EXPERIMENTS IN

FBG

Fiber Bragg Gratings

Photoinduced Refractive Index Changes: Exploring the Densification Theory

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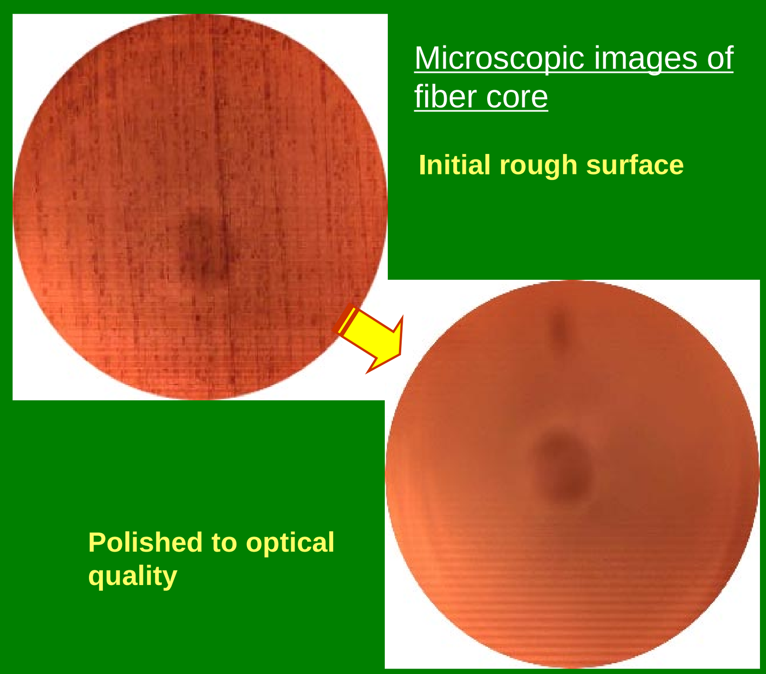
Introduction

This experiment provides further insight into the mechanism by which UV light causes index refraction changes in the fiber core by testing the densification theory. This theory is based on the premise that UV irradiation causes the collapse of a higher-order ring structure in silica leading to index refraction changes in the core. To test this hypothesis, Bragg gratings were fabricated on the core of optical quality preform fiber. A near field scanning optical microscope was used to observe refractive index changes and alterations in the surface topography that would indicate if densification had occurred.

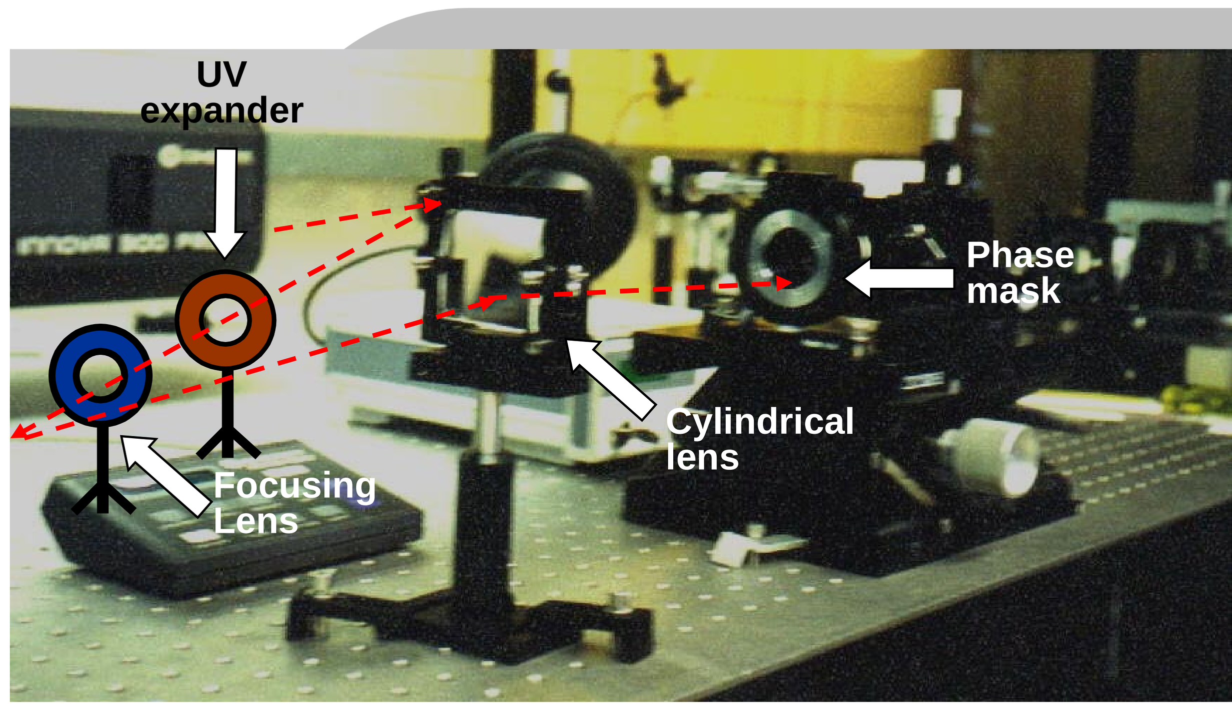
EXPERIMENTAL SETUP

1. Polishing 2. Hydrogen Loading 3. Fabrication 4. Scanning

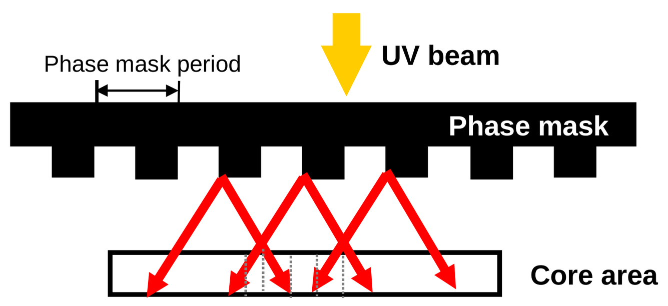
Four disks measuring about 1 cm in diameter and 3 mm in thickness were cut from a rod of preform fiber (fused silica glass doped with germanium dioxide). To insure that any observed densification changes could not be attributed to scratches already present on the sample, we polished one side to optical quality.



The samples were hydrogen loaded before writing gratings to increase photosensitivity and insure that the index refraction changes would be permanent. The fiber samples were stored in a hydrogen tank at 1000 psi, 70 C.



Above: The setup for the phase mask technique. The sample is fixed in a holder behind the phase mask. The laser beam goes through a lens that expands it into many bands and then a lens that turns the bands into a single ray (these optics are not in the actual photo and have been inserted to give the full picture). The cylindrical lens horizontally focuses the beam at the phase mask.



UV beam splits at the phase mask. The resulting beams interfere to create gratings. The phase mask period determines the grating period.

Bragg gratings were fabricated over the 1mm core diameter of the sample using the phase mask technique and 244 nm focused beam from a CW-FRED argon-ion laser. A 1.067 um period phase mask was used to create gratings with a period of 533 nm on one sample. Gratings with a 268 nm period were created on the second sample using a phase mask period of 536.1 nm. Both samples were exposed for 30 minutes at 24 mW.

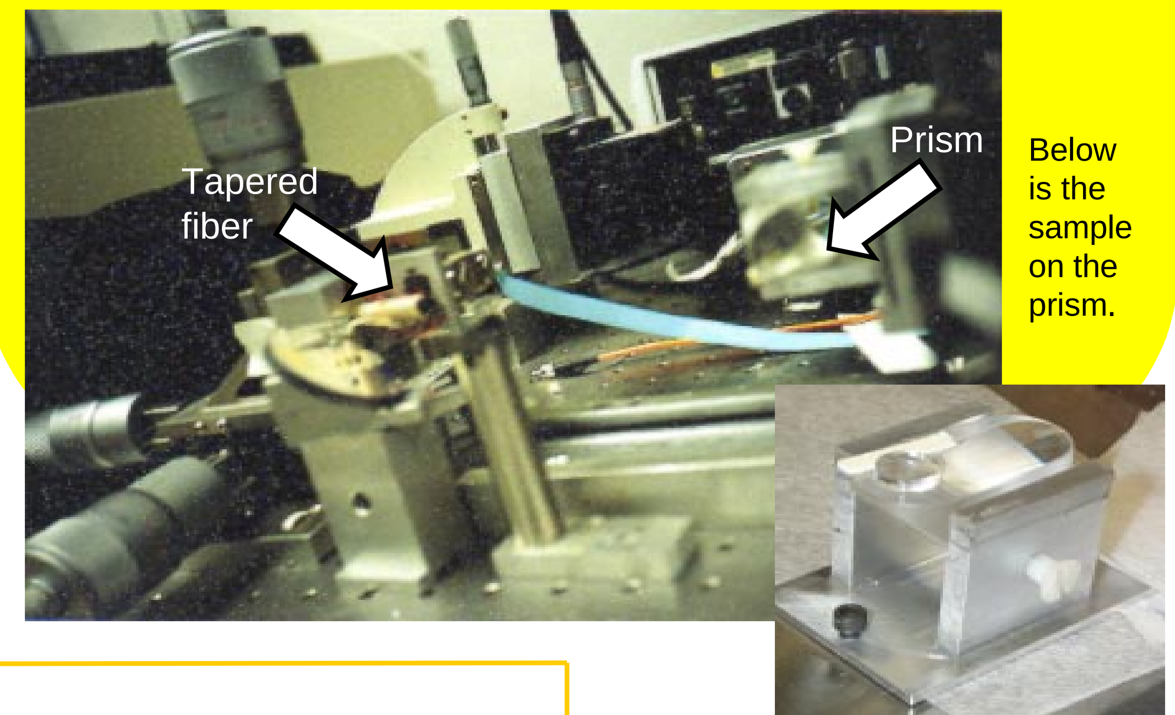
Different gratings were used on the two samples to verify that the observed optical signal was representing index modulations and not interference related to other factors.

We repeated this same procedure for the next two samples except at a slightly higher power level of 42 mW.

Near field scanning optical microscopy (NSOM) was used to study the index modulations and surface topography of the samples. NSOM applies a non-propagating (evanescent) near-field resulting in high resolution.

The sample was placed on the hypotenuse face of a prism. Using the photon scanning tunneling configuration, a He-Ne laser beam was focused on the sample at an angle slightly larger than the angle of total internal reflection. A sharp tapered, single mode fiber was brought near the sample at a range of less than 5 nm. The tapered fiber scanned the sample surface at a constant height across a 4X4 micron area. The surface topography and optical image were recorded simultaneously.

The experimental set-up for the NSOM.



Below is the sample on the prism.

RESULTS

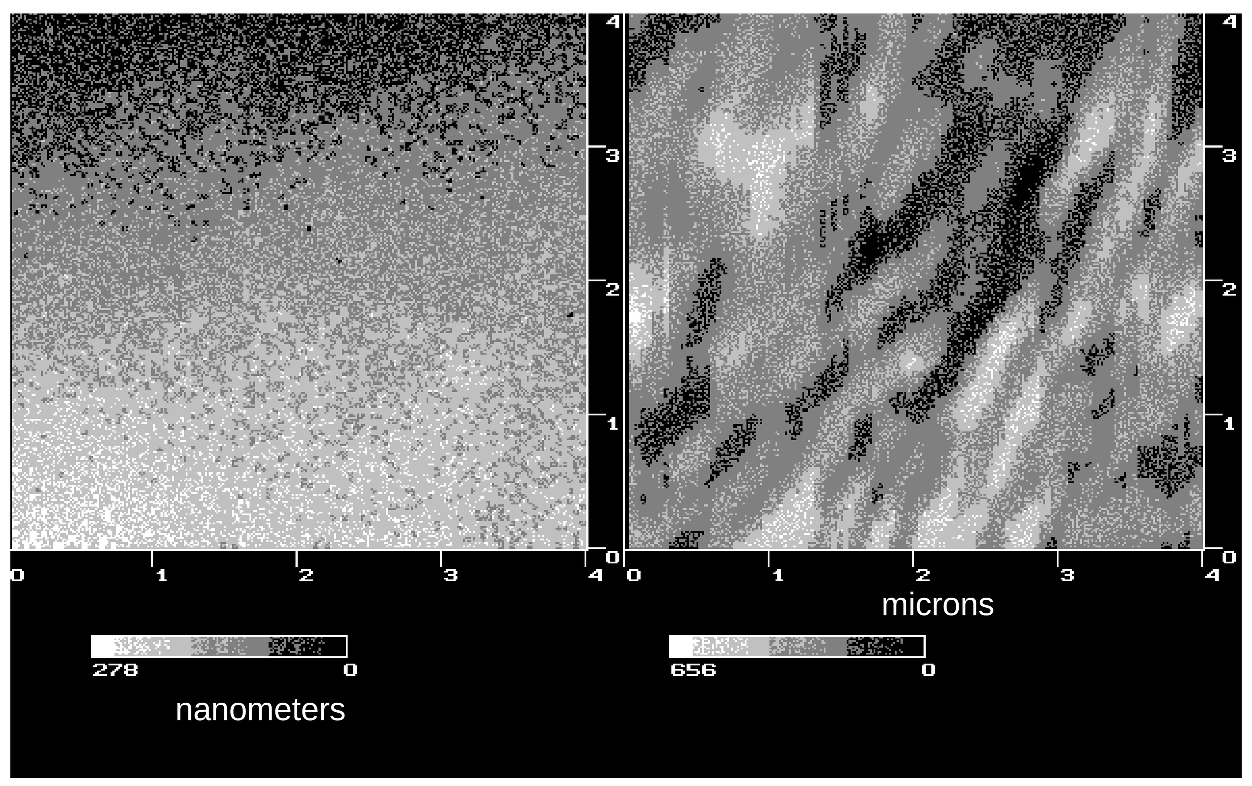
The following results are scans from the first two samples.

Sample 1

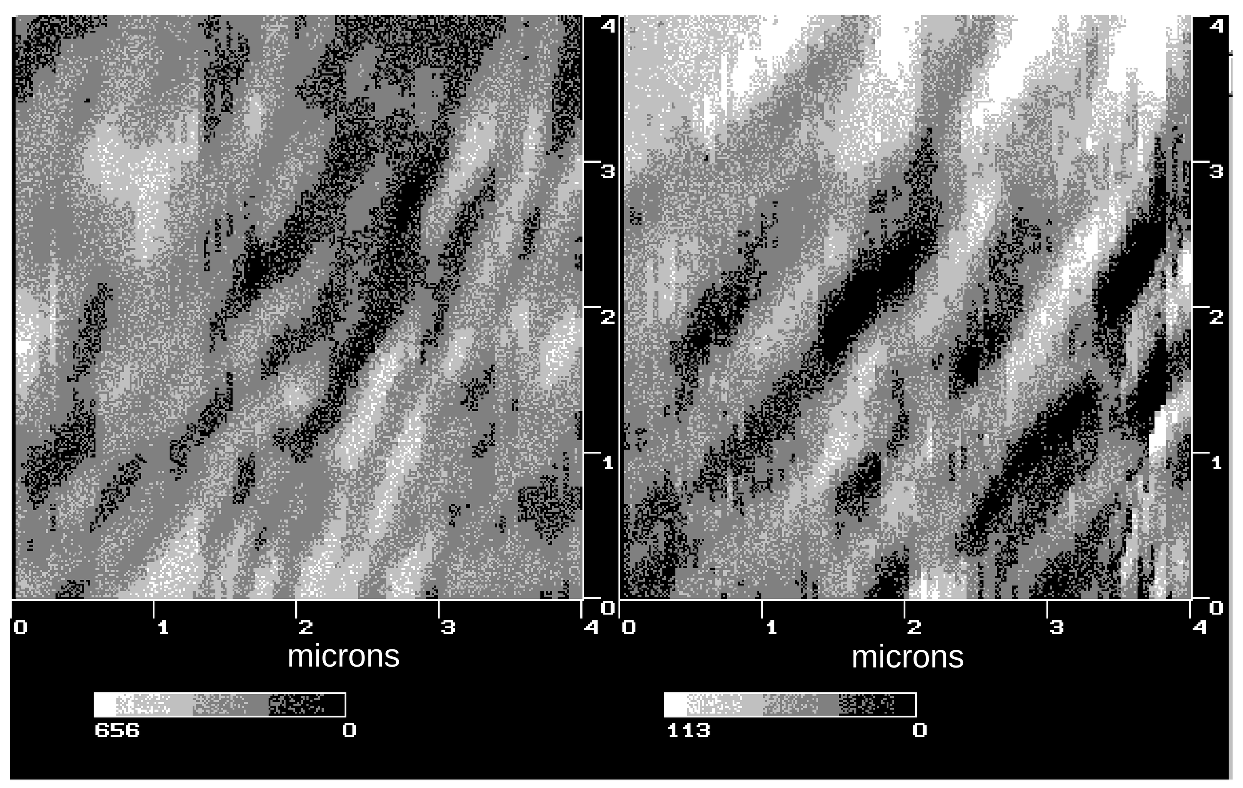
Thickness: less than 1mm
Diameter: 1cm
Hydrogen loaded: 11 days
Grating Period: 533 nm

Sample 2

Thickness: 2mm
Diameter: 1cm
Hydrogen loaded: 11 days
Grating Period: 268 nm



LEFT: Surface Topography **(sample 2) RIGHT:** Optical Signal **(sample 2)**
The sample's topography does not show a periodic change in depth that corresponds to the index modulation seen in the optical signal. The surface is relatively smooth with no apparent density changes. While the optical signal clearly shows three distinct changes in depth over a 1 micron area indicating a periodicity of 333 nm, very close to what the grating period should be.



LEFT: Optical signal **(sample 2) RIGHT:** Optical signal **(sample 1)**
The figure on the right shows two changes in depth over a 1 micron area indicating a periodicity of 500 nm which is consistent with the gratings made on sample 1. The two different index modulations on the samples verify that the optical signal represents the fabricated gratings and not some other interference due to scattering or back reflection.

CONCLUSIONS

From these results we can conclude that at the incident power level of 24 - 42 mW, gratings were written in the fiber core without any evidence of densification.

For further verification of the NSOM results, the samples should be scanned using atomic force microscopy (AFM). One AFM scan of the second sample showed no major densification changes. However, more AFM scans are necessary for conclusive results.

The next step is to repeat the same experiment at higher laser power levels to determine the threshold at which densification does occur in the fiber core.