# MANUFACTURING OF THE FIBER BRAGG GRATINGS

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**ABSTRACT**

This article describes the manufacturing of the fiber Bragg gratings. Fiber Bragg gratings represent the changes of refractive index in the core of the optical fiber. The manufacture of the fiber Bragg gratings is based on the exposure by the laser light beam. For the manufacture is used the interferometric method, point by point method and phase mask method. One of these methods will be used to fabrication of the fiber Bragg grating for the stabilisation of laser diodes. The main aim of this article is comparing these methods and the selection of the optimal method to fabrication of required FBG (Fiber Bragg Grating).

## 1 INTRODUCTION

The fiber Bragg gratings has become very important components in optical applications. Because they have several unique properties, they can be used, e.g. for stabilization of lasers, filtering in telecommunications and for sensor applications. Bragg grating is basically the band-pass filter which represents the phase grating. This filter reflects the wavelength accordant with Bragg condition and transfers the others. Fiber Bragg gratings are represented by the fiber with the refractive index changes in the core. Gratings with highest quality were made by the UV laser beam over the last years. During the exposure by the laser beam is formed the change of the refractive index with spatial period $\Lambda$. Refractive index of fiber grating in the fiber core is like distributive mirror. The wavelength of the light beam, which is reflected with the maximum effect, is called tuned Bragg wavelength $\lambda_{Bragg}$. Equation describes the spatial period and Bragg wave-length depends on effective refractive index of distribution medium $n_{eff}$:

$$\lambda_{Bragg} = \frac{2 \cdot n_{eff} \cdot \Lambda}{N} \tag{1}$$

Where $n_{eff}$ is effective mode index of grating, $\Lambda$ is spatial period, and $N$ is count of refractive index changes of FBG with the spatial period $\Lambda$.

Effective mode index of grating depends on diffusion constant $\beta$ and on the wave-number of vacuum $k$:

$$n_{eff} = \frac{\beta}{k} \tag{2}$$

The spatial period $\Lambda$ of FBG can be proposed to obtain of wide spectrum of wavelength.

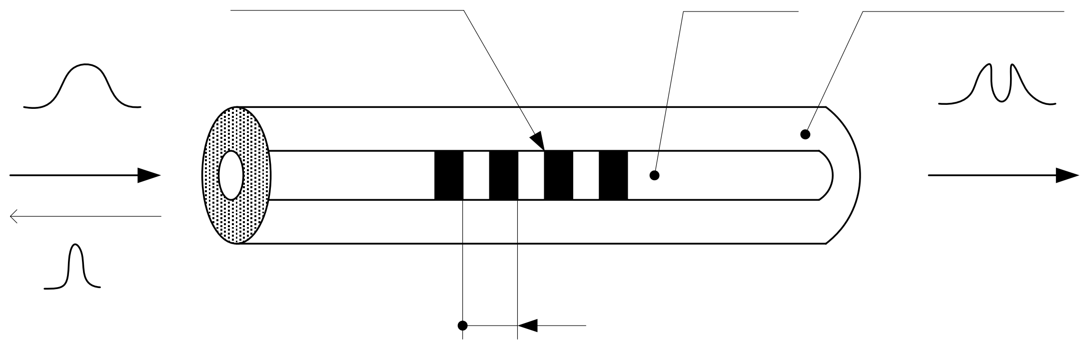


**Fig. 1:** *Schematic description of the fiber Bragg grating (where $\Lambda$ is spatial period of FBG, $\lambda_{Bragg}$ is the Bragg wavelength)*

## 2 FABRICATION TECHNIQUES

Most of methods intended to fabrication of fiber gratings are used to exposure of the fiber the UV laser light. Several methods of the writing processes are used for FBGs creating. Methods, which are used to the creating of required FBGs, are called Off-line methods. These methods are used after the optical fiber fabrication. The Off-line methods contain three main techniques: The interferometric technique, the point by point technique and the phase mask technique. Each of technique has own advantages and disadvantages.

### 2.1 THE INTERFEROMETRIC TECHNIQUE

This technique is based on the interferometer which splits the incoming laser beam into two beams and then recombines them to form an interference pattern. The interference pattern induces a refractive index modulation in the fiber core with the same spatial periodicity as the interference pattern [1].

Obtaining of very high refractive index changes is depended on the high contrast and stability of the interference pattern. The spatial period $\Lambda$ is related with the writing wavelength on the basis of equation:

$$\Lambda = \frac{\lambda_{UV}}{2\sin(\theta/2)} \tag{3}$$

Where $\lambda_{UV}$ is wavelength of the basic laser beam, $\theta$ is the intersecting angle between two writings beams (Shown in fig. 2).

By changing the intersecting angle $\theta$ between the two writing beams, having a wavelength equal to $\lambda_{UV}$, it is possible to write Bragg grating for almost any wavelength. This method offers a good flexibility for producing gratings of different lengths [1].

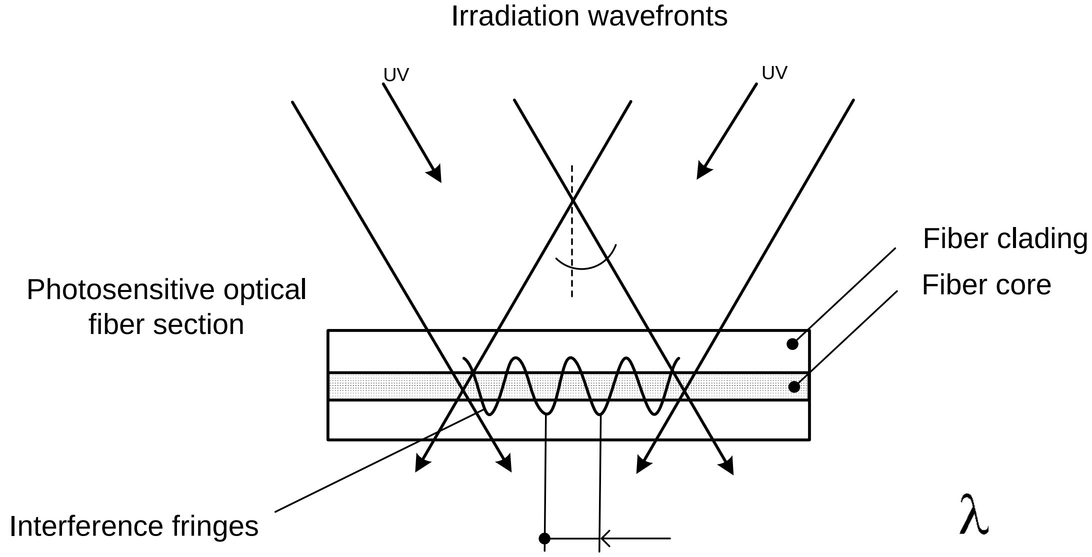


**Fig. 2:** *Interference fringes induced by two interfering UV beams (where $\lambda_{UV}$ is wavelength of the basic laser beam, $\theta$ is the intersecting angle between two writings beams, $\Lambda$ is spatial period of FBG)*

## 2.2 THE POINT BY POINT TECHNIQUE

In this technique the pulse excimer laser is used to writing the changes of refractive index to the core of the optical fiber.

The change of refraction index is induced along the core of the fiber a step at a time. A single pulse of the UV light from an excimer laser passes through a mask to the core of the fiber containing a slit and thus the refractive index of the corresponding core section increases locally. The fiber is then translated through a distance corresponding to the grating pitch in parallel direction to the fiber axis and the process is repeated to form the grating structure in the fibers core [1].

The main advantages of this technique are the possibilities to locally modify the $\Lambda$ and to realize very long gratings. The main disadvantage is the shift in the axis core direction. This shift must be very accurate. Moreover, it is a long process [1].

## 2.3 THE PHASE MASK TECHNIQUE

This is the widely used technique for reproducible Bragg gratings fabrication. The phase mask is a diffractive optical element that spatially modulates the UV laser writing beam. The phase mask can be formed by holographically or by electron-beam lithography in a high quality fused silica, transparent for the UV writing beam. The advantage of holographic formed phase mask is no stitching error. The stitching error is normally present in the electron-beam formed phase mask. The profile of the periodic grating corrugation is chosen to suppress the zero order diffracted beam to a very small percentage of the transmitted power (less than 5%). On the other side, the diffracted plus and minus first orders are maximized, each containing typically more than 35% of the transmitted power. A near-field fringe pattern is produced by the interference of the plus and minus first-order diffracted beams. This pattern photo induces a refractive index modulation in the core of the photosensitive optical fiber placed in close proximity, immediately behind the mask. At negligible zero order contribution, for fibers aligned parallel to the phase mask, the period of the fringes is one-half of the phase mask period, $\Lambda_{pm}$ [1].

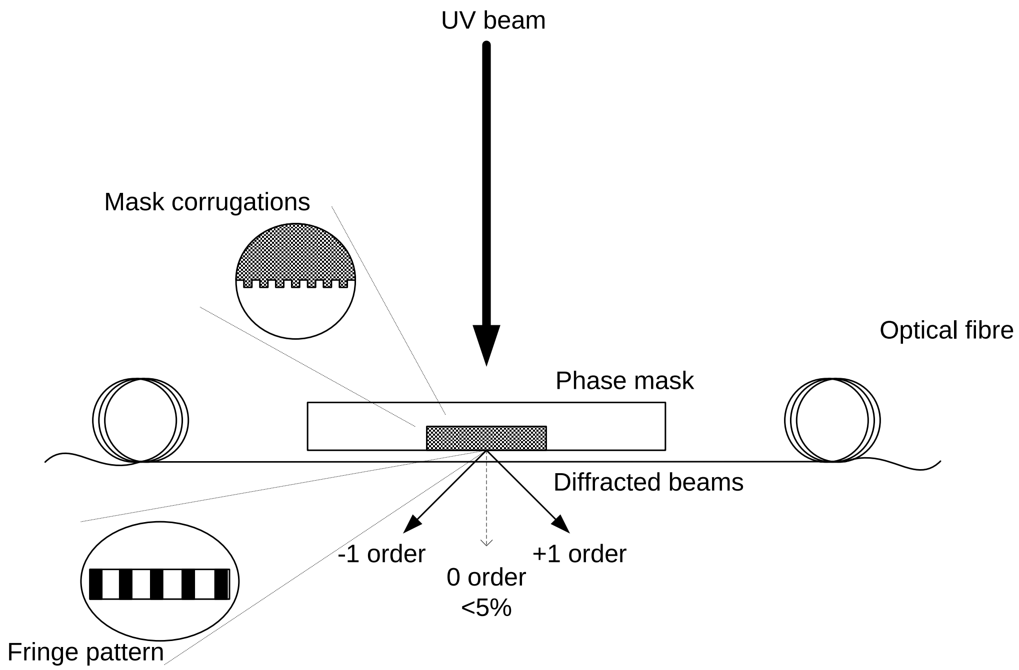


**Fig. 3:** *The phase mask writing technique*

The simplicity of the phase mask writing technique provides a robust and inherently stable method for producing fiber Bragg gratings. Since the fiber is usually close to the mask, the sensitivity to mechanical vibrations and stability problems are minimized [1].

The main disadvantage of the phase mask technique is the need of a mask for each desired Bragg wavelength.

## 3 THE COMPARING OF FABRICATION TECHNIQUES

In the table are presented advantages and disadvantages accordant to the individual fabrication technique. The comparing is the key factor for fabrication technique selection. This technique will be used for fabrication of requested FBGs.

| Fabrication technique | **The interferometric** | **The point by point** | **The phase mask** |
|---|---|---|---|
| Advantages | Good flexibility for producing gratings with different Bragg wavelengths | The possibility to modify $\Lambda$. The possibility to realize very long gratings. | Simplicity of the writing. No sensitivity to mechanical vibrations and stability. |
| Disadvantages | Susceptible to mechanical vibrations and air currents | It is long process. Thermal effect and small variations in the fiber strain can produce errors in the grating spacing | The need of a mask for each desired Bragg wavelength |

**Tab. 1:** *Comparing of the fabrication technique*

The most used fiber Bragg grating writing method is the phase mask technique, because it is the steadiest and the most effective fabrication technique.

## 4 CONCLUSION

From the above described fabrication techniques should be used the point by point method and the phase mask method for the fabrication of FBGs. The masks needed to fabrication can be realized by the electron litograph. This litograph is disposable in Institute of Scientific Instruments Brno as well as lasers needed for FBG fabrication. The fabricated FBGs will be used for the wavelength stabilization of Lasers diodes.

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