660-km boundary. An increase in viscosity across the boundary associated with the transition could produce strong slab distortion[10]. And the precise pressure–temperature relation of the phase transformation could conspire to produce slab deflection, impeding any penetration of the lower mantle[11].

These results seem to dispense with models of a chemically layered mantle in which the 660-km discontinuity is viewed as only a chemical contrast which prevents mass transport across the boundary. However, this is not to say that layered convection and a difference in the bulk chemistry between the upper and lower mantles are ruled out. There is continuing debate over whether the perovskite phase transformation near 660 km predicts the correct density for the lower mantle; some evidence indicates that there is a greater proportion here of iron or other high-density material relative to the upper mantle[12]. It is plausible that there is a chemical contrast between the upper and lower mantles, associated with deeper seismic discontinuities (at 710 km, for example) or linked to the phase transition near 660 km. Such a chemical boundary may reflect seismic waves only weakly, so that any strong deflections of the contrast need not be apparent from the seismic studies. Such a chemical contrast could contribute to an increase in viscosity across the mantle transition zone, abetting the deflection of the downwelling slab. Resolution of the overarching issue of dynamic configuration of the mantle is thus not yet in hand, but the work of Shearer and Masters has certainly narrowed some of the options. □

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1. Shearer, P. M. & Masters, T. G. *Nature* **355,** 791–796 (1992).
2. Olson, P., Silver, P. G. & Carlson, R. W. *Nature* **344,** 209–215 (1990).
3. Morelli, A. & Dziewonski, A. *Nature* **325,** 678 (1987).
4. Doornbos, D. J. & Hilton, T. *J. geophys. Res.* **94,** 15741–15751 (1989).
5. Hager, B. H. & Raefsky, A. *EOS* **62,** 1074 (1981).
6. Woodhouse, J. H. & Dziewonski, A. M. *J. geophys. Res.* **89,** 5953–5986 (1984).
7. Su, W. & Dziewonski, A. *Nature* **352,** 121–126 (1991).
8. Woodward, R. L. & Masters, T. G. *J. geophys. Res.* **96,** 6351–6377 (1991).
9. Revenaugh, J. & Jordan, T. H. *J. geophys. Res.* **96,** 19763–19780 (1991).
10. Gurnis, M. & Hager, B. *Nature* **335,** 317–321 (1988).
11. Machetel, P. & Weber, P. *Nature* **350,** 55–57 (1991).
12. Jeanloz, R. & Knittle, E. *Phil. Trans. R. Soc.* A**328,** 377–389 (1989).

LASER PHYSICS

Ultrason et lumière

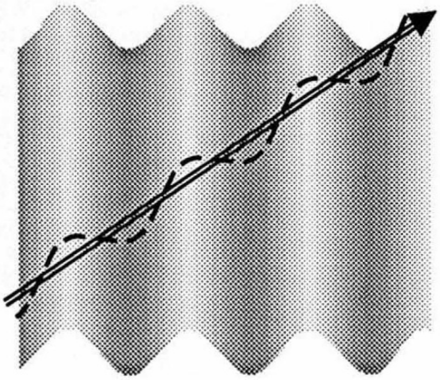
R. G. Evans

RECENT developments in micro- and nanoengineering have been brought about only through the application of the most sophisticated electron and atomic beam technology. But now K. R. Chen and J. M. Dawson propose what must be the simplest example of microengineering yet discussed (*Phys. Rev. Lett.* **68**, 29–32; 1992), with the promise of tunable coherent radiation in any part of the spectrum, from microwaves to soft X-rays, from a single device. To make the periodic structure that forms the heart of their proposed laser, Chen and Dawson take the most straightforward approach: using ultrasonic sound waves.

The best-known tunable source of radiation in the optical region is the free electron laser (FEL). This works by modulating the motion of high-energy electrons using the periodic magnetic field produced by a 'wiggler' magnet. The undulating field induces the electrons to radiate and, as the system is periodic, the radiation reacts back on the beam electrons to bunch them together. This gives an exponential growth in the intensity of scattered radiation. The electron beam moves relativistically, so that the relatively long wavelength of the wiggler magnet (say 1 cm, corresponding to radio waves) is Doppler shifted to far shorter wavelengths. The radiation frequency is tuned through the optical spectrum by changing the beam energy.

The drawbacks of the FEL are many. In particular, producing high-frequency radiation requires high-energy electrons, in the range 10–100 megaelectronvolts. And small, powerful, precise and, consequently, expensive wiggler magnets are necessary. Chen and Dawson's new contribution is to note that the periodic modulation of the electron beam can be achieved equally well by a density variation in a plasma of ions and electrons, and that the easiest way to make such a periodic variation is with a sound wave. Normally the multitude of instabilities that plague plasmas would undo any regular density modulation, but Chen and Dawson propose using a method developed at Imperial College to make a relatively cold plasma, immune to the instabilities, using multiphoton ionization. The density of the plasma is exactly equal to the background density of the gas before ionization.

Chen and Dawson's ion-ripple laser is delightfully simple: set up a standing ultrasonic wave in a hydrogen gas cell, ionize the gas with a short, intense pulse of laser light, and fire through the resulting plasma an electron beam of just a few megaelectronvolts energy. Because of the very short wavelength of the sound wave, compared with that of a wiggler magnet, only a moderate Doppler shift is needed to boost the electrons' radiation to optical frequencies and the efficiency can be much higher than with the 'mechanical' FEL.



The path of a high-energy beam of electrons, passing through a plasma excited by a standard ultrasonic wave, will deviate about its mean. Laser radiation will emerge along the beam direction.

The ion-ripple laser has the potential to be more of a table-top device than the FEL, through its reduced requirement for high-energy electrons. It is also delightfully simple to tune; of course, it is not that difficult to change the energy of the electron beam in an FEL, but it is more elegant to tune your laser radiation by altering the pitch of a sound wave.

At first sight, the ion-ripple laser has many features in common with the channelling radiation produced by electron beams passing through ion arrays in crystals. But the three-dimensional structure of solids and the higher background electron densities mean that channelling radiation is a less controllable phenomenon.

There are diverse applications possible for a table-top tunable radiation source: selective excitation and ionization make possible new measurements in atomic physics; selecting vibration frequencies in molecules can produce specific radicals and initiate chemical reactions; colour selectivity can be biologically and medically useful; and narrow-band tunable radiation can be used to investigate the surface properties of new engineering materials such as low-dimensional structures and quantum wells.

On a more speculative level, our humble piece of microengineering, using nothing more sophisticated than a sound wave, may well find application in the preparation of new generations of microelectronic circuits. Yet again we may see the applications of science coming full circle to feed the next generation of sound and sometimes brilliant ideas. □

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