Manuscript not received in time for publication.

Burst-mode femto-machining of Copper and Lexan

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Abstract

Femtosecond ablation of both absorbing and transparent materials has several distinct advantages: the threshold energy fluence for the onset of damage and ablation is orders of magnitude less than for traditional nanosecond laser machining, and by virtue of the rapid material removal of approximately an optical penetration depth per pulse, femtosecond machined cuts can be cleaner and more precise than those made with traditional nanosecond or longer pulse lasers. However, in many materials of interest, especially metals, this limits ablation rates to 10-100 nm/pulse. We will present the results of using multiple pulse bursts to significantly increase the per-burst ablation rate compared to a single pulse with the same integrated energy, while keeping the peak intensity of each individual pulse below the air ionization limit. Femtosecond ablation using 850-nm single and eight-pulse 30-ns duration bursts with 4-mJ integrated energy was seen to yield a five-fold increase in the copper ablation rate in ambient air.

Laser-Induced Damage in Optical Materials: 2003, edited by G. J. Exarhos, A. H. Guenther, N. Kaiser, K. L. Lewis, M. J. Soileau, C. J. Stolz, Proceedings of SPIE Vol. 5273 (SPIE, Bellingham, WA, 2004) · 0277-786X/04/$15 · doi: 10.1117/12.528636

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Q –: Have you thought of using that in a purged shrouding gas environment?

Y – Yes. You can use a helium purge for example, to try and solve this problem. Again, this is kind of troublesome. If you go into the hospital for laser surgery they don't want to blow helium over your face while you are getting your mole removed.

Q – Did you look at what stage the separation between each pulse in the train occurs? Does it start behaving like separate pulses as opposed to a burst?

A – In the system that we were using, this regenerative amplifier out-coupled with the end mirror, we were fairly well fixed in that system to a particular pulse separation. We did do a trick where we interleaved two pulsed strings to try to get a shorter pulse interspacing, but no we haven't done any scaling on that. If you look more in detail in terms of the numbers of the ablation rates, it would suggest that there is some sort of cross talk between these adjacent pulses. That's a very good experiment. We have done some experiments with multiple pulses in a burst mode where the pulses are stacked very close together, a few hundred femtoseconds together. There you see what you would expect to see from a longer pulse.

Q - How confident are you in extrapolating these kinds of ablation rates to drilling holes at a high rep rate? It seems to me that you might run into things like what looks like CW heating at very high rep rates and also tapering because you can't get that material out of that deep hole.

A – Absolutely. These are experiments that again remain to be conducted. Doing ablation experiments with high average power from the second system would be a great experiment to do. We haven't been there yet. You have got to make that system. I would say that the one advantage that burst mode does have in the sense that it can come in with this fast burst, and hopefully ameliorate some of effects such as getting debris out of the hole and what not. This gives you a fairly long inter-burst spacing to allow materials removal and what not. There is definitely some optimization to be done on that parameter space as well.