Neutral-Density Filters

Neutral-density (ND) filters attenuate, split, or combine beams in a wide range of irradiance ratios with no significant dependence on wavelength. These carefully prepared filters find wide application for precise attenuation or control of light. For example, beams can be attenuated to levels where photometers or radiometers are most accurate and linear, thereby extending their useful range.

All CVI Melles Griot ND filters pass stringent optical and mechanical tests. Individual ND filters and ND filter sets are in stock and ready to ship. Our applications engineers will be pleased to assist you in the selection and application of standard or custom filters.

Optical density (D) is defined as the base 10 logarithm of the reciprocal of transmittance (T):

$$D=\log(1/T), \text{ or } T=10^{-D}.$$

Optical density is analogous to the definition of decibel as used in electronics. ND filters used in combinations are additive if multiple reflections between filters do not occur in the direction of interest. The reciprocal of transmittance, $1/T$, is called opacity. Also in widespread use is relative optical density, D_r, the difference between density D of a coated substrate and density D_0 of an uncoated region of the same substrate:

$$D_r = D - D_0$$
$$\text{or } D = D_r + D_0.$$

In terms of refractive index n,

$$D_o = 2\log\frac{(n+1)^2}{4n}.$$

At 550 nm, D_0 is typically about 0.0376 for BK7, and about 0.0309 for synthetic fused silica. Relative density D_r, not absolute density D, is the quantity that appears on individual microdensitometer traces supplied with CVI Melles Griot circular variable filters, because many variable filter applications require focal plane position or plate aberration constancy. This requirement prohibits removal or perforation of the substrate to achieve D=0.0 accurately. In such instruments, performance is referenced to a blank, and density differences, not the densities themselves, are important.

Transmittance and density values may, like reflectance values, refer to either small angular fields (specular or undeviated values) or very large angular fields (diffuse or hemispherical values). The measurements that determine hemispherical values include both specular and scattered contributions. Density and relative density values for CVI Melles Griot ND filters are specular values based on external transmittance.

Because of Beer's and Fechner's laws (sensation proportional to logarithm of stimulus, applicable to vision as a special case), it has been historically convenient to use the logarithmic density scale, instead of a transmittance scale. While optical density is dimensionless, the notation 0.50 D is sometimes used to mean 0.50 density units, or simply a density of 0.50.

Two or more ND filters can be used to achieve values of transmittance or density not otherwise available. If they are arranged so that multiple reflections between them do not occur in the direction of interest, transmittance values are multiplicative, whereas optical densities are additive. By combining various filters, many separate density values may be achieved.

CVI Melles Griot provides two types of ND filters: metallic (reflective) and glass (absorptive).

METALLIC NEUTRAL-DENSITY FILTERS

All CVI Melles Griot metallic ND filters are made with BK7-fine annealed glass, or optical-quality synthetic fused silica. Vacuum deposition is used to apply a thin film of several special metallic alloys to the substrate. These alloys have been chosen to create a spectral-density curve that is flatter over a wider range than the curves of most pure metals. Substrate materials are chosen for homogeneity, transmittance uniformity, finishing characteristics, and (in the case of synthetic fused silica) ultraviolet transmittance.

Substrates are polished to minimize light scattering. Metallic ND filters can be used at any wavelength between 200 and 2500 nm (fused silica), or between 350 and 2500 nm (BK7). Their operation depends on absorption in, and reflection from, the thin metallic film.

When used in high-intensity beams, ND filters should be oriented with the metallic film facing toward the source to minimize substrate absorption and heating. Alloy films are corrosion resistant and do not age at normal temperatures. Adhesion of alloy films to their substrates is tenacious and unaffected by moisture and most solvents from −73°C (−100°F) to +150°C (302°F). Exposure to higher temperatures should be avoided because it causes film oxidation and increased transmittance. These filters are not suitable for use with high-power pulsed lasers.

ABSORPTIVE NEUTRAL-DENSITY FILTERS

Absorptive ND filters provide an alternative to metallic ND filters. The neutrality of the filter is a function of material and thickness. Since there can be large variations between glass melts, actual thickness and glass material may vary in order to guarantee optical density. These filters are recommended for low-power applications only, because of their absorbing properties.

FILTER SET CONTENTS

Each individual filter is checked, and an optical density spectrophotometer curve from the coating run is included with each filter. Measured ranges are from 200 to 700 nm for sets on synthetic fused silica, and from 350 to 700 nm for sets on BK7 substrates. Individual spectrophotometer curves are available on special request.

Some sets include a blank (uncoated) substrate of the same material and thickness used for the filters. This blank is often very helpful for aligning and focusing optical systems before inserting the ND filter.

Each ND filter set is packaged in a wooden case.