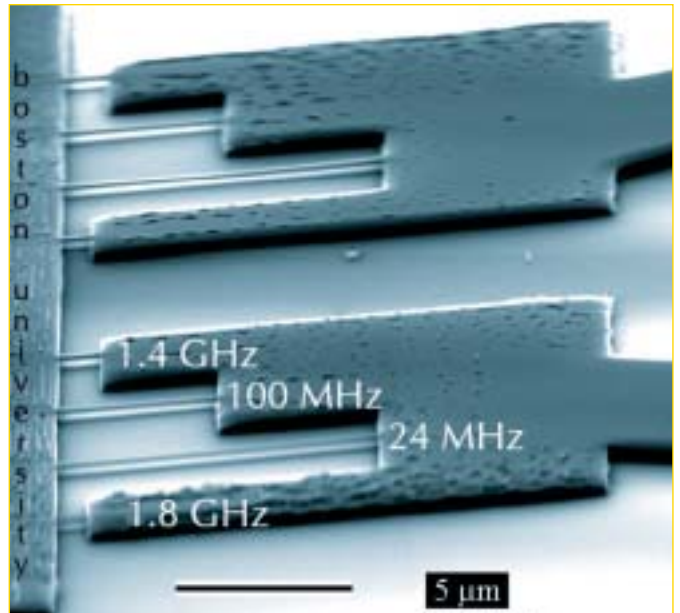


Nanomechanical beams for gigahertz memory

MECHANICAL BEHAVIOR

A Boston University team, led by Pritiraj Mohanty, has developed the first high-speed nanomechanical memory element from single-crystal Si that could rival electronic data storage and processing [Badzey *et al.*, *Appl. Phys. Lett.* (2004) **85**, 3587]. The memory consists of a doubly clamped, suspended vibrating beam, typically 8 μm long, 300 nm wide, and 200 nm thick, fabricated using standard electron lithography and surface nanomachining. When driven strongly enough, the beam can be switched controllably between two different stable positions, representing two distinct binary states '0' and '1', respectively. To test a single device, the researchers clamp the beam at both ends and drive a current at megahertz frequency through an attached electrode, which causes the beam to vibrate at its resonant frequency. Because of its small size, the resonant frequency is 23.57 MHz, compared with the few hundred kilohertz rates possible in conventional computer hard drives. Memory density could exceed the current 100 Gbit per square inch superparamagnetic density limit of magnetic disk drives, believe the researchers. Another advantage is the angstrom-sized range of motion, which allows the device to operate using just femtowatts of power. This is a million-fold lower than the milliwatts or microwatts needed for today's devices. Also, unlike conventional electronic or magneto-electronic storage systems, the cells are resilient to electrical and magnetic fields. The team hopes to make even smaller beams that could operate at gigahertz frequencies. A 1 μm -long beam has a fundamental mode above 1 GHz. The team also plans to make



A scanning electron micrograph of two sets of Si beams operating as nanomechanical memory bits over a wide frequency range. (Courtesy: Pritiraj Mohanty, Boston University.)

nanomechanical structures from single-crystal diamond, rather than Si, for better performance.

Mark Telford

Probing individual carbon nanotubes using Rayleigh scattering

CARBON NANOTUBES



A scanning electron micrograph overlaid by an image of Rayleigh scattering from a carbon nanotube suspended across a 30 μm slit. (Courtesy: Feng Wang.)

Columbia University researchers have identified electronic transitions in both metallic and semiconducting individual single-walled carbon nanotubes (SWNTs) using Rayleigh scattering spectroscopy [Sfeir *et al.*, *Scienceexpress* (2004) doi:

10.1126/science.1103294).

SWNTs comprise a family of over 200 structures, with varying chiral angles and diameters, each having a distinct electronic structure that can be either metallic or semiconducting. But a general optical characterization technique that permits noninvasive measurements of the electronic structure of an arbitrary individual nanotube has been lacking. Resonance Raman scattering has provided vibrational spectra of individual SWNTs, but requires tunable excitation and yields weak signals. Fluorescence observations, and corresponding excitation spectra, are inherently limited to semiconducting nanotubes and, currently, small-diameter tubes. In contrast, Rayleigh scattering occurs

whether the sample luminesces or not, and is intrinsically stronger than inelastic Raman scattering as it does not require the incident light to couple to the vibrations of the system. However, it is not normally considered for nanoscale objects because it was assumed that signals would be very weak. But now spectra from individual SWNTs have been obtained with high signal-to-noise ratio in less than one minute using a high-brightness laser-generated visible and near-infrared white-light supercontinuum source. By analyzing spectral lineshapes in relation to excitonic effects and correlating the results with Raman data on individual nanotubes, the structure is shown to stay the same over distances of tens of microns.

Small nanotube bundles retain distinct Rayleigh spectroscopic signatures of their component nanotubes, allowing the probing of tube-tube interactions. The researchers expect that the approach will enable optical probing of many other individual nanoscale structures. For carbon nanotubes, a systematic study should yield firm assignments of spectroscopic information individually for all semiconducting and metallic nanotubes. This should allow complementary investigations of transport, mechanical, and chemical properties to be conducted with a convenient spectroscopic identification of the precise structure of the nanotube under study.

Mark Telford