Fabry-Perot Interferometer

The Fabry-Perot interferometer consists of two partially-reflecting parallel mirrors. When monochromatic light is viewed through the interferometer, an interference pattern composed of numerous sharply-defined concentric circles is seen. In this lab you will set up a Fabry-Perot interferometer and use it to measure the wavelength of the light emitted by a He-Ne laser, as well as to analyze the longitudinal modes of an open-frame He-Ne laser with a variable length cavity.

Before You Come to Lab

Go to the library and read an optics text to gain an understanding of the Fabry-Perot interferometer. Jenkins and White is available for your perusal in the lab.

I) Setting up the F-P

Examine the F-P that has been constructed using the Ealing "Universal Interferometer" system. Note (but do not touch) the mirrors and examine the micrometer and linkage that is used to adjust the mirror spacing. The linkage provides a reduction of a factor of 5 between the micrometer and the moveable mirror, though the mirror translation is not quite linear in the micrometer translation. Illuminate the F-P with a He-Ne laser with a spatial filter or lens to diverge the beam. (Using an undiverged laser beam could damage your eye!) Look through the telescope (focused at infinity) and fine-tune the adjustment screws to get nice sharp bright fringes separated by large dark rings. If the interferometer seems to be badly out of alignment, remove the telescope and adjust the mirrors so they are approximately parallel by turning the two adjustment screws until you see a single image of a pencil point or similar object held on the far side of the F-P. Then replace the telescope.

II) Measurement of the wavelength of the light from a He-Ne laser

A new fringe appears for each half-wavelength change in the separation between the mirrors. Determine the wavelength by counting fringes as the separation is changed by a known amount. *Be prepared to count a lot of fringes if you want a precise result.* Estimate the uncertainty in your result. You may use a photodiode and counter if you like.

III) Longitudinal Mode Structure of a Laser

The emission line of a HeNe laser is not a delta function, but is instead broadened due to the Doppler effect. In the rest frame of an excited Ne atom, a photon is emitted whose energy equals the energy-level difference between the excited and ground states (with some small energy broadening due to the uncertainty principle). In the lab frame, however, the photon is emitted from a moving source and thus the photon frequency (and energy) is Doppler-shifted by an amount that depends on the thermal velocity of the atom. The

(OVER)

effect of the Doppler-shift is for the intensity spectrum to be Gaussian in frequency, with a standard deviation $\sigma_\nu = \sqrt{k_B T / m_{Ne} \lambda_o^2}$, where T is the gas temperature, m_{Ne} is the mass of a neon atom (3.351×10^{-26} kg), and λ_o is the central wavelength of the spectral line (632.8 nm for the He-Ne red line). Note: the full width at half maximum of a Gaussian is 2.355 σ_ν.

There is one more complication: the effect of the laser cavity. The presence of the highly-reflective mirrors on both ends of the cavity forces there to be nodes at the two mirrors. As a result, the laser cavity is only resonant with a discrete set of frequencies for which the cavity length L is an integer multiple of half-wavelengths. The back mirror (hidden under the styrofoam cup) is concave with a 60 cm radius of curvature; the front mirror is movable and has a 45 cm radius of curvature. The plasma tube is 26.52 cm long from back mirror to the end of the Brewster window. You can position the front mirror close to the Brewster s window, in which case the modes should be spaced apart by $\delta\nu^\circ = c/2L$. Alternately, you can position the front mirror to create a confocal cavity, in which the modes will be spaced apart by $\delta\nu^\circ = c/4L$. In either case, the laser s frequency spectrum will look like a comb whose teeth, separated by $\delta\nu$, have been cut to a Gaussian shape.

You will be working with the open-frame He-Ne laser. DO NOT TOUCH THE STYROFOAM CUP AT THE END! HIGH VOLTAGES ARE PRESENT! You will need to adjust the mirror with the 45 cm radius of curvature until you see the system lase. (Adjust the height of the mirror first, if necessary. Then dither the beam left and right as you move the mirror toward or away from the discharge cavity until you see the system lasing. NEVER LOOK INTO THE BEAM OF AN UNDIVERGED LASER!) Direct the beam into the hole of the Coherent Fabry Perot cavity. Align the cavity so that the beam reflection hits the front mirror of the laser, and make fine adjustments with the micrometers. You should see a trace on the oscilloscope.

Measure the mode separations for the laser both with the 45 cm radius mirror and the 120 cm radius of curvature mirror. Estimate the temperature of the gas in the laser cavity (you will have to wait about half an hour for the laser to finish warming up). The Fabry-Perot cavity has a 7.5 GHz free spectral range. It is useful to calibrate the oscilloscope to the free spectral range in the following way. First set the FP controller to 1x expansion. Then adjust the time base until you see a few identical peaks on the screen; the spacing between peaks is 7.5 GHz in frequency. Now use the red knob in the center of the time-base control to adjust the spacing between identical features in the spectrum to be 7.5 divisions. Your oscilloscope is now calibrated to frequency, with one large division corresponding to 1.0 GHz. If you change the time base or the expansion factor on the controller to expand the , you change the calibration by a proportional factor. For example, changing the expansion to 5x makes the calibration 0.2 GHz per large division on the scope.

C.E.C. rev. 4/27/98