

Femtosecond laser micromachining: Applications in Technology and Biology



Eric Mazur*

Department of Physics and Division of Engineering and Applied Sciences,
Harvard University, Cambridge, MA 02138, USA

When femtosecond laser pulses are tightly focused into a transparent material, the intensity in the focal volume is high enough to cause absorption through nonlinear processes. The absorption of the laser energy excites a submicrometer-sized region of plasma inside the material, and the energy is subsequently transferred to the atoms in the form of heat and shock waves. This process permanently alters solids and ablates cellular structures in biological media [1]. Applications include high-density data storage in three dimensions, writing of waveguides and waveguide splitters in bulk glass, fabrication of micromechanical devices in polymers, and subcellular nanosurgery in vivo.

Irradiation of fused silica with focused pulses of 300-500 nJ records data in submicrometer-sized regions of increased refractive index. We have demonstrated 2- μm in-plane bit spacing and 15- μm interplane spacing (17 Gbits/cm³) [2]. Optical devices such as waveguides (see Figure 1), gratings, splitters, and couplers are machined in glass by translating the sample during irradiation. Preliminary experiments fabricating waveguides in poled polymers indicate it might be possible to micromachine a tunable electro-optic switch or nonlinear wavelength conversion device.

Pulses focused into biological samples ablate structures with submicrometer resolution and no collateral damage [3]. Actin stress fibers retract upon severing, indicating that they are under tension in a cell. Another experiment examines the thermotactic circuit of the nematode worm *C. elegans*. Severing neuronal fibers (see Figure 2) and ablating cell bodies disrupts their contribution to behavior, thus permitting identification of their role.

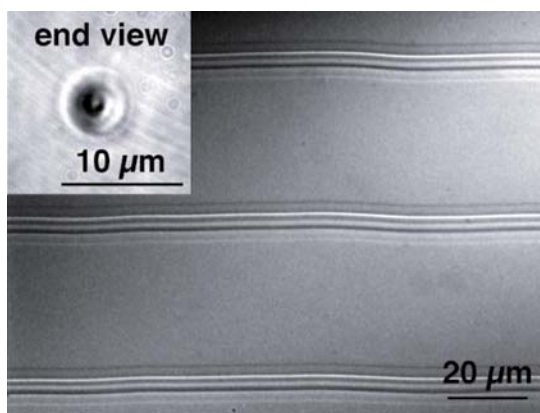


Figure 1: Microscope image of optical waveguides written using femtosecond laser micromachining technique.

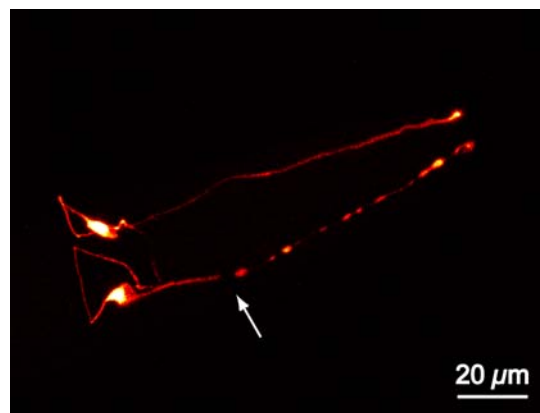


Figure 2: Confocal microscope image of thermosensory neurons in worm nose. Lower neuron severed with 3.2-nJ pulses.

[1] E.N. Glezer, and E. Mazur, *Appl. Phys. Lett.* **71**, 882 (1997).

[2] E.N. Glezer, *et al.*, *Opt. Lett.* **21**, 2023 (1996).

[3] N. Shen, *et al.*, *Mech. Chem. Biosys.*, in press.