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DESIGN OF A NONLINEAR, THIN-FILM MACH-ZEHNDER INTERFEROMETER

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Optical waveguides are the optical equivalent of wires in electronic circuits. An optical waveguide is a device along which or through which a beam of light is confined to travel(1-3). The confinement is accomplished by creating a narrow channel (a few micrometers in width) with an index of refraction slightly higher than that of anything surrounding it. Assuming a glass substrate and single mode of1.06 micron light, the change in the index of refraction between the channel and the surrounding substrate required for confinement of a light beam is about 0.01.

When two channel waveguides are placed close together, the "tail" of the light in the input channel will overlap the "tail" of light in the other channel and power will be exchanged back and forth between the two channels. As light originally focussed into channel 1 moves along the directional coupler, some of its energy is transferred into channel 2 until at some distance (called the

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3db length) its power is reduced to 50% of the original power and the other 50% will reside in channel 2. At twice this distance, (called the coupling length) all of the original power input into channel 1 will be resonating in channel 2. At twice the coupling length, all the power will have returned to channel 1 and this switching back and fourth continues until the light beam reaches the end of the directional coupler.

The coupling length is determined by the index of refraction, the change in the index of refraction inside the channel, the wavelength of the light and the spacing between the channels. The performance of waveguide directional couplers depends critically on the construction parameters especially film uniformity and design length. Waveguide directional couplers can be used to split a beam of light into a number of output channels and to control the relative intensity in each channel. However, they can not be used to change the total output power (switch power on and off). These considerations together with the unpredictable or unstudied influence on the properties resulting from the use of nonlinear materials make the directional coupler less attractive for initial fundamental studies.

of its components has been investigated by Najafi, et. al.(5). Since an optical path difference is required for its function, the performance of a Mach-Zehnder interferometer is not very sensitive to construction parameters.

An optical path difference can be produced by creating a physical path difference by making one arm of the interferometer longer than the other arm or by causing the index of refraction to be different in one of the arms if they are the same length.

In addition the wavelength cutoff caused by its component waveguide parts, a Mach-Zehnder interferometer will pass wavelengths (constructive interference) which will fit evenly into the optical path difference. (The optical path difference = index * difference in length of the two arms.) Wavelengths which are halfway between any two wavelengths passed by the interferometer will be completely blocked due to destructive interference.

At any fixed wavelength, the intensity may be switched on or off by varying the index of refraction of the material composing the two arms. The index of refraction may be varied by varying the voltage of an electric field penetrating the arms of the interferometer(6), or by heating one arm of the interferometer(7). The interference may also be observed in an interferometer made of nonlinear materials by changing the intensity of light resonating in the two arms of the interferometer if the arms are of different lengths or if the light intensity is not split equally between them.

In designing an interferometer for this work, the following considerations must be observed:

1. The interferometer is to be made of phthalocyanine or polydiacetylene thin films.
2. In order to avoid thermal effects which are slower, the wavelength chosen must not be absorbed in either one or two photon processes.
3. The wavelength chosen must be easily generated (laser line.)
4. The spacing between the interferometer arms must be large enough to allow attachment of external electrodes.
5. The vapor deposition apparatus can accept disks no larger than 0.9 inches.
6. The design must allow multiple layer coating in order to determine the optimum film thickness or to change to another substance.

A symmetrical Mach-Zehnder interferometer which meets each of these requirements is illustrated in Figure 1.

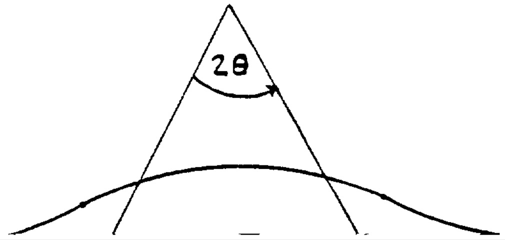

Figure 1

Each arm of the interferometer is composed of six(6) segments two short linear segments (0.05 inches) for input and output coupling, two adjacent concave outward circular arcs and two concave inward circular arcs in the middle. Each arc is the same length and has the same radius of curvature (40 mm). Studies have shown that a circular arc with a radius greater than about 60 mm behaves as if it were linear with no significant additional losses(8). Such large radii lead to insufficient spacing between the arms. Small radii which separate the arms better have significant excess bending losses. A radius of 40 mm is expected to have less than 1db excess bending loss and was chosen as an appropriate compromise. The angle of bending is calculated to be 7.30 degrees of arc. The spacing between the arms is 1.30 mm and the length of each arm is 20.38 mm.

The symmetrical design of Figure 1 may not be appropriate to the experiments involving physical vapor transport. Since there is no way to attach the electrodes after vapor coating without risking damage to the delicate film, a nonsymmetrical Mach-Zehnder interferometer is more appropriate. See Figure 2.

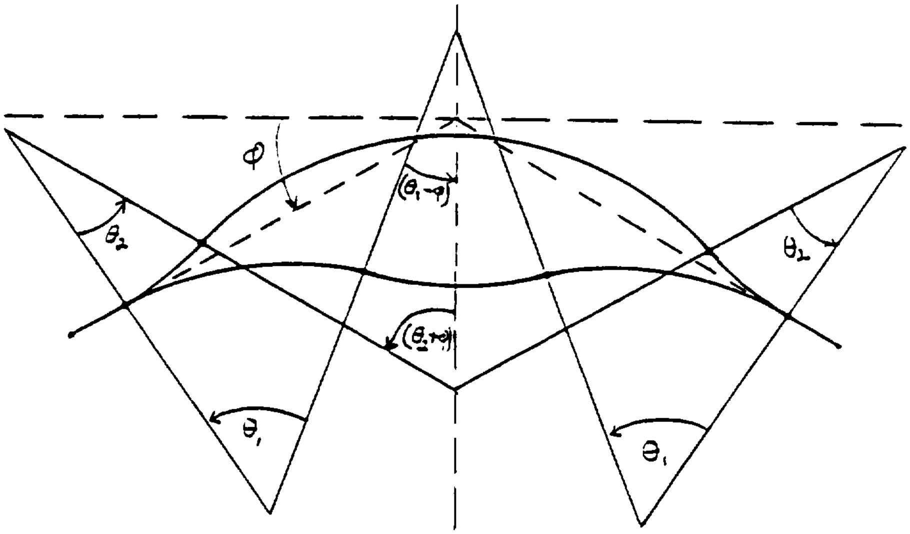

Figure 2

The master patterns will be generated using standard lithographic techniques. Photoresist is coated over a layer of gold which has been sputtered on the surface of a substrate disk. The pattern of the Mach-Zehnder interferometer is exposed on the photoresist and developed exposing the gold in the areas of the

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without removing the photoresist or the gold under it which surrounds the interferometer. The unexposed photoresist is then washed away completing the fabrication of the master pattern. These master patterns can be used to create duplicate patterns for use in experimental studies. Electrodes may be attached to the gold if the electro-optical effect is to be investigated. The symmetrical pattern with attached electrodes is ideal for the polydiacetlyene studies.

A more robust pattern may be generated for the unsymmetrical Mach-Zehnder interferometer using buried potassium ion channel waveguides. The technology for constructing ion-exchanged channel waveguides has been thoroughly investigated (9-13). The Mach-Zehnder interferometer can be fabricated by immersion of a dupliguide at the second harmonic of the YAG laser (532 nm) but not long enough to permit guiding at the fundamental (1064 nm). The gold pattern may be removed (ion milling which would also clean and polish the surface) and the entire surface coated by vapor deposition with a phthalocyanine film. The thickness of the film should be adjusted to allow guiding at 1064 nm AT LOW INTENSITY. The entire surface should then be coated with an index-matching optical epoxy and a cover disk attached.

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