§1 Preliminaries

§1.1 Laser safety [1]. *Never* look into the concentrated (un-diverged) beam of any laser. Also, do not look into the reflection of such a beam by a mirror. When adjusting optics, make sure no beam is ever accidentally reflected or refracted into any person's eye. Accidental reflections of concentrated beams by shiny rings or the glass surface of watches are also to be avoided. Remove all such items when adjusting optics which involve concentrated beams. The standards given by ANSI Z-136 for exposure to helium neon laser light of wavelength 633 nm are as follows. The maximum permissible exposure level (MPE) for brief (0.25 sec) exposure to the eye is 2.5 mW/cm^2; for prolonged exposure (3 x 10^5 sec) it is 17 μW/cm^2. Prior to the lab, *determine* by calculation how wide (what diameter) a collimated beam derived from a 5 mW laser is safe to view. *Do not* remove any safety screens.

§1.2 Care of optical surfaces. Treat all mirror and lens surfaces with the same respect you give your eye or eyeglass lens or camera lens. Leave no fingerprints, scratches or other damage; do not impair efforts of others. Handle optics by edges or by supports.

§1.3 Preparation. Read the web material on interferometry.

§2 Michelson interferometer. Observe the Michelson interferometer provided. Make a detailed sketch of the setup; include a description of all optical components. Project the fringes on a white card or a ground glass. Use the micrometer screw adjustments on the translation and rotation stages to move a mirror. How do the fringes move in response? Perturb the system in various ways, e.g. tap the table, stomp the floor. Observe the fringes and describe them.

To do quantitative measurements, detect the light with a silicon sensor connected to an oscilloscope. Adjust rotations so that fringe spacing is as large as possible so the sensor captures a uniform fringe field. One fringe corresponds to half a wavelength. The red helium neon laser has a wavelength 633 nm. The green diode pumped doubled YAG lasers have a wavelength 532 nm. *Remark*: the silicon light sensor provides a current proportional to light intensity. It is Newport type 818 SL, a short black cylinder about 38 mm in diameter and 28 mm thick including a screw in attenuator filter. If the sensor is connected directly to the scope, which has an internal resistance of 1 MΩ, the output may saturate because there is a maximum output of about half a volt. Also, such a high resistance severely limits the frequency response of the sensor. The input resistance can be lowered either by attaching an external resistor box or by setting the input resistance of the scope. The digital scope allows one to set the input resistance to 50 Ω, a value which is sensible if the light sensor is operated without the screw in attenuator filter to detect the laser light at a power level of a few milliwatts.

Measure the sensitivity of the piezoelectric bender, in meters per volt (or μm/V or nm/V or pm/V). Do not disassemble the interferometer. There are additional mirrors for the holography experiment. Use an input frequency of 1 Hz. If time permits, use higher frequencies to determine the resonant frequency of the piezoelectric element.

§2.1 Coherence

The Michelson interferometer is also used to measure the coherence of light. Displacement of one mirror by several millimeters has caused the fringes to lose contrast as shown in the web tutorial. Contrast of the fringes provides a measure of the coherence of the laser source. A perfectly coherent laser would emit light at a single frequency. Suppose the light is spread uniformly over a band of frequency of width ν_0. Then, by Fourier transformation, there is full contrast for zero path difference, but contrast drops to zero for a path difference $\Delta = c/\nu_0$ with c as the speed of light. This path difference, as measured by the Michelson interferometer, is a measure of the coherence length of the laser light.

Measure the coherence length of each laser; start with equal arm length; translate one mirror until the fringe contrast fades away; write down the distance the mirror was moved. The optical path difference, hence the coherence length, is twice the distance moved. Measure the coherence length of the green solid state laser and the helium neon laser (in service more than 15 years) using the Michelson interferometer. Keep in mind that the coherence length may exceed the travel of the micrometer screw. If that is the case, move one mirror mount by at least 2.5 cm and realign the interferometer.

§3 Questions.

1. Does the fringe signal quality allow one to measure 1/20 fringe? If so, what is the corresponding displacement? Compare with the displacement resolution of the servo frame.

2. The intrinsic sensitivity of piezoelectric ceramics is 100 to 500 pm/volt. Why is the bender more sensitive?

[1] Analyzing laser hazards, R. J. Rockwell, Jr., *Lasers and Applications*, 5: 97-103, May 1986.

[2] Reynolds, G. O., DeVelis, J. B., Parrent, G. B., Thompson B. J., Physical optics notebook: tutorials in Fourier optics, SPIE, 1989.

[3] R. S. Longhurst, Geometrical and physical optics, third edition, Longman, 1981.