Influence of MHz bursts on the ablation efficiency of thin metal foils

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Ultra-short pulse laser bursts have attracted a lot of attention in industrial micromachining due to their advantages over conventional laser modes, especially their high ablation efficiency.

In burst mode, a packet of multiple pulses with the same total energy replaces the single pulse with the energy E_p. The main feature is the intra-burst repetition rate within the burst, which is higher than the (inter-) pulse repetition rate of conventional single pulses. Burst-mode lasers usually operate at different repetition rates, either in the MHz or GHz range, with intra-pulse delays in the nanosecond or picosecond range, respectively. The high intra-pulse repetition rates lead to strong heat accumulation, which in turn promotes ablation efficiency. This high ablation efficiency, which cannot be achieved in conventional single-pulse mode, offers considerable advantages in material processing.

Since Kerse et. al [1] introduced ablative cooling, many research groups have investigated the use of GHz bursting in metal processing [3-4]. However, relatively little attention has been paid to the less expensive and more accessible MHz burst mode. This motivates us to investigate the ablation efficiency of the MHz burst mode for industrial applications. In this contribution, we investigate the possibility of using MHz burst lasers (wavelength 1030 and 343 nm, intra-burst repetition rate 40 MHz, and inter-pulse repetition rate 333 kHz) to achieve similar advantages to GHz burst lasers in the processing of metal foils.

Our experimental focus is on measuring ablation efficiency as the material removed per fluence ($\Delta d/F = h/ft/F$), calculated from the foil thickness (h), repetition rate (f), and time to drill through (t). The peak fluence is $F = 2E_p/(\pi w_0)$, where E_p is the pulse energy and w_0 is the beam waist radius. We investigated the ablation efficiency of the MHz burst mode by varying the parameters including the laser wavelength (1030 nm or 343 nm), the material of the foils (SS, Al, Ti, and Cu) with different thicknesses (25µm, 50µm, and 75µm), the pulse durations (300fs - 10ps) and the number of pulses in the bursts (1-43). In addition, the results obtained are compared with those obtained with ns pulses at pulse durations corresponding to the total burst durations.

Our results show the potential of MHz bursts as a viable and cost-effective alternative to GHz bursts for wider use in industrial applications such as laser drilling and micromachining.

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References:

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