APPLICATION FOCUS

INDUSTRIAL LASER
APPLICATIONS LAB

NO.
41

Burst Machining of Copper and Stainless Steel with IceFyre® Picosecond Laser for Enhanced Material Removal Rates

It has been well documented over the years that ultrashort pulse lasers can machine a wide variety of materials with excellent quality. With a properly optimized process, such lasers can create features with extremely high quality without heat-related flaws such as edge burrs and/or molten material in metals, and chipping or cracking in glass. A key aspect of process optimization is to generate an optimal fluence (energy per unit area, in J/cm^2) on the workpiece which is high enough to remove material efficiently and at the same time low enough to avoid thermal damage in the surrounding material. Today's lasers offer ever increasing pulse energy and average power which should allow higher material processing throughput rates. However, with this increasing power and energy, there are greater challenges in defining the proper equipment and strategies for efficiently machining material with high quality and throughput.

While picosecond lasers are commonly used to machine high bandgap materials such as glass and sapphire, they are increasingly being used to machine materials such as metals and semiconductors as well. To avoid excessively high fluence levels which can cause thermal damage, one can increase the beam size or simply operate at a higher pulse repetition frequency (PRF). Both cases, however, require increased scanning speeds to avoid cumulative heating and at some point equipment such as AOM deflectors or polygon scanners is required, thereby increasing system complexity and cost.

Alternatively, the laser intensity can be divided in the time domain, such as by splitting a single high energy pulse into multiple lower energy pulses, each of which generates a fluence level that is much closer to optimal. For this type of "burst" processing, Spectra-Physics' IceFyre® picosecond laser platform excels, due to its highly tailorable pulse output made possible by TimeShift™ ps technology. The IceFyre 1064-50 laser offers >200 µJ pulse energy as well as >50 W average power at wavelength of 1064 nm. In burst mode operation, the temporal spacing, number of pulses within the burst envelop, and the shape of the burst envelope can be widely varied while still maintaining the same maximum output power, a unique capability among competing products.

Two metals that are widely used in a variety of important industries are copper and stainless steel. With its excellent electrical conductivity, copper is used as a conducting medium in various electronics applications such as PCB and flex-PCB manufacturing as well as advanced electronics packaging. In addition, copper has excellent thermal conductivity and is used as a cooling medium not only in macro-scale applications, but also in smaller scale applications such as thermoelectric coolers (TECs) and cooling LEDs. Stainless steel is valuable in many industries due to its combination of high strength, corrosion resistance, and bacterial resistance. In automobile manufacturing, laser drilling of fuel injector nozzles is a large and growing application, particularly for ultrafast lasers. It is also used extensively in medical device manufacturing where lasers are used for cutting, drilling and marking. In addition, laser machining of stainless steel molds for industrial printing and embossing of intricate textures is a large and growing application space. Both copper and stainless steel have relatively low ablation thresholds and hence splitting a single pulse into multiple pulses should prove to be beneficial.

In a series of experiments, Spectra-Physics applications engineers characterized the ablation efficiency in bulk copper and stainless steel materials for a variety of burst outputs from the IceFyre 1064-50 laser. The experiment consisted of pocket milling volumetric regions in bulk copper and 304 stainless steel plates using various experimental conditions, measuring the depth of the milled pockets, and determining volume ablation rates and efficiencies. In addition, quality assessment of the milled surfaces was performed using an optical microscope. Variables including the number of pulses in the burst as well as the intra-burst pulse separation time were explored. For all combinations of burst output, the average power was constant at ~43 W after the AOM. Therefore, when comparing a 4-pulse burst with a 2-pulse burst, the pulse energy of each of the 4 pulses is half that of the individual pulses in the 2-pulse burst.

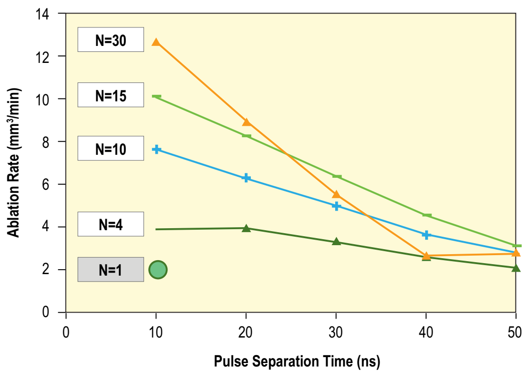

Figure 1: Ablation rate in copper with varying number of burst sub-pulses and with increasing sub-pulse separation time.

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Results of the tests demonstrate the advantage of burst machining for enhancing material removal rates. Figure 1 shows the increase in volumetric ablation rate for copper as the number of pulses within the burst is increased. Figure 2 shows a similar trend in volumetric ablation rates in stainless steel.

Clearly, distributing the energy among several pulses helps achieve a more optimal fluence condition in both copper and stainless steel. Using a burst of 30 pulses, the ablation rate is ~6x higher compared to that for a single pulse. Furthermore, the data indicates that shorter intra-burst pulse separation times result in higher material removal rates.

In both metals, the highest ablation rate occurred with the shortest tested pulse separation time of 10 ns. For this short intra-burst pulse separation time of 10 ns, the ablation rate as a function of number of sub-pulses in a burst is plotted for both copper and stainless steel in Figure 3.

Figure 3 shows that for below 20 pulses in the burst, the ablation rate for copper is higher than stainless steel. Beyond 20 pulses, however, the rate in copper levels off while it is still climbing for stainless steel.

Given the very low ablation thresholds in metals when processing with picosecond pulse laser sources, it is important to carefully manage the applied laser fluence to maximize material removal efficiency while at the same time minimizing detrimental heat effects. Although spatial beam shaping and ultra-high speed beam scanning allow for such optimizations, these approaches are costly, complex, and inflexible. Alternatively, Spectra-Physics' IceFyre laser allows for simple pulse intensity tailoring in the time domain, and this approach has proven to enable enhanced material removal rates in copper and stainless steel.

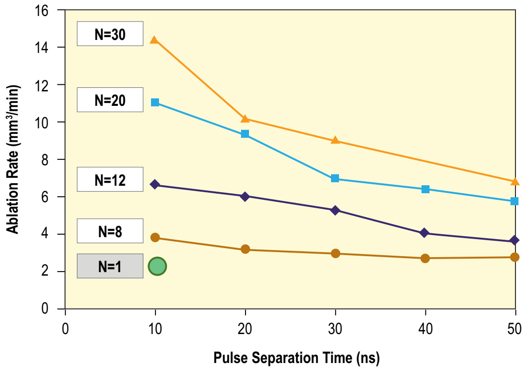

Figure 2: Ablation rate in stainless steel with varying number of burst sub-pulses and increasing sub-pulse separation time.

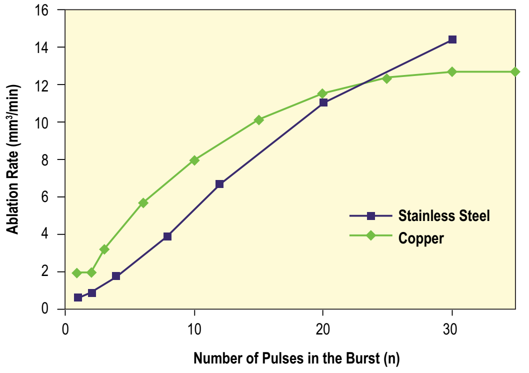

Figure 3: Ablation rate in stainless steel and copper with varying number of burst sub-pulses with 10 ns intra-burst pulse separation time.

	IceFyre 1064-50
Wavelength	1064 nm
Power	>50 W
Maximum Pulse Energy, typical	>200 µJ single pulse at 200 kHz
Repetition Rate Range	Single shot to 10 MHz
Pulse Width, FWHM	<20 ps
Spatial Mode (TEM_{00})	<1.3
Laser Dimensions (L x W x H)	29.50 x 12.13 x 7.50 in (749.5 x 308.0 x 190.6 mm)

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