Fabrication of a Binary Phase Grating on a Fiber End by Utilizing Interference Lithography

Ching-Tung Tseng, Shih-Chieh Lin, Yung-Pin Chen, Yang-Kai Wu, Yi-Chuan Tseng, and Lon A. Wang

Department of Electrical Engineering and Graduate Institute of Photonics and Optoelectronics, National Taiwan University, Taipei 106, Taiwan, Republic of China

lon@ntu.edu.tw

Recently the fabrication of micro and nano structures on fiber ends has attracted a lot of interests because various applications could then be developed such as wavelength division multiplexing (WDM) [1], optical coupling [2], beam shaping [3], etc. Here we demonstrate the fabrication of a binary phase grating (BPG) on the facet of an optical fiber and its potential for mass production.

In the process, one-end cleaved fibers are inserted into a capillary tightly, which is then placed inside a quartz cylinder. A few drops of epoxy gel are used to glue together the capillary, the fibers, and the quartz cylinder after being heated. Then the uncleaved fiber ends at one facet of the quartz cylinder are polished. Afterwards a layer of SiO_2 is sputtered on the polished facet, and followed by standard anti-reflection and photoresist coatings. Then, two-beam interference lithography with 364 nm wavelength from an argon-ion laser is utilized to make 730-nm-period 1-D grating patterns. By properly adjusting the parameters, BPG is eventually transferred to the SiO_2 layer as shown in Fig. 1.

To couple laser light with wavelength 364 nm, a UV-SMF is chosen and spliced with a 1550 nm-SMF with which the fiber equipped with BPG on top is connected. Laser coupled into UV-SMF is diffracted by the BPG at the fiber end. The measured power intensity ratio of $\pm 1^{st}$ to 0^{th} diffraction beams is 10:1 in which $\pm 1^{st}$ diffraction beams are the light source of two-beam interference lithography. The simulated interference patterns resulted from 0^{th}, $\pm 1^{st}$ diffraction beams with different gaps from BPG to exposure plane and different power intensity ratios are shown in Fig. 2. It is shown that only when the gap is less than 5 μm and the power intensity ratio of $\pm 1^{st}$ to 0^{th} is large enough will the interference fringes have good contrasts. The preliminary result of 1-D grating fabrication by employing the fiber equipped with BPG is shown in Fig. 3 after fine tune of the gaps. The diameter of the exposure grating area is 9 μm, and the period is around 364 nm, which verified the effect of BPG, i.e. the resultant halved period from the original is obtained.

The sputtered SiO_2 layer on the polished facet is to avoid direct contact of RIE plasma with epoxy gel which will lead to undesired surface roughness. Such sputtering step can be omitted if epoxy gel is substituted with acid soluble glass, for its etching properties are similar to fiber glass.

In conclusion, a novel method of fabricating BPGs on facets of several fibers simultaneously is presented. The result of 1-D grating of period 364 nm proves the concept and implicitly indicates the possibility of mass production.

[1] Shin, W., et al., *Microstructured Fiber End Surface Grating for Coarse WDM Signal Monitoring.* Photonics Technology Letters, IEEE, 2007. **19**(8): p. 550-552.

[2] Feng, S., et al., *Fiber coupled waveguide grating structures.* Applied Physics Letters, 2010. **96**(13): p. 133101-3.

[3] Cojoc, G., et al., *Optical micro-structures fabricated on top of optical fibers by means of two-photon photopolymerization.* Microelectronic Engineering. **87**(5-8): p. 876-879.

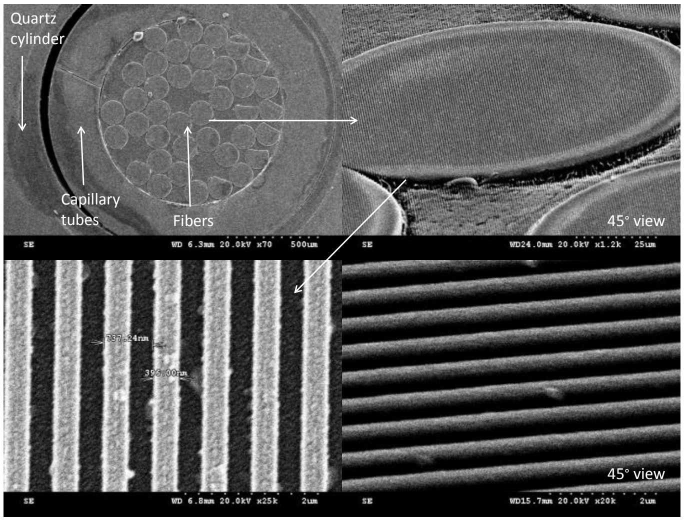

Fig. 1 SEM images of the SiO_2 BPGs on the top of fibers with increasing magnifications.

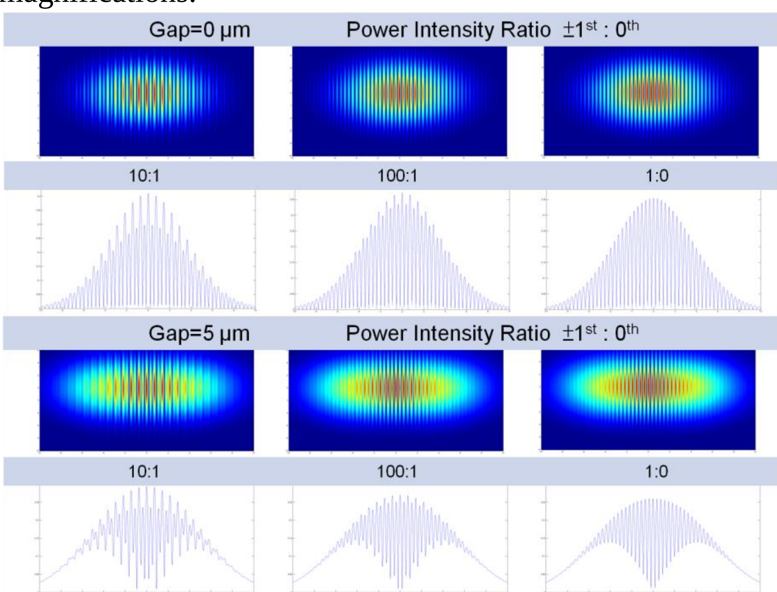

Fig. 2 Simulated results of two-Gaussian-beam interference with different gaps form BPG to exposure plane and varied power intensity ratios of 0^{th} to $\pm1^{st}$ diffraction beams.

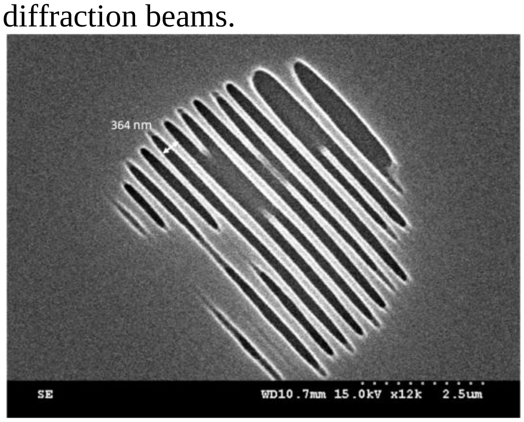

Fig. 3 SEM image of photo-resist grating obtained by two-beam interference from a BPF equipped fiber.