Being Coherent: Three Decades of Laser Development

In 1916 Albert Einstein published a proof of Planck's law of radiation in which he introduced the phenomenon of stimulated emission. This phenomenon [It was first called "stimulated emission" in 1924 in a paper by J. Van Vleck] was the basis of the laser principle. Unfortunately, knowledge of quantum physics was then too primitive to put the phenomenon to any practical use.

With the development of microwave technology during World War II, scientists turned to studying the interactions of microwaves with matter. This led, in 1952, to the first public proposal of a "maser." Joseph Weber, a young electrical engineering professor described the concept at the Electron Tube Research Conference in Ottawa, Canada. Interested in the idea, RCA asked Weber to give a seminar on the topic and paid him $50.

The following year at Columbia University, Charles H. Townes, James Gordon, Herbert Zeiger, and their team achieved the first functional device using microwaves to create stimulated emission from ammonia molecules.

Townes and his team of students supposedly went to a restaurant to celebrate their discovery and to brainstorm a Latin or Greek name for the device. When no one could agree on a name, they eventually adopted the acronym MASER, for microwave amplification by stimulated emission of radiation. Townes, who had been working for two years and had spent $30,000 of a grant on the project, faced detractors who translated the acronym as "Means of Acquiring Support for Expensive Research"!

Three years later, working with Arthur L. Schawlow, a research physicist at Bell Laboratories, Townes proposed extending the maser principle into the infrared and optical range. Schawlow wrote,

> "October 1957, Charles Townes visited Bell Labs....and we had lunch...he was interested in trying to see whether an infrared or optical maser could be constructed, and he thought it might be possible to jump over the far infrared region and go to the near infrared or perhaps even the visible portion of the spectrum. He had some notes and said that he would give me a copy. We agreed that it might be worthwhile for us to collaborate on this study and so we began."

In July 1958 Townes proposed to the Air Force Office of Scientific Research that light amplification by stimulated emission be investigated. After eight months, Schawlow and Townes published "Infrared and Optical Masers," a theoretical paper that appeared in *Physical Review*, December 15, 1958. This paper described their idea for a system that used potassium vapor instead of ammonia [as used in the maser].

At first, the Bell Laboratories patent office declined to take notice of the invention, stating that "optical waves had never been of any importance to communications and hence the invention had little bearing on Bell System interests." But two years later, both men did receive a patent for their idea.

Gordon Gould, another researcher working independently for TRG, Inc., also filed for a similar patent in 1959, which led to a long-running legal battle over the priority of the development of many aspects of the laser. Finally in 1977 Gould received one patent from his application 18 years previously, and another patent in 1979.

Charles Townes received the Nobel Prize in 1964 for his work in the development of the laser, and Schawlow received the Prize in 1981 for his work in laser spectroscopy. Two Soviet physicists, Nikolai G. Basov and Aleksandr M. Prokhorov, independently proposed related ideas about the laser in 1958. They shared the Nobel prize with Townes in 1964 "for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based in the maser-laser principle."

Once the idea had been proposed, progress moved rapidly.

In July 1960 the first working laser was constructed at Hughes Aircraft Co. in Los Angeles by Theodore H. Maiman. Maiman, head of the quantum electronics division, found that the potassium vapor arrangement proposed in the initial Shawlow and Townes paper did not work. He had been investigating ruby crystals for many years and their applications in masers, and he decided for his laser medium to use a crystal of synthetic pink ruby [aluminum oxide with a small amount of chromium ions...the chromium provided the lasing action]. By 1958, scientists could artificially grow ruby crystals up to an inch in diameter and several inches long. This relative availability made ruby an attractive candidate for Maiman's first laser.

For his crystal, Maiman used a ruby with approximately 0.05% wt.% of Cr_2O_3 to Al_2O_3. Working in late 1959 and early 1960, Maiman reported in *Physical Review Letters* that he had observed "certain ground-state population changes in ruby due to optical excitation and the detection of optical absorption between two excited states in this crystal." His paper was first turned down by *Physical Review Letters* on the basis that maser physics had reached a stage where new research was no longer topical enough to warrant rapid publication!

Maiman's laser operated in the pulsed mode, and researchers soon found that focused ruby laser light could cut through solid objects. A favorite target object was the razor blade, which led to the [apparently serious] suggestion that laser output be measured in units of "Gillettes"!

Other than ruby, many rare-earth elements have also been used for their lasing properties, especially neodymium. In 1961 Elias Snitzer, working at the American Optical Company, made the first neodymium-doped glass laser. Such materials have spectral and fluorescent properties that make them attractive as lasing substances. Ruby lasers and neodymium-doped glass lasers operate at room temperatures and usually in the pulsed mode.

Other lasers use neodymium-doped yttrium aluminum garnet (Nd-YAG) and operate well in either the pulsed or continuous-wave mode. Nd-YAG lasers are used widely in industry and research because the favorable mechanical and thermo-optical properties of yttrium aluminum garnet are shared with the laser characteristics available from the Nd doping. Also adding to the success of Nd-YAG for lasers are the good optical properties of the garnet itself and the relative availability and low cost of the raw materials needed.

When researchers began to look into the lasing properties of rare-earth ions, actinide ions, and transition-metal ions, a flurry of publications made it difficult to keep track of progress. In 1966 researcher B.A. Lengyel wrote in frustration,

> "Systematic and exhaustive description of [such] lasers is a difficult task because of the large number of combinations possible with a variety of active ions embedded in a variety of host lattices. The compilation of information in this field is further hindered by

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investigators whose aim is to maximise the number of their publications."

New laser developments had branched in many other directions as well. Early in 1961 Ali Javan and his team at Bell Laboratories announced the first continuously operating laser—a gas laser. In 1962 near-concurrent announcements of the first semiconductor-junction laser, using gallium-arsenide crystals as the lasing media, were made by General Electric [September 24], by International Business Machines [October 4], and by Lincoln Laboratories of Massachusetts Institute of Technology [October 23].

Laser progress was being made so rapidly that it prompted science writer Kurt Stehling to write in 1966,

"Many laser research workers are worried about premature claims of enthusiastic editors and public relations men. Medical scientists, especially, are concerned about exaggerated stories of cancer cures and other claims."

After three decades of laser progress we know that many of these miraculous stories are by no means exaggerated. Progress in lasers, whether it be new research as in x-ray lasers or new applications such as holography, continues to proceed so rapidly that another historical summary 30 years from now may tell an entirely different story.

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