Introduction

- Optical fiber gratings have been widely employed in optical communications and modern fiber sensors. Fiber sensors with fiber Bragg gratings (FBGs) are often used in temperature or strain sensing applications.
- Focused ion beam (FIB) techniques can be used to fabricate novel optical fiber gratings. By sputtering out molecules of the fiber with accelerated ions, holes or cavities in the nano- or micro-scale can be formed.
- In this work, we focus on developing fiber grating structures on single-mode optical communication fibers (SMFs), using FIB. We first fabricate a Fabry-Perot (FP) cavity, which is the building block element for gratings, and we then fabricate a long-period fiber grating (LPFG) structure.

Potential Applications

When a FP Cavity is placed within a fluid, molecules passing through the cavity can cause a change in the transmission and reflection spectra, due to the difference in the refractive index (RI) and/or absorption. Through this effect, the presence of these molecules can be detected if the RI is known. Alternatively, the RI can be calculated from the altered spectrum for an unknown substance.

Long-period fiber grating structures can be used as biosensors, since biomolecules can be placed inside the cavities. These molecules can be designed to have strong interaction with the external field. Once the target material has a biological or chemical reaction with the acceptor molecules, the internal field distribution in the fiber core will change accordingly.

Fabry-Perot Simulation Results

- 2D FDTD computations
- Source: 1.40 to 1.85 µm
- \( n_{\text{cladding}} = 1.4615 \)
- \( n_{\text{core}} = 1.4682 \)
- Cavity RI between 1 and 2
- Trapezoid-shaped cavity

- Transmittance of the FP cavity depends on the refractive index.
- This structure can be used as a RI-shift sensor, allowing the detection of a known material through the cavity.
- Sensitivity to RI increases for larger index contrasts (between core and cavity).

Conclusion

- We demonstrate the feasibility of fabricating grating structures on single-mode fibers using focused ion beam.
- These structures are based on Fabry-Perot cavities with high aspect ratio (about 4:5:1).
- A single FP cavity can also be used, depending on the desired applications.
- During the FIB milling process, secondary effects (such as redeposition) have a large impact on the final cavity sidewall profile, which influences the overall performance of the structure.
- The sputter yield is the key factor of the fabrication in terms of time and quality.
- Better sputter yield can be achieved by using gas assisted etching.

Fabrication Details

- The protective polymer layer of an SMF is physically removed, exposing the cladding.
- It is then placed on a scanning electron microscope (SEM) sample holder with conductive carbon tape.
- The FIB tool used in this experiment is an FEI Quanta 3D FEG Dual Beam.
- High voltage: 30 keV; current: 50 nA; beam-spot diameter: about 300 nm.
- The etching process is split into several sequential partial steps.
- The pattern is initially set to be a 25×25 µm² square.

- The top opening is about 28 µm, and the bottom opening about 6 µm.
- Aspect ratio is about 4.5:1.
- V-shaped profile is created due to secondary effects.
- Roughness of the sidewall caused by redeposition of sputtered material.
- Lateral dimension is about 12% larger than desired.

Long-Period Fiber Grating

- LPG formed by 10 partially-etched cavities.
- The top opening dimension is about 28 µm, and the period A is about 30 µm.

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