DID YOU KNOW?

A piece of aerogel in a petri dish. Inset shows cubes of the aerogel.

Lawrence Livermore National Laboratory

Researchers captured 3D images of the internal structure of an aerogel, which allowed them to determine the material's strength. Anton Barty at Lawrence Livermore National Laboratory and others used inverted coherent X-ray diffraction patterns to capture the 3D bulk lattice arrangement of a micron-sized piece of aerogel (Phys. Rev. Lett. **101**, 055501).

Aerogels, also called nanofoams, are very low-density foams of polymer, metal or ceramic. They appear in nature in both geology and biology. With high strength-to-weight ratios, they also offer unmatched abilities as solid electrical, acoustic and thermal insulators. In addition, aerogels have the highest internal surface area per gram of any material, with a complicated internal structure full of tiny pores, with pore sizes ranging from about 2 to 50 nm.

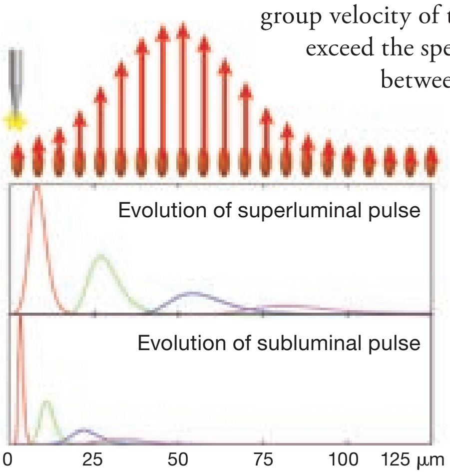
Although researchers have broadly known the internal structure, actual imaging has been difficult because conventional microscopes cannot observe the smallest pores. The researchers used X-ray diffraction to image the internal structure of a tantalum oxide nanofoam and determine its mechanical properties.

The structure consisted of nodes connected by thin beams. "This blob-and-beam structure explains why these low-density materials are weaker than predicted and explains the high mass-scaling exponent seen in the materials," Barty said.

Putting Plasmons Through Their Paces

Researchers at the University of Pennsylvania have found that a number of unusual effects are possible when light is guided along a chain of metal nanoparticles—including the generation of wave packets that move faster than the speed of light. The research, by Vadim A. Markel and Alexander Govyadinov, also suggests ways that surface plasmon-polaritons (SPPs) traveling along linear periodic chains of metal nanoparticles could be used for optical computing (Phys. Rev. B **78**, 035403).

Light can be guided along metal-dielectric interfaces in the form of SPPs, which are collective oscillations of the electromagnetic field in the dielectric and charge density waves inside the metal. Instead of spreading over an entire surface, SPPs can be more closely guided along linear periodic chains (LPCs) of metal nanoparticles. This allows sub-wavelength waveguides, which might enable very compact optics.



(Top) Light is coupled into the first in a line of saucer-shaped metal nanoparticles. This causes the particle's dipole moment amplitude (red arrow) to rise and fall, with a Gaussian time profile. Between-particle coupling results in the excitation of neighboring particles and propagation of a wave packet. (Bottom) Simulations of the (normalized) dipole moments along the line of particles, with different colors representing different times. The top trace simulates a superluminal pulse; the bottom, a subliminal pulse.

Most earlier work on metallic chains assumed spherical nanoparticles. In these systems, the dispersion curve was very flat. (Because the energy in the waveguides propagates in the form of wavepackets, dispersion is important.) But these systems transmitted only a relatively narrow band of frequencies that would not be useful for many practical applications.

In an attempt to increase the bandwidth and extend the propagation distance of the SPPs, Stephan Maier in Harry Atwater's group at Caltech suggested squashing and stretching the spheres. When Markel and Govyadinov modeled oblate spheroids, they found that the nanoparticles altered the dispersion curves of the SPPs—in some cases by quite a lot. Reshaping the nanoparticles results in an enormous increase in the operating bandwidth of the waveguide and in decreased power loss.

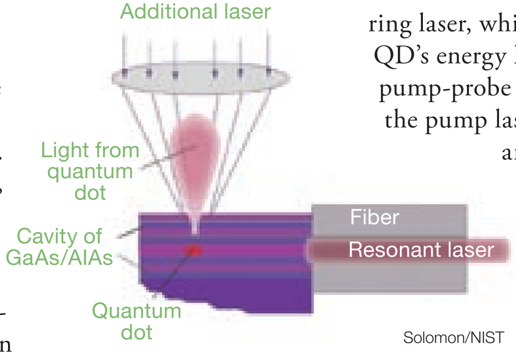
One surprising result was that the group velocity of the packet could exceed the speed of light. Coupling between the particles results in the excitation of neighboring particles, and in propagation of a wavepacket (of dipole moments) along the chain.

"By knowing the dipole moment of each particle, one can easily find the electromagnetic field everywhere," Govyadinov explains. "You can think of the dipole moment as the field strength at the location of each particle." Because the group velocity is, in general, the speed of a geometrical rather than a physical object, it is not subject to the limitations of the special relativity theory and can exceed the speed of light.

— Yvonne Carts-Powell

Lasers Manipulate Quantum Dots for Cryptography

Researchers at the National Institute of Standards and Technology (NIST) and the Joint Quantum Institute (JQI) have measured, for the first time, the complete biexciton-exciton emission spectrum of a single quantum. Their system was able to generate single or entangled photons (Phys. Rev. Lett. **101**, 027401).



Solomon/NIST

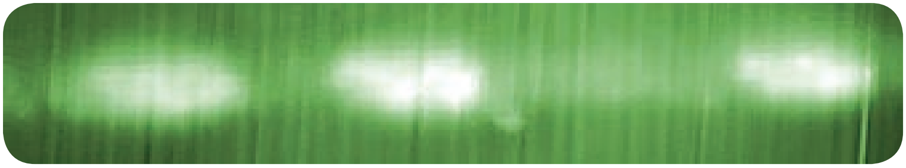
Experimental set up. Orienting the resonant laser at a right angle to the quantum dot light minimizes scattering.

Pairs or groups of entangled photons are used in quantum experiments as well as for quantum cryptography. They can be created from individual atoms, but semiconductor quantum dots (QDs) would be a more convenient source because QDs offer narrow optical linewidths and large and stable photon flux. In addition, they are both robust and mass-producible. A QD's small dimensions cause the entire particle to share energy states as though it were a single atom. However, this only occurs if the dots are sufficiently close to perfect, which most are not.

Andreas Muller and others at JQI and NIST manipulated the energy levels of QDs using lasers, much as single atoms are controlled. A HeNe pump laser emitting at a frequency above the GaAs band edge (at 633 nm) generated photoluminescence from a single QD. At the same time, the QD was "dressed" from the side by a near-resonance tunable CW Ti:sapphire ring laser, which controlled the QD's energy levels. This is unlike pump-probe systems in that the pump laser's wavelength and amplitude don't directly affect the QD's emission spectrum. When a pulsed pump was used, the QD emitted pulses that were still dressed by the near-resonant laser. The group demonstrated that laser-tuned QDs can efficiently generate photons one at a time, or batches of entangled photons.

The current system lacks control over the excitation polarization, however. The researchers believe that they can change this by either moving the side "dressing" laser to a different location, or possibly by adding more light to the waveguide from a second dressing laser, phase-locked with the first one but rotated 90 degrees. With this setup, they could create arbitrary polarizations in both the dressing lasers and the QD output.

J.R. Tucker



Cross-section scanning tunneling microscope image shows InAs quantum dots—about 30 nm long—embedded in gallium arsenide.

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