GETTY

MILESTONE 15

Lasers for the masses

Today, the use of lasers is nothing particularly exciting. DVD players, laser pointers, bar-code scanners and telecommunications all use lasers made from semiconductor materials. The situation was different in 1962, when only expensive lasers based on atomic gases existed (MILESTONE 9). Yet, that year, Robert Hall at General Electric realized a first electrically operated solid-state laser, based on the semiconductor gallium arsenide, followed, within 1 month, by similar discoveries by teams lead by Marshall Nathan, Benjamin Lax and Nick Holonyak. However, with high laser thresholds and poor lasing efficiencies even at cryogenic temperatures, prospects for the practical use of these lasers appeared uncertain.

The following year, Herbert Kroemer, as well as Zhores Alferov and Rudy Kazarinov from the Ioffe Physico-Technical Institute of the Russian Academy of Sciences, independently came up with an ingenious suggestion: the concept of double-heterostructure lasers.

Instead of using a bulk semiconductor, they suggested a layered structure made of a thin semiconductor film with a smaller band gap sandwiched between semiconductor layers with a larger band gap. The large gap of the neighbouring layers leads to an efficient confinement of carriers in the central layer, which enhances the performance of the lasers.

It being the time of the cold war, research groups in the West as well as the East began a race to fabricate the first room-temperature semiconductor laser. This important milestone was eventually achieved in 1970, when groups first from the Ioffe Physico-Technical Institute and then from Bell Laboratories realized continuous room-temperature lasing made from gallium arsenide sandwiched between aluminium gallium arsenide.

These and consequent achievements would not have been possible without the parallel drive towards thin film-deposition systems during the late 1960s. Of particular relevance were metallo-organic chemical-vapour deposition originating from the work of Harold Manasevit at the North American Aviation Company, and molecular-beam epitaxy pioneered by Alfred Cho and John Arthur at Bell Laboratories. Despite such advances in fabrication, it was not until 1996 that the first blue semiconductor laser was realized in gallium nitride by Shuji Nakamura (MILESTONE 19).

In addition, more complex laser designs have become possible. An example is vertical-cavity surface-emitting lasers. However, the crowning achievement of such efforts is the quantum-cascade laser developed by Federico Capasso and colleagues at Bell Laboratories in 1994. Quantum-cascade lasers are designed so that during the 'cascading' of electrons through several hundreds of layers, more than one photon is emitted per electron. Being capable of operating across a broad spectral range, quantum-cascade lasers are a useful source of tunable laser radiation with applications to spectroscopy and chemical sensing.

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