Direct Writing of Bragg Gratings in Optical Fibers with the Femtosecond Laser

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Abstract

This work aimed at the direct writing of Bragg gratings in optical fiber using the femtosecond laser. This objective was achieved with some success.

Introduction

In recent years, microfabrication by femtosecond laser pulses in transparent materials has received much attention. When femtosecond laser pulses are focused inside the bulk of a transparent material, the intensity in the focal volume can become high enough to cause nonlinear absorption, which leads to localized modification in the focal volume, while leaving the surface unaffected. By translation of the sample with respect to the focal point, fabrication of waveguides, couplers, gratings, binary storages, lenses are possible.

Theory

Direct writing of optical devices using femtosecond laser pulses in glass has potential applications in the telecommunication and optical signal processing industries. The most important feature of the microfabrication technique in glass is its ability for three-dimensional integration of optical or photonic devices inside transparent materials: sequential direct writing of individual devices inside bulk transparent materials simply results in the integration of a 3-D photonic signal-processing system.

The current prosperity of the semiconductor industry relies on the progress of microelectronics technologies and no one can deny the possibility that the present 3-D microfabrication techniques may make some contributions to the industrial fabrication of integrated photonic circuitry.

Under computer control, a wide range of devices can thus be fabricated immediately. The development process is streamlined because devices can be designed, fabricated and tested rapidly.

We then fabricated waveguides by scanning the sample in the X-Y plane perpendicular to the incident beam by using submicrometer-resolution scanning stages. We scanned in the Z direction to create multilayer three-dimensinal structures.

Glass material has been widely used to make photonic devices such as Bragg gratings. Glass is attractive because it is cost-effective, has a wide range of possible material characteristics depending on composition and can be easily connected to glass fibers. The photosensitivity of glass enables device to fabricated by use of optical exposure techniques.

When a spectrum of light beams is sent to an FBG, the reflections of each segment with variations in the refractive index constructively interfere only for a given wavelength of light, called the Bragg wavelength. This causes the FBG to reflect a specific frequency of light during the transmission of all the others.

$$\lambda_b = 2n\Lambda$$

In this equation, λ_b is the Bragg wavelength, n is the effective refractive index of the fiber core, and Λ is the spacing between grids, known as the graduation period.

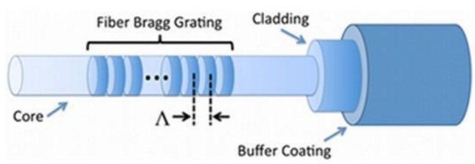

Figure 1: Example of a Fiber Bragg Grating (FBG)

Experimental Details

This experiment was performed according to the following scheme:

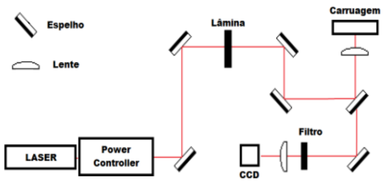

Figure 2: Experimental Setup

In this scheme, the mirrors and lenses control the conduction of the beam, whereas the motor controls the execution of the writing.

A half wavelength blade was used to rotate the bias of the 180 ° beam, and two polarizers to divide the bundle according to the type of polarization (s and p). For writing the polarized beam s was used.

The laser had to be aligned, which was not an easy task. To align it, the following steps were followed:

1) First align the mirrors, trying to make them look at 45º, starting with what is closest to the laser, always taking into account that the beam must be completely parallel to the table. For this a piece of paper was used to verify that the beam always reached the same mark.
2) Finally, the lenses were placed so that the beam passes through its centers.

All this process is done with the laser at a low power so as not to burn the sample nor the chamber.

The carriage is used to make the XYZ calibration. In XY it is relatively easy, however in the Z direction it is more complicated because we do not have a notion of depth.

Throughout the experimental activity, eye protection was used and the area was isolated from the experiment so as not to injure anyone not connected to it, as the laser intensity is quite high and can cause severe eye damage.

All parameters used in the experiment, such as signal frequency and sample rate were controlled by LabView.

Optical Spectrum Analyzer (OSA) was also used to observe the emission spectra, varying the power of the laser.

Results and Discussion

Using a more common Bragg wavelength in telecommunications, λ=1550nm, a refractive index of the fiber, n=1,447 at a write speed, v=20µm/s and using the following ratio:

$$\Lambda = \frac{v}{f}$$

It was concluded that the laser should be modulated with a frequency given by f=37Hz.

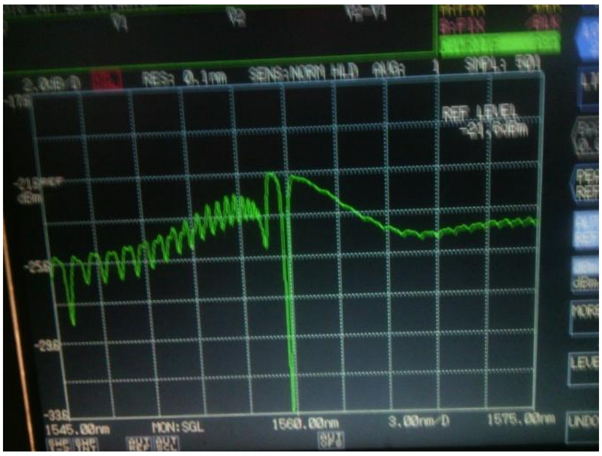

Figure 3: Result obtained in OSA

Through this result obtained in the OSA, it is verified that the lower the power, the more precise is the Bragg wavelength, and that the reflection peak decreases in intensity, as expected.

I also visualized, through the camera, that when the power is reduced, the network becomes more and more uniform.

Conclusion

With the realization of this experience, I had a more direct contact with an Optics technique, direct writing of femtosecond laser in fiber, a technique that is still in development.

I got an idea of the physical mechanisms that this technique involves, as well as its difficulties. One of the great adversities is the alignment of the laser and its calibration process, because if these two processes are not done with the utmost care, the respective writing on the optical fiber will not be done successfully.

It can be concluded that the results obtained were good, because they are within what was expected, although some observed phenomena are still to be explained, which is normal, since this technique is still in the development phase.

References

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