ABLATED SINGLE-MODE FIBER POLARIZER

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An in-line fiber optic polarizer is constructed and demonstrated using a proprietary ablation method. A throughput loss of 3.6 dB and an extinction ratio of 14 dB was measured with an evaporated Aluminum coating at 632.8 nm. SEM and alpha-step were used for surface analysis.

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I. Introduction.

As mentioned in our project proposal, polarizers are needed in fiber optic sensors, such as gyroscopes, magnetometers, etc. To build such a device bulk components are generally used, which are very sensitive to temperature, vibration, and alignment. A much more compact way of polarizing light in a fiber has been done by Eickhoff[1] and Hosaka, et al[2]. By bringing a metal layer in close proximity to the core, light polarized perpindicular to the metal/glass interface was attenuated much more than light polarized parallel to the interface. See figure 1.

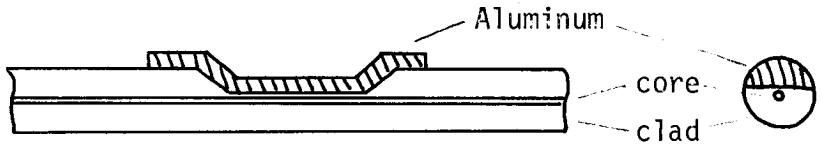

Figure 1. Polarizer construction.

This experiment differs from the above references in the method of core exposure. Eickhoff used a special grinding technique, while Hosaka employed an offset-core fiber. In this experiment, the core was approached by laser ablation, which is the process of blasting the fiber side with a high power laser pulse that removes the cladding from one side.

[1]W. Eickhoff, "In line Fiber Optic Polarizer", Electron. Lett. V.16 N.20 (Sept 80), pp762-3.

[2]T. Hosaka, K. Okamoto, J. Noda, "Single-mode Fiber-type Polarizer", IEEE Quantum Electronics, V.QE-18 N.10 (Oct 82), pp1569-72.

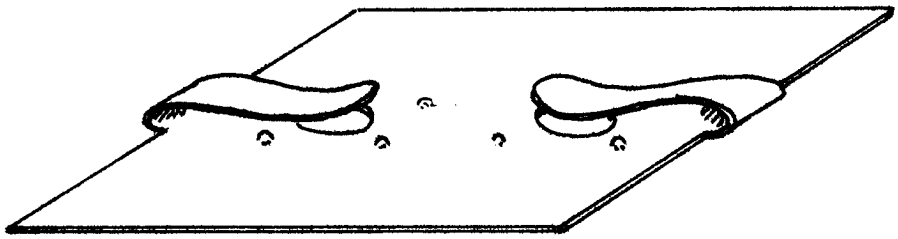

Figure 2. Evaporation mask.

Following is the procedure followed for construction of the evaporation mask:

1) Cut mask out of 0.030" steel.
2) Degrease in Trichloroethane vapors.
3) Scrub with abrasive cleaner and DI water rinse.
4) Nitric-Acetic acid bath - 2 min.
5) Rinse thoroughly with DI water.
6) Placed in ultrasonic tank for 2 min.
7) N_2 blow off.
8) Placed in 200°C oven.

Two dimpled-foil type Tungsten boats were loaded with cut pieces ($\sim$1 cm length) of 99.99% Aluminum (Balzers). Samples #2 and #4 were inserted into the mask, which was placed on top of the evaporation chamber. With the bell jar in place the chamber was pumped down to 25 millitorr mechanically; then the diffusion pump was used to pump down to 6.5×10^{-7} mm Hg. At $\sim 5 \times 10^{-6}$ mm Hg the ion gauge was degassed and its ranges calibrated. The initial resonance frequency of the deposition gauge was 53 MHz, and the density was set to 2.70; set point 1 was 400 Å and set point 2 was 2400 Å. The shutter was checked to make sure it was closed.

The boat current was gradually brought up to 120 A when it was noticed that a hole was starting to burn in the boat. The shutter was opened at a reading of 450 A and the boat burned through at 889 Å. The shutter was then closed, and the power was switched to boat #2. The new set points were 300 Å and 2300 Å. Boat current was gradually brought up to 285 A (a high value because a thicker boat was used). The shutter was opened at 309 Å and the second boat burned through by 750 Å into the evaporation. The evaporation was carried out until the second boat burned up completly. The ion gauge was then turned off, the high-vacuum valve was closed, and the system was bled up with N_2. The bell jar and samples were removed (See figure 3).

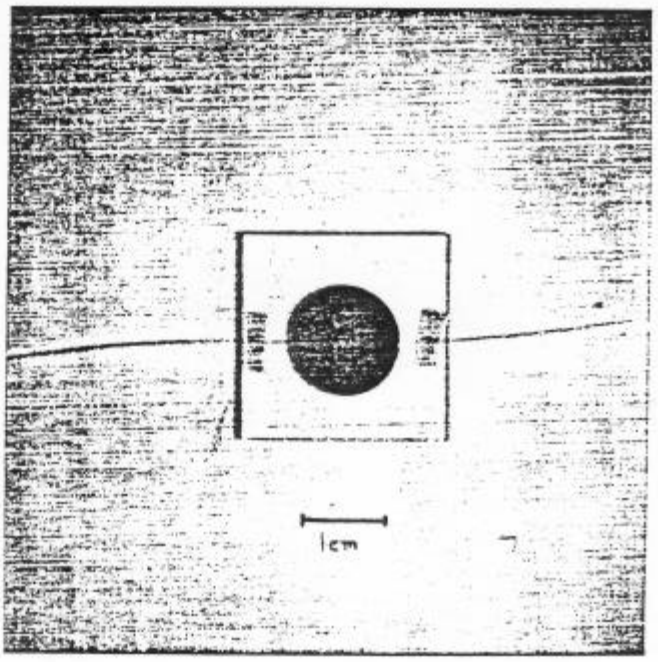

Figure 3.
Fiber Polarizer.

According to the thickness monitor, approximately 2140 Å of an Aluminum-Tungsten mixture was evaporated onto samples #2 and #4.

III. SEM Analysis

The SEM was used to observe the surface roughness of the ablated region, and also to see how far the edge of the core was from the ablated region.

Sample #1 was used for the cross sectional analysis. After cleaving sample #1 in the middle of the ablated region, it was etched in 10:1 Hydrofluoric/H_2O for approximately 20 seconds. Since the core of the fiber is more highly doped with Germanium than the cladding, it was thought that the core would etch faster giving a depressed region that would be detectable on the SEM.

After etching, samples #1 and #3 were mounted on the Aluminum SEM sample holders and coated with carbon in the SEM sample preparation room.

Figure 4 shows the cross-sectional view of the ablated region. Note that the fiber has taken on a D shape, with a flat surface on the side that was ablated. Knowing that the Amfox fiber cladding O.D. is 100μ and that the core dia. is 6μ, a rough graphical approximation shows the core to be 8μ away from the ablated edge. The white line on the right side of the picture is caused by the jagged edge left behind after cleaving.

Figure 5 shows a 3/4 view of the cross-section. The electrons are reflecting off the surface better at this angle, giving better resolution and less shadow. Still, no core depression is evident. Finally, lighter patches can be seen on the surface. These patches could be due to etching, or charging where the carbon sample coating was sparse.

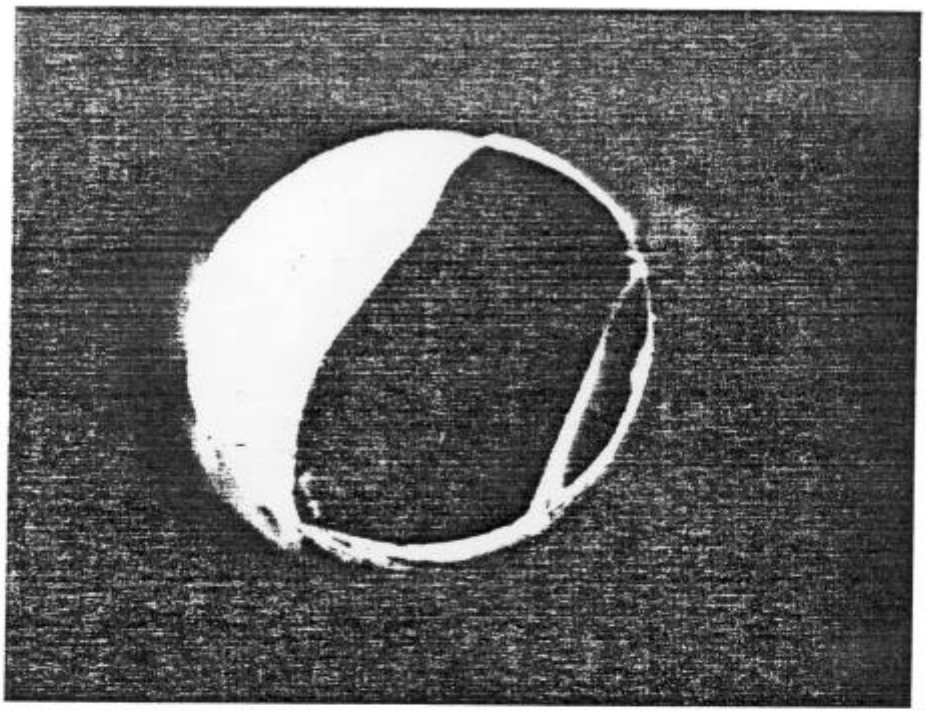

Figure 4. Cross-sectional view of the ablated fiber sample #1 at 500X.

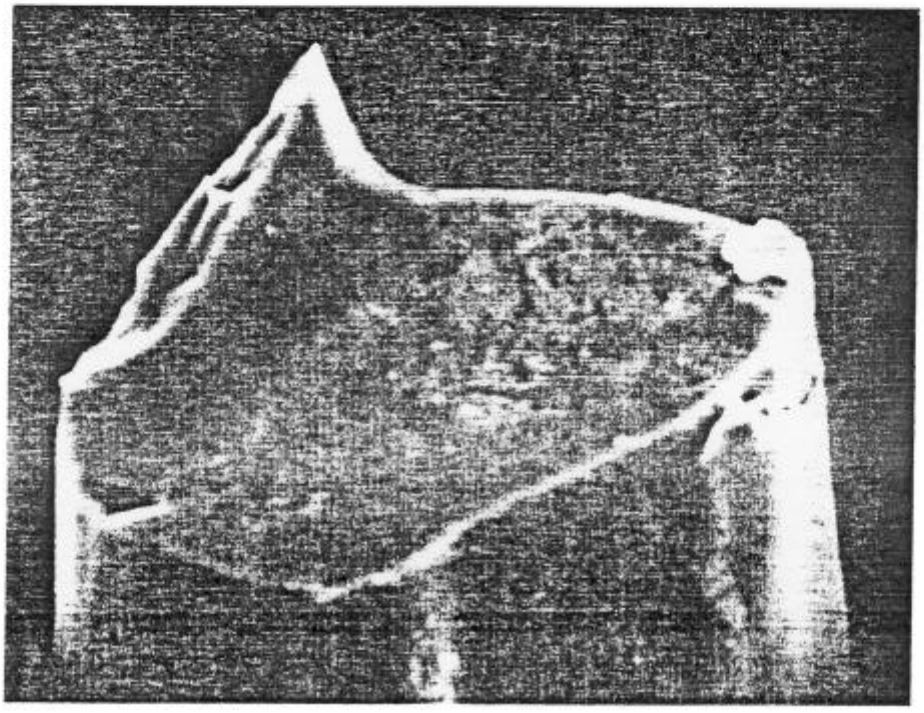

Figure 5. 3/4 cross-section view of the ablated fiber sample #1 at 960X.

Figures 6 and 7 show side and close up views of the surface roughness in the ablated region. The surface appears to be relatively smooth and satisfactory for polarizer purposes.

The Alpha Step was used to determine the approximate thickness of the evaporated Al-W film. Sample #4 was evaluated since it had a break in the core. The fiber was carefully removed from the coverslip and the Al-W step on the quartz coverslip was measured with the Alpha Step. After finding a clean region, the four traces shown in figure 8 were made and the average film thickness was found to be 1400 Å.

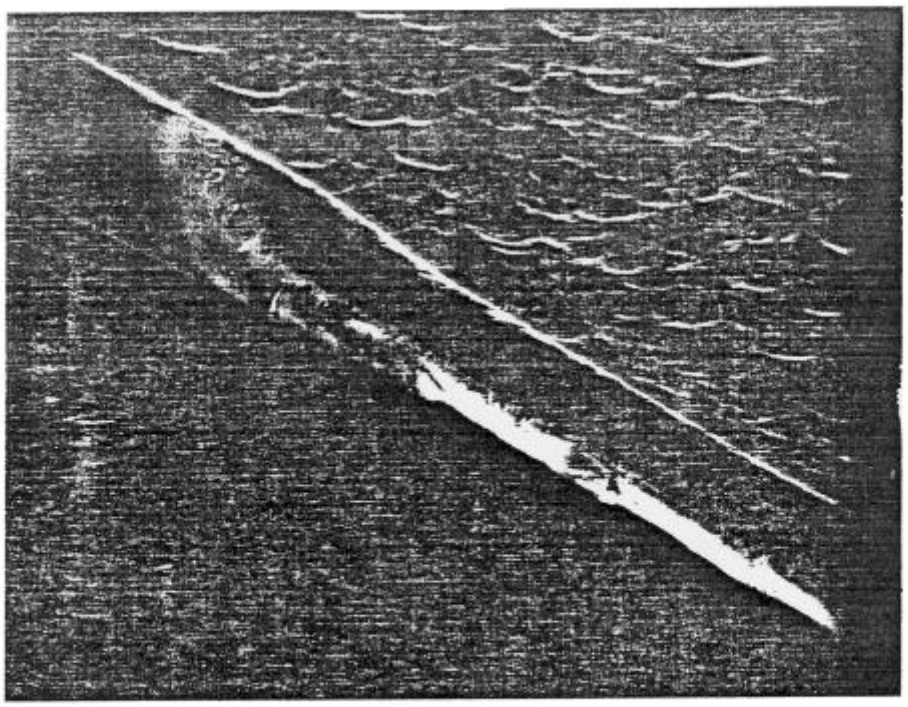

Figure 6. Side view of the ablated surface of sample #3 at 150X.

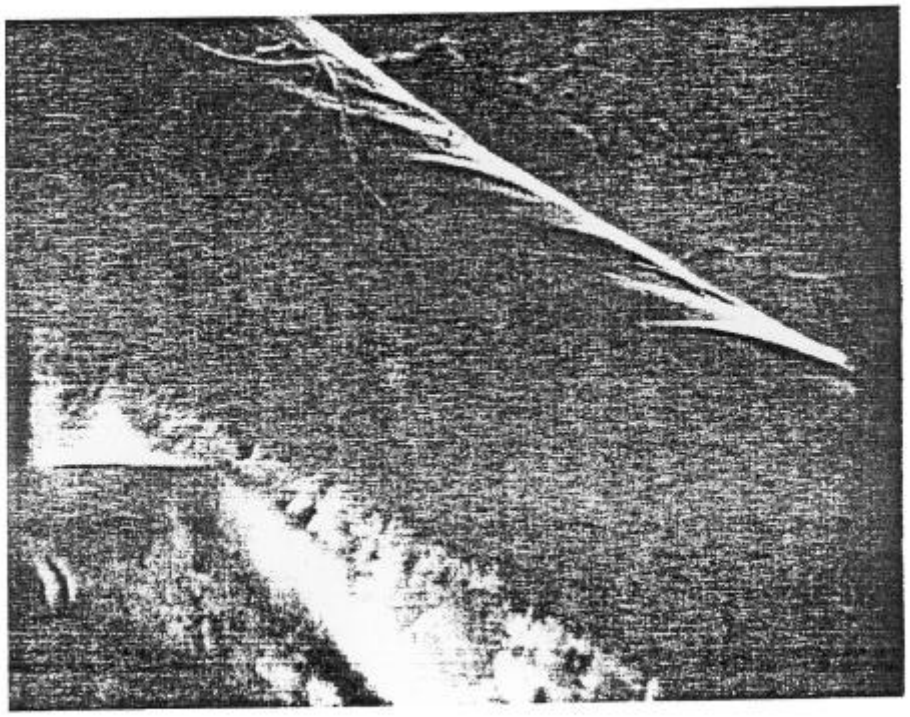

Figure 7. Close up of the ablated surface of sample #3 at 790X.

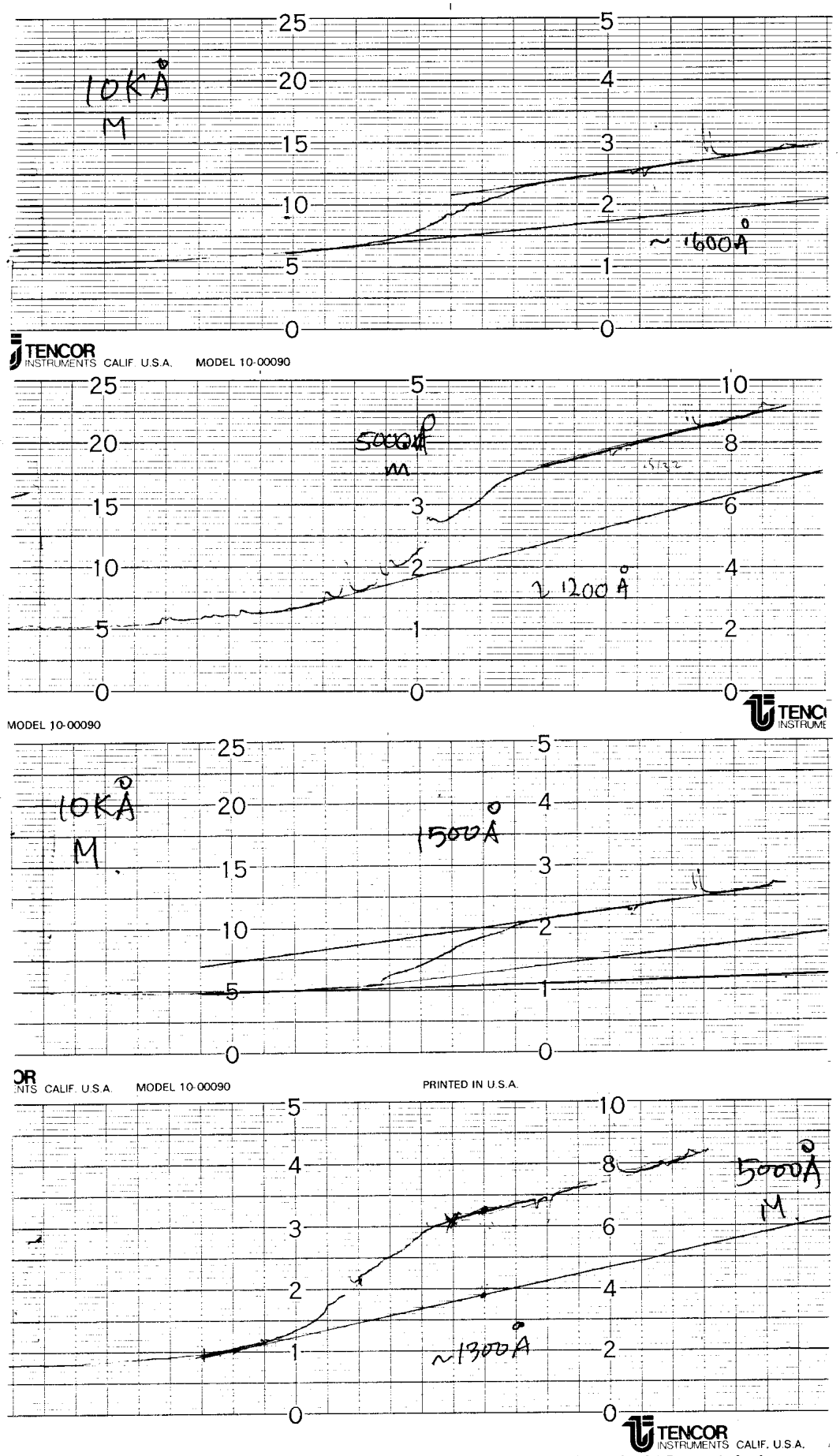

Figure 8. Alpha Step traces showing the Al-W film thickness on the sample #4 cover slip.

IV. Optical Analysis.

After the two samples were coated, ¼" of the plastic buffer layer was stripped at the ends of the fiber and also halfway from the ends. Corona dope was applied to the middle regions to absorb any cladding modes. The ends were then carefully cleaved, to allow maximum coupling into the fiber.

Figure 9 shows the method for determining attenuation of the polarizer. A Coherent model 2000 single-mode linearly polarized HeNe laser was aligned so the plane of polarization was parallel to the substrate. The beam was focussed with a 20x microscope objective onto the cleaved fiber end mounted to a three-axis stage. The output of the fiber polarizer, p_o, was coupled into an EG&G model 460-1A laser power meter. This was compared to the power leaving the laser, p_i.

Sample #4 exhibited very high loss. No light at all would pass through the core, and it appeared that all of the light was scattered into the cladding after the ablated zone.

Sample #2 was much better. In this arrangement:

p_i = 0.58 mW

p_o = 0.25 mW

loss = 3.6 dB

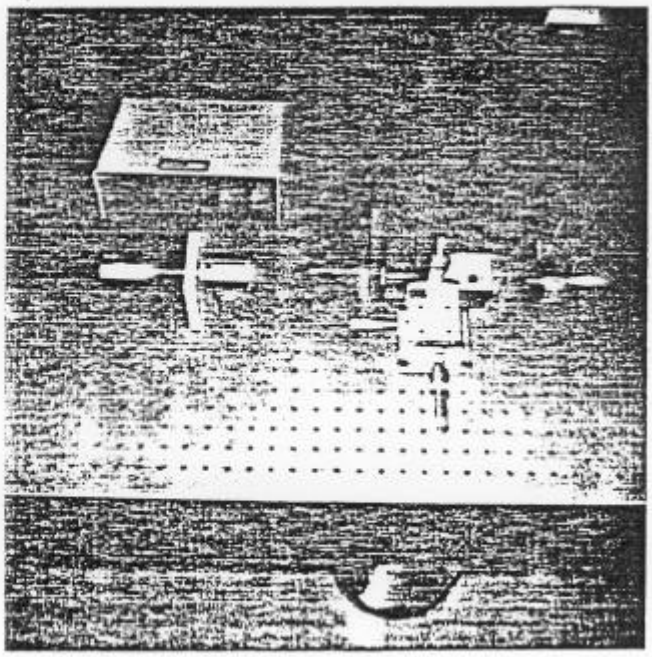

Figure 9. Optical loss analysis.

Now the laser was rotated 90° and the measurements were repeated:

p_i = 0.58 mW p_o = 5.0 nW loss = 50.6 dB

Clearly there is much more loss for the perpendicular polarization. However, this was far better than was expected. Could the realignment of the laser and fiber be responsible for such high loss? To eliminate this possible source of error, a second approach was taken (See figure 10). We aligned the laser's polarization to 45° with the substrate, sending equal amounts of light polarized parallel and perpendicular to the substrate. The setup used the laser; a polarizer (to ensure a pure 45° linear polarization input); the 20x lens; the fiber polarizer; and the power meter. In between the output end of the fiber and the power meter head was an additional polarizer that was mounted on a 360° stage. This was used as an analyser to select only one polarization angle at a time. The angle could now be changed without altering the critical fiber-to-laser alignment.

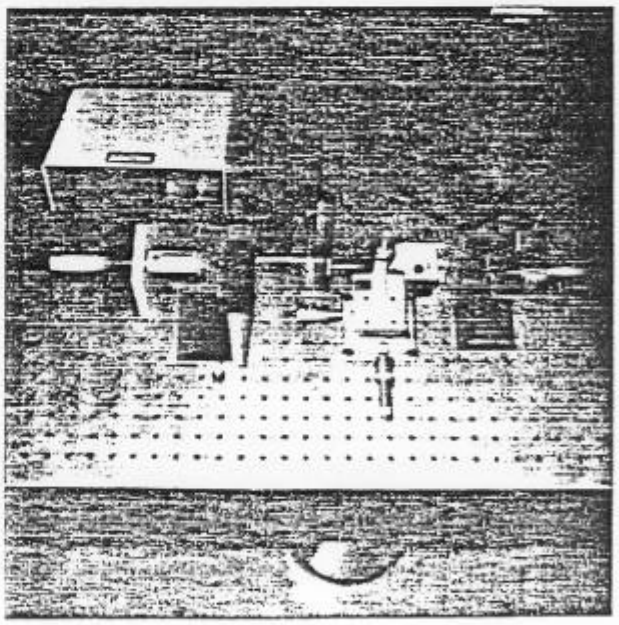

Figure 10. Optical polarization analysis.

By taking data every 10° and plotting loss (referenced to the maximum 90° value) versus analyser angle, the plot of figure 11 was derived. This shows a more realistic extinction ratio of 14 dB, more in line with previous expectations. The reason that the second null does not approach the -14 dB point could be due to the laser not being exactly 45° to the metal/glass interface. There is also no garuntee that the state-of-polarization is constant as light travels down the fiber past the ablated region.

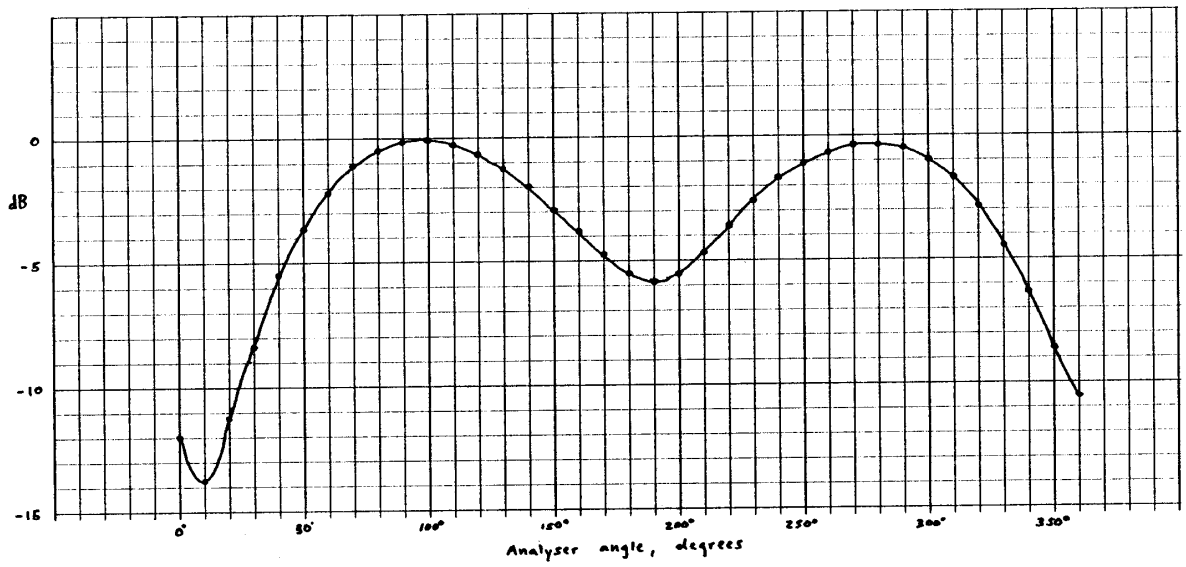

Figure 11. Loss vs. analyser angle.

V. Conclusion

In this project, a new fabrication technique of a solid state polarizer, was demonstrated. By ablating away the cladding of the fiber almost to the core and then coating this surface with evaporated Aluminum, a significant polarization effect was achieved. While the polarizer was only 3 mm long and had a core to ablated edge separation of $\sim 8\mu$, it still exhibited an extinction ratio of 14 dB and an insertion loss of 3 dB. The sample #4 polarizer failed in test because it was ablated to close to the core (The orignal sample underwent 7 passes and had 3 dB of loss before evaporation). Also, some time during the fabrication process, a break occured in the core near the Al-W step.

These results are on the same order of magnitude as those obtained from eccentric core and other types of solid state polarizers. However, the ease and speed with which this fabrication technique can be carried out (ie. Ablation is not fiber selective, no grinding or complicated mechanical set up's are needed, and no splicing.) lends itself readily to mass production techniques.

This project was originally conceived by Hans Mocker (Honeywell SRC) and has been an informal co-operative effort between the University of Minnesota and Honeywell. We would like to thank Ron, Byun and John for help with the coating, SEM, and Alpha Step. We would also like to thank Paul Bjork for the ablated fiber samples, and Dave Cummins for general vacuum advice.