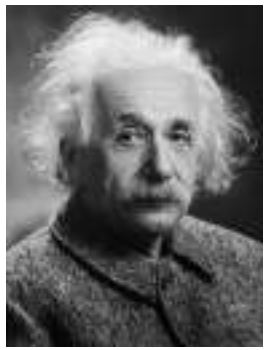
LASERS: A Walk Through History

Max Planck

- In his most important work, published in **1900**, Planck deduced the relationship between energy and the frequency of radiation, essentially saying that energy could be emitted or absorbed only in discrete chunks – which he called **quanta**.

- In **1905**, Einstein released his paper on the **photoelectric effect**, which proposed that light also delivers its energy in chunks, in this case discrete quantum particles now called photons.

Albert Einstein



- In **1917**, Einstein proposed the process that makes lasers possible, called **stimulated emission**. He theorized that, besides absorbing and emitting light spontaneously, electrons could be stimulated to emit light of a particular wavelength.

- But it would take nearly 40 years before scientists would be able to amplify those emissions, proving Einstein correct and putting up lasers.

Charles Hard Townes

- *April 26, 1951*: Charles Hard Townes of Columbia University in New York conceives his maser idea while sitting on a park bench in Washington.

- 1954: Working with Herbert J. Zeiger and James P. Gordon, Townes demonstrates the first maser at Columbia University. The ammonia maser, the first device based on Einstein's predictions.

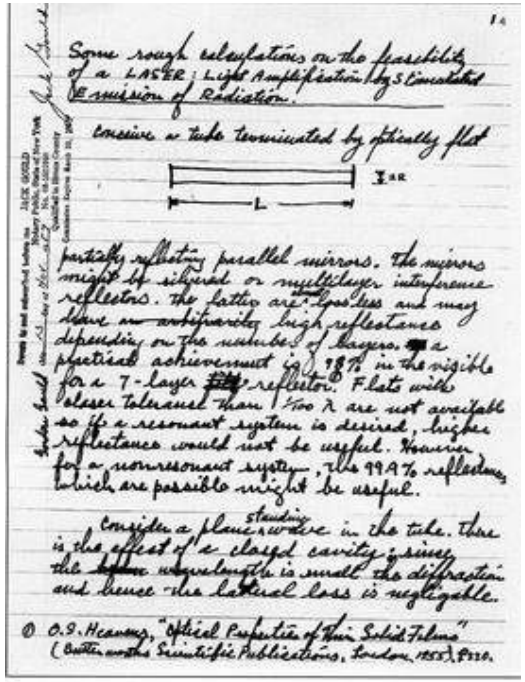
- **1955**: At P.N. Lebedev Physical Institute in Moscow, **Nikolai G. Basov** and **Alexander M. Prokhorov** attempt to design and build oscillators. They propose a method for the production of a negative absorption that was called the pumping method.

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

- **1958**: **Townes**, and his brother-in-law, **Arthur L. Schawlow**, in a joint paper published in *Physical Review*, show that masers could be made to operate in the optical and infrared regions and propose how it could be accomplished.

- At a conference in 1959, **Gordon Gould** published the term LASER in the paper The LASER, Light Amplification by Stimulated Emission of Radiation

This is the first page of Gordon Gould's famous notebook, in which he coined the acronym LASER and described the essential elements for constructing one.



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

Consider a tube terminated by optically flat

partially reflecting parallel mirrors. The mirrors might be silvered or multilayer interference reflectors. The latter are lossless and may have an arbitrarily high reflectance depending on the number of layers. A practical achievement is 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% reflectors which are possible might be useful.

Consider a plane standing wave in the tube. There is the effect of a closed cavity since the wavelength is small the diffraction and hence the lateral loss is negligible.

© O.S. Heavens, "Optical Properties of Thin Solid Films" (Butterworths Scientific Publications, London, 1955), p. 220.

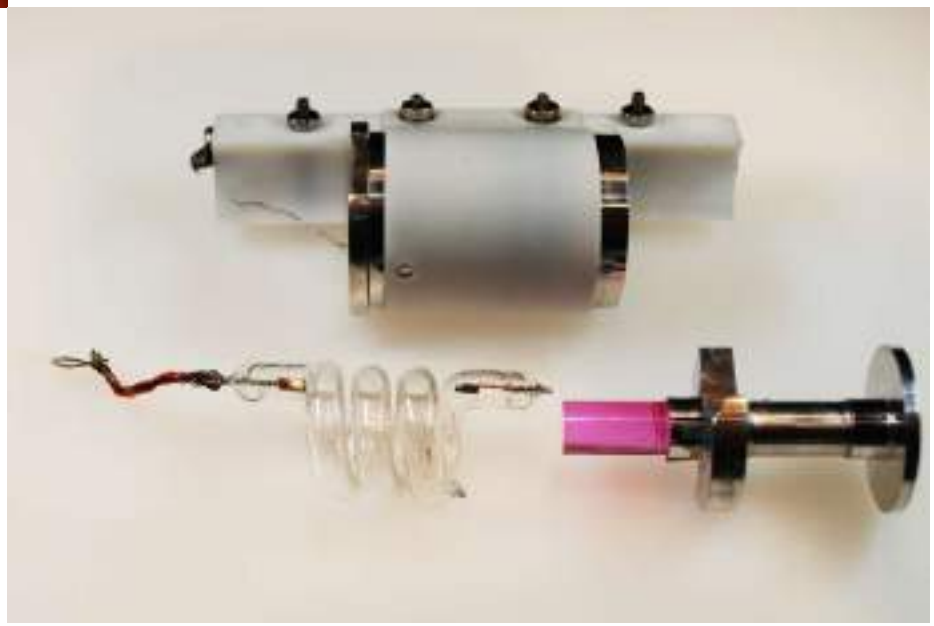
Finally!!!!

Theodore H. Maiman

- May 16, **1960**: **Theodore H. Maiman**, a physicist, constructs the first laser using a cylinder of synthetic **ruby** measuring 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 flash lamps as the laser's pump source.

Theodore H. Maiman

Ruby Laser



- November 1960: **Peter P. Sorokin** and Mirek J. Stevenson demonstrate the uranium laser, a four-stage solid-state device.

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

- March 1961: At the second International Quantum Electronics meeting, Robert W. Hellwarth presents theoretical work suggesting that a dramatic improvement in the ruby laser could be made by making its pulse more predictable and controllable.

- October 1961: Elias Snitzer reports the first operation of a neodymium glass (Nd:glass) laser.

- December 1961: The first medical treatment using a laser on a human patient is performed by Dr. Charles J. Campbell and Charles J. Koester. An Optical ruby laser is used to destroy a retinal tumour.

- 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.

- October 1962: Nick Holonyak Jr, publishes his work on the “visible red” GaAsP (gallium arsenide phosphide) laser diode, a compact, efficient source 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.

- June 1962: Bell Labs reports the first yttrium aluminium garnet (**YAG**) laser.

- 1963: Logan E. Hargrove, Richard L. Fork and M.A. Pollack report the first demonstration of a **mode-locked laser**. Mode locking is fundamental for laser communication and **is the basis for femtosecond lasers**.

- 1963: Herbert, and the team of Rudolf Kazarinov and Zhores Alferov, independently propose ideas to build semiconductor lasers from heterostructure devices. The work leads to Kroemer and Alferov winning the 2000 **Nobel Prize** in physics.

- March 1964: William B. Bridges discovers the pulsed argon-ion laser, which, although bulky and inefficient, could produce output at several visible and UV wavelengths.

- **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.”

- 1964: The **carbon dioxide 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: The Nd:YAG (neodymium-doped YAG) laser is invented by Joseph E. Geusic and Richard G. Smith. The laser later proves ideal for cosmetic applications, such as laser-assisted in situ keratomileusis (lasik) vision correction and skin resurfacing.

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

- 1966: **Charles K. Ka**o, working with George Hockham, makes a discovery that leads to a breakthrough in **fibre optics**. He calculates how to transmit light over long distances via optical glass fibres, deciding that, with a fibre of purest glass, it would be possible to transmit light signals over a distance of 100 km, compared with only 20 m for the fibres 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. The technique, known as optical pumping, was an important step toward the creation of the maser and the laser.

- 1966: Sorokin, P. and Lankard, J. - Demonstration of **first Dye Laser** action at IBM Labs.

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- 1970: Basov, V.A. Danilychev and Yu. M. Popov develop the **excimer** laser.

- 1970: Arthur Ashkin 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.

- 1972: Charles H. Henry invents the **quantum well laser**, which requires much less current to reach lasing threshold than conventional diode laser and which is exceedingly more efficient. Holonyak and students first demonstrate the quantum well laser in 1977.

- June 26, 1974: A pack of Wrigley's chewing gum is the first product read by a bar-code scanner in a grocery store.

- 1976: John M.J. Madey and his group at Stanford University in California demonstrate the first free-electron laser (FEL).

- 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 use infrared laser diodes.

- 1982: Peter F. Moulton develops the titanium-sapphire laser, used to generate short pulses in the picosecond and femtosecond ranges.

- 1985: Steven Chu and his colleagues use laser light to slow and manipulate atoms. Their laser cooling technique, also called “optical molasses,” is used to investigate the behaviour 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.

- 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 Jérôme Faist, Federico Capasso, Deborah L. Sivco, Carlo Sirtori, Albert L. Hutchinson and Alfred Y. Cho.

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

- September 2003: A team of researchers from NASA's Marshall Space Flight Centre, from NASA's Dryden Flight Research Centre and from the University of Alabama successfully flies the first laser-powered aircraft.

- 2004: Electronic switching in a Raman laser is demonstrated for the first time by Ozdal Boyraz and Bahram Jalali . The first silicon Raman laser operates at room temperature with 2.5-W peak output power.

- September 2006: John Bowers and colleagues and Mario Paniccia, announce that they have built the first electrically powered hybrid silicon laser using standard silicon manufacturing processes.

- August 2007: 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.

- May 29, 2009: The largest and highest-energy laser in the world, the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory is dedicated. In a few weeks, the system begins firing all 192 of its laser beams onto targets.

- June 2009: NASA launches the Lunar Reconnaissance Orbiter (LRO). The Lunar Orbiter Laser Altimeter on the LRO will use a laser to gather data about the high and low points on the moon.

- March 31, 2010: Rainer Blatt and Piet O. Schmidt and their team at the University of Innsbruck in Austria demonstrate a single-atom laser with and without threshold behavior by tuning the strength of atom/light field coupling