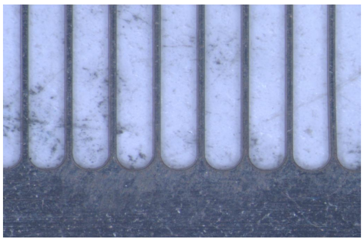
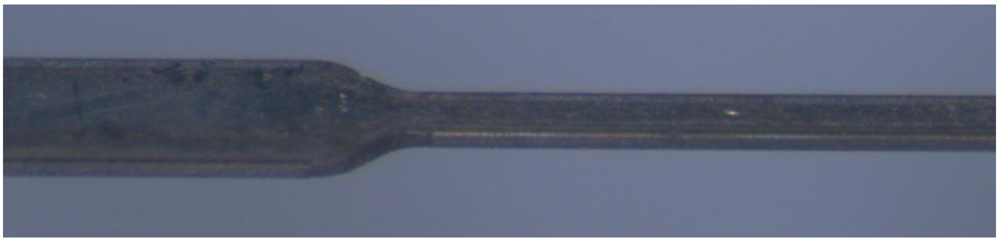
Ultra Short Pulse (USP) Lasers for Precision Cutting

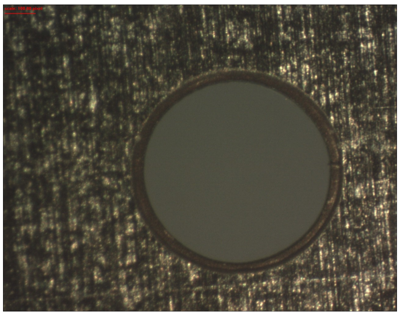
Traditional CW or pulsed lasers cut metals by generating a molten zone, and using a coaxial high pressure gas jet to blow the molten material out of the cut region. In general, there is significant HAZ and exit burrs, which require post-processing.

For very short duration pulses, a small volume of material beneath the laser spot is heated to vaporisation temperatures before heat has had time to diffuse away, either laterally or in depth; in this connexion, a good 'approximation formula' to remember is $x^2=4\alpha t$, where x is the thermal diffusion distance, t the timescale, and α the thermal diffusivity. For e.g. s/s has α=0.05cm²/s, so thermal diffusion distance in 1ps is on the order of 0,5μm,- significantly less than the spot size; in those circumstances machining can be regarded as essentially athermal. N.B. 'short pulse'= USP in the present context means low or sub ps. Optec, and other suppliers, offer systems based on so-called fs lasers, but generally these have pulse duration (often tunable) over the range approximately 300fs – 10ps, so might better be called ps lasers; there is little advantage in taking the step further to true low fs lasers, at higher cost, lower reliability & with attendant problems of group velocity dispersion etc.

In USP laser processing, spot size is typically 10-50μm, useful ablation e.d. a few J/cm², depth removed 10-100nm per shot, rep. rates up to around (& in some case well above) 1MHz, maximum material removal rate on the order of 1mm³/min for a 10W laser. There is a limit to aspect ratio, so that for e.g. one cannot make a 15μm cut through 1mm stock, though Lasea offer trepanning optics to produce vertical cuts.

^Cutting of 0,1mm thick Pt, feature pitch 650μm; ^^detail from same part; thin bar width 100μm

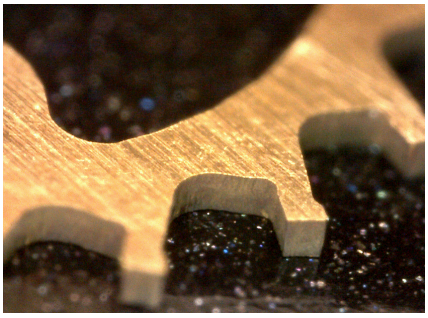


<<800μm dia. Through hole in steel with 40μm x20μm deep lip.

The first thing to note is that USP laser is very slow compared to, say, fibre laser, whilst the laser source cost is higher, though coming down fast! One can quote from Lumera GmbH's own presentation:- '..most applications do NOT require a USP laser. It has to be an application where burrs; HAZ, recast; microcracks and/or surface finish are critical issues…'

Ablation 'strategy' needs optimization in each case; highest quality is often obtained with 2nd or 3rd harmonics mostly because spot size scales with wavelength, whilst burst machining has been shown to be a useful, if largely unexplored area. For micromachining applications, as opposed to scribing, it is important to select a USP laser which can be freely triggered & synchronized to galvo operation.

With traditional laser cutting, where there is a definite limit to thickness at any particular laser power, since if the melt is not completely formed it cannot be ejected. With USP lasers one simply needs to ablate through a thicker layer. However, speed drops both inversely with thickness according to volumetric removal rate, but also because of the limit on aspect ratio. For these reasons, there are few viable applications for cutting thicker material; for e.g. 1mm thick material can be cut, but effective speed would not exceed a few mm/min.



N.B. figures herein should be regarded as maxima; in specific cases the interplay between cut quality & speed may result in lower cutting rates.

In conclusion, USP lasers are very good at the highest precision machining, with most applications in the range 50-200μm; on thicker parts, process speed is an issue. Quality can be stunningly good, as at left, cut in 200μm thick brass (Lasea).