Maiman examines the ruby crystal tube that would be inserted into a coiled flashlamp. The original laser had a three-ring coiled flashlamp.

Maiman's Work

In 1984, former Hughes Research Laboratories Director Dr. George F. Smith recounted Maiman's building and demonstration of the laser.

The story of the ruby laser has its roots in T.H. Maiman's ruby maser program, which commenced in 1957. At that time, the new ruby maser was being investigated at several laboratories. Maiman succeeded in building a cavity-type maser that was lightweight, compact and generally suitable for use as a low-noise X-band preamplifier for communications or radar systems. When operated at 4.2 degrees K, it gave a 100 MHz gain-bandwidth product and a noise temperature of 2.4 degrees K. At a more practical operating temperature of 77 degrees K, the noise temperature was still a respectable 93 degrees K.

Early in 1959, Maiman examined the possibilities of optical pumping of the maser. Since the theoretical expression for the noise temperature of a maser amplifier varies as the reciprocal of the pump frequency, it is obvious that a much lower noise temperature could be achieved if the pump frequency were increased from the conventional 24 GHz to an optical frequency. Investigators at Westinghouse were also exploring optical pumping. They tried to pump paramagnetic resonance saturation in ruby. *Physical Review Letters* (vol. 13 p. 469-472, Nov. 15, 1959) attributed their failure to a low value (1%) for the quantum efficiency of ruby fluorescence.

Meanwhile, the classic laser article by Schawlow and Townes ("Infrared and Optical Masers," *Physical Review Letters*, vol. 112, pp 140-158) appeared in December 1958. This article described generally how one might build a laser and listed some of the problems to be solved. During 1959, interest in the possibility of making a laser grew rapidly at many laboratories in the U.S. and abroad. Maiman felt that a solid laser offered some advantages: 1) the relatively simple spectroscopy made the analysis tractable and 2) construction of a practical device should be simple.

Although Maiman had at first given some consideration to the use of the gadolinium ion, in gadolinium methyl sulfate or some other salt, he was drawn to the possibility of making a ruby laser, perhaps due to his extensive experience with the ruby system. In fact, there were two counts against using ruby: 1) the literature value for the quantum efficiency of ruby fluorescence was very low, as mentioned above, and 2) the fluorescent transition upon which the prospective laser was based terminated in the ground state. The second factor especially had led many investigators to rule out ruby as a laser candidate since it meant that the achievement of inversion would require the emptying of more than half of the population of the ground state. Lasers in which the laser transition terminates on an excited state do not have this constraint.

Excerpted from *"The Early Laser Years at Hughes Aircraft Company,"* by George F. Smith, *IEEE Journal of Quantum Electronics*, Vol. QE-20, No. 6, June 1984. ©IEEE. Reprinted with permission.

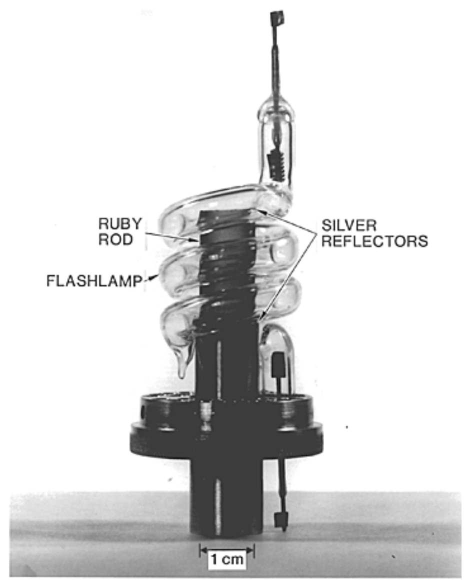
At this point, Maiman decided to re-measure the quantum efficiency of ruby fluorescence. The prospects for both the optically pumped ruby maser and the ruby laser critically depended on that parameter. Furthermore, Maiman felt that it was important to understand why the quantum efficiency might be low, to guide a search for a better material, should that be necessary. When Maiman's measurements gave a value of 70% for the quantum efficiency, the race was on!

First Maiman developed criteria for laser action as a function of gain per pass and mirror reflectivity. He concluded that the brightest continuous lamp readily available—a high-pressure mercury vapor arc lamp—would be marginal. A pulsed xenon flash lamp, on the other hand, appeared promising.

Before proceeding with the laser experiment, Maiman conducted an optical microwave experiment in which he monitored the 11.3 GHz absorption of a cube of ruby during application of a pulse of light from a xenon flash lamp through a Lucite light pipe. A significant decrease in the microwave absorption indicated that an appreciable fraction of the ground state was being depleted. With this encouragement, Maiman was ready to build his ruby laser.

As it happened, the timing was poor. In the spring of 1960, just when Maiman was ready to begin his laser experiments, Hughes Research Laboratories commenced its move from the Hughes Culver City plant to the labs' new home in Malibu, CA. Needless to say, Maiman's group made the move very expeditiously; he was back in the lab within two weeks, during which time he prepared the paper reporting the quantum efficiency and optical/microwave experiments.

Maiman obtained his first laser action in ruby on May 16, 1960. The first laser was a simple device. It consisted of a pink ruby cylinder 1-cm-diameter by 2-cm-long. Both ends were ground and polished flat and parallel and were coated with evaporated silver. A 1-mm-diameter hole in one of the silver coatings was provided to couple out the radiation. The ruby was mounted on the axis of a GE FT-506 xenon flash lamp, which was placed inside a polished aluminum cylinder.



One of Maiman's early lasers, which included a three-loop flashlamp, ruby rod and silver reflectors

The first laser demonstrated both spectral and beam narrowing, together with lifetime reduction. In mid-July 1960, Maiman acquired three new ruby crystals of much improved optical quality. When tested in the original set-up, they provided more dramatic spectral and beam narrowing, a sharp threshold for laser action, and the relaxation oscillations characteristic of the ruby laser.

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