Non-thermal Material and Tissue Processing with 100 MHz and 500 MHz Repetition Rate Bursts

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There are a number of applications that would avail a pulse pattern in the form of closely grouped and uniformly spaced pulses, i.e., bursts [1]. Closely grouped pulses with pulse to pulse separation in the order of a few nanoseconds have a potential for increasing material removal rates [2] and thereby reducing the thermal effects. Besides, keeping the burst repetition period in the order of thermal relaxation time has the advantage of keeping the overall average power at lower levels in order to prevent the cumulative heating of the material.

Here, we demonstrate results on ablation efficiency for three different pulse repetition rates for Cu targets and results on human dentine samples to emphasize the detrimental thermal effects for low repetition rate mode. We used custom built Yb fiber amplifier, which produces bursts at an overall repetition rate up to 1 kHz comprising of 25 pulses each with up to tens of μJs of energy, $\sim$1ps pulse duration and intra-burst repetition rate of 100 MHz and 500 MHz (Fig. 1(a)). The system can also produce pulses with 25 kHz uniform repetition rate (not bursts), which we used it for our low repetition rate mode. We kept the individual pulse energy, average power, pulse width, spot size and total number of incident pulses (hence total processing time) strictly constant. Fig. 1(b) shows results obtained on a 100 μm thick Cu targets in ambient atmosphere at room temperature using the three modes of operations, where we have characterized the depth of ablation per pulse. Fig. 1(c) shows results obtained on human dentine, where areas of 1 mm^2 in each sample were raster scanned with scan velocity of 0.1 mm/s.

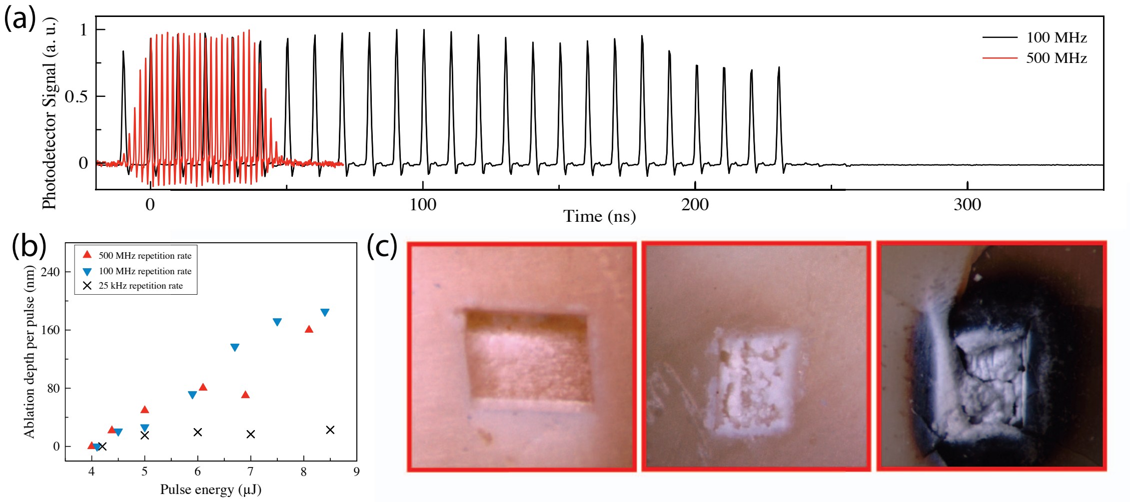

Fig. 1 (a) Experimentally measured temporal profiles of the 100 MHz and 500 MHz pulse bursts. Note that the bursts themselves are repeated at 1 kHz. (b) Comparison of material ablation rate per pulse for copper target using 25 pulses at repetition rates of 25 kHz, 100 MHz, and 500 MHz; showing that ablation per pulse increases by $\sim$6 times at higher repetition rates. (c) Human dentine samples processed using uniform repetition rate of 25 kHz (i), and 25-pulse bursts at 1-kHz burst repetition rate with 100-MHz intra-burst (ii) and 500-MHz intra-burst (iii) repetition rate. Average power, processing time, pulse width, pulse energy, spot size are the same in each case.

In conclusion, we have developed a mJ-level burst-mode integrated fiber amplifier with high in-burst repetition rates, and compressed pulses of $\sim$1 ps. Our micromachining results demonstrate almost an order of magnitude increase in volume of ablated material per pulse at higher repetition rates, along with much reduced thermal effects.

References

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