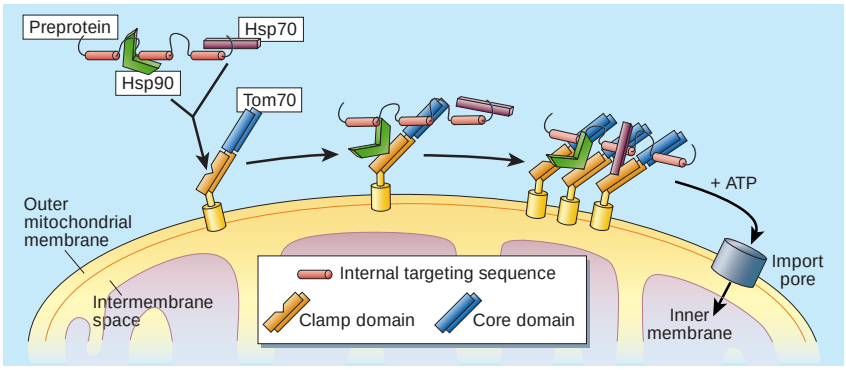

Figure 1 **Targeting proteins to mitochondria, as proposed by Young *et al.*[1]. Newly synthesized preproteins that are destined to function in mitochondrial membranes are imported via the Tom70 receptor. From left to right: in mammals, the chaperones Hsp90 and Hsp70 bind to the preprotein in the cytosol (in yeast, just Hsp70 is required). The chaperones dock onto Tom70's clamp domain, allowing internal targeting sequences in the preprotein to be recognized by Tom70's core domain. Further Tom70 proteins are then recruited. ATP hydrolysis, probably by the chaperones, is needed to transfer the preproteins from Tom70, through the import pore in the outer mitochondrial membrane, to import machinery in the inner membrane. (Modified from ref. 1.)**

indication of the importance of Tom70's clamp domain to mitochondrial protein import, yeast cells die if the normal Tom70 receptor is replaced by one with the clamp mutation. Moreover, import of the phosphate-carrier protein by isolated rat liver mitochondria is inhibited by adding surplus Hsp90 carboxy-terminal domain, which competes with the complete Hsp90 for binding to Tom70's clamp domain. The import of preproteins that use the Tom20 receptor is not affected. Similar experiments with yeast mitochondria indicate that Hsp70–Tom interactions are also essential for preprotein import via Tom70.

Young *et al.* also start to disentangle the respective roles of Hsp90 and Hsp70. Both chaperones have the ability to hydrolyse ATP molecules, and the turnover of ATP causes release of bound preprotein. The ATP-hydrolysing activity of Hsp90, unlike that of Hsp70, is inhibited by the antibiotic geldanamycin, providing a means of testing the specific involvement of Hsp90 in protein transport. Young *et al.* find that geldanamycin inhibits the import of the phosphate-carrier protein both into isolated rat liver mitochondria and into mitochondria of a mammalian cell line. As might be expected, it does not affect the import of the adenine-nucleotide carrier into isolated yeast mitochondria. Moreover, the carboxy-terminal domain of another cochaperone, Bag-1, binds to the ATP-hydrolysing site of Hsp70 but not to that of Hsp90. Surplus Bag-1 carboxy-terminal domain inhibits the import of the two carrier preproteins into mitochondria from either rat liver or yeast by interfering with the turnover of ATP by Hsp70.

These observations suggest that Tom70 is not only a preprotein receptor, but also a cochaperone that aids chaperones in the targeting of carrier preproteins to mitochondria (Fig. 1). This dual function of Tom70 can be rationalized in terms of the need to protect hydrophobic membrane proteins from aggregation as they pass from ribosomes to mitochondria — a hazardous journey for which such proteins need the continued protection of chaperones. Cytosolic Hsp70 was known to chaperone the folding of many newly synthesized proteins[7], whether they are destined for mitochondria or remain in the cytosol, but Hsp90 was thought to be largely restricted to the folding and assembly of signal-transduction proteins in the cytosol[8]. Why mammalian mitochondria require Hsp90 for carrier-protein import whereas yeast mitochondria do not is just one of the questions raised by these observations[1]. The study of molecular chaperones continues to spring surprises. ■

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Applied physics

Son et lumière

John M. Worlock and Michael L. Roukes

The confinement of photons in a resonant cavity is the basis of laser operation. A device that has a resonant cavity for acoustic phonons inside an optical cavity enhances the interaction between sound and light.

A quintet of physicists has created some interesting 'tunes' using coupled resonant cavities. The double-resonator structures described by Trigo and colleagues[1] in *Physical Review Letters* are unusual in that they are designed to resonate at optical frequencies (with photons) and at acoustical frequencies (with phonons) — simultaneously.

Resonant cavities are ubiquitous. They form an essential part, for example, of orchestral instruments such as brass and woodwind, of pipe organs, and of the vocal cavities of many species. Their study also has a long and illustrious history. In 1877, Lord Rayleigh published his *Theory of Sound*, launching, among other things, the study of waves in confining geometries, or resonators. A notable early optical resonator is that of Fabry and Perot, unveiled in 1897, which has served the optical community well over the intervening years, and whose variants are crucial elements in the feedback systems of lasers. The function of a resonator is to provide space for wave propagation within reflective walls, so as to support a standing wave with a particular wavelength, and hence frequency. But to be useful, the resonator walls must not be perfectly reflective — they must radiate some energy to the outside world.

Now Trigo *et al.* have performed the first studies of the scattering of standing-wave photons from standing-wave phonons by placing an acoustic cavity inside an optical cavity, carefully positioning the acoustic cavity at the peak of the optical amplitude to maximize the strength of the interaction between light and sound. Their approach may engender new possibilities for the generation of coherent (single-wavelength) phonons, and may even ultimately help to enhance coherence in quantum electronic devices of the future, through the modification of electron–phonon interactions.

The cavities used by Trigo *et al.* were grown by molecular beam epitaxy — the well-developed technique of atomic layer-by-layer growth — as a semiconducting superlattice with alternating layers of AlAs and a related alloy, AlGaAs (Fig. 1). To understand how these structures behave, it is helpful to start with the notion of a Bragg mirror, a periodic assemblage of identical planes that is highly reflective only for certain bands of

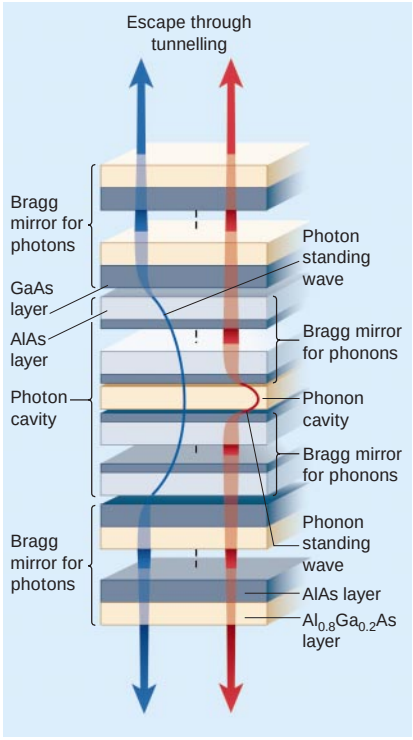

Figure 1 **A cavity within a cavity. Trigo *et al.*[1] arranged layers of semiconducting material to make Bragg mirrors (which reflect certain frequencies but transmit others) for photons and phonons, creating an acoustic cavity inside an optical cavity. When a light beam of an appropriate wavelength enters the structure, it sets up a standing wave in the cavity. The light–sound interaction allows a photon of the incident beam to split into two parts: a phonon resonant in its cavity and a photon resonant, and trapped, in its cavity. But as the mirrors are not perfectly reflective, both light and sound can escape the cavity.**

photon frequencies, in much the same way that crystal planes reflect X-rays and that electronic forbidden-energy bands occur in crystals. In such a one-dimensional optical Bragg structure, introducing an additional phase-shifting layer that is different from the others can create an optical bound state whose distinct resonant frequency lies within the range that is reflected at the Bragg mirror. The structure then provides an efficient transmission channel: light of an appropriate frequency passes through the Bragg lattice, then is phase-shifted and resonantly enhanced within what is, in essence, a 'microcavity' in the additional layer; gradually the light escapes the microcavity through tunnelling and passes out of the Bragg lattice at its original frequency.

Various authors[2,3] (in fact, combinations and subsets of the present authors) have made good use of such microcavities in a range of experiments, using optical resonances to enhance processes such as inelastic or Raman scattering. The new twist in this experiment by Trigo *et al.*[1] is the insertion of a second microcavity within the optical one.

The second cavity is conceived in direct analogy to the first, and is constructed as a resonator for acoustic phonons. Here, the Bragg mirrors have periods of about 10 nm, the central cavity is only 5 nm thick, and the whole structure fits snugly inside the central layer of the optical cavity (Fig. 1). The photons, with wavelengths of hundreds of nanometres, are unaffected by the thin acoustic layers (they simply take the appropriate average refractive index). The resonant frequency of the acoustic phonons in this structure is about 5×10^{11} Hz, well beyond the range of frequencies studied by either microwave or normal Brillouin scattering techniques.

In Trigo and colleagues' experiment, an incident photon is 'scattered' into the resonant, localized state in the optical microcavity, and at the same time a phonon is generated in the resonant, localized state in the acoustic cavity. The incident or absorbed photon must carry energy equal to the sum of the energies of these states and, to achieve resonance and the highest possible efficiency, the photon must be incident at a small angle to the structure (not quite 'head-on'). To resume its journey, and be observed, the 'scattered' photon must escape from the cavity by tunnelling through the Bragg mirror. As the resonant states inside the cavity are standing waves, there is no distinction between forward and backward scattering, and the scattered photon tunnels out simultaneously in both directions. The spectrum of scattered light measured by Trigo *et al.* clearly shows the peak expected for such a device.

Returning to the resonant, or localized, phonon that is produced alongside the scattered photon, it also tunnels out through the Bragg mirrors that form the acoustic cavity. This raises the prospect of realizing a coherent monochromatic source of very-high-frequency acoustic phonons. Trigo *et al.* have not observed these phonons directly, and their intensity outside the microcavity must be very small. But it is not difficult to imagine the steps towards enhancing the phonon intensity — by raising the intensity of the incident light, and also by seeding the optical cavity with photons to stimulate the scattering process. ■

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100 YEARS AGO

The fact that the message from the King to President Roosevelt, in reply to the latter's wireless telegram greeting, had to be sent to America by cable occasioned at the time much comment and correspondence in the daily papers on the attitude of the Post Office towards Mr. Marconi… Mr. Marconi made the following statements:— "We asked the Post Office authorities whether they would allow us to connect our station at Poldhu by wire with Mullion — at our own expense, mind you — but they refused absolutely and entirely. The message (that from the King) was not received at our offices until after Mullion Post Office had closed for the night, and one cannot very well keep a King's message lying about for twelve hours. I think it would have been much more discourteous to the King to have kept his message waiting for a day than it was to send it by cable."… In these circumstances, it is not surprising that Mr. Marconi's feelings towards the Post Office are rather bitter… He now proposes to go to Italy and build a huge station there, partly, no doubt, because, as he says, "Abroad I can get everything I want. Here in England I can get nothing." This is a little sweeping, for all England has not been so backward in supporting Mr. Marconi's enterprise as the officials of the Post Office.
From *Nature* 19 February 1903.

50 YEARS AGO

We have formulated a structure for the nucleic acids which is compatible with the main features of the X-ray diagram and with the general principles of molecular structure, and which accounts satisfactorily for some of the chemical properties of the substances. The structure involves three intertwined helical polynucleotide chains. Each chain, which is formed by phosphate di-ester groups and linking β-D-ribofuranose or β-D-deoxyribofuranose residues with 3′, 5′ linkages, has approximately twenty-four nucleotide residues in seven turns of the helix. The helixes have the sense of a right-handed screw. The phosphate groups are closely packed about the axis of the molecule, with the pentose residues surrounding them, and the purine and pyrimidine groups projecting radially, their planes being approximately perpendicular to the molecular axis. The operation that converts one residue to the next residue in the polynucleotide chain is rotation by about 105° and translation by 3.4 A. **Linus Pauling, Robert B. Corey**
From *Nature* 21 February 1953.