

DESIGN AND CONSTRUCTION OF A INTERFEROMETER SYSTEM FOR THE STUDY OF THIN METAL FILMS

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ABSTRACT

A deposition chamber and a laser interferometer are currently under development at Houghton College. The deposition chamber produces and heats thin metal films under high vacuum. In order to measure curvature of the films as they are heated, the laser interferometer generates a topographical map of each film using a three-inch collimated beam of light and several optics components. The chamber and interferometer work in conjunction with one another, allowing for the films to be measured without breaking vacuum. Using the relationship between curvature and temperature, the stresses of the films can be calculated.

BACKGROUND

While one may have not noticed, thin films surround us every day. These specific metal films range in thickness from less than a nanometer, up to a few micrometers. Thin films have distinct properties, of molecular structure and stress. This in turn lends for a great number of applications for thin films. They are used in optical devices as mirrors, anti-reflective coatings, or simply for decoration. Thin films also are very important in electronics such as computer chips and fiber optic cables. Furthermore these films can serve thermal, mechanical, magnetic, chemical, and biological functions; the possibilities of these films are virtually endless.

The properties of thin films are still to this day not completely understood. Factor such as thickness and temperature greatly affect and change these properties. By studying thin films we hope to analyze how these factors affect the stresses supported by thin films. Silver will be used to construct our film as it has high electrical and thermal conductivity. A better understanding of this type of highly conductive thin metal film could be used in a number of electrical applications.

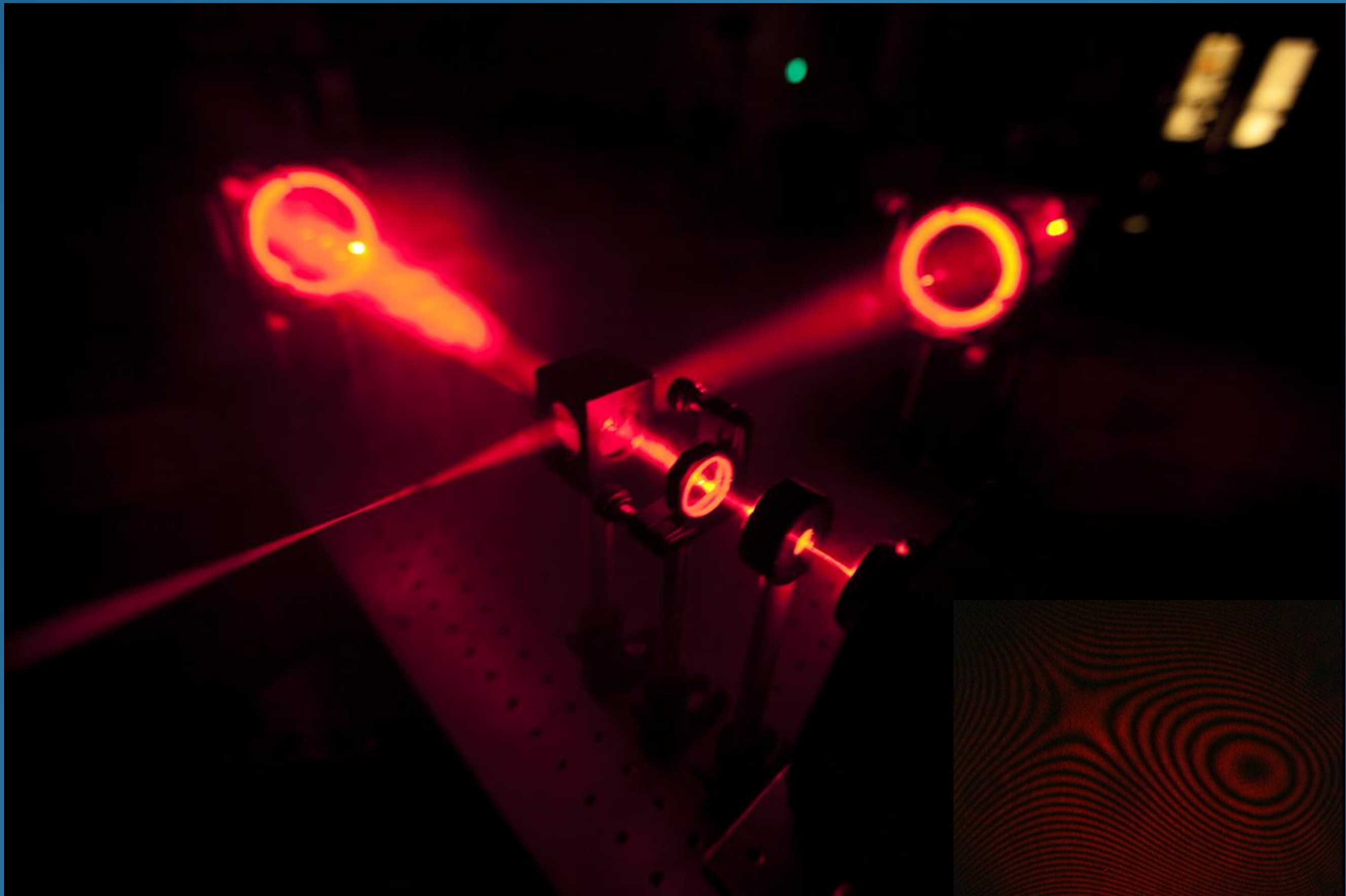


Figure 1: a photo of Houghton's interferometer setup and an interference pattern (inset).

THEORY

The credit for the interferometer's ability to project images is due to the characteristic of light travelling as a wave. Conveniently, it travels specifically as a periodic sine wave as seen in Figure 2. Also seen in Figure 2 is what happens when two light waves interfere with each other. Effectively, this is like a collision, causing the overall resulting wave to be dependent on the two waves that existed beforehand. If the two waves are "in phase," or they have the same period and frequency, they will add together to produce a wave with an amplitude equaling the sum of their amplitudes. If the two waves are "out of phase," or have the opposite period or a different frequency, the waves will cancel out, leaving no resulting light. The waves may be partially in or out of phase, thus are not limited to the two situations depicted in Figure 2.

Built on the grounds of light waves adding and subtracting, the interferometer uses that property to produce an image based wave interference seen in Figure 1. The possible issue with differing frequencies or waves starting out of phase is resolved simply by using the same laser. The setup of a basic interferometer is seen in Figure 3. Houghton's interferometer setup is seen in Figure 4.

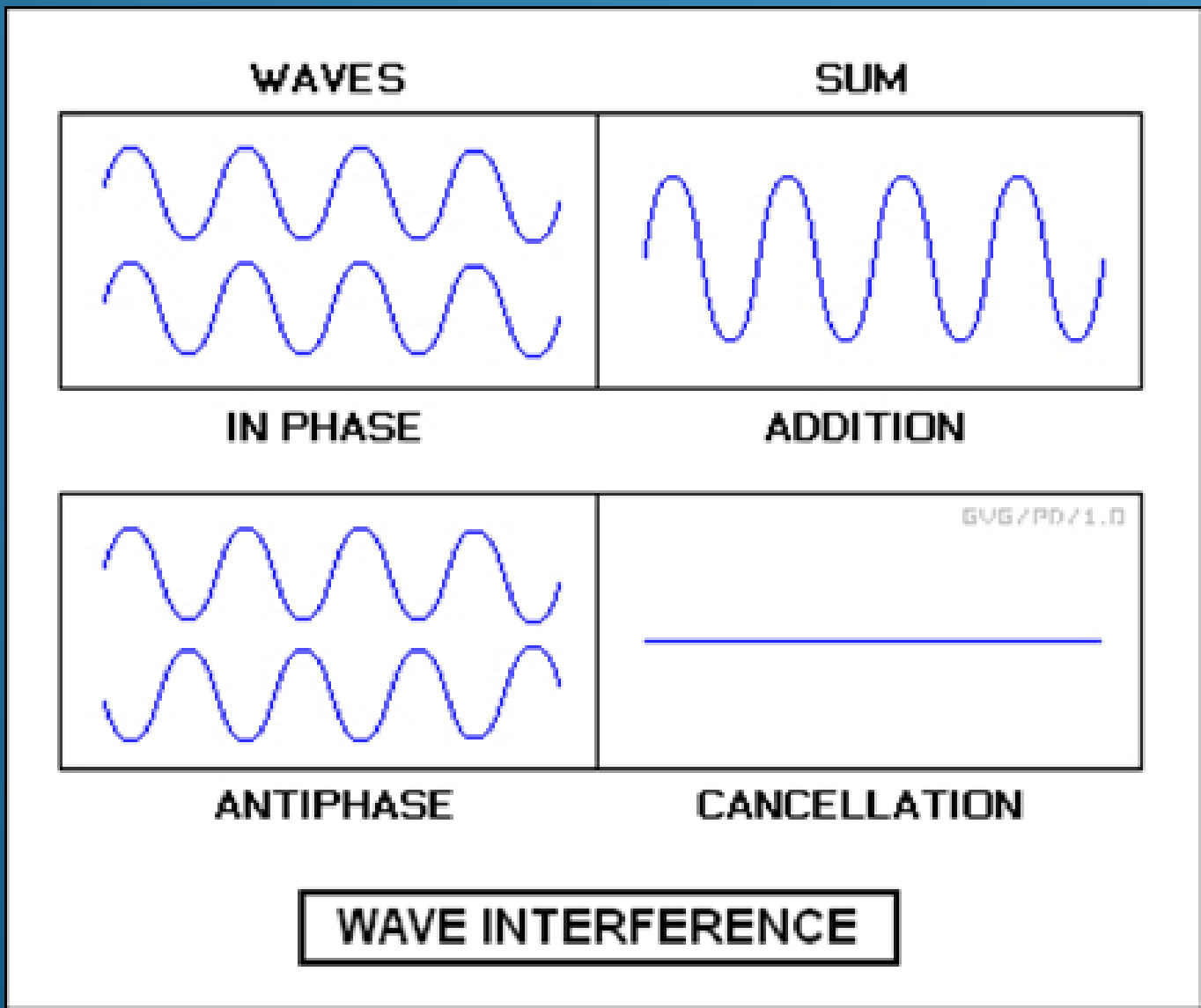


Figure 2: Light and Interference Characteristics.

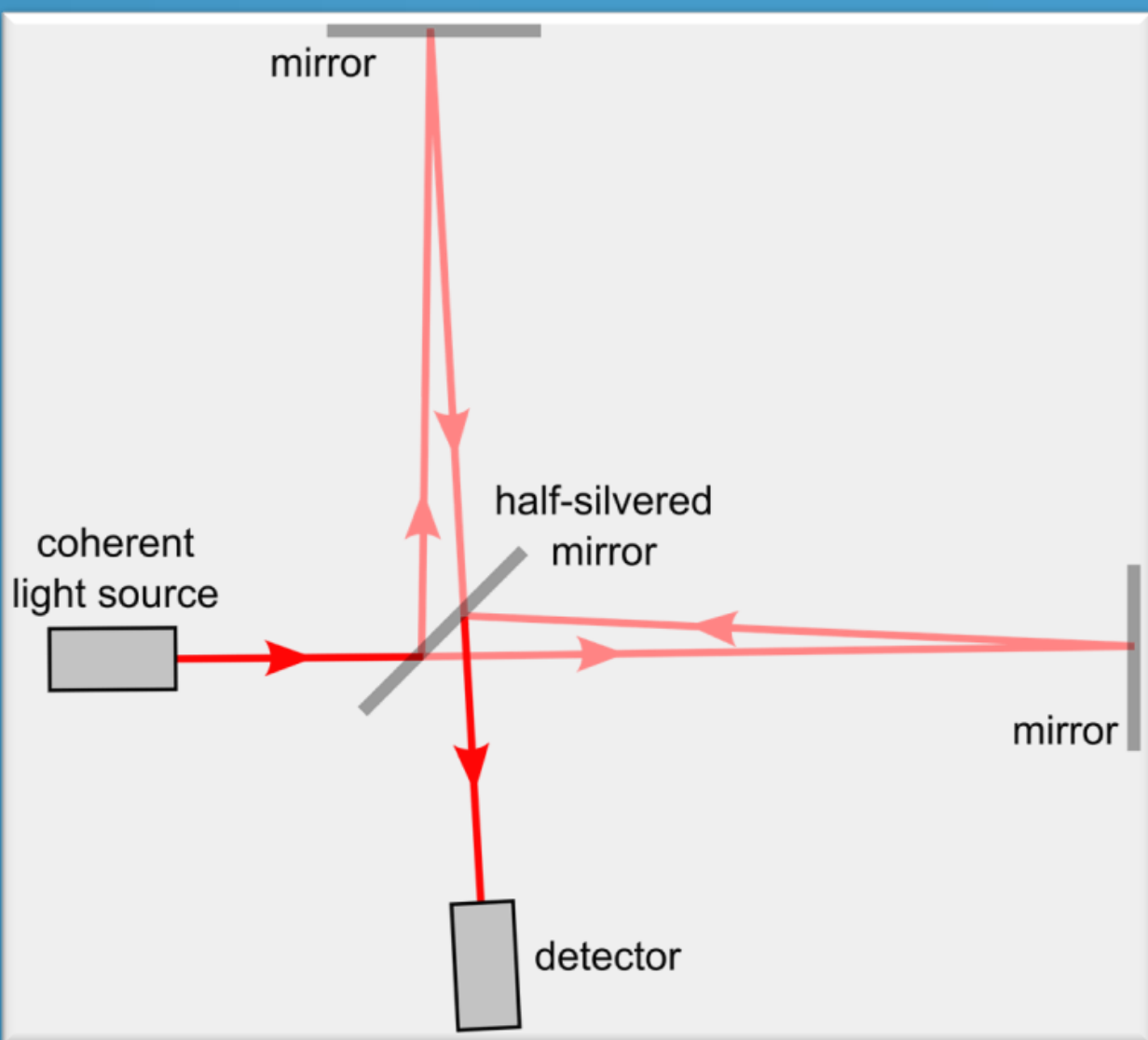


Figure 3: Basic Michelson Interferometer.

APPARATUS

The apparatus used employed the characteristics of optics to create an advanced interferometer that could study a portion of a surface three inches in diameter. This interferometer was built on an optics table, or a steel table with a grid of threaded holes. An optics table is used because of its versatility, mainly the user's ability to add, move, or remove items from it by simply using a screwdriver.

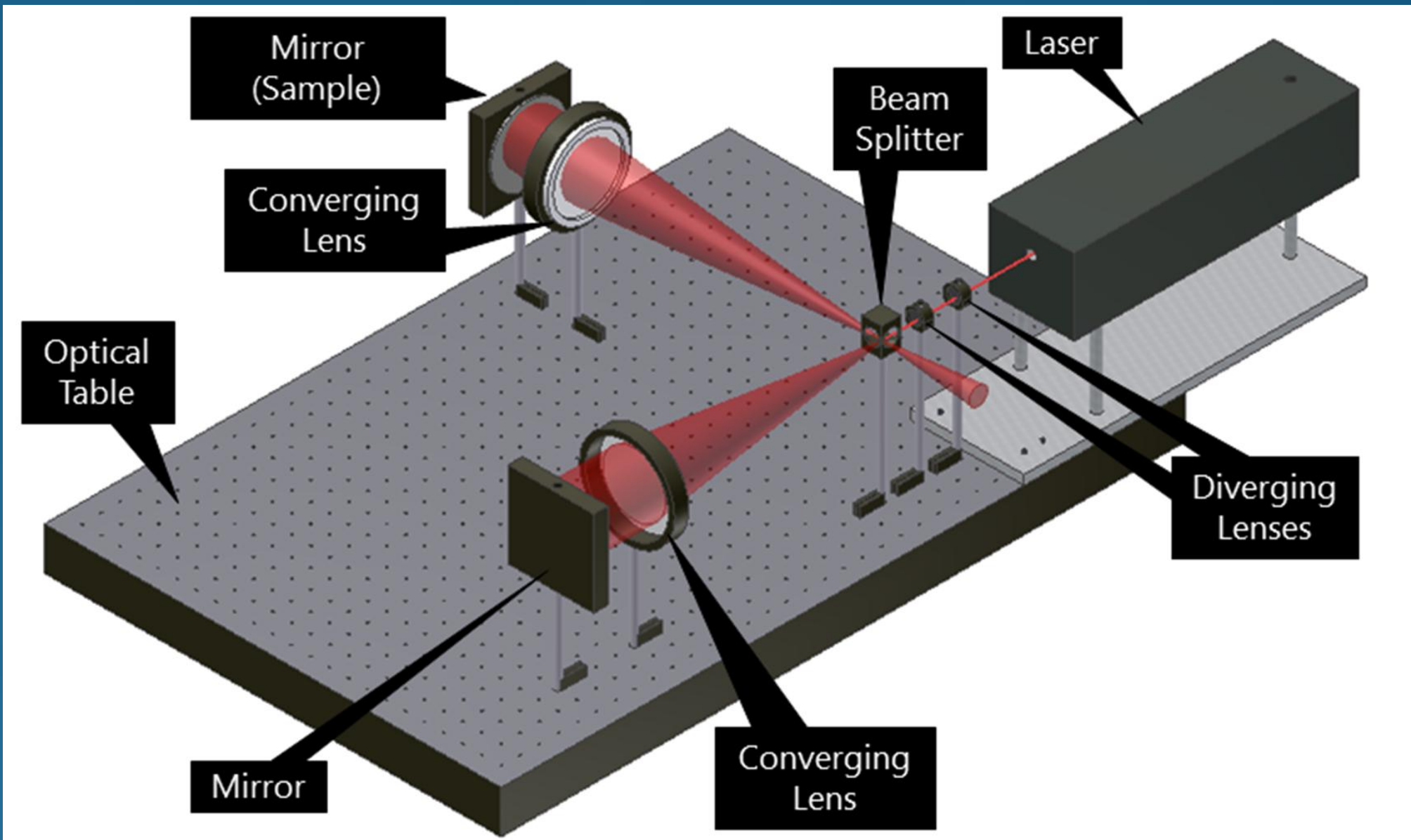


Figure 4: A 3D rendering of the optics table.

The interferometer works by sending light, such as a laser, through a beam splitter to two different surfaces. One surface is a near-perfect mirror, and the other is the target to measure. The beams are reflected back through the beam splitter and combine to form a result that varies in brightness due to differing distances. The determination of what any single wave will do is based on the surface of the mirror and the reflective sample. If a pair of waves combine and are in-phase, they will produce a bright spot at the location of observation. If the pair combines and are out of phase, they will produce a dim or even dark spot to the observer. Theoretically, due to the use of individual light waves with near-perfect mirrors, this system could produce images of a surface in atomic resolution.

This assembly works by the emission of a uniform light beam from a laser and functions like a Michelson interferometer. An image is projected on any surface from the combined beams should exhibit the lines of interference that represent the topography of the sample inside the chamber.

The optics assembly would sit underneath the chamber, tilted vertically so that the sample collimating lens in Figure 4 would be in line with the window in the bottom of the chamber. This would allow the three inch diameter beam of the interferometer to "view" the sample through the deposition chamber. A three-dimensional model of the entire system can be seen in Figure 5. This image shows an open interferometer. In reality, the interferometer was enclosed in a wooden box, with holes cut in it for beams. This was done to minimize the effect of air currents.

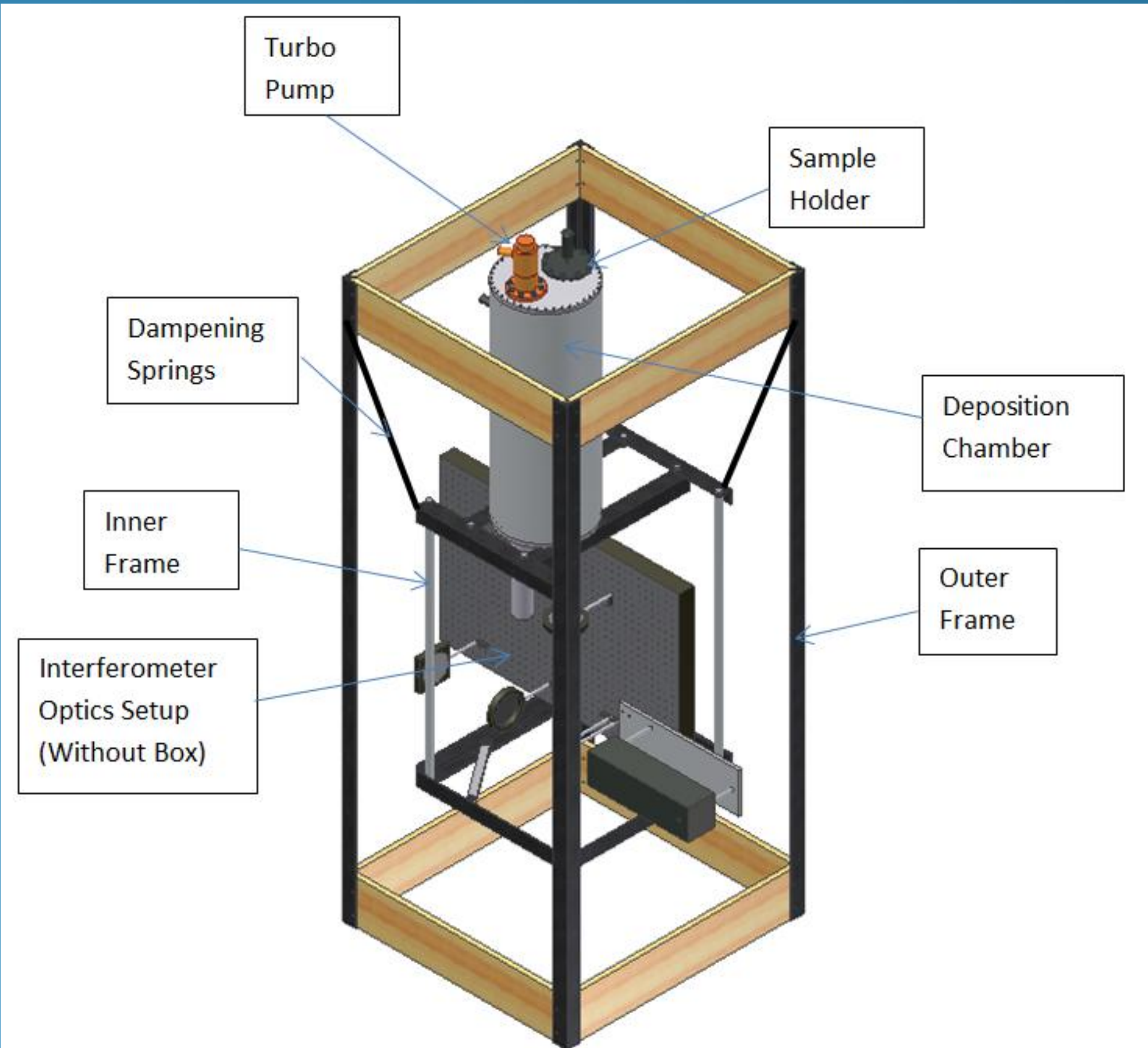


Figure 5: A 3D rendering of the full assembly.

APPLICATION

The important characteristic that is currently the focus of our testing and the reason we are creating this equipment is to research how the film handles stress caused by heat expansion. We can take advantage of the fact that the film is one type of metal and the substrate is silicon. Since the materials are attached, to each other, their differing expansion rates will cause them both to bend one way or another as shown in Figure 6. The interferometer will allow us to both observe this bending and measure how much has occurred.

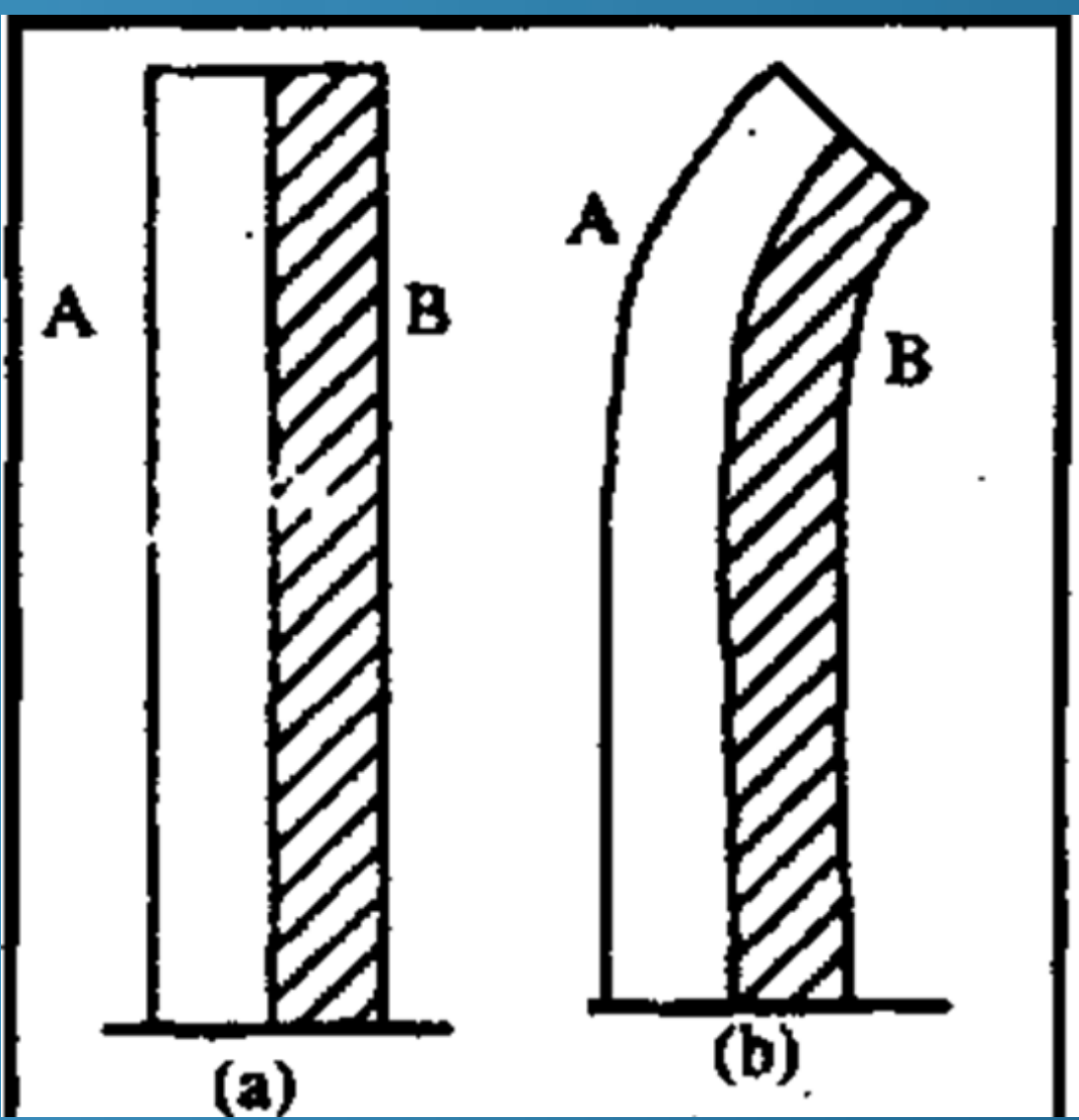


Figure 6: Effects of temperature change on two bound differing materials