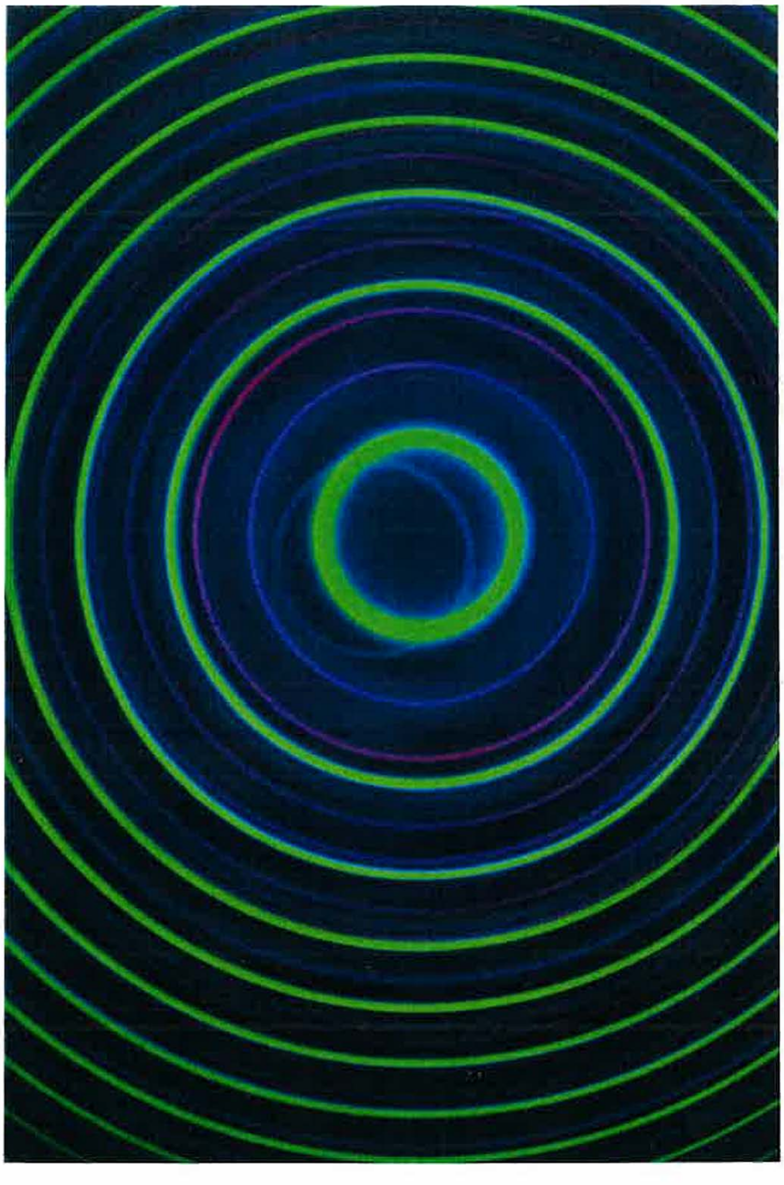

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# Using Etalons

Eetalons are most commonly used as line-narrowing elements in narrowband laser cavities, and as bandwidth limiting and coarse tuning elements in broadband and picosecond lasers. Further applications are laser line profile monitoring, diagnosis.

Etalons described in this section are all of the planar Fabry-Perot type and are classified as follows:

**Air-Spaced etalons** – pairs of very flat plano-plano plates separated by optically contacted spacers. The inner surfaces of the plates are coated with partially reflecting coatings, the outer surfaces are coated with anti-reflection coatings.

**Solid Etalons** – parallel sides plano-plano plates with partially reflecting coatings on both sides. The cavity is formed by the plate thickness between the coatings.

**Deposited Solid Etalons** – a special type of solid etalon in which the cavity is formed by a deposited layer of coating material. The thickness of this deposited layer depends on the free spectral range required and can range from a few nanometers up to 15μm. The cavity is sandwiched between the etalon reflector coatings and the whole assembly is supported on a fused silica base plate

Etalon plates need excellent surface flatness and plate parallelism. To avoid peak transmission losses due to scatter or absorption, the optical coatings also have to meet the highest standards.

For a plane wave incident on the etalon, the transmission of the etalon is given by:

$$T = \frac{I_{trans}}{I_{inc}} = \frac{1}{1 + \frac{4R}{(1-R)^2}\sin^2(\delta/2)}$$

Here, R is the reflectance of each surface; δ is the phase shift:

$$\delta = \frac{2\pi}{\lambda} nd \cos\theta$$

Where,

**n** is the refractive index (i.e. 1 for air-spaced etalons)
**d** is the etalon spacing or thickness
**θ** is the angle of incidence

The free spectral range (FSR) is given by:

$$FSR = \frac{c}{2nd} \text{ in Hz}, = \frac{1}{2nd} \text{ in cm}^{-1} = \frac{\lambda^2}{2nd} \text{ in nm}$$

The reflectivity finesse is given by:

$$F = \frac{\pi\sqrt{R}}{1 - R}$$

Figure 1 shows the reflectivity finesse as a function of the coating reflectivity.

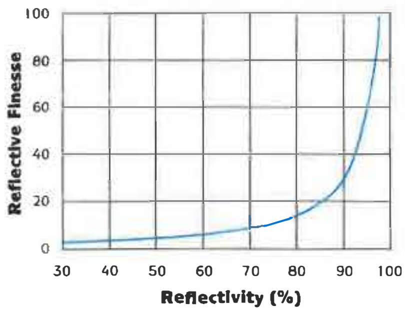


*Figure 1. Reflectivity finesse vs. coating reflectance of each surface.*

The bandwidth (FWHM) is given by:

$$FWHM = \frac{FSR}{F}$$

See Figure 2 for transmission characteristics of Fabry-Perot type etalons.

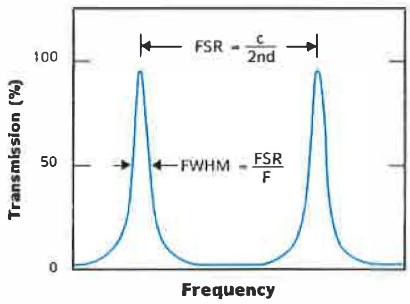


*Figure 2. Transmission characteristics of an etalon.*

However, the above applies to theoretical etalons which are assumed to be perfect. In reality, even the best etalon will show defects that limit theoretically expected performance. Therefore, in a real etalon, the actual finesse will usually be lower than the reflectivity finesse.

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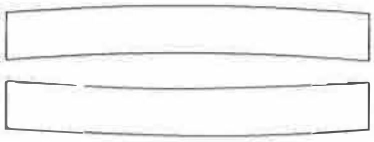
# Using Etalons

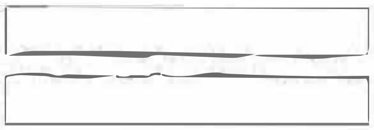
The defects that contribute to this reduction are as follows:

(graphical representations are exagerated for clarification)

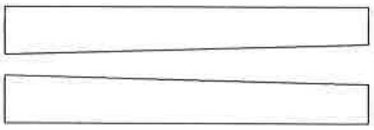
Spherical Defects ($F_{ds}$)



Surface Irregularities ($F_{dg}$)



Parallelism Defects ($F_{dp}$)



All three types of defects contribute to the total defect finesse $F_d$:

$$\frac{1}{F_d^2} = \frac{1}{F_{ds}^2} + \frac{1}{F_{dg}^2} + \frac{1}{F_{dp}^2}$$

The beam divergence also influences the actual finesse of an etalon. Taking into account all these contributions, the effective finesse of an etalon (with $F_r$ being the reflectivity finesse and $F_{div}$ the divergence finesse) is:

$$\frac{1}{F_e} = \sqrt{\left[\frac{1}{F_r^2} + \frac{1}{F_d^2} + \frac{1}{F_{div}^2}\right]}$$

The effective finesse a user sees when using the etalon depends not only on the absolute clear aperture, but also on the used aperture of the etalon, especially when a high finesse is required.

The examples below show how the effective finesse varies with plate flatness and used aperture.

Air-spaced etalon,
95%(±1%)R @ 633nm plate reflectivity
Plate clear aperture:
25mm, **used aperture: 20mm,**
1mm spacer
Spherical / parallelism defects:
<**lambda/20,**
Plate RMS: **0.80nm,**
Beam divergence: 0.1mRad
Reflectivity Finesse: 61
**Effective Finesse: 10**

Air-spaced etalon,
95%(±1%)R @ 633nm plate reflectivity
Plate clear aperture:
25mm, **used aperture: 5mm,**
1mm spacer
Spherical / parallelism defects:
<**lambda/20,** Plate RMS: **0.80nm,**
Beam divergence: 0.1mRad
Reflectivity Finesse: 61
**Effective Finesse: 40 (±4)**

Air-spaced etalon,
95%(±1%)R @ 633nm plate reflectivity
Plate clear aperture:
25mm, **used aperture: 20mm,**
1mm spacer
Spherical / parallelism defects:
<**lambda/100,** Plate RMS: **0.40nm,**
Beam divergence: 0.1mRad
Reflectivity Finesse: 61
**Effective Finesse: 40 (±8)**

These examples illustrate that especially in applications where a large aperture of the etalon is used, it is important to use very high quality plates to ensure a high finesse and good transmission values.

Etalons can be tuned over a limited range to alter their peak transmission wavelengths. These techniques are:

1. Angle tuning or tilting the etalon.
   As the angle of incidence is increased, the center wavelength of the etalon can be tuned down the spectrum.

2. Temperature tuning.
   This is mostly for solid etalons. The tuning result can be given by:

$$\frac{\partial(FSR)}{\partial T} = -(FSR) \bullet \left[\frac{1}{n}\frac{\partial n}{\partial T} + \frac{1}{d}\frac{\partial d}{\partial T}\right]$$

3. Pressure tuning.
   Tune the index of refraction with the appropriate gas pressure for air-spaced etalons.

The above examples illustrate how critical the optical surface flatness, plate parallelism and surface quality are to the overall performance of the etalon. We have developed sophisticated software that allows us to simulate all effects that influence the performance of an etalon. To order an etalon, FSR, finesse and used aperture are required.