ND Filters

Introduction

Attenuation is necessary in many beam profiling applications. Neutral density (ND) filters are the most straightforward way to attenuate your source. DataRay offers three different types of ND filters, each suitable for a different wavelength range. For each type of filter, we offer varying levels of attenuation. Some filters are available in multiple sizes and some are available in different housings. The purpose of this application note is to clearly identify which filters are best for which applications and allow the user to easily identify their filters.

General Info

All of our filters are available both mounted and unmounted. We have adapters to match different mounts to different systems if necessary. The ND value for any given filter refers to its optical density. The optical density (OD) of the filter is defined based on the percent of total power transmitted (see Equation 1).

$$Transmittance = 10^{-OD} \tag{1}$$

The filter holders are color coded to make the OD easy to identify (see Figure 1). The given ND value is a general guideline. The specific ND value varies as a function of wavelength.

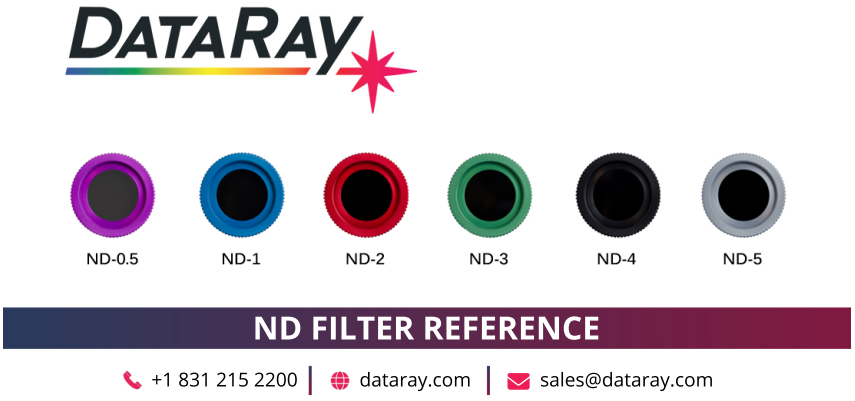

Figure 1: ND filter color scheme. A magnet with this information is included with each camera for your convenience.

Filter Housings

DataRay currently offers ND filters in 4 different housings. Figure 2 shows these housings side-by-side.

- **ND** filters are .875” diameter filters set inside a standard C-mount holder. These can directly interface with any of the BladeCam models and WinCamD models excluding the WinCamD-IR-BB. These filters are tilted at approximately 3° to reduce fringing caused by multiple reflections.

- **NDL** filters are 1" filters. These filters are tilted at approximately 3° to reduce fringing. The NDL thread type is 1.3"-20. This is not a common thread type, but NDL filters are typically packaged with the appropriate thread adapter.
- **MagND** filters are our customized magnetic filters, which interface with the WinCamD-LCM models. Each of the filters are tilted at 2° rather than 3°.
- **NDXL** filters are 2" filters used for the TaperCamD-LCM. These filters are not mounted at an angle, but the TaperCamD-LCM comes with an adapter that tilts the entire filter holder 3°.

Figure 2: All four filters housings. From left to right: ND, NDL, MagND, and NDXL

Absorptive ND Filters

Our standard ND filter is absorptive and suitable for visible, NIR, and TEL wavelengths (350-1550 nm). They consist of various types of Schott glass with varying thickness. Table 1 shows the thickness and type of glass for each unmounted filter. Figure 3 shows examples of these filters. The transmission curve for these filters is shown in Figure 4.

(a) ND housing (c-mount)

(b) MagND housing

Figure 3: Absorptive Filters in different housings

Product ID	Target ND @ 675 nm	Material	Nominal Thickness (mm)	Tolerance (mm)
ND-0.5-U	0.5	NG4	0.975	±0.05
ND-1-U	1	NG9	0.815	±0.05
ND-2-U	2	NG9	1.661	±0.05
ND-3-U	3	NG9	2.508	±0.05
ND-4-U	4	NG9	3.355	±0.05
ND-5-U	5	NG9	4.202	±0.05

Table 1: Material and thickness of absorptive ND filters

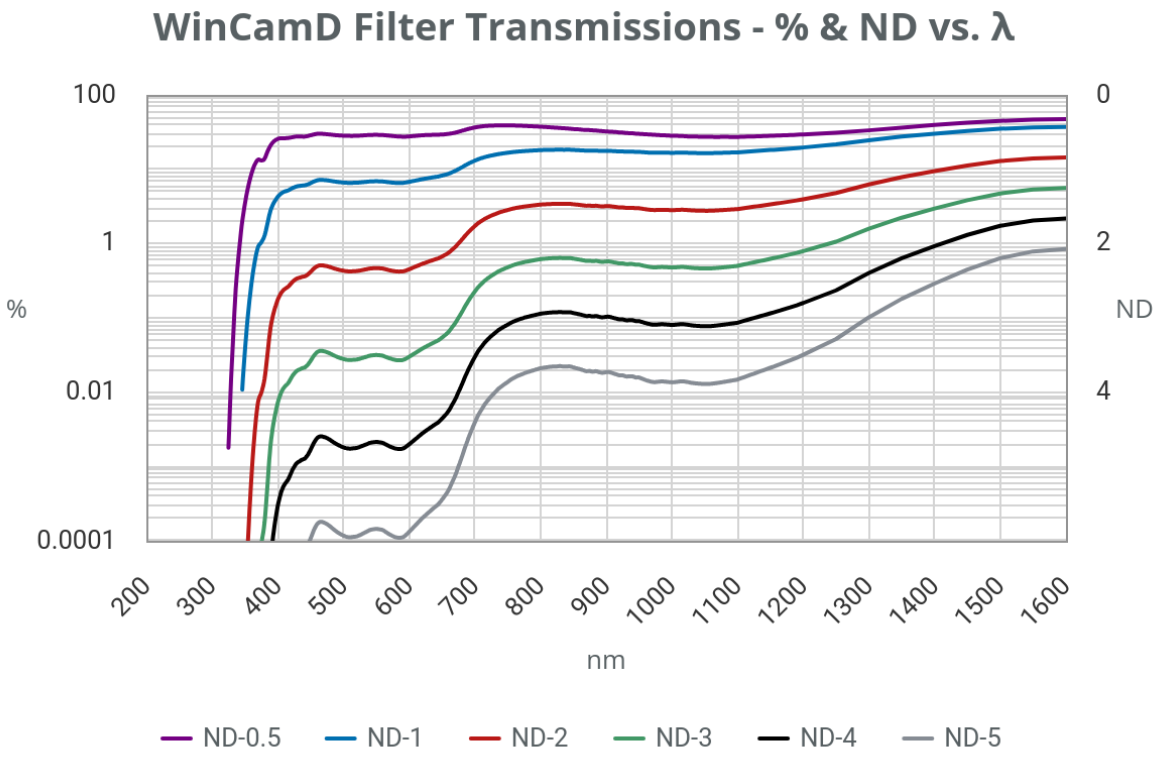

Figure 4: Absorptive ND Filter transmission curve

Reflective UV Filters

Our UV range filters (190 - 355 nm) are reflective rather than absorptive. Instead of the power being absorbed into the filter itself, the bulk of the beam is reflected back at an angle. Where the reflected beam is pointing can be adjusted by simply turning the filter. It is the user's responsibility to ensure that the reflected beam is handled safely. Please note that due to their reflective nature, it is not advisable to stack reflective ND filters as the reflections between adjacent filters will cause interference fringing in the output image. The housing on these filters is marked with golden bands as shown on the right-hand side of Figure 6. The filter cap is also marked with UV. The transmission curve for these filters is shown in Figure 5.

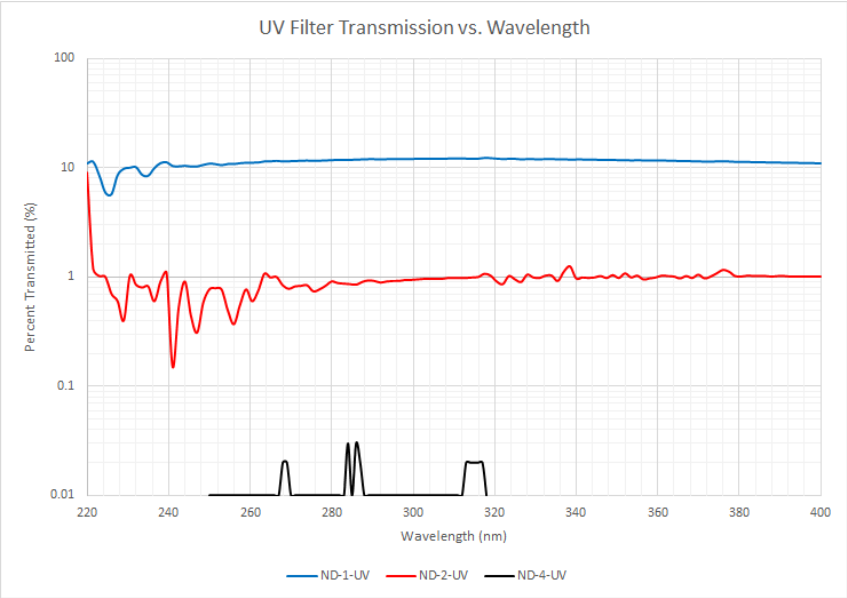

Figure 5: Reflective ND-UV Filter transmission curve

Figure 6: Visual differences between reflective UV and Infrared Filters

Reflective Infrared Filters

For MIR and FIR (2-14 µm) applications that use our WinCamD-IR-BB, we recommend our NDL-Ge filters. These filters consist of a metal alloy coating on a Germanium substrate and attenuate through a combination of absorption and reflection. This combination allows a relatively flat transmission across an extremely broad wavelength range. It is the user's responsibility to ensure that the reflected beam is handled safely. Please note that due to their reflective nature, it is not advisable to stack reflective ND filters as the reflections between adjacent filters will cause interference fringing in the output image. The filter cap for these filters are marked with Ge as shown in the left of Figure 6. The transmission curve for these filters is shown in Figure 7.

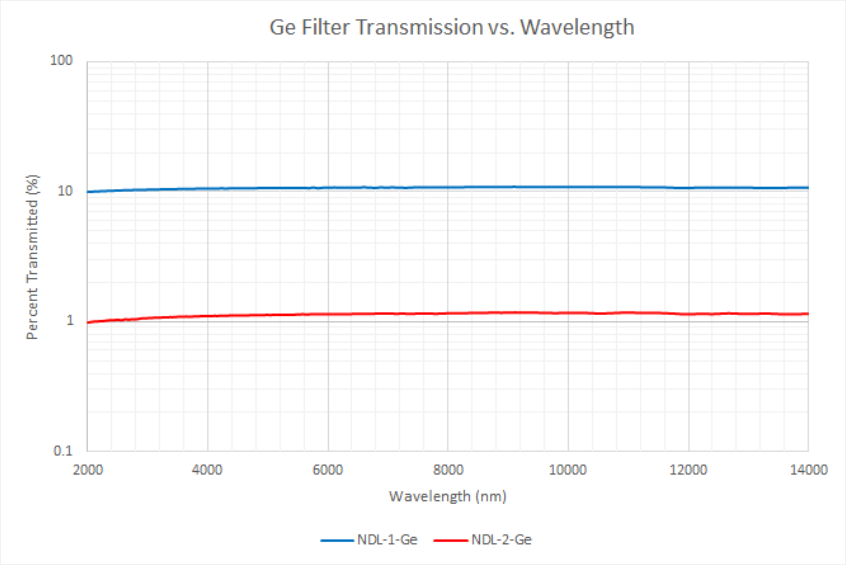

Figure 7: Reflective Infrared ND Filter transmission curve

Adapters and Custom Filters

The DataRay NDL threading is not common. We sell adapters that convert from NDL thread to C-mount (ADAPTER-NDL-EX-CM-IN, ADAPTER-CM-EX-NDL-IN). If you have a specific application that requires a custom filter, we can install any 1" or 0.875" filter in one of our filter holders or you can purchase empty filter holders. We can also procure non-standard ND values for most of our filter types.

Part Numbers

Nearly all of DataRay's camera systems come with several ND filters. If you need to order additional filters, refer to Table 2 for the part number to use when ordering filters.

	Unmounted	ND	NDL	MagND	NDXL	Notes
Absorptive	ND-2-U	ND-2	NDL-2	MagND-2	NDXL-2	Available in NDs 0.5,1,2,3,4,5
Reflective UV	NDL-2-UV-U	N/A	NDL-2-UV	MagND-2-UV	N/A	Available in NDs 1,2,3,4
Reflective IR	NDL-2-Ge-U	N/A	NDL-2-Ge	N/A	N/A	Available in NDs 1,2,3
Empty Holder	N/A	ND-H-2	NDL-H-2	MagND-H-2	NDXL-H-2	

Table 2: Part number for ordering filters. Example part numbers given for an ND value of 2.

Additional Filter Considerations

The following considerations should not affect measurements in the majority of cases. However, there are edge cases where they will have non-neglible effects. Please contact support@dataray.com if you have questions or concerns.

Optical Path Length

Absoprtive filters attenuation depends on the thickness of glass. Therefore, the edges of a divergent or convergent beam may be attenuated more than the center. Therefore the beam shape may be distorted and/or diameter reduced before reaching the sensor.

Angle of incidence

In addition to the optical path length, the incident angle will also affect the amount the beam is attenuated. Therefore divergent/convergent beams will non-uniformly attenuated.

Fabry Perot Effects

With reflective filters, it is also possible to see Fabry Perot effects due to the beam interfering after multiple reflections between the two parallel faces of filter.