Spherical light, arbitrary nonparaxial accelerating beams and femtosecond laser micromachining of curved profiles

F. Courvoisier, A.Mathis, L. Froehly, M. Jacquot, R. Giust, L. Furfaro, J.M. Dudley

Département d'Optique P.M. Duffieux, Institut FEMTO-ST, UMR 6174 CNRS Université de Franche-Comté, 25030 Besançon Cedex, France

Abstract— We review our recent results applying caustics wave theory to the generation of arbitrary curved accelerating beams and their use in the field of femtosecond laser materials processing. We report experimental realization of highly nonparaxial accelerating beams with circular, parabolic and quartic trajectories that extend over more than 95° of arc as well as spherical optical fields. We also report femtosecond laser curved edge profiling.

Accelerating optical beams are a novel class of electromagnetic wave associated with a localized intensity maximum that propagates along a curved trajectory. In the nonparaxial regime, beams accelerating along circular, parabolic (Weber beams) and elliptic (Mathieu beams) trajectories were predicted from Maxwell's equations and experimentally demonstrated [1-3]. Here, we review our recent results on generating arbitrary nonparaxial accelerating beams with another approach, i.e. from optical caustics, and report an important novel application, i.e. curved laser processing.
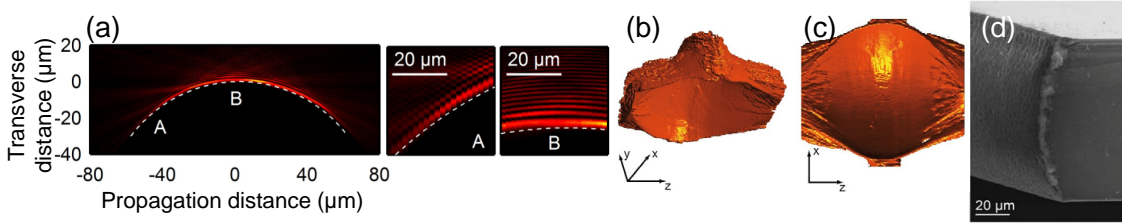

Figure 1: (a) Intensity distribution of a highly nonparaxial beam accelerating along a circle (b)-(c) 3D isointensity surface of experimental spherical field (radius 50 μm). (d) SEM view of a 100 μm thick silicon sample with the edge processed as a circular profile.

Caustics accurately describe non-paraxial wave propagation using an appropriate wave-diffraction integral. In our case, Debye-Wolf integral is used to determine the phase mask to be applied at the entrance plane of a high numerical aperture aplanatic microscope objective [4]. Analytical integration provides results identical to those obtained from Maxwell's equations and numerical integration also allows other arbitrary profiles. Figure 1(a) shows the experimental intensity distribution of a 632.8 nm beam accelerating on a circular trajectory. The high agreement with the target trajectory (dashed white line) is shown in the magnified views A and B. This approach also allowed us to generate spherical fields, as predicted by [2]. Figure 1(b-c) show experimentally generated field that takes the form of a spherical cap extended down to the equator.

The same approach was applied to the spatial shaping of amplified femtosecond pulses at 800 nm and we used it for a novel technique of femtosecond laser micromachining[5]. Fig. 1(d) presents a 3D view of a silicon sample where the initial square-cut edge was processed into a circle. We anticipate a broad range of applications in different technological fields such as the processing of flat panels and photonic components.

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