Optical Filter Coatings

Absorption, Transmittance, and Optical Density

Absorption, particularly wavelength-selective absorption, is an important factor in the function of many of the filters described in the catalog. The two most commonly used absorbers are thin metallic films and "colored" glass. Some metallic films, such as Inconel®, chromium, and nickel, are particularly insensitive to wavelength for absorption. On the other hand, the amount of absorption by colored glass can vary by as much as several orders of magnitude in only tens of nanometers.

Metallic films, colored glasses, and thin dielectric films (sometimes all in the same unit) are used in CVI Melles Griot filters. These filters include wavelength-invariant varieties (neutral-density filters) and various wavelength-selective filters (colored-glass, high-pass and low-pass filters, edge filters, dichroics, and interference filters).

ABSORPTION

All materials will absorb radiation in some parts of the electromagnetic spectrum. The amount of absorption depends on the wavelength, the amount of absorbing material in the radiation path, and the absorption of that material at that wavelength. Materials that absorb some visible wavelengths appear colored. For purposes of this catalog, colored glass refers to glass that is a wavelength-selective absorber in the near-ultraviolet to the near-infrared region.

Absorption occurs when the electric field of a light wave interacts with absorbing atoms or molecules in an oscillating dipole interaction. The photon is absorbed and the atom or molecule is placed in an excited state. This process occurs only at resonant wavelengths. In a solid or liquid absorber, excitation energy is dissipated as heat (vibrations of particles). Therefore, filters that rely mainly on absorption are not ideal for high-power laser applications. The intense local heating can lead to structural damage.

TRANSMITTANCE

As a beam of light passes through an absorbing medium, the amount of light absorbed is proportional to the intensity of incident light times the absorption coefficient. Consequently, the intensity of an incident beam drops exponentially as it passes through the absorber. This is often expressed as Beer's law:

$$T_i = 10^{-\alpha c x}$$

where T_i is internal transmittance, α is the absorption coefficient, c is the concentration of absorbers, and x is the overall thickness of the absorbing medium. Clearly α, and hence T_i, are wavelength dependent. For solid absorbing mediums, $c = 1$.

Internal transmittance is the transmittance of an optical element when surface (coated or uncoated) losses are ignored. The measured transmittance of the element (including surface effects), transmittance, is called external transmittance, T.

Alternatively, a filter is defined by the amount of light it blocks, as opposed to the amount of light it transmits. This parameter is opacity, which is simply the reciprocal of the transmittance, $1/T$.

The transmittance of a series of filters is the product of their individual external transmittance, $T_1 \times T_2 \times T_3$, etc. Because transmittance (and hence opacity) is multiplicative, and since transmittance may extend over many orders of magnitude, it is often more convenient to use a logarithmic expression to define transmittance.

OPTICAL DENSITY

Optical density, or "density," is the base 10 logarithm of opacity:

$$D = \log(1/T)$$

As optical density increases, the amount of light blocked by the filter (by reflection and/or absorption) increases. The most important point to note is that optical density is additive. If several filters are stacked in series, their combined optical density is the sum of the individual optical densities.

Optical density is particularly useful for neutral-density (ND) filters. These filters, which have a very flat wavelength response, are used to attenuate light in a calibrated, chromatically invariant fashion. ND filters are supplied in sets of various calibrated densities. Combinations of these filters can be used to produce many different calibrated optical densities.

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