# Direct curved micromachining with femtosecond accelerating beams

A. Mathis, F. Courvoisier*, L. Froehly, L. Furfaro, M. Jacquot, P.A. Lacourt, and J. M. Dudley

FEMTO-ST Institute, Department of Optics P.M. Duffieux, UMR CNRS 6174,
Université de Franche-Comté, 25030 Besançon, France
* Tel: (+33)3 81 66 64 01, Fax: (+33)3 81 66 64 23, e-mail: francois.courvoisier@femto-st.fr

Abstract: We report direct micromachining of curved profiles with femtosecond tailored accelerating beams, in order to avoid the need for complex beam steering and workpiece rotation. Spatial shaping of the beam trajectory allows the processing of arbitrary curved profiles in both opaque and transparent materials. We report surface curvatures with radius as small as 70 µm in silicon, glass and diamond. Direct trenching is also demonstrated and interpreted in terms of ablation threshold model. Interestingly, highly asymmetric debris deposition is observed and interpreted.

A particular challenge in material processing is machining structures that have controlled longitudinally-varying characteristics, because this requires the simultaneous control of beam steering, workpiece rotation and ablation rate. This is especially difficult when the desired features are of micron scale. Here, we report for the first time to our knowledge, a novel solution to this problem using accelerating beams. These beams consist of a strongly localized high-intensity lobe whose trajectory displays curvature in a dimension transverse to its propagation. We show that the curvature can be arbitrarily shaped since the properties of accelerating beams can be usefully interpreted in terms of optical caustics. These beams have recently attracted much attention in the fields of particle trapping and nonlinear optics. With this novel approach, we machine initially square sample edges to arbitrary curved profiles (circular, quartic) with radius of curvature as small as 70 µm. This approach is applicable to both opaque and transparent materials, and we report results on silicon, glass and diamond. We also show experimental results in silicon where accelerating beams have been applied to the direct writing of curved trenches within the bulk sample. Our results are interpreted in terms of an ablation threshold model. Interestingly, highly asymmetric debris deposition is observed and interpreted in terms of the optical properties of the incident accelerating beam. This approach is not restricted to femtosecond laser micromachining and we anticipate a broad range of applications in different technological fields such as the processing of flat panels and precision photonic components.

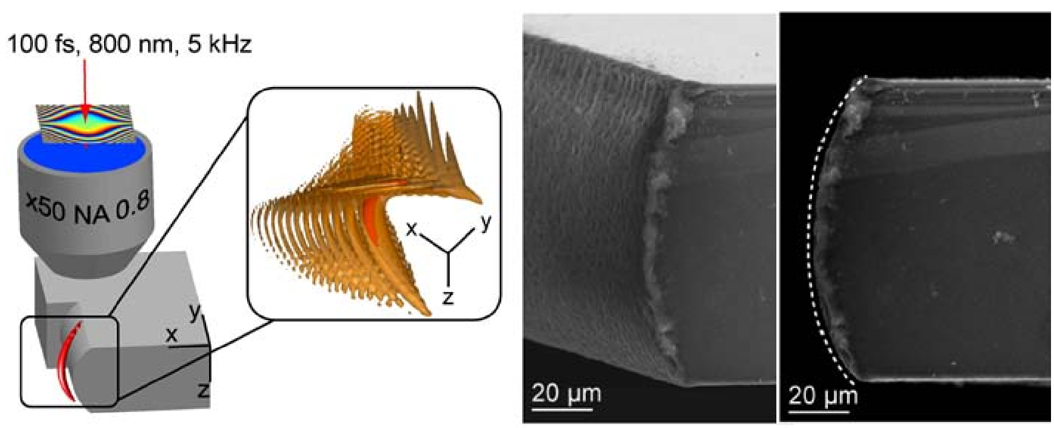


Figure 1 : (left) Setup: an accelerating beam generates a high intensity curved tube shown in red. The full beam is shown on the zoomed part of the figure. Middle and right parts show SEM images of a circular profile (R=120 µm) processed on silicon.