Forty Years

Quantum electronics, historically defined as the extension of electronics to higher (optical) frequencies, started with the development of laser sources. It is now 40 years old (if one dates back the advent of lasers to an original proposal formulated in 1958 by Arthur Schawlow and Charles Townes). Lasers were first conceived as an extension to the optical range of coherent microwave sources (MASERs). Since the first experimental realisation by Th. Maiman in 1960, laser action has been demonstrated in a wide variety of media: gas discharges, liquids, dyes, solid-state media, crystals, fibres *etc.* Progress in solid-state lasers such as semiconductor lasers, rare-earth doped crystals and fibres is particularly noticeable, in terms of compactness, robustness, lifetime and lasing efficiency (the ratio between emitted optical power and input power). These lasers have a strong industrial impact for their application in a number of technologies: optical communications, optical data storage, displays...

Laser sources now span a wavelength range extending from the far-infrared to the ultraviolet domain. Wavelength-tuneable and frequency-stabilized continuous wave laser sources have been steadily improved. This, along with the development of high resolution nonlinear spectroscopic techniques, has brought forward formidable advances in laser spectroscopy, allowing unprecedented accuracy in measurements in atomic and molecular physics, giving access to particle physics and fundamental processes in low-energy experiments. Implications in time and length metrology are quite important (highly accurate optical clocks *etc*), with in particular the decision, in 1983, to fix the numerical value of the speed of light.

In the time domain, the development of laser technology has also been impressive with the realisation of ever shorter laser pulses, lasting now just a few optical cycles (femtosecond pulses) and giving access to the domain of femtosecond spectroscopy with its many applications in ultrafast physics, chemistry and biology (*see the article by S. de Silvestri and O. Svelto*). Correlated to this shortening in pulse duration, extremely large instantaneous optical powers have been obtained (petawatt lasers), and higher intensities are actively pursued in view of reaching laser thermonuclear fusion by inertial confinement.

Inertial confinement relies on radiation pressure to increase the temperature by several millions of degrees. At the extreme opposite of the temperature range, exchange of momentum between atom and laser light has also been used to manipulate atoms, control their motion and lower their temperature well below the microkelvin level, *ie* less than one millionth of degree above absolute zero. (*Recent progress is described in this issue by W. Ertmer and G. Birkl.*)

From the very beginning of the laser era, the peculiar properties of laser radiation have been underlined. The analysis and control of these properties is now known as the field of quantum optics. The quantum optical field is a case study in quantum physics and dynamical systems, and allows one to study in ideal conditions such fundamental, nonclassical concepts as wave-particle duality, Heisenberg uncertainty relations, quantum correlation and entanglement (Schrödinger's cat), theory of quantum measurement *etc.*
All these advances in the knowledge of fundamental processes in laser physics and spectroscopy, and the progress of laser technology, have important repercussions in frontier disciplines, such as analytical chemistry, biology, medicine and environment (pollution monitoring). Indeed, from the very beginning, the development of laser sources has been an interdisciplinary phenomenon. Laser spectroscopy allows one to perform selective and accurate *in situ* diagnostics of given species, and has been applied to remote detection of trace elements in environments as different as upper atmosphere, reaction flames and living tissues. (*See article by S. Svanberg and C. Fotakis.*)

When the laser was discovered some forty years ago, few scientists would have predicted the fantastic development it has undergone, the renewal of old disciplines (*eg* electronics, atomic and molecular physics...) that it has triggered and the creation of new disciplines like opto-electronics. When entering the third millennium, one can safely predict a brighter and brighter future for lasers and quantum electronics, with increasing applications in many fields like optical communications, optical computing, metrology and bio-medical optics.
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