Why celebrate laser birthday?

Lasers were first constructed 25 years ago. An historical account and some recent work appear in this issue. There can hardly ever have been an instrument that so quickly became pervasive.

WHY celebrate the 25th anniversary of the invention of a scientific instrument, the laser? Why not instead be patient, and wait for the more conventional half-century? Or, since lasers are mostly tools rather than objects of interest in their own right, why not celebrate the discoveries their existence has made possible rather than the means by which these ends have been successfully attained? These questions are all properly provoked by the group of articles on pages 307 to 330 of this issue. What follows is the explanation.

First, the supposition that lasers are merely tools for doing an admittedly huge diversity of jobs is easily made but is also false. With all that has happened in the past 25 years, it tends to be forgotten that the development of the first working laser was also the first occasion on which it became possible to study coherent electromagnetic radiation at or near the wavelength of visible light. By contrast, the study of coherent microwave radiation was in no sense dependent on the earlier invention of the microwave analogue of the laser, called the maser.

Both devices were also, as it happens, in their time the most vivid practical demonstrations of the reality of the phenomenon, originally inferred by Einstein during the development of his quantum theory of radiation (in 1912), that an excited atom capable of emitting a photon of a certain frequency will be stimulated to do so by radiation of that frequency or something like it, and that the likelihood of stimulated emission will be proportional to the intensity of the stimulating radiation. Although there was never any reason to quibble about Einstein's conclusion, which was enthusiastically used in the 1920s by R.H. Fowler and A.S. Eddington (for example) for the calculation of the transmission of radiation through stellar atmospheres, and although the direct calculation of the Einstein coefficient became one of the first successes of the wave mechanics of 1926, it always helps to turn a phenomenon into a fact of life that there should be a direct demonstration of it.

The device constructors now have an open licence. Their objective seems simply to make every possible kind of electronic excitation into the working principle of a laser, whence the emergence of solid-state semiconductor lasers (where the excitation is that of electrons into the conduction band). The outcome is coherent radiation because the stimulated emission is always in phase with that which stimulates it. The practical difficulties are always those of producing a sufficient supply of excited entities, electrons in atoms or in semiconductors, to swamp incoherent spontaneous emission of the same radiation. So pumping (from the ground state to the excited state) is where the designers spend their energy.

Weird and wonderful things are done in the process, as shown by an account in the current issue of *Applied Physics Letters* of an attempt by R.S. Taylor and K.E. Leopold of the National Research Council of Canada to extend the pulse-length of a xenon/chlorine excimer laser (*Appl. Phys. Lett.* **47**, 81; 1985). Here the excited state is that of an ionized atom, the lower level is a loosely-bound outer electronic state and the energy difference corresponds to ultraviolet radiation. Pumping such a device entails the creation of free electrons, which means an electric discharge.

But how can such a phenomenon be sustained for a reasonable length of time, say a microsecond? The answer offered is a double bank of capacitors discharging through one half of a rudimentary transformer, one quickly (in a few tens of nanoseconds) at high voltage and the other more slowly, through the laser gas made electrically conducting by the trigger pulse. The engineering of this equipment entails arguments of the kind now most commonly encountered among those who organize the discharge of the energy of capacitors into the plasma contents of thermonuclear fusion machines (but the laser is on a much smaller scale).

Taylor and Leopold claim an efficiency of 2 per cent for their device, with a 0.4 microsecond pulse of ultraviolet radiation, and indeed look forward to the continuous operation of devices like theirs. The US Strategic Defense Initiative will be interested. Taylor and Leopold calculate that they have extracted 1.5 J of power from each litre of lasing gas in a pulse lasting only 0.4 microseconds, which corresponds to 3.75 MW at continuous operation. Pumping the materials from which X-ray lasers may be made has still some way to go.

These are the practical problems; what are the benefits? Even after so short a time as 25 years, it is easy to overlook, or to take for granted, the way in which the use of lasers has transformed whole areas of investigation. Chemists concerned with the mechanisms of chemical reactions were among the first to appreciate the value of devices that could be used to excite molecules in specific ways and in times short compared with those of chemical transformations and interactions. One tangible outcome, for example, has been a knowledge of the role of molecules of chlorophyll in photosynthesis that was previously entirely inaccessible. Similarly, there is now a whole new field of spectroscopy, that of the highly excited atoms called Rydberg atoms, whose existence has been made possible only by the availability of tools that can be used in the preparation of the Rydberg states. The value of being able to make measurements of the properties of the species involved in, say, the upper atmosphere or in stellar atmospheres should be huge.

The most casual readers of the literature must now be aware of the pervasive influence of lasers in most fields of research. (The issue of *Applied Physics Letters* carrying the article by Taylor and Leopold has no fewer than eight other accounts of schemes for making novel lasers function, but the journal is the device-constructor's running commentary.) Recent demonstrations that lasers, by means of the momentum transferred in the absorption of photons, can be used to rob atoms of virtually all their translational velocity ("cooling" is the term) points the way to a further increase in the accuracy of atomic spectroscopy and thus to the definition of frequency standards, or time standards, more accurate than even those now used (see B.W. Petley, News and Views 27 June, p.716).

It is also now a matter of common knowledge that the stability of certain geological structures, critical parts of the San Andreas fault, for example, are monitored by geodetic lasers, that other instruments are used for the direct measurement from the ground of the constituents of the upper atmosphere (LIDAR) and that the accumulation of data from Earth satellites and from the corner reflectors left on the Moon during the Apollo missions will eventually yield a more precise test of current understanding of the dynamics of the Solar System, relativistic corrections included.

So there is plenty to celebrate. That lasers would turn out to have such an influence in so many different fields was foreseen 25 years ago. The surprise is that so much has happened so quickly.

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