Arbitrary femtosecond highly non-paraxial accelerating beams

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Abstract: Accelerating beams such as Airy beams exhibit a curved trajectory of their point of maximum intensity. They have attracted tremendous interest for applications in linear and nonlinear optics. However, in most previous studies the deviation angles have been confined to the paraxial regime. Here, we report the generation of femtosecond accelerating beams from the Fourier plane of high-numerical aperture microscope objectives with deviation angles exceeding +/- 40°. Catastrophe optics is used to design the phase mask for arbitrary curved trajectories. Intensity and polarization are controlled along the beam trajectory.

Accelerating beams such as Airy beams exhibit a curved trajectory of their point of maximum intensity and can exhibit diffraction-free behaviour. They have recently attracted tremendous interest for diverse applications in both linear and nonlinear optics. However, in most previous studies the deviation angles have been confined to the paraxial regime which prevented high focussing conditions. We have recently shown direct spatial shaping of Gaussian beams to produce nonparaxial circular beams, but the intensity distribution along the trajectory was not maximal in the nondiffracting regime. Here, we report the generation of femtosecond accelerating beams from the Fourier plane of high-numerical aperture microscope objectives. We generate accelerating beams with radius of curvatures as small as 80 µm, <2 µm main lobe width and deviation angles exceeding ± 40°. Excellent agreement is observed between experimental and numerical results. We clarify the links between accelerating beams, caustics and catastrophe optics. We show how this allows the direct calculation of the phase mask to generate arbitrary trajectories even if thick optics are used. We numerically show that polarization can be spatially controlled along the propagation. We also demonstrate both numerically and experimentally intensity control along the beam trajectory.

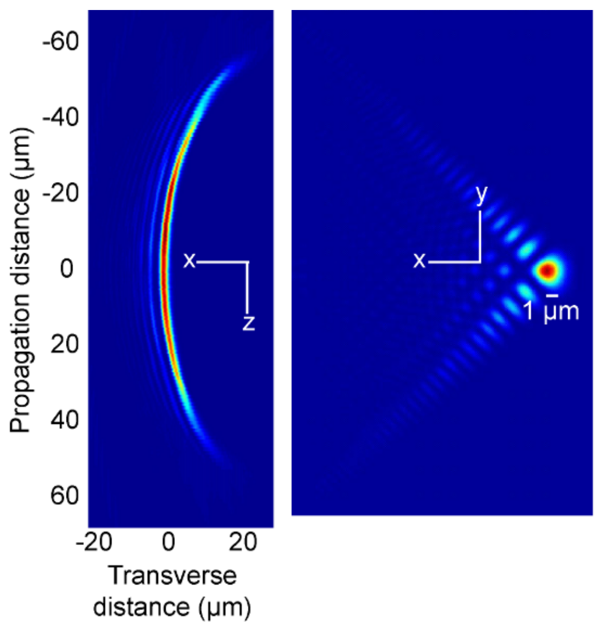

Figure 1 Experimental intensity distribution for a circularly accelerating beam with radius R=120µm. (Left) Intensity distribution in a plane including the longitudinal direction. (Right) Intensity distribution in the transverse plane.