How are Filters Made?

Optical interference filters are made by depositing a complex stack of atomic-dimension layers on a support substrate. When a substrate is coated with a material of refractive index different from the substrate, a Fresnel reflection is created. By alternating between materials with different refractive index, the reflection can be driven to very high values. This reflection only occurs at wavelengths where the phase thickness of the layers is close to 90 degrees, or a multiple of a quarter wavelength of light. Complex stacks, or multiple stacks are deposited to cause the reflectivity to occur over a wide spectral region, such as the range of a detector.

There are essentially three categories of optical layer stacks that are used in creating an optical filter. The most basic is a Long Pass or Short Pass stack, that reflects a region, while passing another that is longer or shorter than the desired transmissive region. The final type of interference costing is a Fabry-Perot ("FP") Bandpass filter. In this case there is deposited a phase inverting layer at the middle of the reflective stack, and at this wavelength the reflected light is reversed in phase as well as direction and becomes the passband.

A filter can be made from a combination of LP and SP coating stacks. Each stack will control about 30% of the frequency of the spectrum of interest. It is obvious that to cover a typical detector, the number of stacks can become large. In the case of the FP bandpass coating, the control region can be extended in some cases to 45%.

The degree of needed signal to noise ("S/N") and the spectral response limits of the detector become the major controls on the design of the filter solution. To achieve reflection of 99.999+% that is needed to achieve an out of band attenuation of OD 5+, each stack needs to have roughly 25 layers. If the detector has the typical sensitivity of 2 octaves, well over 200 layers of precisely controlled thin films is commonly required.

Additional complexity is required when an abrupt transition for reflection to transmission is required. Additional layers or phase thickness are required to achieve these sharp transitions.

As with all optical coatings, the performance is at its theoretical limit, when the light is well collimated and perpendicular to the coated surface. When the direction deviates from the ideal condition, the performance is degraded because of the differences in optical characteristics of materials in the two orthogonal planes of the wave packet's energy.

Show spectral curve of a NB filter at an angle.
Show spectral plot of an edge filter @ 45 degrees.