Two Beam Interferometric Inscription of UV femtosecond Fiber Bragg Gratings

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The inscription of fiber Bragg gratings with femtosecond laser radiation gives access to a wide range of new materials beyond conventional UV-photosensitive and special hydrogen loaded materials. We have therefore investigated the use of an interferometric technique in combination with UV femtosecond laser pulses to generate fiber Bragg gratings in different types of fibers. Additionally, the tolerances and the limits of the used writing setup are analyzed.

1. Introduction

The demand of writing Bragg gratings in non UV-photosensitive materials is growing, such as, for example, active laser fibers or pure silica photonic crystal fibers. To overcome the limits of conventional UV-techniques, the inscription of Bragg gratings with femtosecond laser sources is an attractive alternative. The most commonly used inscription method with IR and UV femtosecond laser pulses is the phase mask technique [1]. The DUV femtosecond inscription gives access to a direct structuring in nanometer scale of pure silica-glasses [2] and of germanium-free aluminum-silicate glasses. The disadvantage of the phase mask technique is the high degradation of the diffractive element because of strong focusing and the low wavelength versatility which does not allows generation of multiple Bragg wavelengths with one single mask. To overcome this problem we suggest the combination of a DUV-femtosecond laser source and the Talbot-interferometer [3]. This interferometer offers high wavelength versatility [4] and increases the space between the phase mask, used as a beam splitter and the target fiber. This fact allows the use of a focusing lens without putting the phase mask into risk. A simple analytic ray tracing model is used to get insight into the impact of temporal and spatial coherence properties [3]. Writing experiments in several types of fibers are demonstrated.

2. Experimental Setup

The used laser system is a master oscillator (Mantis) and power amplifier configuration (Legend Elite) manufactured by Coherent. The IR 130 fs laser pulse is frequency tripled to a wavelength of approximately 266 nm with an average power of 700 mW and a repetition rate of 1 kHz. The laser beam propagates to a phase mask used as a diffractive beam splitter. The first two diffraction orders are used to generate an interference pattern at the position of the optical fiber after passing two rotating mirrors (Fig. 1). The resulting Bragg wavelength depends on the Bragg angle which results from the diffraction angle of the phase mask and from the angle of the rotation mirrors.

$$\lambda_{FBG} = 2n_{eff} \cdot \Lambda_{FBG} = \frac{n_{eff} \cdot \lambda_{UV}}{\sin(\vartheta_{FBG})} \qquad (1)$$

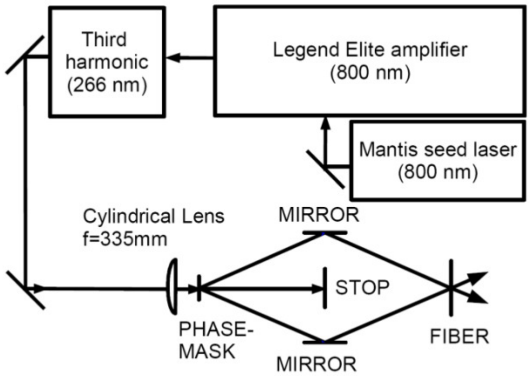

Fig. 1 *Experimental writing setup.*

3. Results

The interferometric writing setup is limited by the spatial and temporal coherence parameter of the UV femtosecond writing laser. With the model from [3] it is possible to identify the spatial and temporal coherence properties of the laser by misaligning the interferometer. One can also measure the coherence parameters of the laser directly by grating writing experiments. The maximum misalignment length of the fiber in the plane of the generated interference pattern is correlated with the spatial coherence length and could be determined to 3.6 mm from the experiments. The temporal coherence length of the writing laser is connected with a misalignment of the two interferometer mirrors and is mainly determined by the short pulse duration. With a special method [3] one can measure the range of the pulse duration by small angle variations of the rotation mirrors. Figure 2 shows the results from the measurements. The grating strength is used as an indicator for good temporal overlap. With an angular tolerance of 0.25 mrad one can calculate the typical UV fs pulse duration as 315 fs. This is in good agreement with an auto-correlation method [3].

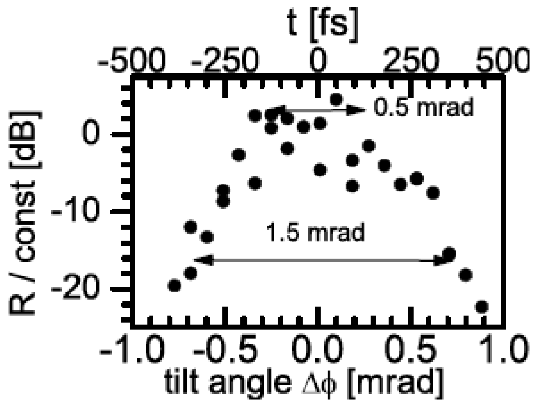

Fig. 2 *Measurement of angular tolerances and of temporal coherence in the interferometer*

With the knowledge of the tolerances one can demonstrate the performance of the interferometric setup by writing multiple Bragg gratings in one fiber. In figure 3, seven different Bragg gratings in the telecommunication C-band (1528 nm- 1565 nm) are generated in single fiber at different positions. All gratings have similar shape and reflectivity and are well suitable for sensor and laser applications.

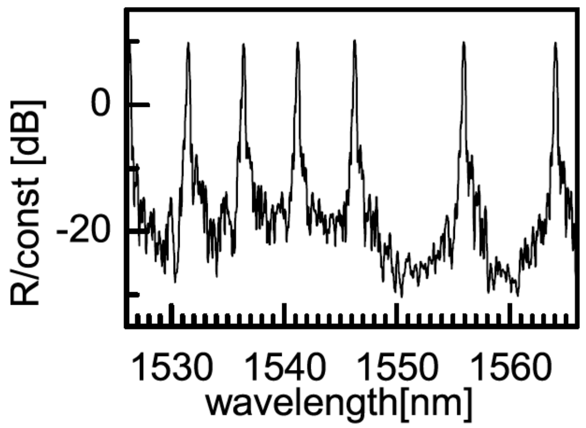

Fig. 3 *Reflection spectra of 7 gratings in one fiber*

To demonstrate the possibility of writing gratings also in undoped pure silica material, fiber Bragg gratings were written in more complex photonic crystal fibers. The fiber is an IPHT made fiber with a diameter of 127 µm, a core diameter of 8.8 µm and a diameter of the holes in the first ring of 5.6 µm. In figure 4 one can see the results of this writing experiment. The generated gratings have a reflectivity of approximately 20% and a spectral width of 0.35 nm

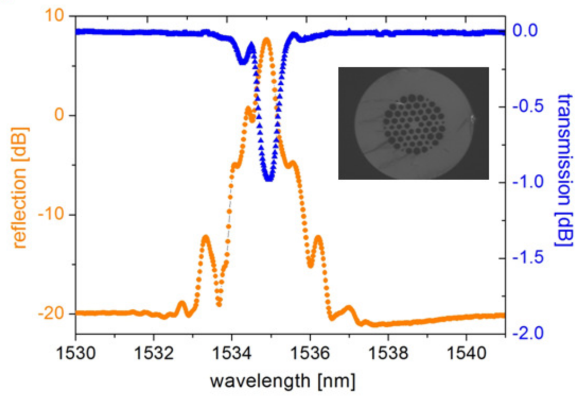

Fig. 4 *Reflection spectra of a Bragg gratings in a pure silica photonic crystal fiber*

4. Conclusion

We have demonstrated the combination of DUV femtosecond laser pulses with a Talbot interferometer setup as a powerful and efficient technique for the generation of fiber Bragg gratings. The tolerances of spatial and temporal coherence of the writing laser were verified in writing experiments. The spatial and temporal coherence length could be determined indirectly by the analysis of the grating strength of inscribed gratings. The wavelength versatility of the setup was demonstrated over the whole telecommunication C-Band. The generation of gratings in non photosensitive pure silica photonic crystal fibers was successfully demonstrated.

5. Acknowledgements

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References

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