PHY2208 Lecture 11

Fabry-Perot as a spectrometer
The Free Spectral Range of the Fabry-Perot interferometer

Pedrotti & Pedrotti Section 11-6 and 11-9

Anti-reflection coatings

Pedrotti & Pedrotti Section 10-4

The Fabry-Perot can be employed as a wavelength selective element in a spectrometer.

Since a strong transmitted intensity requires:

$$\frac{4\pi nd \cos\theta_t}{c}\upsilon = 2\pi m \qquad \text{Eqn. 1}$$

we can select which frequency is transmitted by **altering**:

θ_t change angle of illumination

n often a gas is used between the mirrors and *n* is adjusted by varying the gas pressure

d the mirrors can be moved e.g. using a piezo-electric crystal

The spectrum is acquired by scanning θ_t , *n* or *d* and measuring $I(\theta_t)$, $I(n)$, or $I(d)$ respectively.

When used in a spectrometer, an important figure of merit is the **Free Spectral Range** (FSR).

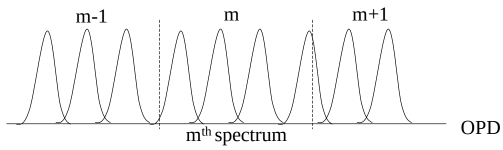
Equation 1 implies that $\phi \propto \nu$. Consider two spectral lines, frequency ν and $\nu+\Delta\nu$. If $\Delta\nu$ becomes two large, we could achieve a situation where:

i.e. both spectral lines will produce an intensity maximum at the **same value** of θ_t , *n* or *d*. The lines will then be indistinguishable. This is the same **order overlap** problem as exists with a diffraction grating.

The value of $\Delta\nu$ implied by these equations is the FSR:

$$\mathrm{FSR}(=\Delta\upsilon) = \frac{c}{2nd\cos\theta_t} = \frac{c}{\mathrm{OPD}}$$

If the spectrum applied to the spectrometer covers a frequency range greater than the FSR then the low and high frequency regions will overlap.



This is cured by pre-filtering the spectrum (e.g. using coloured glass filters) so that the spectral width is less than the FSR.

Internal and External reflection

Internal reflection occurs when the light is travelling *from a higher refractive index medium to a lower refractive index medium.* **No** phase change occurs on reflection.

External reflection occurs when the light is travelling *from a lower refractive index medium to a higher refractive index medium.* A **phase shift of π** occurs on reflection.

Anti-reflection coatings

Interference by amplitude division can be a useful way of suppressing unwanted reflections.

Consider an EM wave striking a refractive index mismatched boundary at normal incidence:

EM wave theory predicts that the amplitude of the reflected wave Ψ_r is:

$$\Psi_r = \Psi_0 \frac{n_1 - n_2}{n_1 + n_2}$$

Consider an air-glass interface where n_2=1.5 and n_1=1.0

$$r = \frac{\Psi_r}{\Psi_0} = \frac{-0.5}{2.5} = -0.2$$

$$R = r^2 = 0.04$$

i.e. glass surfaces are 4% reflective at normal incidence (and more so at larger angles of incidence). Such unwanted reflections reduce the **efficiency** of lenses.

Now consider placing a thin coating of material onto the glass, with refractive index n_c where $n_1<n_c<n_2$

With a coating of the correct thickness, the two reflected waves (1) & (2) will be in antiphase. If they also have equal amplitude they will cancel. The reflected wave will vanish!

To be in anti-phase, the extra OPD for wave 2 must be $\lambda/2$.
(NB both reflections are **external**):

This can be satisfied if $\boxed{n_c = \sqrt{n_1 n_2}}$

For air-glass we need n_c = 1.22. Magnesium fluoride (MgF_2) has n=1.38

Now attempt Question 5 on Problem Sheet 2