# Versatile Airy-Bessel Light Bullets

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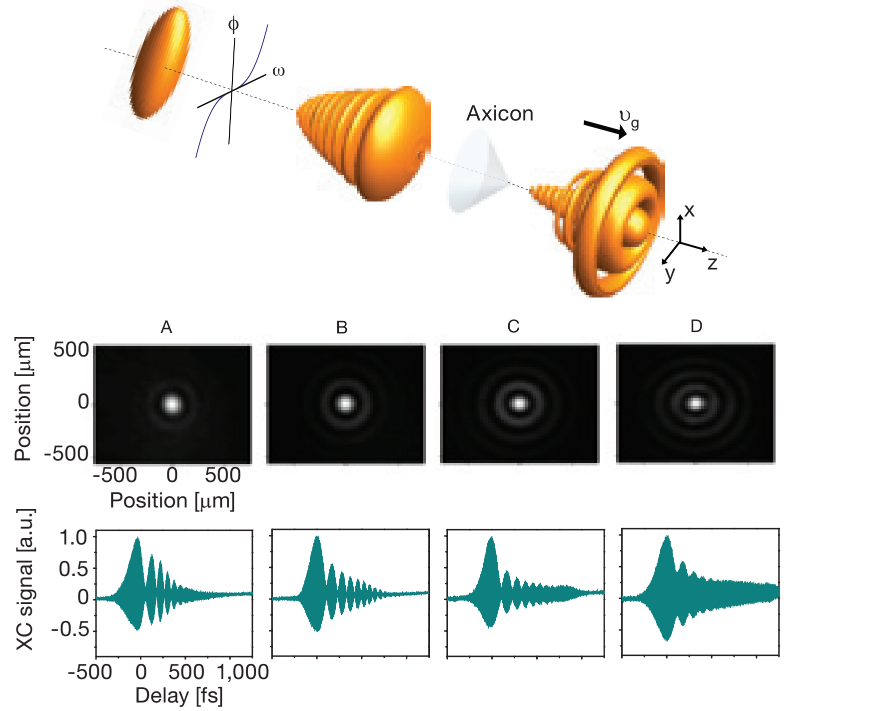
Any localized wave packet tends to broaden in space and time under the combined actions of two universal physical processes: diffraction and dispersion. Researchers have explored strategies to overcome the often undesirable consequences of these two effects since the early days of lasers.

In the early 1990s, nonlinear schemes based on three-dimensional (3-D) soliton solutions (or soliton bullets) have been suggested as a means of overcoming this problem.[1] However, 3-D soliton bullets are by nature highly unstable and thus tend to disintegrate during propagation. In addition, they require high power levels that are on many occasions detrimental, especially in biomedical applications. Researchers have also reported 3-D linear wave packets that can propagate in the form of "O," "X," and Bessel-X waves.

Apart from the fact that such solutions involve complex spectra and often require diffraction/dispersion equalization, their utility is severely limited by the need to tailor the properties of the wave packet precisely to material properties. Ideally, such light bullets should be versatile and able to withstand any level of diffraction and dispersion, irrespective of whether the latter is normal or anomalous. The only way to circumvent this problem is to disengage space and time. To overcome these limitations, we have recently explored a new approach based on the unique properties of one-dimensional Airy wave packets.[3]

Earlier this year, we reported the first observation of a new class of versatile three-dimensional linear light bullets,[4] which combine Bessel beams[5] in the transverse plane with temporal Airy pulses. These Airy–Bessel waves are impervious to both dispersion and diffraction effects. Thus, their evolution does not depend critically on the material in which they propagate. Temporal self-healing and free acceleration, which are signatures of Airy packets, were also demonstrated. These spatiotemporal waves are possible for either sign of dispersion and do not require any diffraction/dispersion equalization. This family of robust and versatile waves can be used in ultrafast probing or imaging in media with poorly known, or even time-varying, properties.




(Top) Schematic to generate Airy-Bessel wave packets. (Bottom) Propagation of an Airy-Bessel wave packet **A** initial spatial and temporal profile, **B** profiles after propagation through 3.3 $L_R$ and 1.8 $L_d$, **C** 5.4 $L_R$ and 3.6 $L_d$, **D** 7.5 $L_R$ and 5.4 $L_d$. ($L_R$ =diffraction length of a beam with a diameter of 180μm, $L_d$ =dispersion length of a 100 fs pulse).

The figure shows the generation of the Airy-Bessel wave packets. An Airy pulse with a Gaussian spatial profile is generated by impressing a large cubic spectral phase on a femtosecond pulse from a mode-locked laser. The spatial profile is then simply converted from a Gaussian to a Bessel beam by an axicon lens. The propagation of an Airy-Bessel light bullet in a dispersive glass is shown. Its nonspreading nature was verified for propagation through seven diffraction lengths and five dispersion lengths of the glass. The peak intensity of the corresponding Gaussian pulse and beam would fall by a factor of 250 during propagation through the same material. We expect that these versatile localized wave packets will find a wide range of scientific applications. ◭

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