High-reflectivity draw-tower fiber Bragg gratings—arrays and single gratings of type II

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Abstract. Fiber Bragg gratings (FBG) were manufactured during the fiber drawing process [draw tower grating (DTG)] with excellent reflectivity values. This was done in the region of 1550 nm by single pulses of a 248-nm excimer laser applied during the fiber drawing process of single mode fibers. An improved setup for the writing process and special photosensitive fibers enable the manufacture of type I DTG arrays with a reflectivity of up to 40% and type II DTGs with a reflectivity near 100%. Details of the setup and results of the DTG arrays and DTGs of type II are reported. [DOI: 10.1117/1.1927517]

Subject terms: fiber Bragg grating; single pulse grating; type II grating.

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1 Introduction

Early work showed the ability to make single FBGs by a transverse holographic method.[1] The large quantity of single pulse photosensitivity in typically Ge-doped or B-/Ge-codoped fibers allows the creation of gratings with one excimer laser pulse only.[2,3] With the single pulse writing technique one can also make the gratings directly during the fiber drawing process.[4]

Experiments in the 800-nm region provided a reflectivity of 26% for 2-cm-long gratings, and a reflectivity of up to 10% in the 1550-nm region was expected.[5] The DTG writing technology was developed during the last 10 years in close connection with the development of highly photosensitive preforms,[6] leading to a reflectivity of up to 20%. All improvements for the writing process together made it possible to inscribe type I DTG arrays with a reflectivity of up to 40% and type II DTGs with a reflectivity near 100%, without the big irregularities in their optical spectra[7] that up to now prevent their use as a sensor element. The possibility to make such high-reflectivity, narrow-linewidth type I DTGs expands their application as distributed sensor elements, also by easier coupling to existing analyzing processor units.

The aim of finding competitive fiber sensors stimulated our investigation into type I DTG arrays and DTGs of type II.[8] DTGs have a tensile strength similar to that of standard telecommunication fibers,[9,10] which makes it possible to handle DTGs like a normal fiber.

2 Experiments

The preforms for the wavelength region of 1550 nm are designed with a moderate germanium content of about 15 mol % and are made under special collapsing conditions (helium atmosphere). With this process a very high UV photosensitivity is achieved for the fiber. Because of the longitudinal speed of about 10 m/min during the fiber drawing process, only one UV laser pulse per grating can be applied. Single or arrayed DTGs were written in the dynamic way during the fiber drawing process. A KrF excimer laser (Compex 150 T, Lambda Physik, emission wavelength 248 nm) in connection with a Talbot interferometer is used to write the DTGs, which have their Bragg wavelength in the region of 1550 nm. The pulse energy of the laser is approx. 200 mJ at a beam size of approx. 8×22 mm. The quality and reproducibility of such DTGs strongly depends on the pulse energy equability and on the beam coherence. The laser was modified to improve the laser beam quality, e.g., high pulse energy, pulse equability, and homogeneous energy distribution.

To focus the laser beam, a cylindrical lens (focal length of approx. 51 cm) was assembled at a two-axis linear positioning stage. One axis controls the distance of the lens to the fiber, the second axis controls the position of the fiber perpendicular to the beam. The focus lens was placed approx. 43 cm in front of the fiber, which gives an energy density of approx. 0.8 J/cm^2 at the fiber. This was chosen for writing type I DTG arrays with a reflectivity of up to 40%. For writing type II DTGs, the focus lens was placed approx. 49 cm in front of the fiber to achieve an energy density of approx. 2 J/cm^2 at the fiber. The length of the gratings was 6 mm.

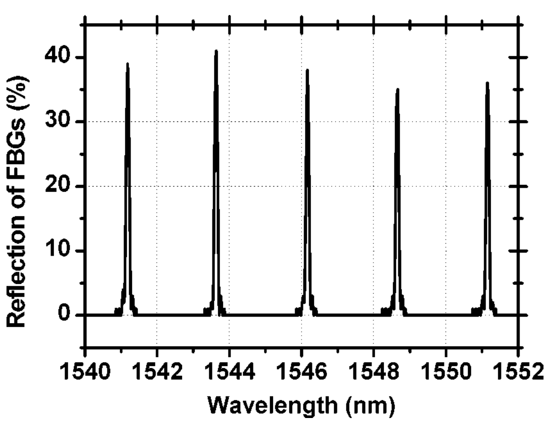

Fig. 1 Reflection spectrum of a DTG array with 5 FBG.

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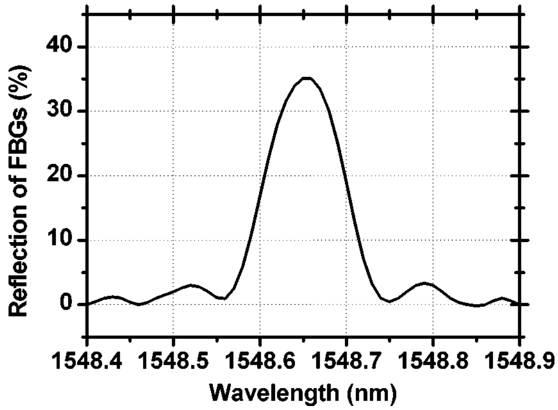

Fig. 2 Reflection spectrum of one DTG of the five-grating array.

3 Measurements and Results

Figure 1 shows the reflection spectrum of a DTG array sample of five gratings with predetermined wavelength and spatial distance. The Bragg wavelength can be changed by an adjustment of the tuning mirrors and the whole interferometer during the fiber drawing process. In this case, a spectral interval of 2.5 nm and a spatial distance between the DTGs in the fiber of 30 mm was chosen. The achieved reflection values are in the range of 35% to 40%. These are very high values for single pulse grating reflectivity with low variation in reflectivity, which points to small adjustment errors and high pulse-to-pulse energy reproducibility. Beside the high reflectivity values, the DTGs show a very smooth spectral shape with small side lobes (Fig. 2).

In addition to the type I DTG array, DTGs of type II were written. The high-energy density of the focused laser beam led to structural changes of the core and the adjacent cladding (Fig. 3), which can be observed with a light microscope. The structural changes are independent of the azimuthal observing direction. A transmission spectrum of a single DTG of type II with a spectral width of approx. 1 nm and a reflectivity near 100% is shown in Fig. 4. The optical spectrum is smooth compared with known spectra of type II gratings.

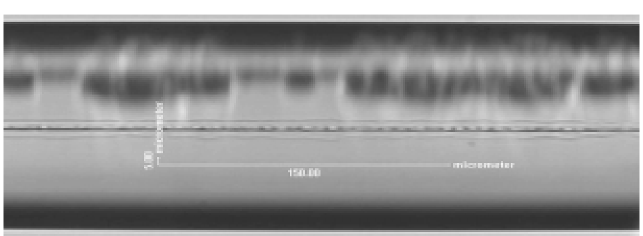

Fig. 3 Microscopical view of structural changes of core and cladding within the Bragg grating region.

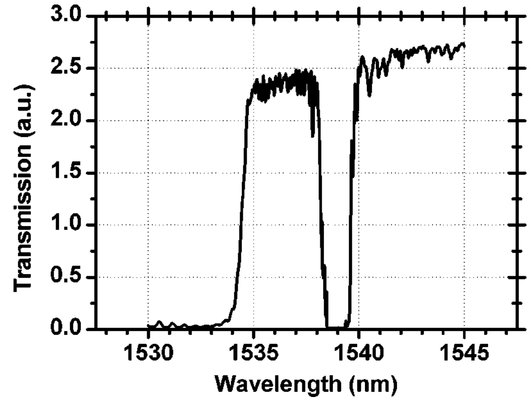

Fig. 4 Transmission spectrum of one DTG of type II.

4 Conclusions

We have shown the realization of draw tower Bragg grating arrays with high reflectivity up to 40% during the fiber drawing process using a KrF excimer laser and Talbot interferometer set up under accurate adjustment. We also realized DTGs of type II with a reflectivity near 100% and smooth spectral behavior. These gratings are very useful elements for optical sensing applications such as strain gauges, vibration sensors, and high-temperature sensors up to about 800 °C.

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