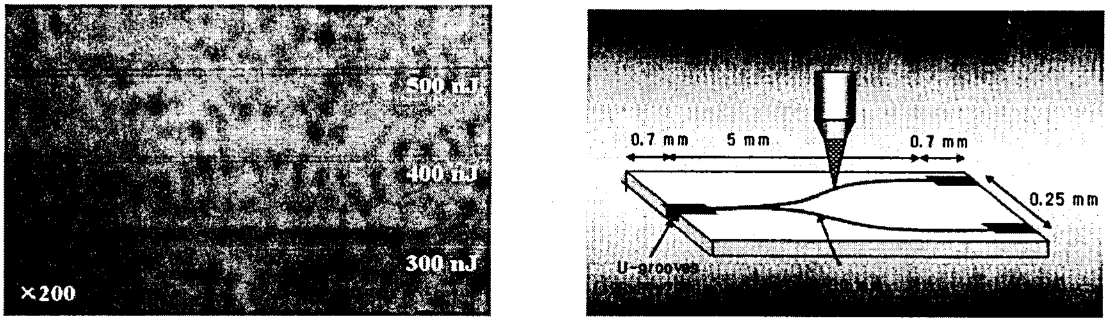
펨토초 레이저를 이용한 3차원 광소자 제작
Fabrication of three-dimensional optical devices by using a femtosecond laser

손익부, 김택중, 이만섭, 우정식*, 이상만*, 정정용*
한국정보통신대학교
*(주)포코
ibson@icu.ac.kr

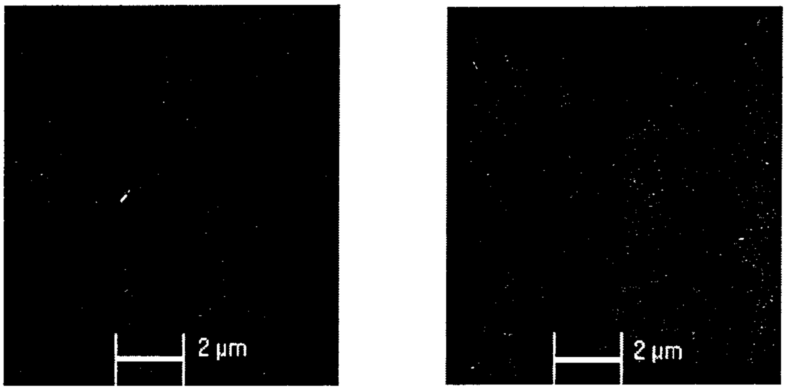
In recent years, using infrared fs lasers to induce a change in refractive index by the multi-photon absorption process in transparent materials has been widely investigated. The application of the fs laser provides a new technique for making three-dimensional integrated photonic structure in various glasses. This technique has been applied to fabricate photonic structures, such as passive optical waveguides in a variety of glasses [1], gratings [2-3], and coupler [4-5]. Here we report the fabrication of the waveguides and optical device by use of a Ti:Sapphire laser.

Using 1-kHz pulse trains of 100-fs laser pulses focused by a 0.42-NA microscope objective, the waveguides were written inside a slab of transparent material about 300-μm beneath the surface of the sample with different laser power of 300, 400, and 500 nJ as shown in Fig. 1(a). We translate the sample at a speed of 10 μm/s in a direction perpendicular to the axis of the fs laser beam and then resolidifies after being moved away from the laser focus. It can be observed that the diameter of the cross section increases with the in-creasing pulse energy of the fs laser beam and is independent of the moving speed of the sample. A schematic diagram of the 1×2 optical splitter is presented in Fig. 1(b). The length of the splitter is 5 mm, and the separation of the two branches is 0.25 mm. The optical splitter was fabricated by fs laser pulses inside fused silica glass with a pulse energy of 400 nJ and scan speed of 10 μm/s. The laser beam was guided into a micro-scope and



(a) (b)

그림 1. Fig. 1 Optical micrograph of (a) waveguides and (b) optical splitter written inside fused silica glass using a 1 kHz, and 100 fs pulse train focused with a 0.42 NA microscope objective.



(a) (b)

Fig. 2 Microscope image of a 2-μm period line and dot gratings directly written inside fused silica with 320 nJ pulse energy. Line width and dot diameter are 0.5 and 0.7 μm, respectively.

focused by a 20x objective (NA, 0.42) into the core. To examine the guiding properties of the optical splitter, we coupled a 1550 nm laser beam into input channel of the optical splitter and imaged the output onto a CCD camera. The splitting ratio of the optical splitter with length of 5 mm is approximately 1:1. Figure 2 show the microscope image of 2-μm period line and dot gratings directly written inside fused silica with 320 nJ pulse energy and a 50× microscope objective as the focusing lens. Line width and dot diameter are 0.5 and 0.7 μm, respectively. Each line and dot represents the optical modification inside the glass in the region of the focus of laser pulses. Only a single scan was performed for each grating line.

In conclusion, the fs micromachining technique is a novel means of fabricating silica PLC devices; it is simple and produces accurate passive alignment. It will also investigate to fabricate photonic structures, such as three-dimensional optical storage and photonic crystals.

참고문헌

1. Miura, J. Qiu, H. Inouye, T. Mitsuyu, and K. Hirao, "Photowritten optical waveguides in various glasses with ultrashort pulse laser," Appl. Phys. Lett., 71, pp. 3329-3331, 1997.
2. M. Li, M. Ishizuka, X. Liu, Y. Sugimoto, N. Ikeda, and K. Asakawa, "Nanostructuring in submicron-level waveguides with femtosecond laser pulses," Opt. Commun., 212, pp. 159-163, 2002.
3. D. Grobnic, C. W. Smelser, S. J. Mihilov, R. B. Walker, and P. Lu, "Fiber Bragg gratings with suppressed cladding modes made in SMF-28 with a femtosecond IR laser and a phase mask," IEEE Photon. Technol. Lett., 16, pp. 1864-1866, 2004.
4. A. M. Streltsov and N. F. Borrelli, "Fabrication and analysis of a directional coupler written in glass by nanojoule femtosecond laser pulses," Opt. Lett., 26, pp. 42-43, 2001.
5. L. Gui, B. Xu, and T. C. Chong, "Microstructure in Lithium Niobate by use of focused femtosecond laser pulses," IEEE Photon. Technol. Lett., 16, pp. 1337-1339, 2004.