Femtosecond Laser Nano-Scissors in Nerve Regeneration Studies

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It is now well established that femtosecond laser pulses can initiate material ablation at much lower fluences than nanosecond or longer laser pulses. Thanks to low ablation threshold levels associated with femtosecond lasers, it is now possible to perform nanosurgery inside living organisms and cells with high repeatability. We have recently demonstrated the feasibility of a high precision femtosecond laser nanosurgery inside a living organism; a 1mm length warm called *C. elegans* [1]. We succeeded in cutting single axons inside *C. elegans* with pulse energies of only 10-40 nJ, 200 fs short laser pulses and observed functional regeneration of operated axons following surgery. We were able to cut individual axons with proximity of a few microns to each other without damaging the nearby axons (see Fig.1). At these low energies, mechanical effects due to plasma expansion and shock waves are expected to be significantly reduced with respect to conventional laser surgery techniques that require much higher energies (e.g. 0.4 μJ with 0.5 ns pulses). Furthermore, the use of low repetition rate pulses (1 kHz, 10 μW average power) reduces heat accumulation and extended thermal damage to the environment. This non-invasive technique keeps the surrounding tissue of the operated axon functional and thus allows the severed axons to regrow and more remarkably to recover their functionality. This precise surgical technique opens for the first time experimental access to study *in vivo* nerve regeneration in its evolutionarily simplest form. A movie demonstrating the behavioral response of an axotomized worm following axotomy is available at www.me.utexas.edu/ben-yakar.

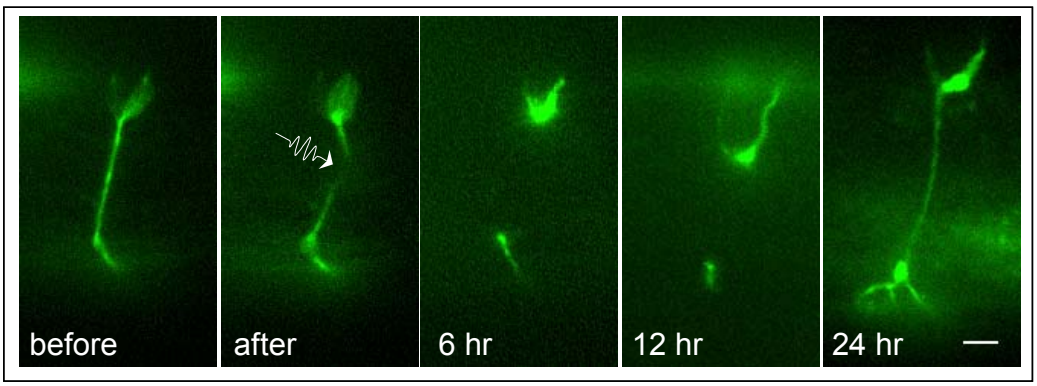

Fig. 1. Nerve regeneration after femtosecond laser axotomy in live *C. elegans*. 100 pulses with 40 nJ energy and 200 fs short duration at 1 kHz repetition rate are used. Fluorescence images of GFP labeled axons before, after, and following axotomy. Scale bar is 5 μm.

[1] M. F. Yanik, H. Cinar, H. N. Cinar, A. Chisholm, Y. Jin, and A. Ben-Yakar, "Neurosurgery: Functional Regeneration after Laser Axotomy" Nature 432, 822 (2004).

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