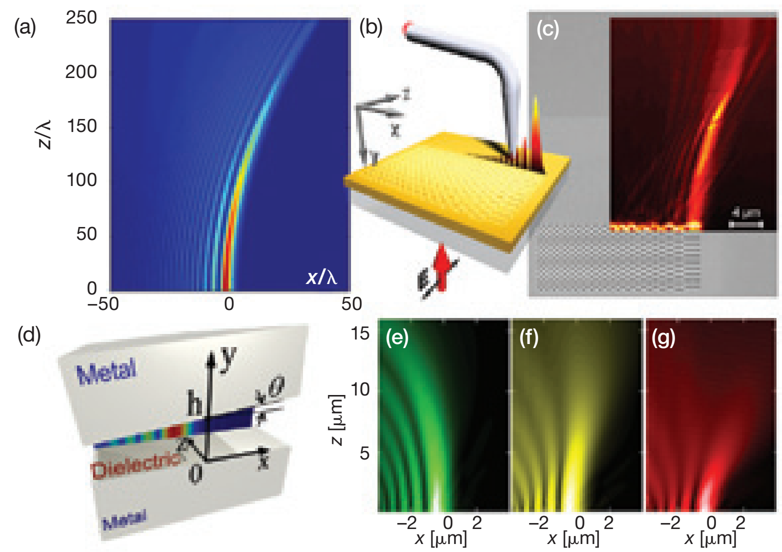
Airy Plasmons: Bending Light on a Chip

A. Minovich, A.E. Klein, W. Liu, A. Salandrino, N. Janunts, I.V. Shadrivov, A.E. Miroshnichenko, T. Pertsch, D.N. Neshev, D.N. Christodoulides and Y.S. Kivshar

Light can travel along a curved trajectory if it takes the shape of a particular caustic—that of nondiffracting "Airy beams." Such non-spreading, accelerating wavepackets are named after the English astronomer Sir George Biddell Airy, who studied the colored curved projections of light in rainbows. A few years ago, Airy beams propagating along curved parabolic trajectories were created in free space at the University of Central Florida.[1] Now, such beams were bound to the surface of a metal film in the form of Airy plasmons,[2] providing an experimental tool for studying non-diffracting waves on a chip.

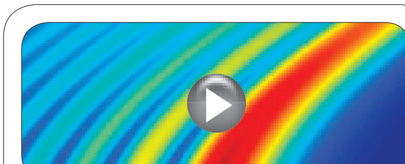
The observed two-dimensional Airy beams exist on the surface of a metal film due to the excitation of surface plasmon polaritons (SPPs)—quasi-particles in which photons are coupled to the free electron oscillations in metals. The plasmon field is tightly confined to the metal surface, decaying exponentially away from it. Such a planar system with a subwavelength confinement is attractive for "flatland photonics." Unlike in free space, where non-diffracting beams may exist (e.g., Bessel and Mathieu beams), in flatland geometry, Airy wavepackets are the only possible nondiffracting waves. Airy plasmons that propagate along curved trajectories (a) have only recently been suggested and can exist despite the strong energy dissipation at the metal surface.[3]

Those predictions are now confirmed in experiments in which researchers excited Airy plasmons on a metal-air interface using an engineered SPP diffraction grating (b).[2] Due to the strong binding of the Airy plasmons to the metal surface, we used near-field scanning optical microscopy to detect their evanescent field. By analyzing the near-field structure of the SPP (c), we saw that the generated Airy wave indeed propagates along a curved parabolic trajectory with a constant beam-width. We also observed a fascinating property—the so-called self-healing phenomenon—which occurs when the wave recovers after passing through surface defects.



(a) Intensity profile of Airy plasmon propagating along parabolic trajectory.[3] (b) Setup for excitation and near-field imaging of Airy plasmon with engineered grating.[2] (c) Scanning electron microscope image of grating pattern and measured near-field intensity profile of accelerating plasmon. (d) Wedged metal-dielectric-metal structure for manipulating Airy plasmon with one metal plate tilted by an angle θ. (e-g) Numerically calculated field distributions of three plasmonic Airy beams of 0.6, 1 and 1.4 μm (in false colors) and θ = 0.458°.[4]

Our theoretical studies show the possibilities for steering the Airy plasmons in different directions, preserving their non-diffracting character[4] by using engineering plasmonic linear potentials in metal-dielectric-metal structures with tilted metal plates (d). With the change of angle between the plates, Airy plasmon propagation can be controlled. Alternatively, at a fixed angle θ, the Airy plasmons generated at different wavelengths will also be steered left or right (e-g), allowing for wavelength-selective routing of plasmon beams.



Visit www.opnmagazine-digital.com to view the video that accompanies this article.

Airy plasmons are an attractive area of recent research,[2,5] with applications in surface particle manipulation and optical communications. In addition, the demonstration of 2-D nondiffractive plasmon waves suggests that similar entities can be used in other low-dimensional systems such as graphene and magnetic surfaces. ◭

A. Minovich, W. Liu, I.V. Shadrivov, A.E. Miroshnichenko, D.N. Neshev (dnn124@rsphysse.anu.edu.au.) and Y.S. Kivshar are with the Nonlinear Physics Centre and CUDOS@ANU, Australian National University, Canberra, Australia. A.E. Klein, N. Janunts and T. Pertsch are with the Institute of Applied Physics, Friedrich-Schiller-Universitat Jena, Germany. D.N. Christodoulides and A. Salandrino are with CREOL/College of Optics and Photonics, University of Central Florida, Orlando, Fla., U.S.A.

References

1. G.A. Siviloglou et al. Phys. Rev. Lett. **99**, 213901 (2007).
2. A. Minovich et al. Phys. Rev. Lett. **107**, 116802 (2011).
3. A. Salandrino and D.N. Christodoulides. Opt. Lett. **35**, 2082 (2010).
4. W. Liu et al. Opt. Lett. **36**, 1164 (2011).
5. P. Zhang et al. Opt. Lett. **36**, 3191 (2011); L. Li et al. Phys. Rev. Lett. **107**, 126804 (2011).