לייזרים

סוף המאה ה-19 **פברי ופרו Charles Fabry & Aflred Perot**

1900 מקס פלנק – אנרגיה נפלטת ונבלעת רק בקוונטה דיסקרטיים

1905 איינשטין – אפקט פוטואלקטרי – אור בא בפוטונים

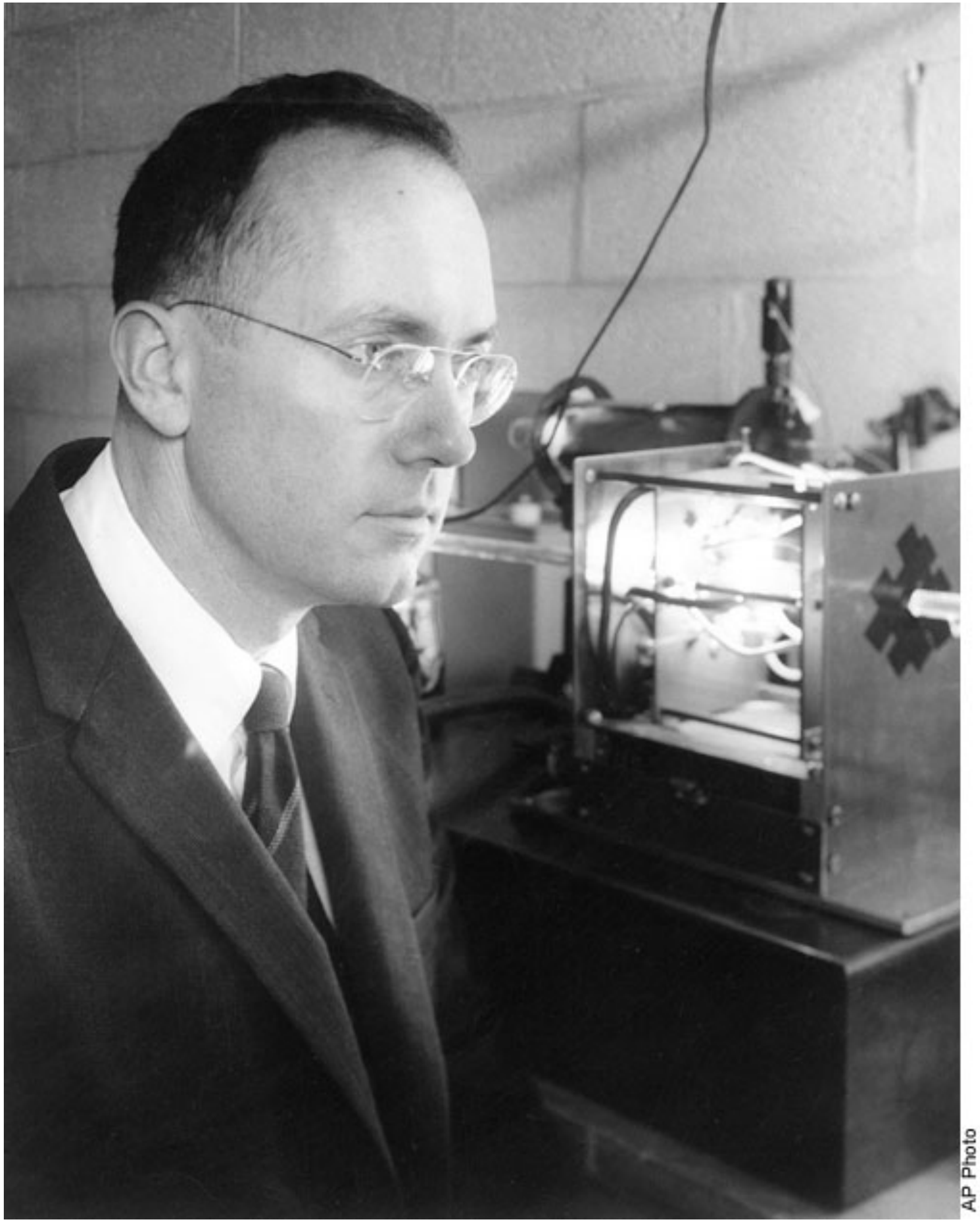
1917 איינשטין מציע פליטת אור stimulated emission שהיא הבסיס ללזירה

1940 ולנטין פבריקנט מתאר איך הפוך אוכלוסית אלקטרונים ייצר הגברה מולקולארית

1951 צ'רלס הרד טאונס מתכנן MASER אורך גל 1 ס"מ ועם ציגר וגורדון בונה מייזר אמוניה

1952 יוסף וובר מתאר קרינת מיקרוגל קוהרנטית

האטום של בוהר ומעברים אלקטרונים

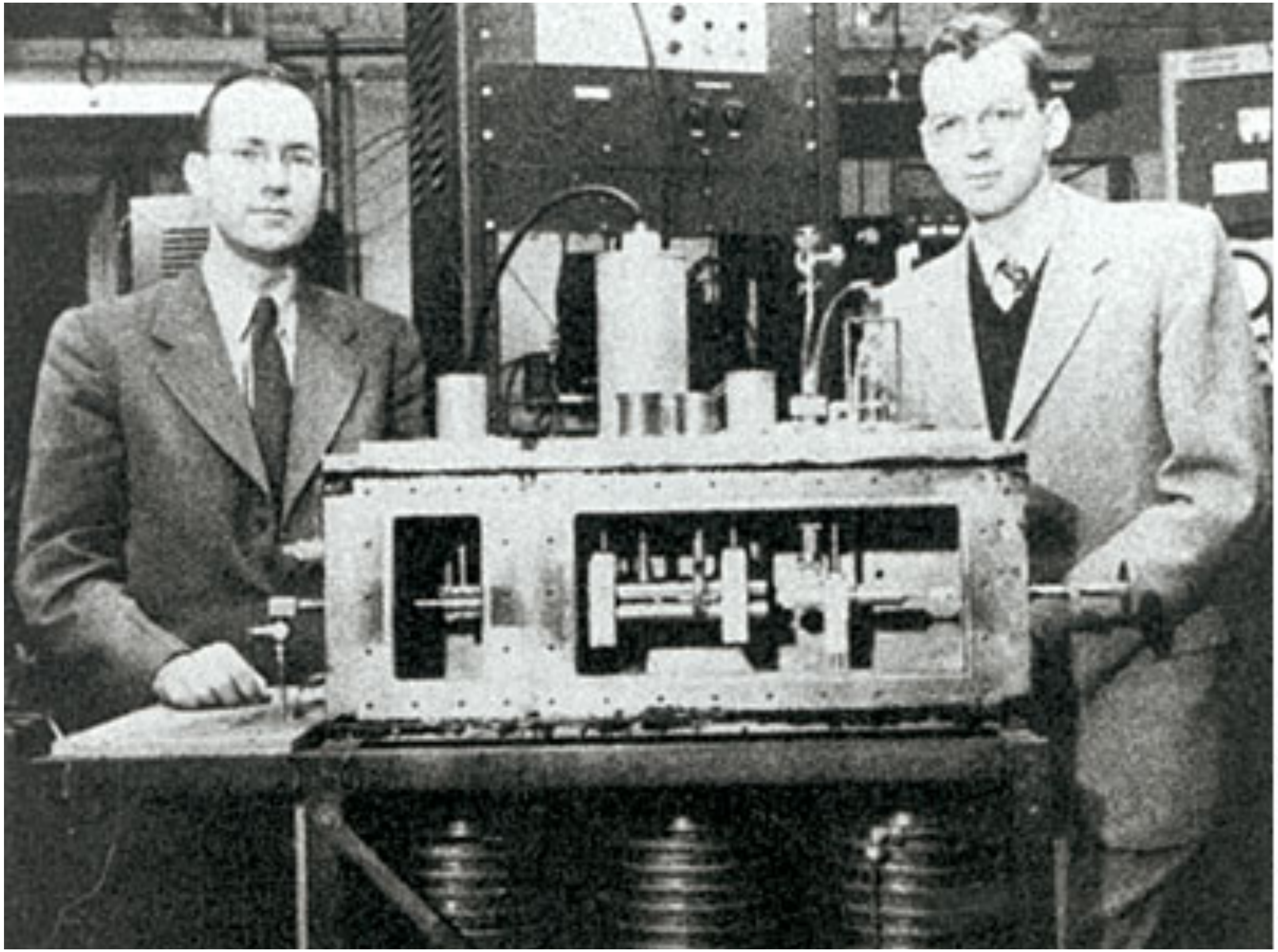


MASER concieved

1951: Charles Hard Townes of Columbia University conceives his **maser** (microwave amplification by stimulated emission of radiation) idea while sitting on a park bench in Washington.

MASER demonstrated

1954: Working with Herbert J. Zeiger and graduate student James P. Gordon, Townes demonstrates the first maser at Columbia University. The ammonia maser, the first device based on Einstein's predictions, obtains the first amplification and generation of electromagnetic waves by stimulated emission. The maser radiates at a wavelength of a little more than 1 cm, and generates approximately 10 nW of power.



Pumping method proposed

1955: At P.N. Lebedev Physical Institute in Moscow, Nikolai G. Basov and Alexander M. Prokhorov attempt to design and build oscillators. They propose a method for the production of a negative absorption that was called the pumping method.

Wikimedia Commons

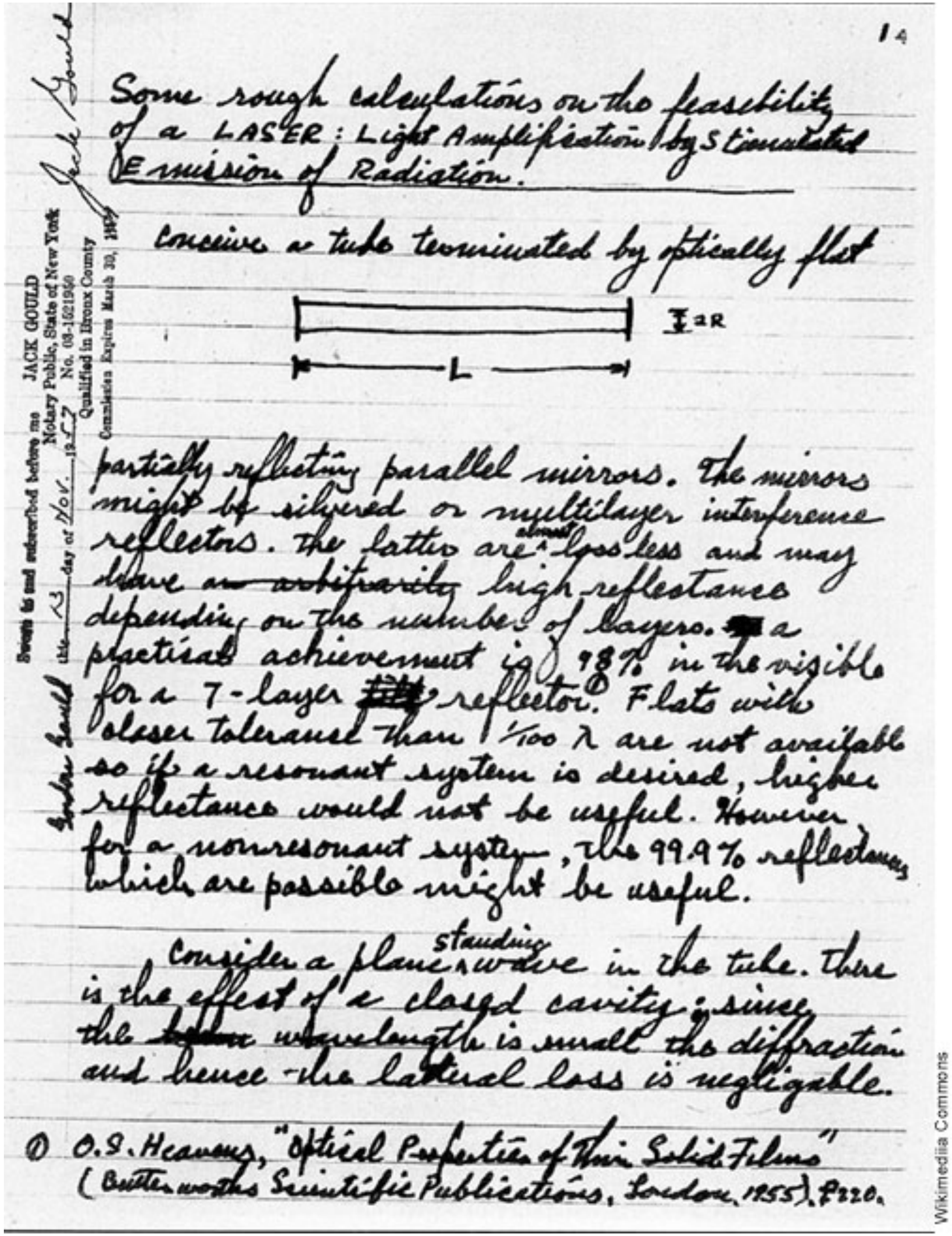
Nikolai G. Basov

Wikimedia Commons

Alexander M. Prokhorov

1964: Townes, Basov and Prokhorov are awarded the **Nobel Prize in physics** for their “fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser-principle.”

1956: Nicolaas Bloembergen of Harvard University develops the microwave solid-state maser.



Wikimedia Commons

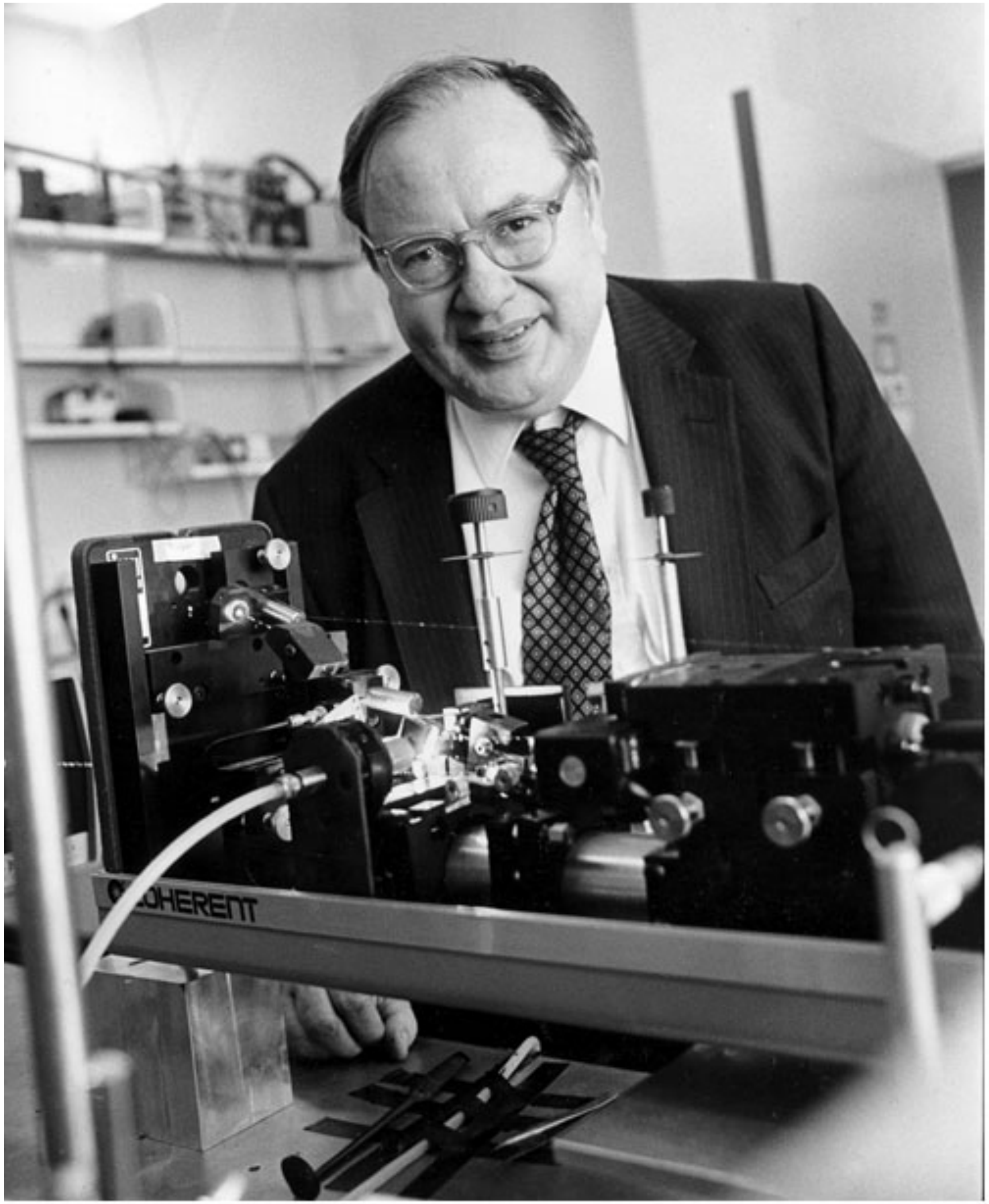
LASER

1957: Townes sketches an early optical maser in his lab notebook.

1957: Columbia University graduate student **Gordon Gould** jots his ideas for building a laser in his notebook and has it notarized by Jack Gould (no relation) at a candy store in the Bronx. It is considered the first use of the acronym LASER, light amplification by stimulated emission of radiation. Gould leaves the university a few months later to join private research company TRG (Technical Research Group).

1959: Gould and TRG apply for laser-related patents stemming from Gould's ideas.

1957 Derrick Scovil, George Feher & Harold Seidel at Bell labs – build the first 3 level MASER

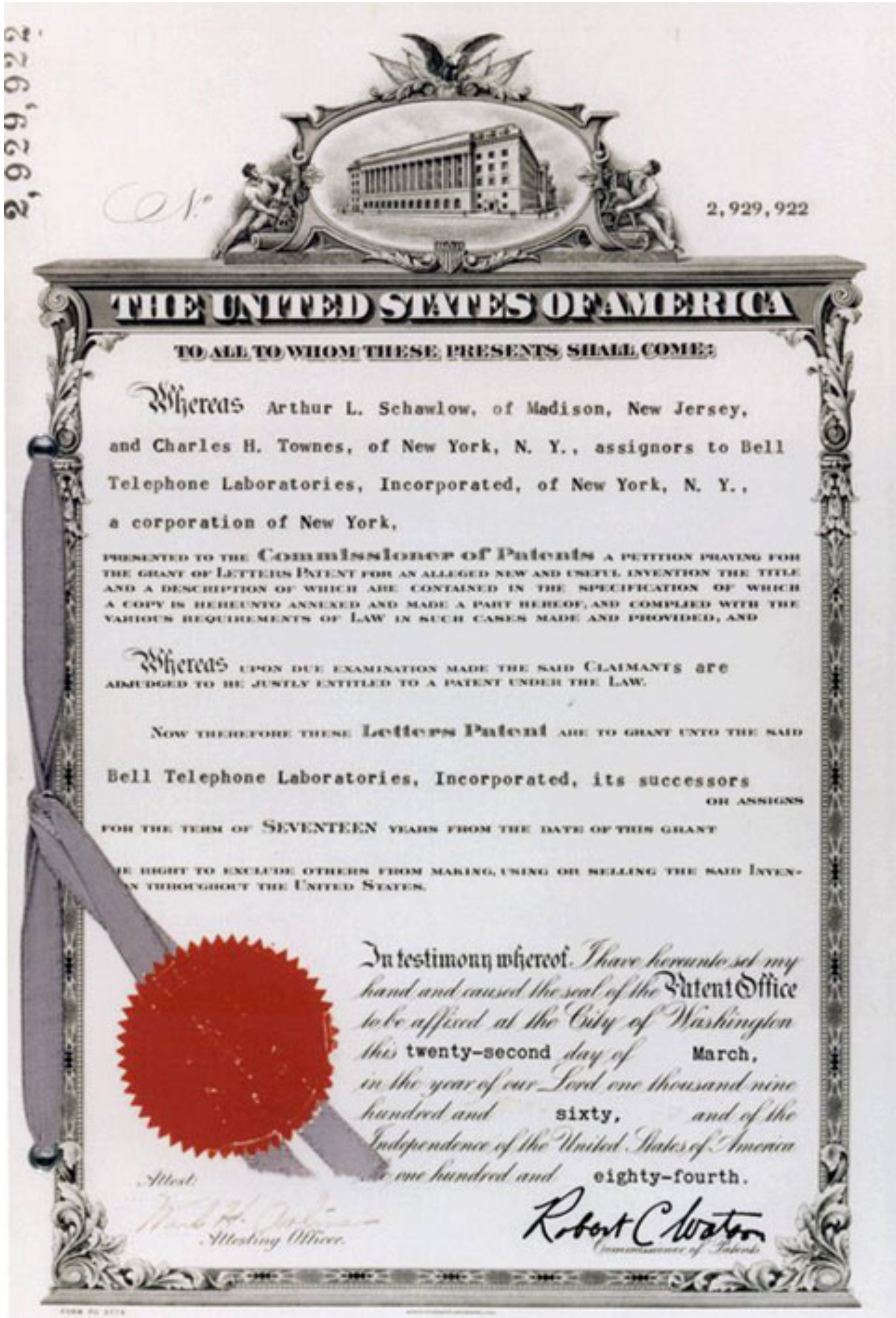


AP Photo/Paul Sakuma

Professor Arthur Schawlow

OPTICAL MASER THEORY

1958: In a joint paper published in *Physical Review Letters*, **Townes**, a consultant for Bell Labs, and his brother-in-law, Bell Labs researcher **Arthur L. Schawlow**, theoretically show that masers could be made to operate in the optical and infrared region and propose how this could be accomplished. At Lebedev Institute in Moscow, Nikolai Basov and Alexander Prokhorov are also exploring the possibilities of applying maser principles in the optical


2,929,922

No. 2,929,922

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas Arthur L. Schawlow, of Madison, New Jersey, and Charles H. Townes, of New York, N. Y., assignors to Bell Telephone Laboratories, Incorporated, of New York, N. Y., a corporation of New York,

PRESENTED TO THE Commissioner of Patents A PETITION PRAYING FOR THE GRANT OF LETTERS PATENT FOR AN ALLEGED NEW AND USEFUL INVENTION THE TITLE AND A DESCRIPTION OF WHICH ARE CONTAINED IN THE SPECIFICATION OF WHICH A COPY IS HEREUNTO ANNEXED AND MADE A PART HEREOF, AND COMPLIED WITH THE VARIOUS REQUIREMENTS OF LAW IN SUCH CASES MADE AND PROVIDED, AND

Whereas UPON DUE EXAMINATION MADE THE SAID CLAIMANTS are ADJUDGED TO BE JUSTLY ENTITLED TO A PATENT UNDER THE LAW.

NOW THEREFORE THESE Letters Patent ARE TO GRANT UNTO THE SAID Bell Telephone Laboratories, Incorporated, its successors OR ASSIGNS

FOR THE TERM OF SEVENTEEN YEARS FROM THE DATE OF THIS GRANT

...E RIGHT TO EXCLUDE OTHERS FROM MAKING, USING OR SELLING THE SAID INVEN-...N THROUGHOUT THE UNITED STATES.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the City of Washington this twenty-second day of March, in the year of our Lord one thousand nine hundred and sixty, and of the Independence of the United States of America the one hundred and eighty-fourth.

Attest:

Attesting Officer.

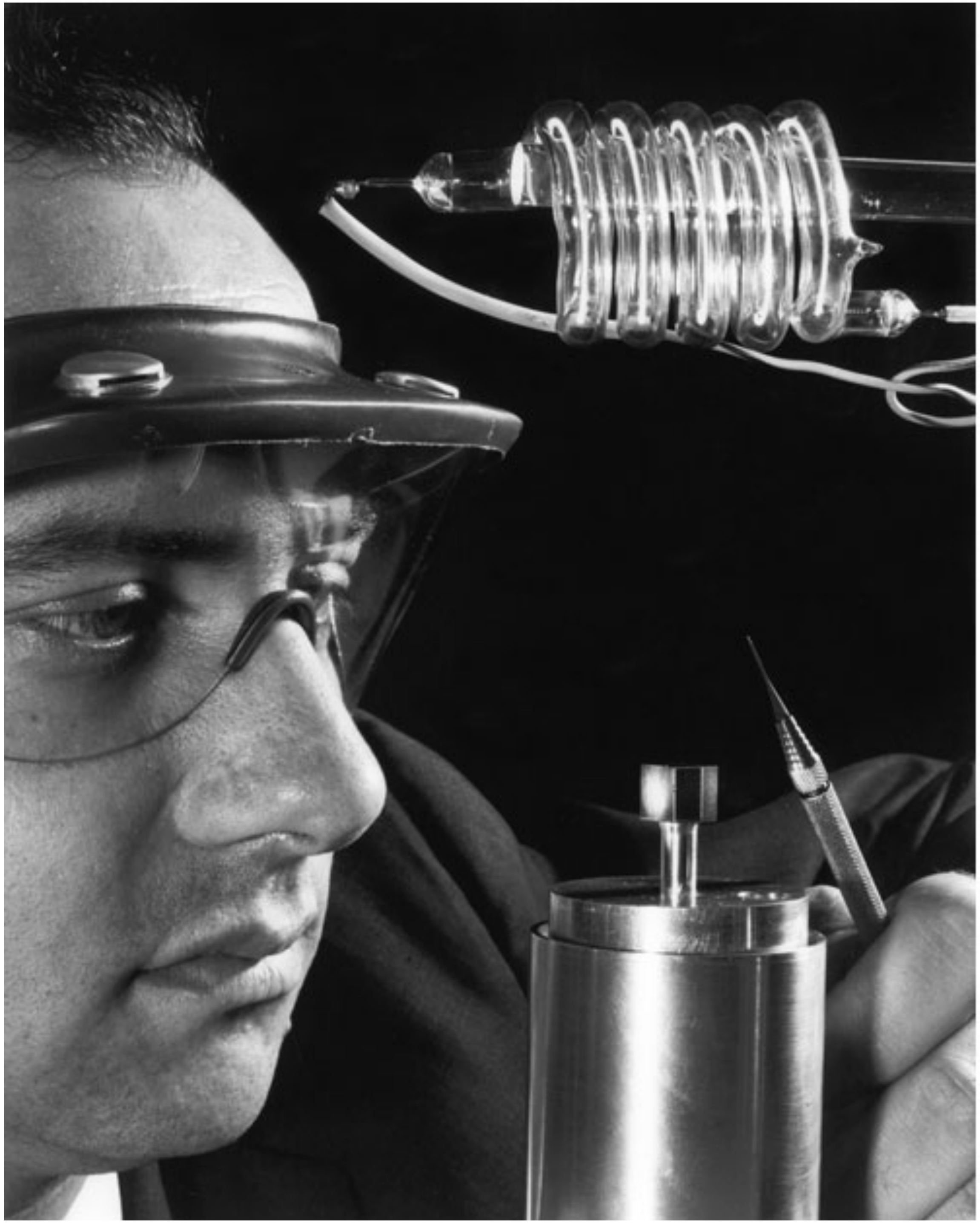
Robert C. Watson

Commissioner of Patents.

ell Labs

1960: Townes and Schawlow, under Bell Labs, are granted US patent 2,929,922 for the optical maser, now called a laser. With their application denied, Gould and TRG launch what would become a 30-year patent dispute related to laser invention.

1981 Nicolaas Bloembergen, Schawlow & Kai Siegbahn Physics Nobel



1960: Theodore H. Maiman, a physicist at Hughes Research Laboratories in Malibu, Calif., constructs the first laser using a cylinder of synthetic ruby 1 cm in diameter and 2 cm long, with the ends silver-coated to make them reflective and able to serve as a Fabry-Perot resonator. Maiman uses photographic flashlamps as the laser's pump source.

1960: Hughes holds a press conference to announce Maiman's achievement.

PerkinElmer HeNe laser circa 1966

SECOND LASER DEMONSTRATED

1960: Peter P. Sorokin and Mirek Stevenson of the IBM Thomas J. Watson Research Center demonstrate the uranium laser, a four-stage solid-state device.

1960: Ali Javan, William Bennett Jr., and Donald Herriott of Bell Labs develop the helium-neon (HeNe) laser, the first to generate a continuous beam of light at 1.15 µm.

1961: Lasers begin appearing on the commercial market through companies such as Trion Instruments, Perkin-Elmer and Spectra-Physics.

1961: The first medical treatment using a laser on a human patient is performed by Dr. Charles J. Campbell of the Institute of Ophthalmology at Columbia- Presbyterian Medical Center and Charles J. Koester of the American Optical Co. at Columbia-Presbyterian Hospital in Manhattan. An American Optical ruby laser is used to destroy a retinal tumor.

RUBY LASER IMPROVED

1961: At the second International Quantum Electronics meeting, Robert W. Hellwarth of Hughes Research Labs presents theoretical work suggesting that a dramatic improvement in the ruby laser could be made by making its pulse more predictable and controllable. He predicts a single spike of great power could be created if the reflectivity of the laser's end mirrors were suddenly switched from a value too low to permit lasing to one that could.

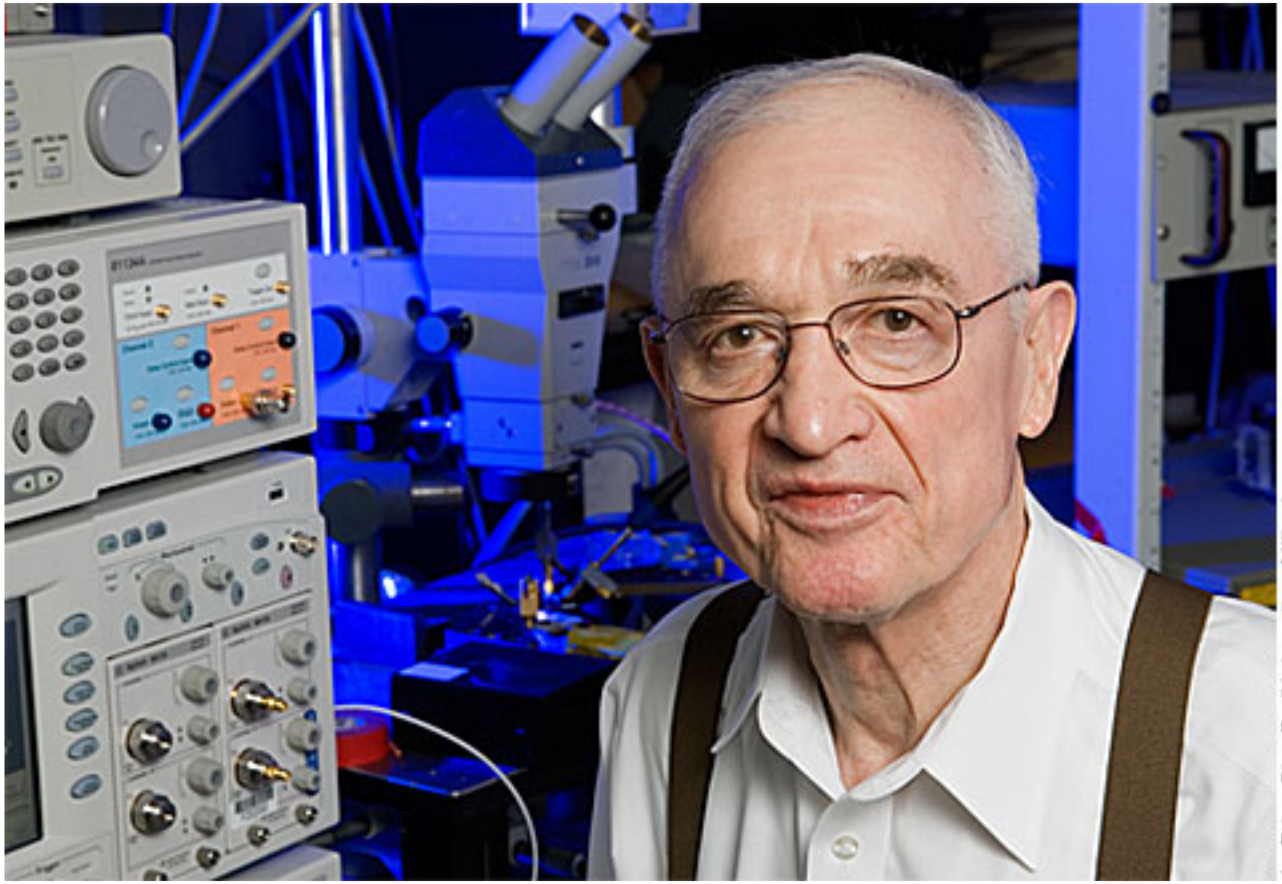
1962: With Fred J. McClung, Hellwarth proves his laser theory, generating peak powers 100 times that of ordinary ruby lasers by using electrically switched Kerr cell shutters. The giant pulse formation technique is dubbed Q-switching. Important first applications include the welding of springs for watches.

1961: American Optical Co.’s Elias Snitzer reports the first operation of a **neodymium glass (Nd: glass) laser**.

1962: Groups at GE, IBM, and MIT's Lincoln Laboratory simultaneously develop a **gallium-arsenide laser**, a semiconductor laser that converts electrical energy directly into infrared light but which must be cryogenically cooled, even for pulsed operation.

1962: Bell Labs reports the first **yttrium aluminum garnet (YAG) laser**.

1962: Nick Holonyak Jr., a consulting scientist at a General Electric Co. laboratory in Syracuse, N.Y., publishes his work on the "visible red" GaAsP (gallium arsenide phosphide) laser diode, a compact, efficient course of visible coherent light that is the basis for today's red LEDs used in consumer products such as CDs, DVD players and cell phones.



1963: Logan E. Hargrove, Richard L. Fork, and M. A. Pollack report the first demonstration of a mode-locked laser, i.e. a helium-neon laser with an acousto-optic modulator. Mode locking is fundamental for laser communication and is the basis for femtosecond lasers.

1963: Herbert Kroemer of the University of California, Santa Barbara, and the team of Rudolf Kazarinov and Zhores Alferov of the A.F. Ioffe Physico-Technical Institute in St. Petersburg, Russia, independently propose ideas to build semiconductor lasers from heterostructure devices. The work leads to Kroemer and Alferov winning the 2000 Nobel Prize in physics.

1964: The carbon-dioxide (CO_2) laser is invented by Kumar Patel at Bell Labs. The most powerful continuously operating laser of its time, it is now used worldwide as a cutting tool in surgery and industry.

1964: Nd:YAG (neodymium-doped YAG) laser invented by Joseph E. Geusic and Richard G. Smith at Bell Labs. The laser later proves ideal for cosmetic applications, such as LASIK vision correction and skin resurfacing.

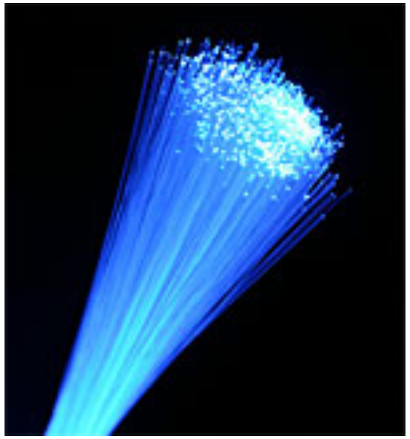
1964: After working for two years on HeNe and xenon lasers, William B. Bridges of Hughes Research Labs discovers the pulsed argon-ion laser, which, although bulky and inefficient, could produce output at several visible and UV wavelengths.

1965: Jerome V.V. Kasper and George C. Pimentel demonstrate the first chemical laser, a 3.7-µm hydrogen chloride instrument, at the University of California, Berkeley.

1965: At Bell Labs, two lasers are phase-locked for the first time, an important step toward optical communications.

1966: The dye laser is discovered by Peter P. Sorokin and John R. Lankard at IBM's Thomas J. Watson Research Center in Yorktown Heights, NY.

1966: **Charles K. Kao**, working with George Hockham at Standard Telecommunication Laboratories in Harlow, England, makes a discovery that leads to a breakthrough in **fiber optics**. He calculates how to transmit light over long distances via optical glass fibers, deciding that, with a fiber of purest glass, it would be possible to transmit light signals over a distance of 100 km, compared with only 20 m for the fibers available in the 1960s. Kao receives a 2009 Nobel Prize in physics for his work.



1966: French physicist **Alfred Kastler** wins the Nobel Prize in physics for his method of stimulating atoms to higher energy states, which he developed between 1949-51. The technique, known as optical pumping, was an important step toward the creation of the maser and the laser.

1967: Bernard Soffer and Bill McFarland invent the tunable dye laser at Korad Corp. in Santa Monica, Calif.

1970: Arthur Ashkin of Bell Labs invents optical trapping, the process by which atoms are trapped by laser light. His work pioneers the field of optical tweezing and trapping and leads to significant advances in physics and biology.

1970: Nikolai Basov, V. A. Danilychev, and Yu. M. Popov develop the excimer laser at P.N. Lebedev Physical Institute in Moscow.

1970: At Corning Glass Works (now Corning Inc.), Drs. Robert D. Maurer, Peter C. Schultz and Donald B. Keck report the first optical fiber with loss below 20 dB/km, demonstrating the feasibility of fiber optics for telecommunications.

Donald B. Keck

1970: Zhores Alferov's group at the Ioffe Physico-Technical Institute in Russia and Mort Panish and Izuo Hayashi at Bell Labs produce the first continuous-wave room-temperature semiconductor lasers, paving the way toward commercialization of fiber optics communications.

1977: The first commercial installation of Bell Labs fiber optic lightwave communications system is completed under the streets of Chicago.


AP Photo

1970: Gordon Gould buys back his patent rights for $1 plus 10 percent of future profits when TRG is sold.

1977: Gordon Gould is issued a patent for optical pumping, then used in about 80 percent of lasers.

1979: Gordon Gould receives a patent covering a broad range of laser applications.

1988: Nearly 30 years after his laser-building brainstorm, Gordon Gould begins receiving royalties from his patents.

1972: Charles H. Henry invents the quantum well laser, which requires much less current to reach lasing threshold than conventional diode lasers, and which is exceedingly more efficient. Nick Holonyak Jr. and students at the University of Illinois at Urbana-Champaign first demonstrate the quantum well laser in 1977.

1972: A laser beam is used at Bell Labs to form electronic circuit patterns on ceramic.

1974: A pack of Wrigley's chewing gum is the first product read by a bar-code scanner in a grocery store.

1975: First quantum-well laser operation made by Jan P. Van der Ziel, R. Dingle, Robert C. Miller, William Wiegmann, and W.A. Nordland Jr. The lasers are actually developed in 1994.

1975: Engineers at Laser Diode Labs Inc. develop the first commercial continuous-wave semiconductor laser operating at room temperature. Continuous-wave operation enables the transmission of telephone conversations.

1976: John Madey and his group at Stanford University demonstrate the first free-electron laser (FEL). Instead of a gain medium, FELs use a beam of electrons that are accelerated to near light speed, then passed through a periodic transverse magnetic field to produce coherent radiation. Because the lasing medium consists only of electrons in a vacuum, FELs don't have the material damage or thermal lensing problems that plague ordinary lasers and can achieve very high peak powers.

1981: Arthur Schawlow and Nicholaas Bloembergen receive the Nobel Prize in physics for their contributions to the development of laser spectroscopy.

1982: Peter F. Moulton of MIT's Lincoln Laboratory develops the titanium-sapphire laser, used to generate short pulses in the **picosecond and femtosecond** ranges. The Ti:sapphire laser replaces the dye laser for tunable and ultrafast laser applications.

1985: Bell Labs' Steven Chu (now US Secretary of Energy) and his colleagues use laser light to **slow and manipulate atoms**. Their **laser cooling** technique, also called "optical molasses," is used to investigate the behavior of atoms, providing an insight into quantum mechanics. Chu, Claude N. Cohen-Tannoudji, and William D. Phillips win a Nobel Prize for this work in 1997.

US Department of Energy

US Energy Secretary Steven Chu

1976: First demonstration, at Bell Labs, of a semiconductor laser operating continuously at room temperature at a wavelength beyond 1 µm, the forerunner of sources for long-wavelength lightwave systems.

1978: Following the failure of its videodisc technology, Philips announces the compact disc (CD) project.
1978: The LaserDisc hits the home video market, with little impact. The earliest players use HeNe laser tubes to read the media, while later players used infrared laser diodes.
1982: The audio CD, a spinoff of LaserDisc video technology, debuts. While ABBA's new album, “The Visitors,” is the first to be manufactured on CD, the first CD to be released commercially is Billy Joel's 1978 album "52nd Street."

1987: David Payne at the University of Southampton in England and his team introduce **erbium-doped fiber amplifiers**. These new optical amplifiers boost light signals without first having to convert them into electrical signals and then back into light, reducing the cost of long distance fiber optic systems.

1994: The first semiconductor laser that can simultaneously emit light at multiple widely separated wavelengths — **the quantum cascade (QC) laser** — is invented at Bell Labs by Jerome Faist, Federico Capasso, Deborah L. Sivco, Carlo Sirtori, Albert L. Hutchinson and Alfred Y. Cho. The laser is unique in that its entire structure is manufactured a layer of atoms at a time by the crystal growth technique called molecular beam epitaxy. Simply changing the thickness of the semiconductor layers can change the laser's wavelength. With its room-temperature operation and power and tuning ranges, the QC laser ideal for remote sensing of gases in the atmosphere.

1994: The single atom laser, a fundamental system in which a two-level atom is coupled to a single mode of the optical field, is demonstrated by Michael S. Feld, Ramachandra R. Dasari, James J. Childs and Kyungwon An at MIT's George R. Harrison Spectroscopy Laboratory in Cambridge, Mass.

1994: The first demonstration of a quantum dot laser with high threshold density was reported by Nikolai N. Ledentsov of A.F. Ioffe Physico-Technical Institute in Leningrad.

1997: Shuji Nakamura, Steven P. DenBaars and James S. Speck at the University of California, Santa Barbara, announce the development of a gallium-nitride (GaN) laser that emits bright **blue-violet light** in pulsed operation.

1996: The first pulsed atom laser, which uses matter instead of light, is demonstrated at MIT by Wolfgang Ketterle.

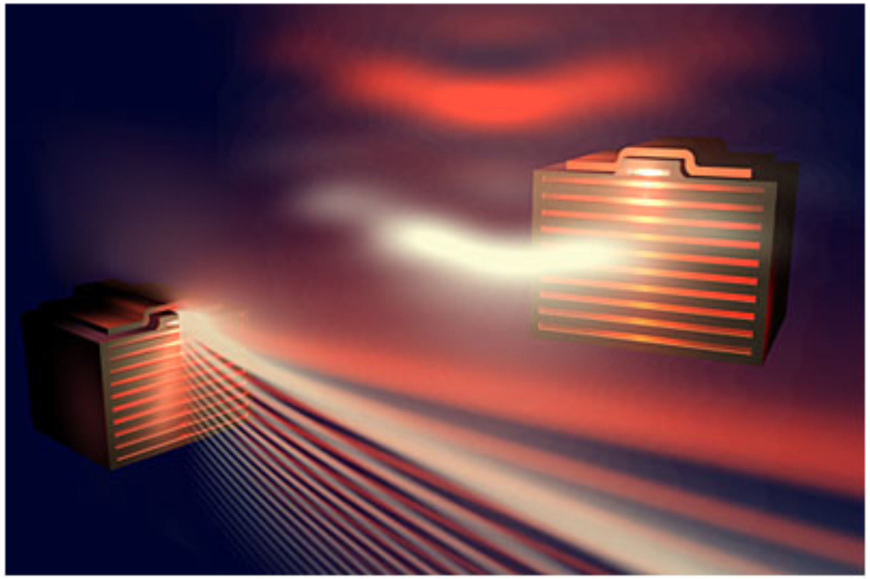
2004: Electronic switching in a Raman laser is demonstrated for the first time by Ozdal Boyraz and Bahram Jalali of UCLA. The first silicon Raman laser operates at room temperature with 2.5-W peak output power. In contrast to traditional Raman lasers, the pure-silicon Raman laser can be directly modulated to transmit data.

2003: A team of researchers from NASA's Marshall Space Flight Center in Huntsville, Ala., from NASA's Dryden Flight Research Center at Edwards, Calif., and from the University of Alabama in Huntsville successfully flies the **first laser-powered aircraft**. The plane, its frame made of balsa wood, has a 1.5-m wingspan and weighs only 311 g. Its power is delivered by an invisible, ground-based laser that tracks the aircraft in flight, directing its energy beam at specially designed photovoltaic cells carried onboard to power the plane's propeller.

2006: John Bowers and colleagues at the University of California, Santa Barbara, and Mario Paniccia, director of Intel's Photonics Technology Lab in Santa Clara, Calif., announce that they have built the first electrically powered hybrid silicon laser using standard silicon manufacturing processes. The breakthough could lead to low-cost, terabit-level optical data pipes inside future computers, Paniccia says.

2007: UCSB's John Bowers and his doctoral student, Brian Koch, announce that they have built the first **mode-locked silicon evanescent laser**, providing a new way to integrate optical and electronic functions on a single chip and enabling new types of integrated circuits.

2009: An international team of applied scientists demonstrates **compact, multibeam and multiwavelength lasers emitting in the infrared**. Typically, lasers emit a single light beam of a well-defined wavelength; with their multibeam abilities, the new lasers have potential uses in chemical detection, climate monitoring and communications. The research is led by Nanfang Yu and Federico Capasso of the Harvard School of Engineering and Applied Sciences (SEAS); Hirofumi Kan of the Laser Group at Hamamatsu Photonics; and Jérôme Faist of ETH Zürich. In one of the team's prototypes, the new laser emits several highly directional beams with the same wavelength near 8 μm, a function useful for interferometry.



Lab of Federico Capasso, Harvard SEAS

An example of a compact, multibeam and multiwavelength laser. Unlike typical semiconductor lasers that emit single beams of light pointing in a single, well-defined direction, the multibeam laser can use versatile light sources.

2009: NASA launches the Lunar Reconnaissance Orbiter (LRO). LOLA, the Lunar Orbiter Laser Altimeter on the LRO, will use a laser to gather data about the high and low points on the moon. NASA will use that information to create 3-D maps that could help determine lunar ice locations and safe landing sites for future spacecraft.

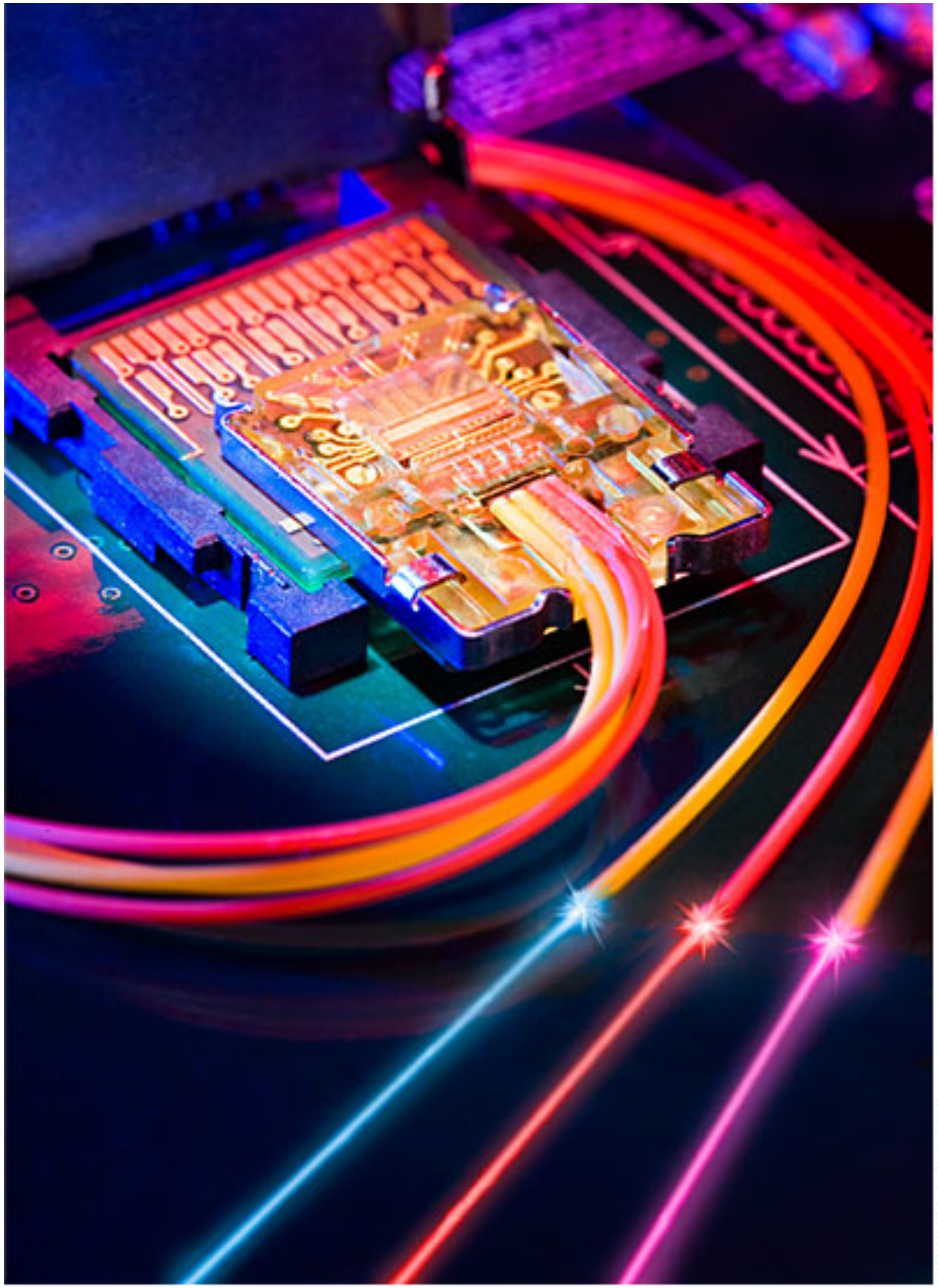
NASA

While orbiting the moon, the Lunar Reconnaissance Orbiter will take pictures and gather information about the moon's surface.

2009: The University of Rochester's Chunlei Guo announces a new process that uses femtosecond laser pulses to make regular incandescent light bulbs superefficient. The laser pulse, trained on the bulb's filament, forces the surface of the metal to form nanostructures that make the tungsten become far more effective at radiating light. The process could make a 100-W bulb consume less electricity than a 60-W bulb, Guo says.

2009: The largest and highest-energy laser in the world, the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in Livermore, Calif., is dedicated. In a few weeks, the system begins firing all 192 of its laser beams onto targets.

2009: Lasers get ready to enter household PCs with Intel's announcement of its Light Peak optical fiber technology at the Intel Developer Forum. Light Peak contains VCSELs (vertical-cavity surface-emitting lasers) and can send and receive 10 billion bits of data per second, meaning it could transfer the entire Library of Congress in 17 minutes. The product is expected to ship to manufacturers in 2010.

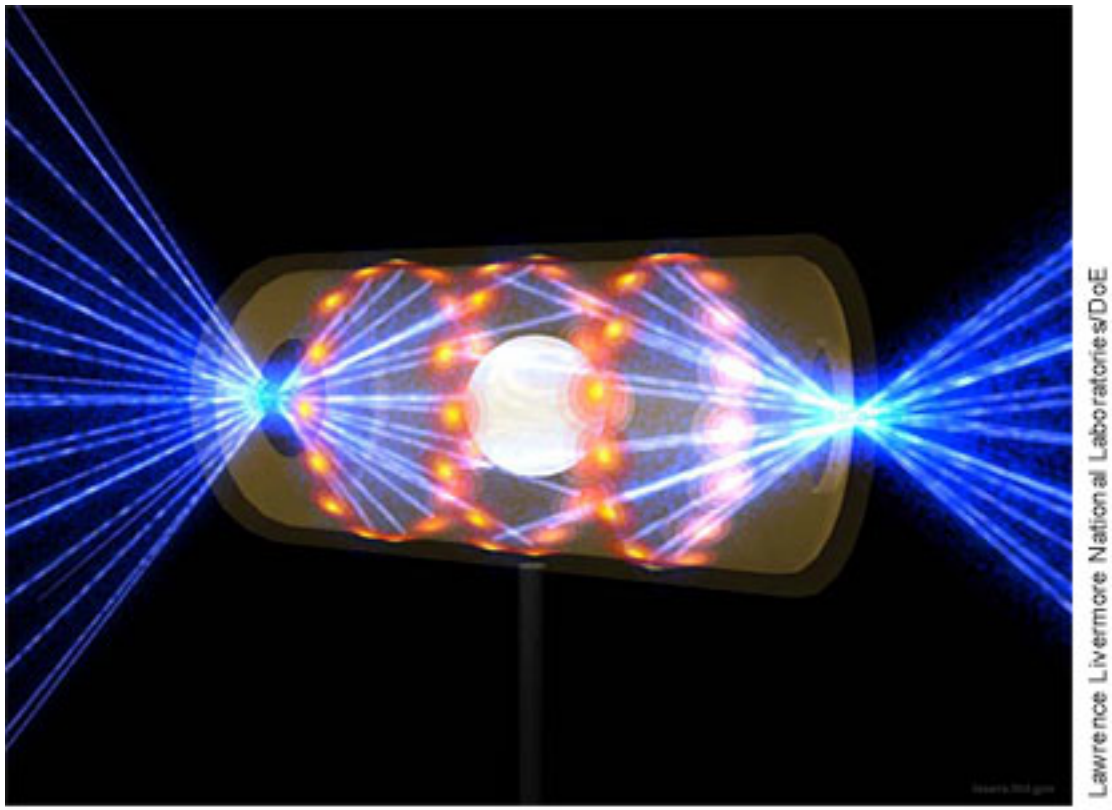


Jeffrey Tseng/Intel

Intel Light Peak module close-up with laser light added for illustration (actual infrared light is invisible to the eye).

2010: A University of Konstanz research group, led by professor Alfred Leitenstorfer, announce they have generated extremely short laser pulses — the duration of only one cycle of light — at the 1.5-μm wavelength used to transmit data, an achievement that could benefit frequency metrology and ultrafast sciences such as ultrafast optical imaging. The group combines two pulses from a single erbium-doped fiber laser source to create the single 4.3 fs pulse.

2010: The National Nuclear Security Administration announces that NIF has successfully delivered a historic level of **laser energy — more than 1 MJ** — to a target in a few billionths of a second and demonstrated the target drive conditions required to achieve fusion ignition, a project scheduled for the summer of 2010. The peak power of the laser light is about 500 times that used by the US at any given time.



Artist's rendition showing a National Ignition Facility target pellet inside a hohlraum capsule with laser beams entering though openings on either end. The beams compress and heat the target to the necessary conditions for nuclear fusion to occur.

סיכום

ליזרים הם מקורות אור בעלי תכונות שהופכות אותם מרכזיים במגוון רחב של שימושים:
אורך גל מוגדר, קוהרנטיות, עצמה, פולסים קצרים,

1. בתקשורת – בגלל יכולת למקד קרן לסיב אופטי דק.
2. בספקטרוסקופיה, פוטוכימיה
3. בהדמיה: מיקרוסקופיה קונפוקאלית, דו-פוטוני, רמן, סריקת ברקוד, מיפוי פני הירח
4. חישה מרחוק (חקר אטמוספירה)
5. ברפואה: פוטוטרפיה, ניתוחים וטיפולי יופי
6. לתאורה: הולוגרפיה, מצגי אור,
7. למדידות (מד מרחק), ולסימון (סימון ליזר בהרצאות)
8. ביקוע גרעיני מבוקר (בפיתוח זמן רב)
9. תותחי ליזר לפגיעה בטילים ומטוסים, ליזר להנחית כלי טיס וטילים.
10. לחימום, חיתוך, הלחמה, בנית מודלים תלת-ממדיים בפלסטיק
11. מדפסות ליזר, CD, DVD
12. מלקחי ליזר לתפישת חלקיקים ואטומים, קירור אטומי.