The Birth of the Laser

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THE BIRTH OF THE LASER

The idea of generating coherent radiation at optical frequencies was conceived in late 1957; by the end of 1960 there were five realizations of the laser idea.

Joan Lisa Bromberg

In a recent study of early radio, Hugh G. J. Aitken (Amherst College) wrote: "We are inclined to think of invention as an act rather than a process because of the bias built into our patent laws. If property rights in a new discovery are to be secured, it is important to be able to establish priority in time.... This bias, however, should not be allowed to corrupt our historical interpretations.... [Invention is] a process with considerable duration in time, one to which many individuals contribute in a substantial way."[1] The birth of the laser was such a process. In this account, which I confine to events in the United States, I take the duration of the process to be the period between September 1957, when Charles H. Townes of Columbia University first wrote into his notebook his preliminary ideas for "a maser at optical frequencies," and December 1960, when Ali Javan, William Bennett and Donald Herriott of Bell Telephone Laboratories operated the first continuous laser. The people I include will be those who had initiated substantial laser research programs before July 1960, when Theodore H. Maiman of Hughes Research Laboratories announced his ruby laser. I shall review the work of these scientists and address two questions: First, what drew these people into laser research? Second, why were they able to command the resources needed to pursue it?

Townes and James P. Gordon, with the help of Herbert J. Zeiger, had put the first maser oscillator into operation, at a wavelength of 1.25 cm, at Columbia in the spring of 1954. The idea of using the same principle to generate coherent radiation at millimeter, submillimeter and even infrared wavelengths was not long in taking hold. Indeed, a staff member of the Air Force Office of Scientific Research had approached Townes and other senior physicists of the Radiation Laboratory at Columbia University early in 1957 to suggest that they undertake work on this idea. It was then widely believed, however, that the higher the frequency of the radiation, the more difficult it would be to generate it with a maser: Spontaneous emission increases with frequency, and so it was thought that the minimum power input might become too large. Furthermore, microwave masers had cavities the size of their wavelengths, and such cavities were impossible to fabricate for submillimeter or infrared wavelengths.

The Schawlow–Townes paper

At the end of the summer of 1957 Townes sat down to think through the problem systematically. A break-

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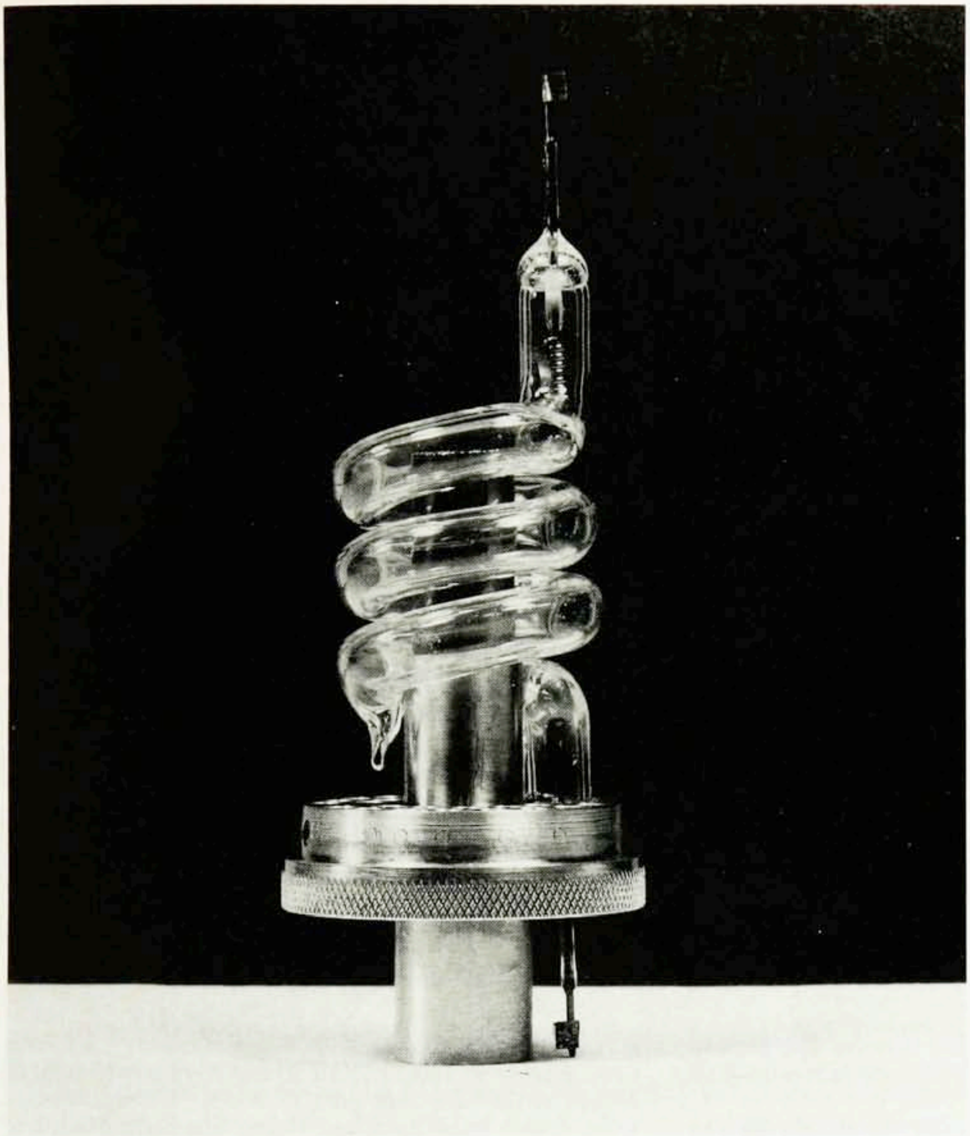


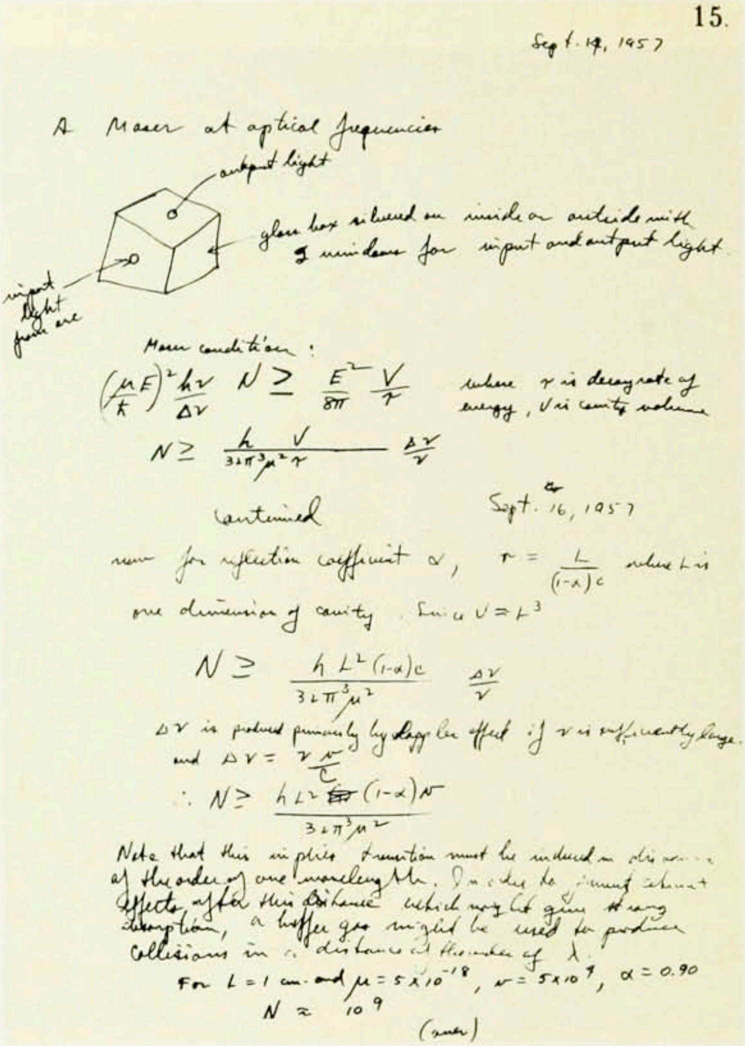
World's first laser. A spiral flashlamp surrounds a ruby rod, about 1 cm in diameter, in this laser built by Theodore Maiman at Hughes Research Laboratories in July 1960. (Courtesy of Hughes Research Laboratories.)

through came when he recognized, as he studied the equations, "that maser techniques could just as easily be applied to the visible region and in fact visible waves would probably be easier than the infrared, because . . . no more excited atoms or molecules were necessary . . . [while experimental] techniques in the visible range were already well developed."[2] It would be necessary to use a cavity large compared with the wavelength, one that could sustain many modes, but Townes hoped that the most favored mode might suppress the others because of nonlinear couplings. In October, Townes, who was a consultant to Bell Telephone Laboratories, approached Arthur L. Schawlow at the laboratories. Schawlow, Townes's brother-in-law and former postdoctoral fellow, had also been mulling over the problem of an infrared maser. The two now began a close collaboration.

Schawlow, prodded by a colleague at the laboratories, gave special attention to the problem of mode selection. He suggested that if a laser medium were placed in a cavity with reflecting end walls of diameter much smaller than the length of the cavity and with transparent side walls, only modes traveling along the cavity axis would oscillate. Townes and Schawlow refined this and other ideas over the winter and spring. In August 1958, after AT&T had filed a patent application, they submitted to the *Physical Review* a paper titled "Infrared and Optical Masers."[3]

Schawlow and Townes showed, both by means of general arguments and by the specific example of potassium vapor pumped by a potassium lamp, that the minimum power needed for oscillation was not impractically large. They explained the usefulness for mode selection of a structure—a variant of the Fabry–Perot etalon—with transmitting walls and mirrors at both ends. They discussed the linewidth and touched on the topic of solid-state optical lasers. Other US scientists had entertained one or another of the ideas in the paper by Schawlow and Townes, but that paper brought all those ideas together in one place, grounded them in calculation and thereby made a significant impact.

In July 1958 Townes applied to the Air Force Office of Scientific Research for funds to initiate work on a potassium laser at the Columbia Radiation Laboratory. An optical maser, he pointed out, would be useful in scientific work such as high-resolution spectroscopy, and it would also have practical applications such as length measurement by interferometry. AFOSR support came quickly. AFOSR, as we have seen, had been seeking to



15.

Sept. 14, 1957

A Maser at optical frequencies

output light

glass box silvered on inside or outside with 2 windows for input and output light

input light from arc

Maser condition:

$$\left(\frac{\mu E}{\hbar}\right)^2 \frac{h\nu}{\Delta\nu} N \geq \frac{E^2}{8\pi}\frac{V}{\tau}$$

where τ is decay rate of energy, V is cavity volume

$$N \geq \frac{h\,V}{32\pi^3\mu^2\tau}\frac{\Delta\nu}{\nu}$$

continued Sept. 16, 1957

now for reflection coefficient α, $\tau = \frac{L}{(1-\alpha)c}$ where L is one dimension of cavity. Since $V = L^3$

$$N \geq \frac{h L^2 (1-\alpha) c}{32\pi^3\mu^2}\frac{\Delta\nu}{\nu}$$

$\Delta\nu$ is produced primarily by Doppler effect if ν is sufficiently large. and $\Delta\nu = \nu\frac{v}{c}$

$$\therefore N \geq \frac{h L^2 \cancel{8\pi} (1-\alpha) v}{32\pi^3\mu^2}$$

Note that this implies transition must be induced in distances of the order of one wavelength. In order to [illegible] coherent effects after this distance which might give strong absorption, a buffer gas might be used to produce collisions in a distance of the order of λ.

For $L = 1$ cm. and $\mu = 5\times10^{-18}$, $v = 5\times10^{4}$, $\alpha = 0.90$

$N \approx 10^9$

(over)

Charles H. Townes's notebook entries of 14 September and 16 September 1957, in which Townes first discussed "A Maser at optical frequencies." (Courtesy of South Carolina State Museum.)

stimulate work on higher-frequency masers. Meanwhile, Schawlow elected to work on solid-state lasers at Bell Laboratories.[4]

In the months that Townes was negotiating his Air Force contract, he was asked by the Office of Naval Research to organize a conference on the technological uses of quantum resonances. These techniques, ONR scientists believed, were revolutionizing microwave technology. Townes assembled a committee representing some of the main American research organizations in the field. They scheduled the conference for September of the following year (1959). The name they chose for the conference—Quantum Electronics–Resonance Phenomena—underlined the position of its topic on the border between physics and engineering.

In October 1957 Townes had asked R. Gordon Gould, a Columbia University graduate student, for information about a lamp for the optical pumping of thallium vapor. Gould later testified that these conversations had alarmed him, because he himself had been thinking about lasers. Sometime on or before 13 November 1957, Gould wrote his design ideas into a notebook and had it notarized. He envisaged a tube terminated by highly reflecting mirrors and filled with a medium that had been put into an upper level by optical pumping (see the figure on the next page). At the end of his note, he listed the "possible uses of the LASER." These included spectrometry, interferometry, photochemistry, light amplification, radar and communication. "Perhaps the most interesting and exciting possibility," Gould wrote, "lies in focussing the beam into a small volume . . . with a tremendous factor of energy concentration. A solid or liquid placed at that focal point would be heated at the rate of about 10^{16} °K/sec. If the substance were heavy water, nuclear fusion temperatures could possibly be reached before the particles were dissipated."

Gould left Columbia University in March 1958 without completing his degree and went to work for TRG. TRG had started in 1953 as Technical Research Group, one of the "scientific job-shops" that came into being after the start of the Korean War and were sustained by military spending on advanced weapons technology. In 1958 TRG was an informal and creative company with perhaps 30–40 scientists out of a total of 100 employees. It had ambitions to field its own commercial products, but most of its work then came from contracts on antennas and radar, naval hull design, nuclear reactor physics, missile guidance, and masers and atomic frequency standards.[5] In the fall of 1958 Gould presented his laser ideas to Lawrence A. Goldmuntz, then president of TRG. Goldmuntz found the ideas exciting enough to have Gould draw up a detailed 100-page proposal to circulate to aerospace companies and government agencies.

One agency TRG approached was the Advanced Projects Research Agency, which had been set up after Sputnik in the secretariat of the Department of Defense and oriented in 1959 toward exploration of innovative weapons technologies. ARPA, which had more money than it could easily spend, proved a good choice: TRG made a request for $300 000 but ARPA, which was interested, *inter alia*, in the possibility of beam weapons,

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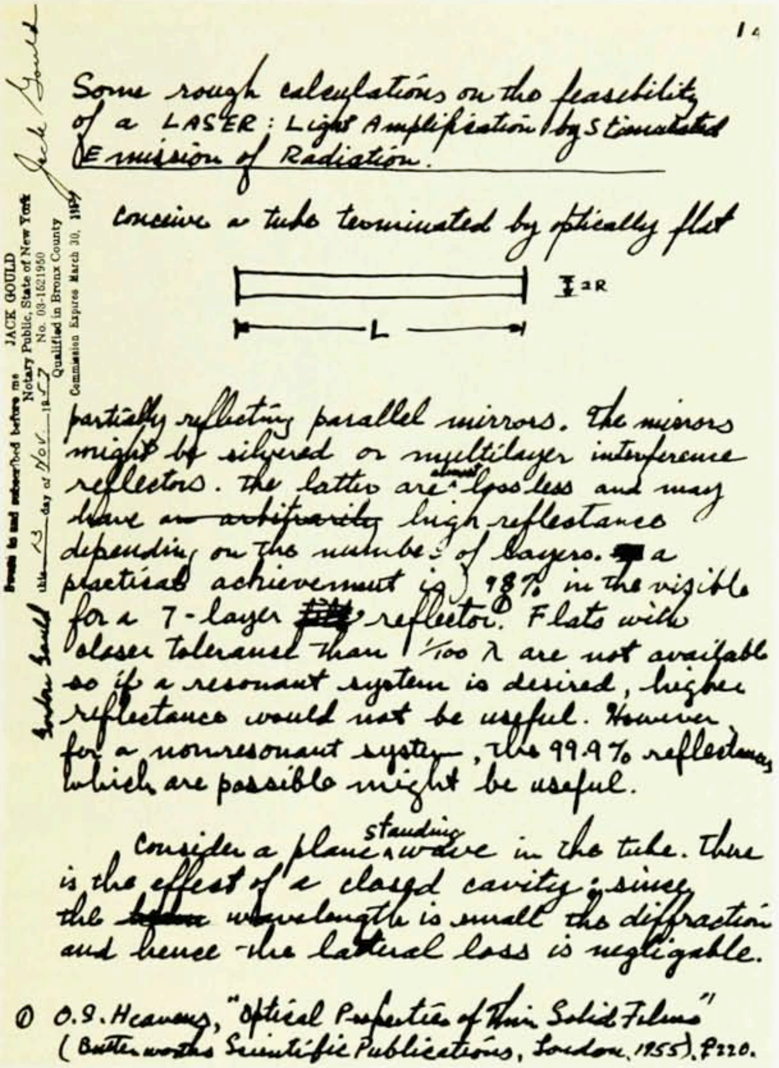

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Some rough calculations on the feasibility
of a LASER: Light Amplification by Stimulated
Emission of Radiation.

Conceive a tube terminated by optically flat

partially reflecting parallel mirrors. The mirrors might be silvered or multilayer interference reflectors. The latter are almost lossless and may have ~~an arbitrarily~~ high reflectance depending on the number of layers. A practical achievement is ① 98% in the visible for a 7-layer reflector. Flats with closer tolerance than 1/100 λ are not available so if a resonant system is desired, higher reflectance would not be useful. However for a nonresonant system, the 99.9% reflectances which are possible might be useful.

Consider a plane standing wave in the tube. There is the effect of a closed cavity; since the ~~[illegible]~~ wavelength is small the diffraction and hence the lateral loss is negligable.

① O.S. Heavens, "Optical Properties of Thin Solid Films" (Butterworths Scientific Publications, London, 1955). P220.

Sworn to and subscribed before me this 13 day of Nov. 1957
JACK GOULD
Notary Public, State of New York
No. 03-1621950
Qualified in Bronx County
Commission Expires March 30, 1959

Jack Gould

Gordon Gould

Gordon Gould recorded his ideas about the "LASER" in a notebook that he had notarized on 13 November 1957. The first page is shown here. (Courtesy of Gould.)

awarded it a \$999 000 contract for a secret program leading to operating lasers.

Two other scientists at Bell Laboratories, in addition to Schawlow, started working on lasers in late 1958 or early 1959. They were Ali Javan, who like Schawlow was employed in Sidney Millman's physical research section at Murray Hill, and John H. Sanders, who was a visitor in Rudolf Kompfner's electronics and radio research section at Holmdel. Javan had done his PhD under Townes at Columbia, and had stayed on in Townes's group for four years as a postdoctoral fellow, working in microwave spectroscopy and on masers. He first heard about the optical maser research from Schawlow in late April 1958, when he talked with him while interviewing for a job with Bell Labs.

Javan joined AT&T in August 1958; by October of that year he had started systematic studies in preparation for laser research. He decided to use gas as the laser medium. He preferred gases because he believed their simplicity made them better vehicles for the study of physical processes.[6] He was not sure, however, if optical sources would supply enough power for pumping. Two other approaches looked more promising to him: These were direct electron excitation, with pure neon as the medium, and transfer of excitation energy from helium to neon in collisions of the second kind.[7]

Sanders was an experimental physicist at Oxford University whom Kompfner had invited to Holmdel from January 1959 until September 1959. Kompfner was then deeply engaged in satellite communication research, but he was also excited about optical communication, which he regarded as the probable next step in comunication technology. In October 1958, shortly before Sanders was to arrive at Bell Laboratories, Kompfner sent him a preprint of the Schawlow–Townes paper, and suggested that Sanders join the "attempts to push the 'Maser' towards the infra-red." Sanders enthusiastically accepted.[8]

Sanders had less than a year of research time at Bell Laboratories, so he elected a cut-and-try attack, using pure helium excited by electron impact in a gas discharge as the laser medium.[9] Javan, by contrast, resolved to study in detail the physical processes that could facilitate or hinder lasing, so as to determine beforehand the optimum conditions for a successful result. He worked in close consultation with William R. Bennett Jr, a spectroscopist at Yale University. Bennett, like Javan, was as interested in elucidating the physical processes going on in the discharge as he was in achieving laser action. Bennett was to join the laboratories in September 1959, expressly to work intensively with Javan. Millman supported this unusual appointment, defended Javan's high budget and protected the project.

Quantum electronics conference

Meanwhile, reports on laser work began to appear at physics meetings. At the Ann Arbor conference on optical pumping in June 1959, one session was devoted to masers and lasers. Gould presented some unclassified calculations done under TRG's secret program, while Sanders described his attempts, so far unsuccessful, to make a helium laser. Schawlow spoke informally on the work he and his colleagues were carrying out on the satellites of the ruby R-lines, and Irwin Wieder of Westinghouse Research Laboratories discussed his program for extending optical pumping techniques from gases to solids to optically pump a ruby maser.

To achieve a higher-intensity pump light, Wieder was using resonance radiation from a second ruby crystal. A tungsten lamp raised the ions of the second crystal into two broad absorption bands lying above the R-levels, from which they relaxed to the R-levels without radiating. Wieder's resonance pump was about ten times more intense than a white light pump.[10] He therefore estimated a value of about 1% for the efficiency with which the light absorbed in the higher bands was being funneled into the R-levels.

At the quantum electronics conference in September 1959 lasers were the topic of much informal discussion, although most of the formal papers were on microwaves.[11] The conference had been initiated to focus on microwave developments, but in the intervening time laser studies had gotten under way. Thus the most important role of the conference was to hasten the birth of the laser. Laser research by three men, in particular, was accelerated by the informal discussions at the conference: Peter P. Sorokin and Mirek J. Stevenson of the IBM Thomas J. Watson Research Center, and Maiman.

The Watson Center

IBM's T. J. Watson Center was relatively new in 1959. IBM had inaugurated a research division in 1956, hired Emmanuel Piore, former chief scientist at the Office of Naval Research, and given him the resources needed to create a "world-class" facility.[12] The 1950s witnessed the founding of many new industrial laboratories and the expansion of many existing ones. (There had been about 3000 industrial laboratories in the country in 1950; there were more than 5400 in 1960.[13]) The Watson Center, located in the pleasant environment of Westchester County, close to the amenities of New York City, is in many respects typical of the research centers set up in the 1950s. The decade was marked by a scarcity of trained scientists, and the Watson Center, with its campus-like atmosphere, testified to industry's willingness to offer physicists more money, more comforts and more freedom to follow their own research directions, to attract them into its employ.[14]

Sorokin and Stevenson were members of a microwave spectroscopy group under the direction of William V. Smith. Smith had started to steer his microwave spectroscopy group toward lasers after the Schawlow–Townes paper appeared in the 15 December 1958 issue of *Physical Review*. Smith was convinced that coherent generation and amplification of light was bound to be useful in IBM's technology. He also believed that laser research would lend high visibility to the new laboratory and help establish its reputation. Sorokin and Stevenson had already identified calcium fluoride doped with trivalent uranium or divalent samarium as suitable laser media before they left for the quantum electronics conference. But the conference accelerated IBM's efforts. "We came back from the conference, and we really decided at that point to drop what we were doing . . . and try to focus on doing some experiment related to this new field that looked like it was going to break," Sorokin recently recalled.

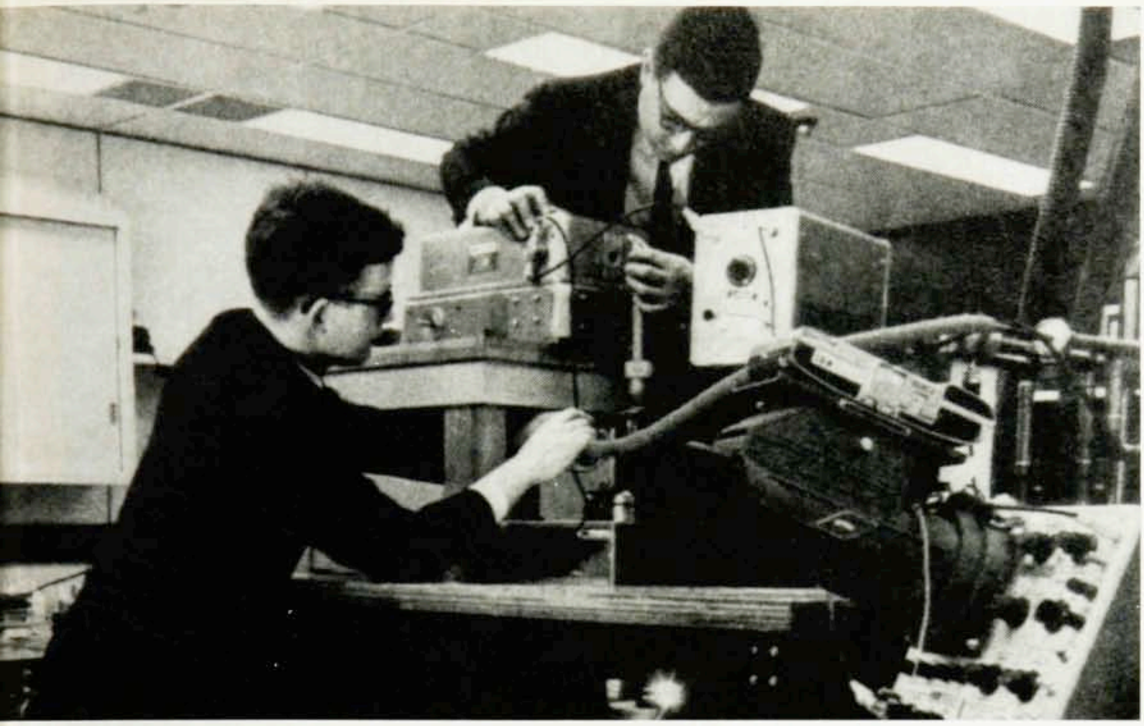
Maiman at Hughes

Hughes Research Laboratories also dated from the 1950s. In a reorganization in 1954, the electronic tube laboratory and the microwave laboratory at Hughes Aircraft Company had been separated from other research and development groups and combined into a centralized laboratory. Greater emphasis began to be accorded to more basic subjects. Harold Lyons, who had recently left the National Bureau of Standards to join Hughes Laboratories, had been made head of a program in atomic physics. Lyons had started a wide-ranging program in gas and solid-state masers, and Maiman was a member of his group. Maiman, who had just designed an innovative lightweight ruby maser for the Signal Corps, was at the quantum electronics conference to deliver a paper. The conference, however, also gave him the chance to learn what the laser groups had been doing.

Ali Javan and Nicolai G. Basov discuss lasers in the recess between formal sessions at the Quantum Electronics Conference, September 1959. (Courtesy of Arthur H. Guenther, Los Alamos National Laboratory, and Basov, Lebedev Institute, USSR.)

In fact, Maiman learned, the laser groups were encountering difficulties. The potassium vapor laser work at Columbia University was bogged down in technical problems. The potassium vapor was darkening the glass tube and attacking the seals. Often it caused blowups during the distillation process; at other times it picked up impurities during distillation that later quenched the excited states. Schawlow had rejected the R-lines of pink ruby because they ended on the ground state, while he expected that the dark ruby, though usable, would be limited to pulsed operation.[15] The noble gas systems with which Javan and Bennett were working showed only marginal gains.

Maiman believed that the emphasis on gaseous media was misplaced; solids struck him as far more promising. They could give higher power, operate under less restrictive temperature conditions and make possible smaller and more rugged devices. Maiman was also skeptical



Peter Sorokin and Mirek Stevenson (standing) make last-minute adjustments to their laser, November–December 1960. (Courtesy of IBM Yorktown Heights.)

about Schawlow's view that a pink-ruby laser would be impossible. Schawlow's conclusion had been reinforced by Wieder's figure of 1% for the quantum efficiency of ruby.[15] Maiman, however, who had been following Wieder's research, mistrusted the 1% figure.

Maiman returned to Hughes and threw himself into laser work. George Birnbaum, the immediate supervisor of both Maiman and Lyons, doubted that ruby had much promise as a laser material. But Maiman had sufficient stubbornness to persist, and Hughes allowed its scientists enough freedom to pursue their own ideas. Thus Maiman and his technical assistant, Irnee J. D'Haenens, could carry out the project on company funds.

Other US companies that had recently expanded their research laboratories also provided venues for laser work. The United Aircraft Corporation set up new research programs in the late 1950s at its East Hartford Research Center and near Stanford, California, to enable it to augment with electronics research its traditional investigations of aerodynamics and engine and aircraft technologies. Changes such as these were then typical for airframe and engine firms, for it was a period when planes were being "electronified" and missiles were replacing bombers as strategic weapons. As a result of the new programs set up at United Aircraft, an electromagnetics research unit was formed in its Hartford Center. The unit consisted of a small group of freewheeling young scientists, and it took a wide range of new technologies as its province. It was as a member of this group that the young engineer Anthony J. DeMaria, who had been captivated by the direction opened by the Schawlow–Townes paper, could take up laser studies in 1959.[16] The American Optical Company, in Southbridge, Massachusetts, was building its research capabilities in the new fields of fiberoptics and electro-optics. In early 1959 it hired the physicist Elias Snitzer. Snitzer's first American Optical project, a study of electromagnetic propagation in optical fibers, soon led him into a program for making glass optical-fiber lasers.

Final rounds

In mid-May of 1960 Maiman and his assistant got their first signs of lasing. They did not get the abrupt onset of laser action they expected—the appearance of a threshold. The ruby, however, was left over from maser experiments and had poor optical properties. Maiman now ordered special rubies from a leading crystal-growing firm.

By this time, however, Maiman felt a pressure to publish. His management, fearful that Columbia University would scoop Hughes, was urging him to make his results known. He himself had just published his finding of the high quantum efficiency of ruby in *Physical Review Letters*, and he was apprehensive that this publication might put others on the trail of the pink-ruby laser. On 24 June Maiman submitted a brief article titled "Optical Maser Action in Ruby" to Samuel Goudsmit, the editor of *Physical Review Letters*. To Maiman's dismay, Goudsmit turned it down.

Maiman next sent an abbreviated version of his letter to the British journal *Nature*.[17] In addition, Hughes Aircraft Company held a press conference on 7 July to announce the discovery. Sections of the scientific community greeted the Hughes announcement with skepticism. Maiman's results strongly indicated lasing, but he had not dotted every *i* and crossed every *t*. The preconception that ruby would not lase was probably one obstacle to acceptance, and the expectation that one of the East Coast laboratories—Columbia, Bell or TRG—would be the first in this race may have been another. In August, a group at Bell Telephone Laboratories put together a near-reproduction of one of Maiman's setups and showed beyond a doubt that the ruby was lasing. But their publication, which came out in the October issue of *Physical Review Letters*,[18] caused still more confusion. In the light of the detailed and explicit write-up from Bell Labs in the leading American physics journal, some scientists initially concluded that it was Bell Laboratories, and not Maiman, who had won the race. Maiman's victory was only belatedly crowned with recognition, and even then, there was wormwood among the laurel leaves.

Maiman's achievement to some extent affected the strategies of the other groups. Sorokin and Stevenson had had their doped CaF_2 fashioned into rectangular parallelepipeds and had been planning to make use of total internal reflection at the crystal–air interface. Now, instead, they ordered new samples shaped as cylindrical rods with silvered ends and bought xenon flashlamps. They got the CaF_2:U^{3+} four-level system to lase over Thanksgiving of 1960 and operated the samarium laser by early December.[19] Schawlow and George Devlin at Bell Laboratories and, independently, Wieder and Lynn Sarles at Varian Associates were prompted to demonstrate lasing in dark ruby.[20]

Javan had already enlisted Bell Laboratories optical specialist Donald R. Herriott to design a resonator for his helium–neon laser. In 1960 Herriott and his group fabricated a delicate apparatus with internal plane mirrors made of multiple dielectric layers and attached to hinges that allowed them to be oriented about two orthogonal axes. On 13 December, after the failure of earlier resonators and many unsuccessful trials on the latest one, Herriott, adjusting the mirrors almost casually late in the afternoon, got the first spike indicating lasing on the oscilloscope. The last of the 1960 lasers had come into operation.

Thus, not only was an operating laser in existence by the end of 1960, but it was available in five different varieties. This happened, of course, because each of the several teams that entered the field had a distinct approach shaped by the scientists' experimental philosophy, prior research experiences and institutional environment. In fact, one can trace at least seven varieties to that time, because some of the approaches then being followed, like Snitzer's work on glass lasers, did succeed at a later date. This raises anew the questions I posed at the start: Why did US scientists embark upon laser research before 1960, and why was support for their projects forthcoming? Any explanation must take into account at least three factors: the idea of the laser and the nature of the scientific and technological interest it generated, the relationships among various sectors of the US research establishment and the climate the country provided for this type of research in the late 1950s and early 1960s.

The idea of a laser appealed to a broad constituency. It promised a scientific instrument—Townes, for example, pointed out that it would be valuable for high-resolution spectroscopy. Its infrared and optical frequencies bespoke its usefulness for communications; hence it could win the support of communications research managers like Kompfner and Millman. The high energy density in a laser beam interested ARPA, which was then investigating every plausible scheme for anti-missile defense. High-resolution, lightweight radar equipment was another obvious possibility among the number of applications considered by the Defense Department research monitors. But the laser offered more than technology. Its development required the solution of interesting scientific problems. Javan and Bennett had to elucidate the physics of the transfer of excitations from helium to neon, and they had to deal also with the problem of determining the lifetimes of atomic states. Schawlow became deeply involved in the pair spectroscopy of ruby and related crystals. The laser, as oscillator and amplifier, also stood at the frontier of electrical engineering. Thus the laser had something in it for everyone, whether an academic physicist or an engineer, an industrial researcher or a military scientist. Indeed, science-based technologies often win support in academic circles, as well as in industry and government, precisely because they pose research as well as development problems.

But it is also important to keep in mind that scientists in academia, industry and the military establishment did not form disjoint groups in the America of the late 1950s. Rather, they were connected in numerous ways. Academic scientists were associated with the military through laboratories like the Columbia Radiation Laboratory, which was funded by the Joint Services Electronics Program; through membership on Department of Defense committees; and through tours of duty in agencies like the Institute for Defense Analysis.[21] Industrial scientists had latitude to tackle "academic" problems, for freedom in research was one of the perquisites that management felt constrained to offer in an era marked by a shortage of scientists. Scientists in government agencies such as AFOSR and ONR were not mere mouthpieces for the needs of the military but often had strong loyalties to their scientific disciplines and to the university and industry groups they monitored.[22] Academic scientists were bound to industrial laboratories through consultancies and through the circumstance that their doctoral students were increasingly entering industrial labs instead of the universities (see the article by M. W. White in PHYSICS TODAY, January 1965, page 32).

When different sectors of a research establishment are so strongly coupled as they were in laser research, the models appropriate for earlier historical epochs become irrelevant. A modern-day Heinrich Hertz would probably not have left to modern-day Guglielmo Marconi the task of turning the techniques he had devised for fundamental experiments on electromagnetism into ship-to-shore radio.[2] His initial vision would at once encompass his invention's scientific, commercial and military possibilities.

The idea of "spinoff" from military to civilian technologies may also be largely obsolete today, at least for science-based apparatus. The scientists doing military work today are sufficiently immersed in their disciplines to perceive the implications of their experiments for scientific questions, and many managers at the US industrial concerns where military R&D is now done have an eye out for commercial applications from the start.

The third factor we must consider when discussing US laser work is the climate that existed for such research in the years 1958–60. In a word, the climate was balmy. Resources for electronics R&D grew steadily through the 1950s, and the successful launch of Sputnik by the Soviet Union in October 1957 superposed a funding spike on an overall upward curve. But among resources may be counted not merely the available dollars and the number of active laboratories but also the prestige accorded science and technology. The national consensus in those years held that science and technology were good in themselves, basic to a healthy economy and vital to our international standing. Lasers could thrive in this environment. Interesting both scientifically and technologically, they were suited on the one hand to bringing in contract dollars and on the other to bringing prestige—to an individual investigator, to a laboratory organization and to the nation.

* * *

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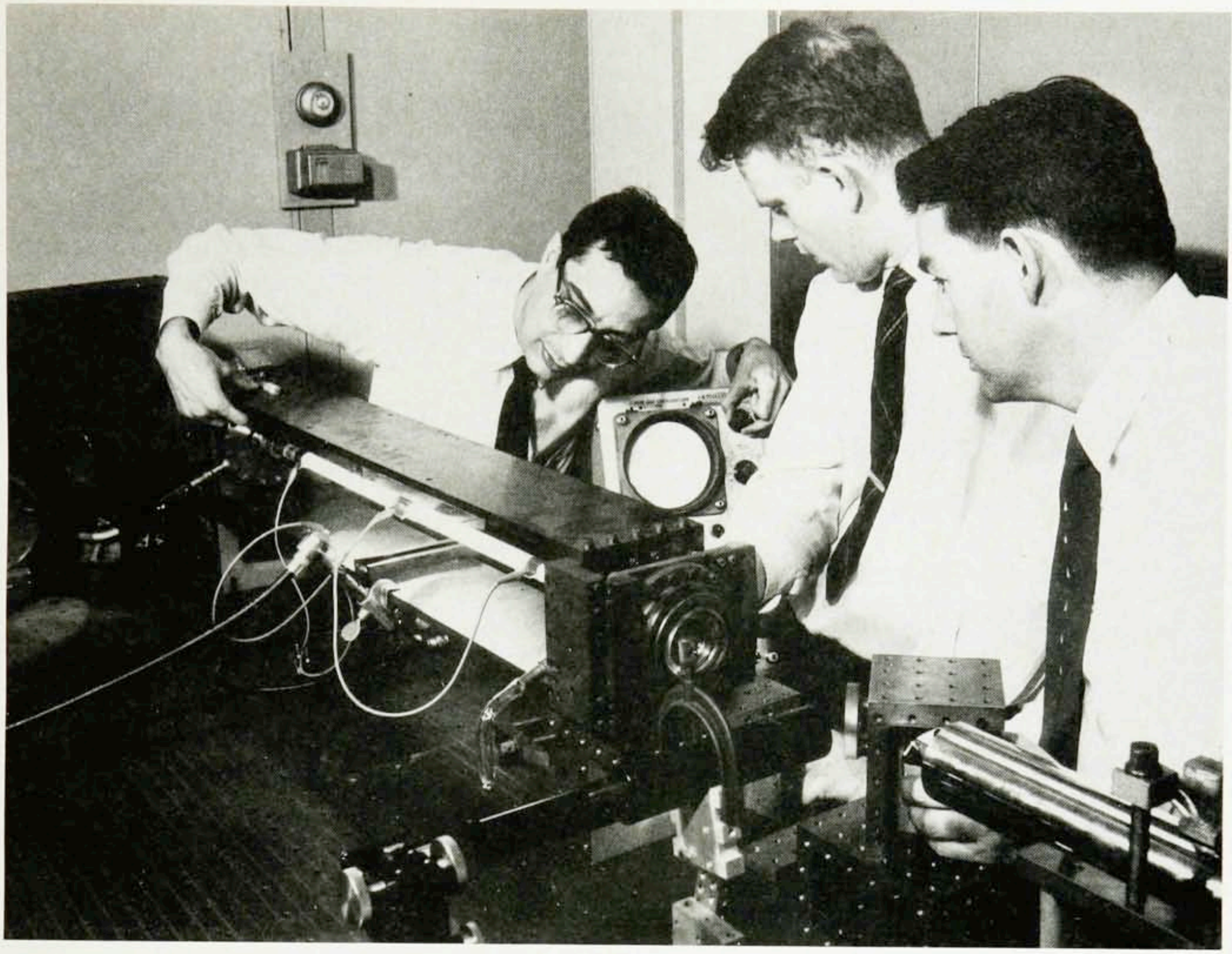

Ali Javan, William R. Bennett Jr and Donald R. Herriott adjust their helium-neon laser. The photo was taken in early 1960. (Courtesy of AT&T Bell Laboratories.)

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