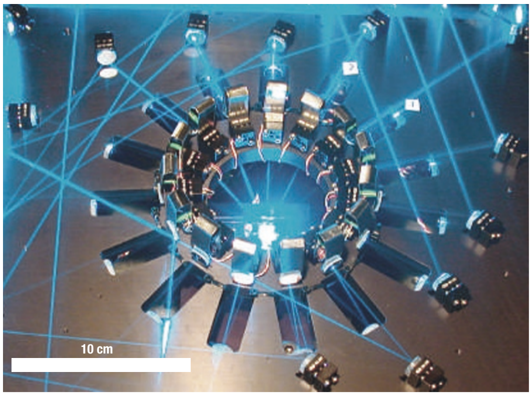
Sharp focus without a lens



©AIP 2006

Refractive lenses provide the most common means of focusing light at near-infrared to visible wavelengths. But for wavelengths outside this range, such lenses simply do not exist. To address this, Stanley Hong and colleagues demonstrate a technique for generating focused patterns of light without lenses (*Appl. Phys. Lett.* **88,** 261107; 2006).

The technique is based on the fact that any monochromatic optical pattern can be treated as the superposition of a series of unfocused plane waves converging from many different directions. Using mirrors to split a single beam from a visible laser into 15 separate beams and allowing them to converge to a point from angles distributed evenly in a circle (pictured), the authors generate a close approximation to an optical Bessel distribution. Moreover, they show that the central spot is focused to almost a third of an optical wavelength, which could be useful for a range of applications from microscopy to optical trapping.

PACK LIGHT

In 1972, in a personal communication to Martin Gardner, Stanisław Ulam conjectured that even when identical spheres are packed in the best possible way, their density will always be lower than that of any other convex body in an optimized arrangement. But John Conway and Salvatore Torquato might now have found a counter-example: they suggest that the regular tetrahedron leaves more empty space (*Proc. Natl Acad. Sci.* 103, 10612–10617; 2006). In fact, they suspect that it could have the lowest possible packing density of all convex solids.

In their densest packing, spheres cover ~74% of space; $\pi/\sqrt{18}$ to be exact, as famously proposed by Johannes Kepler in 1611 (but only proved very recently). The problem, however, becomes even more difficult when bodies with rotational degrees of freedom are involved. Conway and Torquato systematically explored the possibilities, and reoriented and repositioned their tetrahedra to move them closer and closer together — reaching a density close to 72%. They say there is still some leeway but find it unlikely that the spheres' 74% density can be reached.

Superconductor trap for gravitational waves

The detectors designed to measure gravitational waves (GWs) — created, for instance, by the collision of two super-massive black holes — are still awaiting a direct observation, but some researchers are looking more locally.

M. E. Gertsenshtein, in 1962, pointed out that electromagnetic and gravitational waves are coupled as a result of the nonlinear field equations in Einstein's theory of general relativity. So the propagation of an electromagnetic wave can, in principle, generate a high-frequency GW, albeit a weak one. In a superconducting medium, others predicted that the phase velocity of a GW, assumed equal to *c*, can be reduced by a factor of ~300.

Now Clive Woods proposes using an applied magnetic field to control the GWs (*Physica C* **442,** 85–90; 2006). He exploits the basic property of a type-II superconductor, in which magnetic flux lines penetrate the superconductor through vortex cores. Being non-superconducting, the cores effectively act as anti-waveguides, through which GWs cannot propagate. As the size of the cores depends on the magnetic field strength, the GWs propagating in the rest of the superconductor could be manipulated.

Playing *Q* ball

A '*Q* ball' is just what it sounds like — a ball of charge, *Q*. Strictly speaking, it belongs to a class of non-topological solitons, arising when a localization of charge *Q* has lower energy than the more obvious 'ground-state' configuration of *Q* separated, unit-charge particles. Although undoubtedly fun for theorists, the rich behaviour of *Q* balls also makes them attractive for condensed-matter physicists, and astrophysicists (for example, as dark-matter candidates).

M. Deshaies-Jacques and R. MacKenzie (*Phys. Rev. D* 74, 025006; 2006) have turned their attention to the behaviour of gauged *Q* balls in two space dimensions ('gauged' meaning that the complex scalar field of the *Q* ball is coupled to a *U*(1) gauge field). Normally, such an object would have divergent electric-field energy — unless a so-called Chern–Simons term is added to the model. That's interesting, because the Chern–Simons term in two-dimensional systems crops up in studies of the fractional quantum Hall effect and in the anyon-based mechanism for superconductivity.

Deshaies-Jacques and MacKenzie find that such *Q* balls fall into two types, one of which is more stable, with a lower ratio of energy to charge, than the other. The *Q* balls have a certain maximum charge, as might be expected; more surprisingly, that maximum charge is reached when the energy-to-charge ratio is below unity.

Caustic purge

A summer afternoon: the air is hot, and a flock of cumulus clouds hover in the blue sky. Suddenly it pours down. Such an abrupt onset of rainfall from these clouds might be due to the formation of so-called fold caustics in the velocity field of the raindrops, report Michael Wilkinson and colleagues (*Phys. Rev. Lett.* in the press; http://arxiv.org/cond-mat/0604166).

It has been accepted for some time that small-scale turbulence, typical in cumulus clouds, is involved in the process of initiating rain showers. But most studies have assumed that cluster formation might be the relevant mechanism. Wilkinson *et al.* follow a different path. They argue that when the intensity of the turbulence increases, at some point fast droplets suddenly start to overtake slower ones. Then, at certain locations inside the cloud, the velocity field of the droplets takes several values — a caustic forms. This relative motion between the droplets could produce a sudden increase in collision rate, resembling an activation process, where the intensity of the turbulence plays the role of temperature.

And once the intensity passes a certain threshold, you get wet.

GETTY