All-Fiber Burst Mode Femtosecond Laser System Integrated with OCT for Cataract Surgery

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Cataract condition is responsible for two thirds of preventable visual impairments afflicting nearly 190 million all over the world [1]. Every year, 19 million cataract surgeries are performed worldwide [2]. Femtosecond laser-assisted cataract surgery has entered clinical use in recent years as an efficient and safe alternative to the traditional method. However, this laser-assisted surgery is in its infancy period and would benefit from lower pulse energies (to minimize collateral effects), shorter operation durations, and more compact laser systems. Fiber lasers can address these requirements with their robustness, compact size and minimal-alignment requiring structure. Further, burst mode operation [3], where high repetition rate pulses are delivered in packets repeated at a relatively low rate, have been shown to produce efficient ablation with minimal collateral thermal effects [4]. Here, we demonstrate the first fiber based burst-mode femtosecond laser device for cataract surgery. The laser is coupled to an optical coherence tomography (OCT) system with computerized controls (Fig. 1(a)). A home built all fiber Yb laser amplifier is seeded by a 109-MHz fiber oscillator, followed by a double-clad preamplifier, acusto optic modulator (AOM) pulse picker and a double-clad power amplifier. An FPGA based electronic system triggered by the oscillator is used to impose the desired pulse train on the laser beam. The system is able to produce pulses in the 5-10 μJ range compressible to sub-500 fs. The imaging and tissue processing functions are executed with OCT monitoring, using its galvo scanner and a common beam path. Maximum imaging depth is 1.6 mm with 8 μm axial resolution. The galvo scanner can reach a scan speed of 1 m/s with any desired scanning pattern. In our preliminary experiments, bursts comprising of 8 pulses with 3 μJ per pulse at 50 kHz burst repetition rate were applied to agar jells (Fig. 1 (b)), which have optical response similar to that of the cornea, as well as cornea obtained from cow eyes. Smooth cuts on *ex vivo* cow cornea by raster scan pattern with 70% overlapping spots (Fig 1. (c)) and on agar jells with non-overlapping spots pattern (Fig 1. (d)) were obtained. Agar and *ex vivo* cow eye trials show that we can create incisions with different patterns below the surface, in addition to dotted patterns for corneal incision and smooth lines for capsulorhexis.

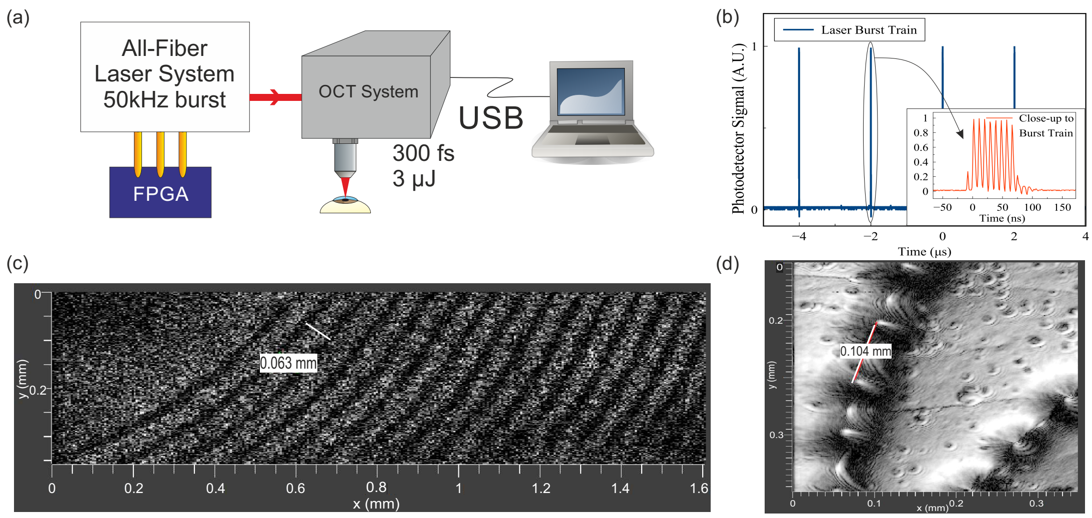

Fig. 1 (a) Laser integrated with OCT. PC controls scanner and gets images from the OCT. (b) Pulse train with bursts. (c) Raster scanning with 1 μJ per pulse on cow cornea bursts. (d) 3 μJ per pulse energy on agar, arch scans with bursts.

In summary, a femtosecond burst mode all-fiber Yb laser amplifier is demonstrated for the first time and integrated with OCT. We show preliminary results with agar and *ex vivo* experiments on cornea. The system will ultimately be able to create corneal incisions, capsulorhexis and lens fragmentation using a single laser with a common optical path for laser processing and *in-situ* imaging.

References

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