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Extended Abstract

Archives of Physics Research, 2021, 13 (1)
(https://www.scholarsresearchlibrary.com/journals/archives-of-physics-research/)

ISSN 0976-0970
CODEN (USA): APRRC7

High power high repetition rate pulse-periodical lasers

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Apollonov V V is the leading specialist in the area of basic principles of creation and development of high power laser systems and high power laser radiation interaction with matter. He has made an outstanding input into creation and development of new branches of science - physical and technical fundamentals of high power laser optics and adaptive optics, investigation of physical processes in a high volume self-controlled volume discharges, creation of high power continuous wave, pulsed and high repetition rate pulse-periodic laser systems, high intensity laser radiation interaction with matter, high power laser application for an effective protection of valuable objects and water surface cleaning from oil films, medical applications for UV lasers. He is the author of more than 1160 publications, 14 books, 350 presentations and 144 patents. (from Research Gate). He is a high profile scientist and well known around all over the world, for more than 40 years of his international scientific activity, he has participated and organized more than 56 international conferences, symposiums and workshops, prepared more than 32 candidates and doctors of physics and mathematics. He is the General Director of ?Energomashtechnika? Ltd. He is the member of European and American Physical Society, SPIE, AIAA, American Society for QE and the member of specialized scientific council of Russia. He is a full member of Russian Academy of Natural Science and Academy of Engineering Sciences, member of the Presidium RANS. He is the laureate of State Prize of USSR (1982) and of Russia (2002).

The recent commercial availability of high average power, high-PRF (pulse repetition frequency) ultrashort pulse lasers joins together excellent machining quality and high processing throughput. On the one hand, the unique advantages of ultrashort laser pulses, in particular high efficiency, fast and localized energy deposition, and minimal thermal load to the work piece, ensure high accuracy and precision of the machining process those are essential in micromachining. On the other hand, high average power lasers supply high-PRF laser pulses of sufficiently high pulse energy for material ablation which significantly increase the processing speeds. As a result, high-PRF ultrashort pulse laser processing can be seen as key enabling technology with the potential to substitute standard manufacturing technologies in micromachining, including automotive, aerospace, electro-optics, photonics, biomedical, semiconductor, etc.

Initial studies investigating high-PRF high average power ultrashort pulse laser microprocessing of low heat-conductive stainless steel reported heat accumulation and particle shielding as significant material removal influencing effects. High-PRF laser processing of copper in the range up to 1 MHz, by contrast, was not influenced by these phenomena. Furthermore, it was shown that the removal rate on copper is almost independent on the wavelength. The variation of the pulse duration in the range between femtoseconds to picoseconds, however, revealed a significant drop of the removal rate for the longer pulses.

In terms of processing speed, a maximum removal rate of 0.16 mm3/min was obtained for copper with a high-PRF picosecond laser source of 3 W average laser power. By using a rotating cylinder with a processing speed of 40 m/s, the removal rate on stainless steel was 3 mm3/min.8 A considerably higher removal rate of 7.0 mm3/min was reported so far for stainless steel, achieved by applying a femtosecond laser system of 31.7 W average laser power.

This laser system was used in this study, among others, to gain greater insights into high-PRF ultrashort pulse laser processing of copper by applying high average laser power. In addition, the range of the optimum processing parameters in terms of wavelength and pulse duration is still under discussion in micromachining. This work will contribute to the research by varying the wavelength (515 and 1030 nm) and the duration (0.2–10 ps) of ultrashort pulses irradiated to copper. High-PRF ultrashort pulse laser microprocessing of copper was investigated in a wide range of parameters. For this, a variety of high average power ultrashort pulse laser systems were studied while a maximum average laser power of 31.7 W was applied. The pulse energy was varied in the range between 1 and 50 μJ for pulses with repetition rates between 200 kHz and 20 MHz, respectively. A high performance galvanometer scan system was applied for fast laser beam deflection providing a maximum scan speed up to 17 m/s.

As a result, higher ablation rates were obtained by using pulses of shorter wavelength (515 nm), compared to near-infrared pulses of 1030 nm. Further, it was shown that the volume ablation rate increased with higher fluence while no significant effect of the repetition rate on copper ablation was observed. This indicates that neither heat accumulation nor particle shielding will have a great impact on material removal. The maximum achieved material removal rate was measured to be 6.3 mm3/min obtained with pulses of 4.9 μJ energy and 6.44 MHz pulse repetition rate. For pulses with the shorter wavelength of 515 nm, by contrast, the highest removal efficiency was achieved with pulses of little lower energy of 4.0 μJ. In addition, it was found that the volume ablation rate decreased with increasing pulse durations those were studied in the range between 0.2 and 10.0 ps in this work.

Bottom Note: *This work is partly presented at International Conference and Trade fair on Laser Technology, July 20-22, 2015, Orlando, Florida, USA*