

Micro-precision additive manufacturing of copper powder using femtosecond laser pulses

Valentin Leuthard*, Manuel Zeyen, and Bojan Resan

Photonic Ultrafast Systems Group, School of Engineering and Environment, University of Applied Sciences and Arts Northwestern Switzerland, 5100 Windisch, Switzerland

Green and blue lasers have seen increased use in manufacturing of copper. They offer great advantages compared to common IR lasers especially in additive manufacturing. We tested the feasibility of a low average power femtosecond lasers at a centre wavelength of 515nm for use in micron-precision additive manufacturing of copper particles. A laser beam with an average power of 4W in the near IR was used to achieve second harmonic generation, and the resulting green beam was used to melt copper particles with sizes between 30 and 50 μ m. Melting of the powder was achieved and small two-dimensional structures were created.

1 Process parameters

The experiments were conducted using a Yb:KYW laser emitting pulses at a central wavelength of 1030nm with pulse duration 260fs and average power of 4W. The beam was focused into a BBO-crystal to double the frequency. The resulting efficiency was only around 12.5%, mainly due to the use of an AR coated crystal for 800/400nm instead of 1030/515nm. The reason for doubling the frequency is the increase in absorption in bulk copper at shorter wavelengths. In the form of powder particles, the absorption increased from 5% at 1030nm to around 60% at 515nm. [1]

Table 1. Process parameters used in the experiment

Spot size	Average power	Repetition rate
20 μ m	490mW	80MHz

The use of femtosecond pulses should reduce the heat transfer inside the copper and enable micron-precision melting. The lattice structure of metals requires about 10ps to transmit heat. The use of pulses shorter than that enables absorption of the entire energy by only the exposed area. If enough energy is absorbed, the exposed area can be melted with little to no formation of a heat-affected zone [2,3].

* Corresponding author: valentin.leuthard@fnw.ch

2 Results

Melting of the particles was achieved and small 2D structures, such as lines were processed. The image below shows an example of a welded line. The centre part of the fully melted zone is approximately $60\mu\text{m}$ wide. The line size is currently limited with copper granule size of around 50 microns in diameter. In the next step, we plan to use smaller copper granules of 5 microns and tighter focused beam to achieve down to 10 microns size 3D printed features. Due to the low power used, the effect of the short pulses could not be exploited properly leading to significant heat-affected zone. The widths of these zones were between 200 and $400\mu\text{m}$ and depended on the sizes of the particles in the proximity of melted particles.

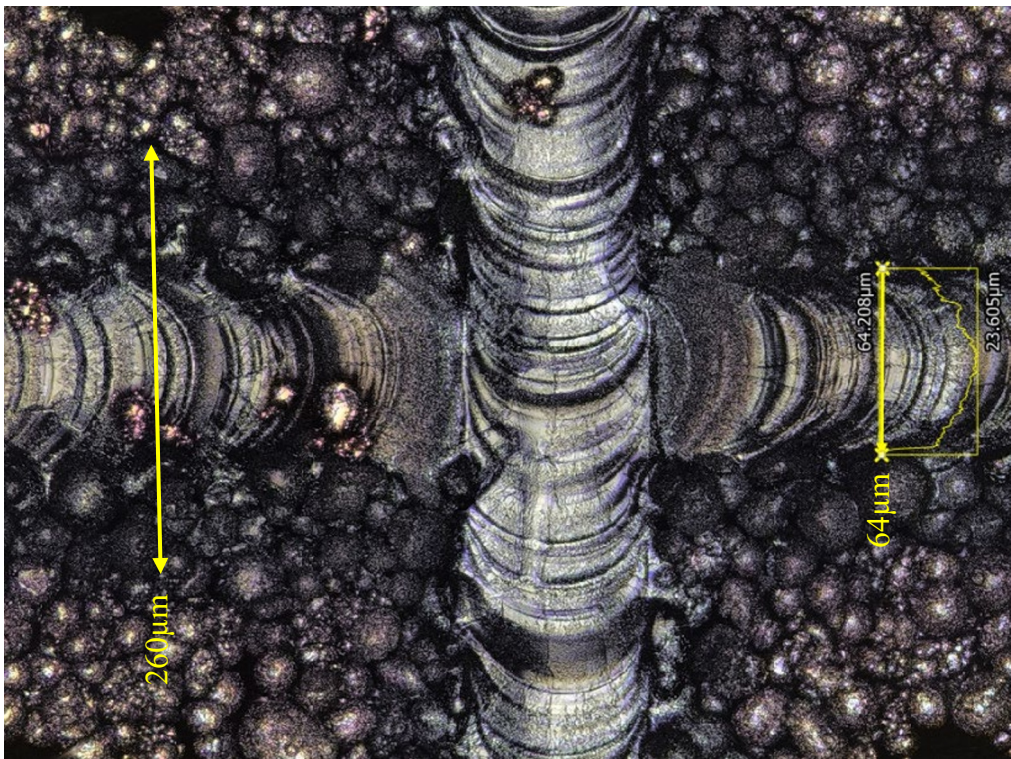


Fig. 1. Image taken of the welded powder. In the centre the fully melted area is visible. Slightly darker zone on either side is the heat-affected zones. The central melted zone is $64\mu\text{m}$.

References

1. T. Pasang, S. Fujio, P.C. Lin, Y. Tao, M. Sudo, T. Kuendig, Y. Sato, and M. Tsukamoto, Weldability and Mechanical Properties of Pure Copper Foils Welded by Blue Diode Laser, *Materials*, **17**, 2140 (2024).
<https://doi.org/10.3390/ma17092140>
2. L. Kaden, G. Matthäus, T. Ullsperger, H. Engelhardt, M. Rettenmayr, A. Tünnermann and S. Nolte, Selective laser melting of copper using ultrashort laser pulses. *Applied Physics A* **123**, 596, 10.1007/s00339-017-1189-6 (2017).
3. A. Hu, Y. Zhou and W.W. Duley, Femtosecond Laser-Induced Nanowelding: Fundamentals and Applications, *The Open Surface Science Journal* **3**, 42-49, 10.2174/1876531901103010042 (2011).