§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 cell phones are also to be avoided. The standards given by ANSI Z-136 for exposure to helium neon laser light of wavelength 633 nm are: 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 $\mu$W/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 which protect others.

§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. Please leave no fingerprints, scratch marks or other damage; do not impair efforts of others. Handle optics by the edges or by supports.

§1.3 Preparation. Read the web material on holographic interferometry. Details on recording media and interpretation of fringes are provided. The static zero order interpretation method can be done using a photograph of the hologram if angles of viewing $\mathbf{k}_{obs}$ and illumination $\mathbf{h}_{illum}$ as expressed by unit vectors are known and the dimensions of the object in the image are known. The dynamic fringe counting method requires observation of the actual hologram and knowledge of initial and final view angles.

§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. Quantitative measurements will be done by the other group.

§3 Hologram formation. Set up an appropriate experimental configuration. Choose a transmission off-axis hologram or a transmission image plane hologram, or a Denisyuk reflection hologram. The reference and object beam path lengths should be equal to within about 1 cm. The green laser is much more forgiving of path length mismatch than the helium neon (large tubular) red laser since it has a longer coherence length. Measure the actual path lengths and verify their equality. Make sure all components including the specimen and plate / film holder are solidly mounted, with no play or looseness since a minuscule motion can spoil the hologram. Make a diagram which shows the position of all the optical components. Also measure the reference beam angle and divergence, and the distance from the object to the film or plate. To interpret fringes in holographic interferometry it is necessary to know the geometry of illumination of the object. Measure, therefore, all pertinent beam angles and distances. Also determine the dimensions of the object. Use of a collimated (parallel) reference beam is recommended since then the vector $\mathbf{h}_{illum}$ is constant over the object surface. Before making the exposure, measure the intensities (power/area) of the object and reference beam and calculate the required exposure time from the recommended exposure energy for the film to be used. Also, measure the power of the laser.

If you are using silver halide film, sandwich it between two glass plates so that it is held by spring clips in a stable manner. Use red sensitive film for the red laser and green sensitive film for the green laser. For silver halide media, the film or plate emulsion (slightly sticky side) should be facing toward the object. Develop the film until it becomes about as dark as sunglasses (for transmission), or considerably darker (for reflection). Use a stop bath to end development, then rinse the film in water. Process with bleach to increase diffraction efficiency hence brightness during viewing. Label your film so that you can distinguish it from other images made later. What is the density of your film or plate? What should the density be? Density is the log of the extinction ratio.

The photopolymer plates are sensitive to all wavelengths and they form holograms without the need for development. However, they require much more light energy for exposure. Therefore the image area must be small or the exposure time must be long. Silver halide media facilitate larger area images as well as split beam configurations.

§3.1 Make a hologram. Make two holographic exposures of the deformable object on the same recording medium: one exposure of the undeformed object and one of the deformed object. If you are deforming the object with dead weights, it is desirable to make the first exposure of the deformed bar, then remove the weight and make a second exposure, to avoid inadvertent bumps to the setup.

[*Optional* ] It is possible to make a hologram that is viewable in white light, provided the source subtends a narrow angle as with sunlight or light from a spotlight at a sufficient distance. The Denisyuk single beam reflection hologram selects a single wavelength by Bragg diffraction, allowing viewing in white light. For a transmission hologram, the object is focused on the film with a lens. If the lens is small, the film will record both a Fresnel off axis hologram and an image plane hologram. The three dimensional image of the object should be partly in front of, and partly behind the plane of the film or plate. Determine the diameter and focal length of the lens and calculate its $f$ number.

§4 Hologram interpretation. If you are doing cantilever bending, determine the downward displacement of points on the bar as a function of position. Determine deflection of points along the beam, and draw a deflection curve. The horizontal displacement of points is directly related to the strain in bending. Write the appropriate governing equations for bending and for fringe interpretation. What Young's modulus do you infer? Is the root of the cantilever truly a built-in constraint? How can you tell? Which interpretation method is most effective in your experiment?

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