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The sound of silence

Physical Review Letters **88,** 104301 (22 February 2002)

Much like electrons in a semiconductor, photons in a photonic crystal are restricted to energy bands that are characteristic of the material's periodic structure. At energies falling between these bands, photon transmission is forbidden – the material has a photonic bandgap. This is a seemingly quantum-mechanical effect, but because its origin is in the wave nature of quantum particles, similar phenomena should occur with classical waves. This was demonstrated for sound waves seven years ago[1] using a two-dimensional array of parallel metallic bars (actually part of a sculpture in Madrid created by Eusebio Sempere). A 'phononic' bandgap was found, with acoustic propagation being largely forbidden for a certain frequency range.

Writing in *Physical Review Letters*, Suxia Xang and colleagues now probe the analogy further using a three-dimensional array of scatterers. They reveal a close connection between classical wave propagation and the quantum physics of tunnelling in crystalline environments.

To create their phononic crystal, Xang *et al.* used tungsten carbide beads 0.8 mm in diameter, which they assembled by hand into a face-centred cubic pattern supported on an acrylite template. Immersing the entire structure in water, the team probed how ultrasonic pulses were transmitted between transducers located on either side of the crystal. The results show striking bandgap behaviour (see figure). Comparison of the Fourier spectra for input and output pulses for a six-layer sample shows that the input is gaussian with centre frequency of 1 MHz, but the output has a significant dip around this frequency, suggesting a gap centred around 1 MHz.

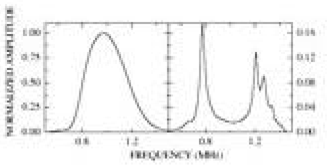

Figure
Fourier spectra for an ultrasound pulse propagating through a six-layer crystal (input on left, output on right). The depression in transmitted amplitude near 1 MHz reflects the acoustic band gap.

| high-resolution version |

The propagation of acoustic waves through a crystalline environment is an excellent illustration of classical scattering theory. Indeed, Xang *et al.* find their results to be in good agreement with numerical calculations, which predict a gap of between 0.8 and 1.2 MHz caused by destructive interference. Pursuing the analogy further, Xang *et al.* also show that for thinner samples, sound waves at the forbidden frequencies can traverse the crystal through a process resembling quantum-mechanical tunnelling – although the underlying physics is certainly different.

But phononic crystals are not just playthings for acoustic physicists. As Xang *et al.* note in their paper, structures of this kind might be useful for the design of noise-proof devices or sound filters.

1. Martínez-Sala, R. *et al.* *Nature* **378,** 241 (1995).

Ultrasound Tunneling through 3D Phononic Crystals

SUXIA YANG, J. H. PAGE, ZHENGYOU LIU, M. L. COWAN, C. T. CHAN, AND PING SHENG

We report the study of ultrasound tunneling in 3D phononic crystals, consisting of fcc arrays of close-packed tungsten carbide beads in water. The transmission coefficient, phase velocity, and group velocity were measured along the [111] direction, allowing us to systematically investigate the tunneling of ultrasound at frequencies in the lowest band gap. Our experimental data are interpreted using multiple scattering theory, which provides a good explanation of our results. The effect of absorption and the difference between the tunneling of classical waves and quantum waves are discussed.

Physical Review Letters **88,** 104301 (22 February 2002)

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