Enhancing metal processing efficiency with femtosecond fiber laser: drilling, deep engraving, cutting, and polishing

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Femtosecond lasers play a significant role in modern industrial metal processing due to the outstanding efficiency, precision, and high productivity achieved by scaling average power. The main applications include cutting masks, drilling metal sheets, texturing molds, or engraving with minimized heat-affected zones. However, achieving scalable productivity with increasing average power encounters challenges due to thermal effects arising at high laser repetition rates or spatial pulse frequencies [1]. This research explores methods of process efficiency optimization utilizing an industrial-grade femtosecond fiber laser. Material removal rate can be maximized by tailoring the laser parameters and pulse spatial distribution for particular materials and applications. We investigate ablation efficiency at different wavelengths (1030, 515, 343 nm) and varying pulse duration. We show record ablation rates for stainless steel and titanium alloy. We demonstrate high-quality and full-power deep engraving with a depth of structures above 1 mm without intermediated polishing steps. Besides engraving, a high removal rate can benefit mass spectroscopy and future extraterrestrial mining. As metal processing benefits from using femtosecond pulses below 300 fs, we demonstrate high-speed drilling of thick metal sheets with minimized hole conicity. We investigate the influence of cutting strategy and burst mode on the processing speed, showing a 50% improvement compared to single pulses. We also demonstrate the potential of femtosecond laser in surface polishing. An example of polishing dies for coin minting will be presented. The applied laser source is the fiber laser Jasper X0 (Fluence, Poland), emitting a fundamental wavelength of 1030 nm, with an average power of 20 W, and a pulse duration in the range of 0.25 – 20 ps.

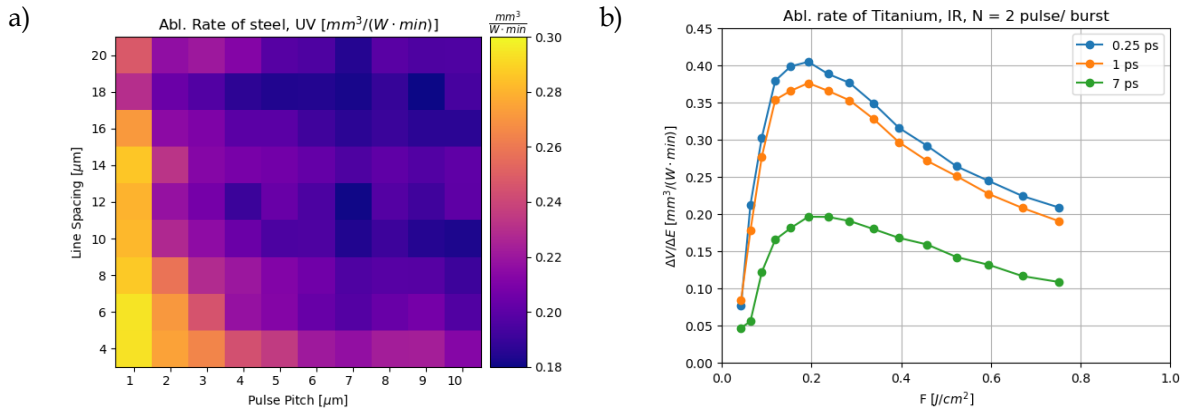

Figure 1. a) Ablation efficiency measured for stainless steel at 343 nm for different pulse spatial frequency; b) ablation efficiency in the laser fluence domain for different pulse duration (Ti6Al4V at 1030 nm)

References: [1] Jaeggi, B., Remund, S., Zhang, Y., Kramer, T., & Neuenschwander, B. (2017). Optimizing the specific removal rate with the burst mode under varying conditions. *Journal of Laser Micro Nanoengineering*, *12*(3), 258-266.