal to a whole number of wavelengths, beams 1 and 2 will reinforce each other. If (AB + BC) is equal to an odd number of half-wavelengths, beams 1 and 2 will subtract from one another. We find the number of wavelengths in the geometrical distance (AB + BC) by dividing that distance by the wavelength of light n in the medium of index n. We identify the result with the symbol p, for the wavelength difference, where p = Geometrical path length difference between beams 1 and 2 Wavelength in the optical medium for beam 2.

Circuit design;

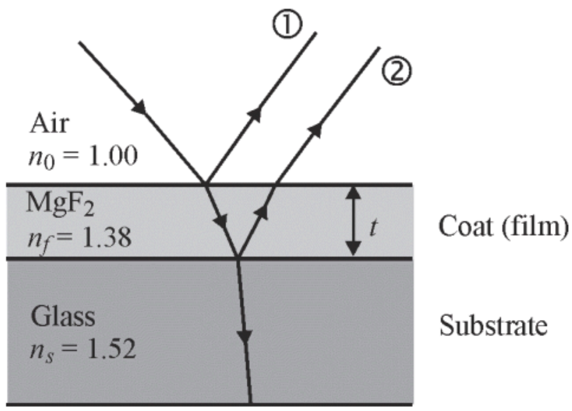


Constructive reference to interferences from wavelength path sources;
The product 2nt is called the optical path length. This product in effect provides a distance larger than the geometrical distance 2t shown in Figure 5-10, and allows one to compare that distance with the wavelength 0 of the light incident on the film. (One could equally well compare the actual distance 2t to the wavelength n in the film to find the number of wavelengths in the path AB + BC.) Either way leads us to a correct value for p. If p = 1, then 2nt = 0. This means that the path length difference between beams 1 and 2 would be equal to one wavelength and such a film thickness would result in constructive interference. If p = ½

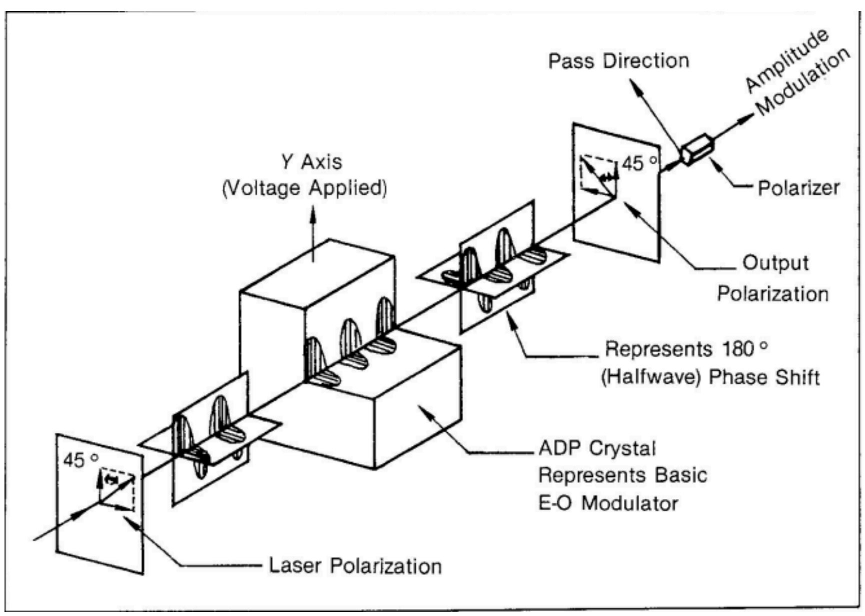
Meaning;
we denote p as the optical path difference and r as the equivalent path difference due to phase changes upon reflection, if any, then we can write a general condition for interference: p + r = m0

where 0 is the wavelength of the incident light in air. If (p + r) equals an integral number of wavelengths (m = 1, 2, 3), then constructive interference occurs. If (p + r) equals an odd number of half-wavelengths (m = 1 2 , 3 2 , 5 2), then destructive interference occurs.

Single-layer antireflection **(AR)** coat—A single-layer film deposited on a glass substrate is a common method of making anti reflecting **(AR)** coatings on optical surfaces, such as those found in lenses for cameras and binoculars.



Laser Voltage supply polarizer example;



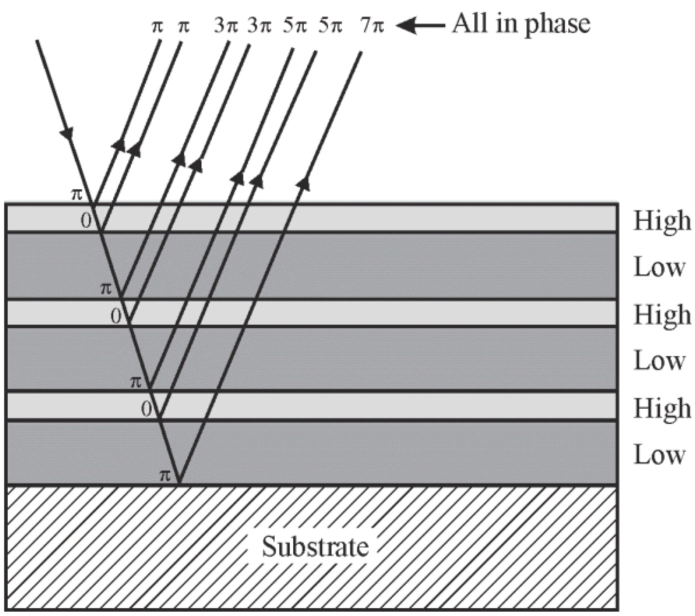
Component Efficiency in Magnetic Fields

How impedance, inductance, reactance, and capacitance affect the performance of a sensor or device in a magnetic field can measure its efficiency.

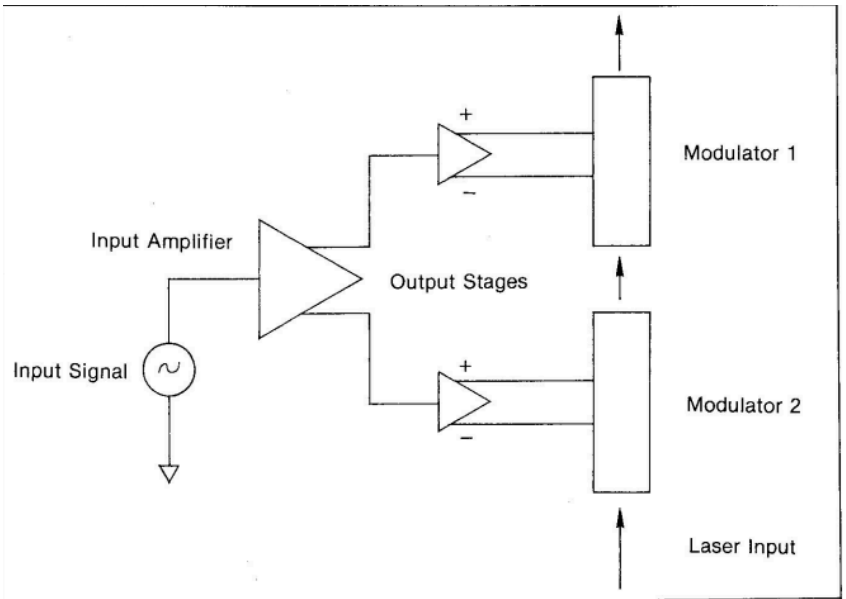
For example: Evaluating the efficiency of a sensor involves considering impedance and inductance to determine the precision with which it measures the magnetic field.

- Researchers analyze how capacitive and inductive reactance affect the resolution and precision of the measurements in efficient quantum interferometers.
- Efficiency in lasers: The capacitance of the power circuits can affect the stability and efficiency of the laser.
- These examples offer a wider perspective on the application of these concepts in practical situations related to magnetic fields, sensors, interferometers, and lasers.

Interference with multilayer films—As an extension of single-layer interference, consider the multilayer stack



Software Examples for A magnetic field or monopole, inductance, reactance and capacitance in a simple way



1. Impedance in a magnetic field (monopole)

In general, impedance is the total resistance a circuit presents to the flow of alternating current (AC). For a magnetic field, if we are talking about a magnetic system, the impedance is related to the inductance and the magnetic field.

Practical definition: Magnetic impedance (in a monopole system) relates to the resistance of a material to the flow of magnetic field. In terms of inductance, it is related to the opposition that a coil offers to the change in current.

```
public class ImpedanceCalculator { public static void
main(String[] args) { double L = 10e-3; // Inductancia en Henry
(10 mH) double f = 50;
// Frecuencia en Hertz (50 Hz) double omega = 2 * Math.PI * f;
// Frecuencia angular // Impedancia inductiva double Z_L =
omega * L; System.out.println("Impedancia inductiva: " + Z_L +
" j"); } }
```

2. Inductance

Practical definition: Inductance is the property of an electrical component (such as a coil) that opposes changes in current passing through it. It is measured in Henrys (H).

3. In quantum interferometers, such as the Mach-Zehnder interferometer, reactance can be related to the interaction of electromagnetic waves with the interferometer material.

Practical definition: Capacitive and inductive reactance can affect interferometer performance at certain operating frequencies.

```
% Parámetros
C = 1e-12; % Capacitancia en Faradios (1 pF)
f = 1e6; % Frecuencia en Hertz (1 MHz)
omega = 2 * pi * f; % Frecuencia angular

% Reactancia capacitiva
X_C = 1 / (omega * C);
disp(['Reactancia capacitiva: ', num2str(X_C)]);
```

4. Capacitance in Lasers
In lasers, capacitance can influence the laser power circuits, especially the modulation and stabilization electronics.

Practical definition: Capacitance affects laser stability and performance by influencing operating frequencies and modulation characteristics.

```
public class CapacitanceLaserCalculator {
    public static void main(String[] args) {
        double V = 2; // Voltaje en Voltios
        double Q = 1e-6; // Carga en Coulombios

        // Capacitancia
        double C = Q / V;
        System.out.println("Capacitancia del circuito del 
láser: " + C + " F");
    }
}
```