Chapter 2
History of Lasers in Ophthalmology

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The history of medicine is full of controversy over the priority of inventions. There are two such controversies in the history of lasers. The first concerns the idea of photocoagulation, the second—the concept of laser.

The Idea of Photocoagulation

Early observations and first attempts

The idea of photocoagulation consists of several observations that have been known for a long time. First, it is the idea of the so-called burning glass, i.e. that the sun's rays can be focused with a lens to ignite or burn an object.

Burning Glass

This technology of using lenses to start fires for various purposes has been known since antiquity, as reported by many Greek and Roman writers [1]. For example, the use of glass vases filled with water to create a heat intense enough to ignite clothing, as well as convex lenses that were used to cauterize wounds was described by Pliny the Elder [2]. This concept was also used in very popular plays of Aristophanes, what shows that this knowledge was quite common and easy available [3]. The most

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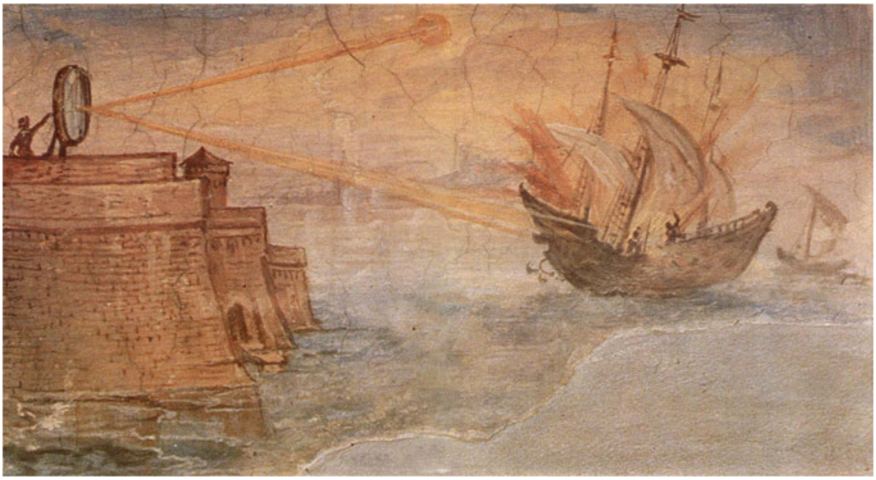


Fig. 2.1 Wall painting from the Uffizi Gallery, Stanzino delle Matematiche, in Florence, Italy, showing the Greek mathematician Archimedes' mirror being used to burn Roman military ships. Painted in 1600. *Source* https://commons.wikimedia.org/wiki/File:Archimedes-Mirror_by_Giulio_Parigi.jpg

famous, although never confirmed, is the story that during the siege of Syracuse in 212 BC, when the city was besieged by Marcus Claudius Marcellus of the Roman Republic, Archimedes devised a burning glass that was used to set fire to Roman warships (Figs. 2.1, 2.2 and 2.3).The Roman fleet was supposedly incinerated, though eventually the city was taken and Archimedes was murdered [3, 4]. This legend probably led to the future interest and research on burning glasses and lenses, by both Christian and Islamic world, including Ibn Sahl in his *On Burning Mirrors and Lenses* (tenth century), [5] Alhazen in his *Book of Optics* (1021), and many others. Both Joseph Priestley and Antoine Lavoisier used burning lenses in their experiments [6] (Fig. 2.4).

Solar Blindness

The second issue related to the concept of photocoagulation was the understanding that the light might be deleterious to human tissues. The dangerous of the light to the eye following the observation of a solar eclipse was known since antiquity. For example, in Plato's Phaedo Socrates admonished that one must take care not to look directly at the sun during an eclipse but to view the sun's reflection in water or some other such medium: „*…there is a danger in looking at the sun during an eclipse, unless the precaution is taken of looking only at the image reflected in the water, or in a glass. (…) Socrates proceeded: —I thought that as I had failed in the contemplation of true existence, I ought to be careful that I did not lose the eye of my soul; as people*

Fig. 2.2 Engraving from the title page of *Opticae Thesaurus*, a Latin edition of Ibn al-Haytham's *Book of Optics*. Among other things it shows how Archimedes allegedly set Roman ships on fire with parabolic mirrors during the Siege of Syracuse. *Source* https://commons.wikimedia.org/wiki/File:Thesaurus_opticus_Titelblatt.jpg

may injure their bodily eye by observing and gazing on the sun during an eclipse, unless they take the precaution of only looking at the image reflected in the water, or in some similar medium" [7].

Galen describes that blindness can be produced by gazing at the sun without blinking, especially during sun eclipse.

„Indeed, if anyone wished to gaze full at the sun without blinking, he would quickly destroy his sight, and at the time of an eclipse many who wish to gain a more accurate understanding of the phenomenon and so look intently at the sun have blinded themselves completely without realizing what they were doing. And how bad for the eyes it is to walk through the snow you may learn by trying it yourself, if you do not believe Xenophon" [8].

Galileo is known to have injured his eyes by observation of the sun with his telescope [9]. The first description of a central scotoma following a solar burn of the retina was reported by Theophilus Bonetus (1620–1689) [10]. One of the early clinical ophthalmoscopy descriptions comes from Coccius in 1853 [11], and in 1858 by Charcot who gave the description of photophthalmia and erythema produced by a small electric laboratory furnace [12]. Since than it was reported by many,

Fig. 2.3 Illustration depicting the sun's rays being focused to start a fire. Source Johann Amos Comenius. Orbis sensualium pictus. Nürnberg, 1658. https://en.wikipedia.org/wiki/Burning_glass#/media/File:OrbisPictus_b_162.jpg

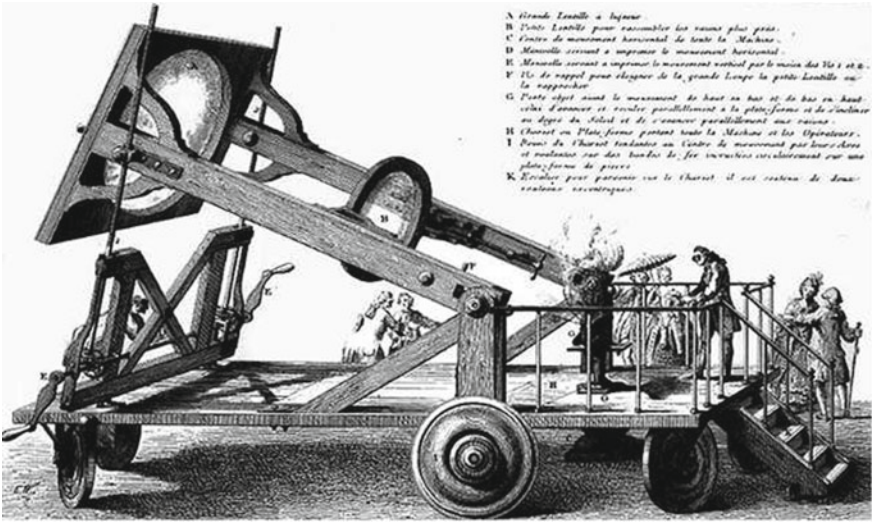


Fig. 2.4 Lavoisier with French Academy of Sciences' *lentilles ardentes*

with one of the largest series of 200 cases reported by Birch-Hirschfeld [13] and Blessig [14] after the eclipse in 1912. Interestingly, early experimental studies on the use of light energy to affect the retina started in the nineteenth century. Czerny in 1867 [15] and Deutschmann in 1882 [16] described their studies based on the use of mirrors and lens system to produce the retinal lesion in rabbits. Czerny found marked destruction of retinal elements in 10 to 15 s exposure with concentrated sun rays [15]. Deutschman reported that these changes could be noted in 1 s in the same manner [16]. In 1898 Herzog confirmed these results and reduced the exposure time to less than 1 s [17]. The introduction of the arc light in years 1879–1880 helped for more accurate and extensive study of ultra violet light which the electric arc supplies; and produced many cases of new entity „ophthalmia electrica". In 1893 Widmark reported to produce a retinal lesion with an arc light [18]. Verhoeff et al. published in 1916 an interesting study on pathological effects of radiant energy to the eye, including retinal burns conducted by carbon arc [19].

In 1927 Maggiore performed the first experimental photocoagulation of the human retina in eyes with malignant intraocular tumors by reflecting sunlight. He focused sunlight for 10 min into an eye that was to be enucleated because of a malignant tumor, and eyes were studied histologically and were found to show marked hyperemia and edema of the retinal structures [20]. In 1944, Cordes described macular burns in the military personnel who observed Japanese airplanes into the sun during the WWII [21].

Gerd Meyer-Schwickerath (1920–1992)

Meyer-Schwickerath developed the technique to obtain clinically useful results and is worldwide considered the father of retinal photocoagulation. In 1946 he, 26-year-old at that time, started his seminal work that led to the introduction of a light photocoagulation into clinical practice. It was due to his teacher Marchesani who requested his help with a medical student who was describing his own macular burn which he received while watching the sun eclipse of July 10, 1945 [22, 23]. His thesis was accepted at the University of Hamburg in 1947 [24] (Fig. 2.5).

It took him more than four years to translate the idea into the first instrument for clinical use. The first experimental device was based on a huge carbon arc from an old episcope. Although the experiments on rabbits were promising, the human results were disappointing. This led him to develop the next instrument that used the sun as the light source. This device made use of heliostate to compensate for the movement of the earth what otherwise would remove the sunlight out of the optical axis of the instrument (Fig. 2.6). The major limitation of this approach was that it could be used only on bright sunny days. In 1949, he started working on high-intensity arc, known also as Beck arc (Fig. 2.7), that he used between 1950–1956 in several hundreds of patients. In 1956, in collaboration with Dr. Hans Littmann from Zeiss they developed first commercially available device, Zeiss photocoagulator with xenon arc (Fig. 2.8). The first cases treated with photocoagulation were a peripheral horseshoe-shaped

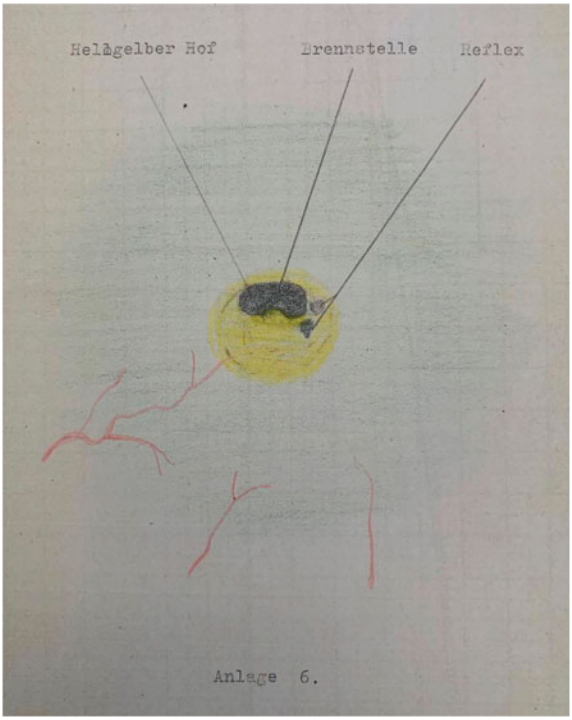


Fig. 2.5 The 1947 drawing of a "retinopathia solaris" that sparked Meyer-Schwickerath's idea of photocoagulation. (*Source* Hamm H. Zentralskotom nach Sonnenblendung. [dissertation]. University of Hamburg, Hamburg, Germany. 1947)

tear with no retinal detachment and a traumatic macular hole. He later developed treatment protocols for intraocular tumors, Eales disease, Coats disease, and von Hippel-Lindau angiomatosis [25–29].

He was also first to treat diabetic retinopathy with light coagulation between 1955 and 1959, but results were disappointing [30]. In 1964, Schott from Essen in Germany reported the convincing and positive results of treating 58 patients. He advocated the treatment in advanced background and early proliferative phase retinopathies. He proposed the number of up to 200 individual coagulations within 2–3 sessions. This gave the origin to panretinal coagulation [31]. In 1968, Meyer-Schwickerath and Schott, proposed that the signs and symptoms of diabetic retinopathy can be reversed if treatment if performed in the early stages and that photocoagulation in the early stages can prevent the late complications of proliferation, hemorrhage, and retinal detachment [30].

José Morón Salas (1918–2000)

What is much less-known that before Meyer-Schwickerath, Spanish ophthalmologist José Morón Salas (1918–2000) conducted similar experiments [32, 33]. In fact, he

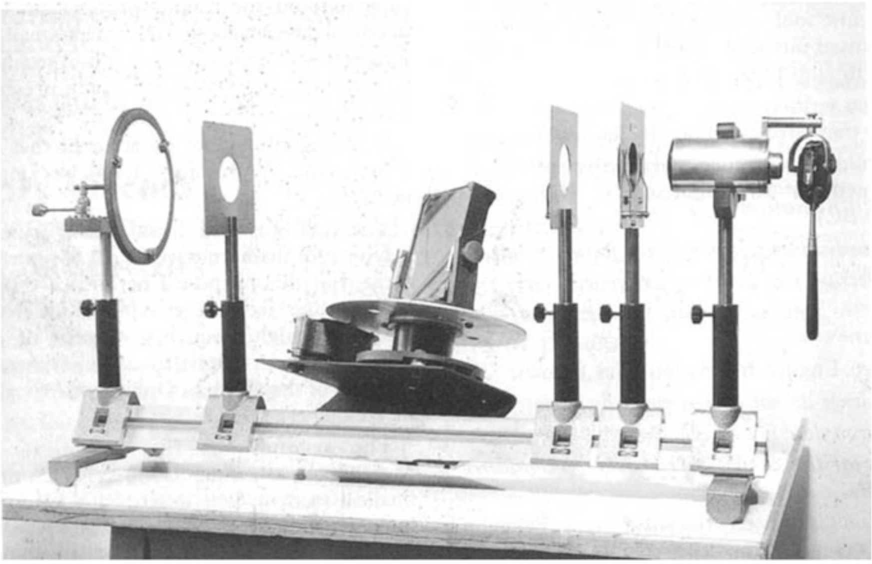
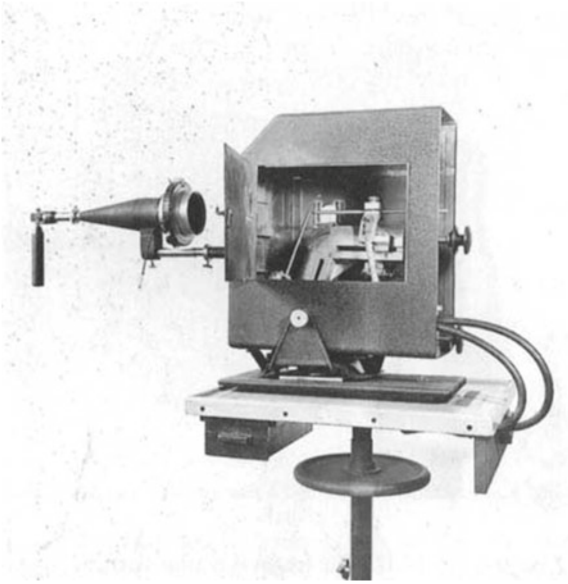


Fig. 2.6 Sunlight photocoagulator with heliostate

Fig. 2.7 Beck arc photocoagulator



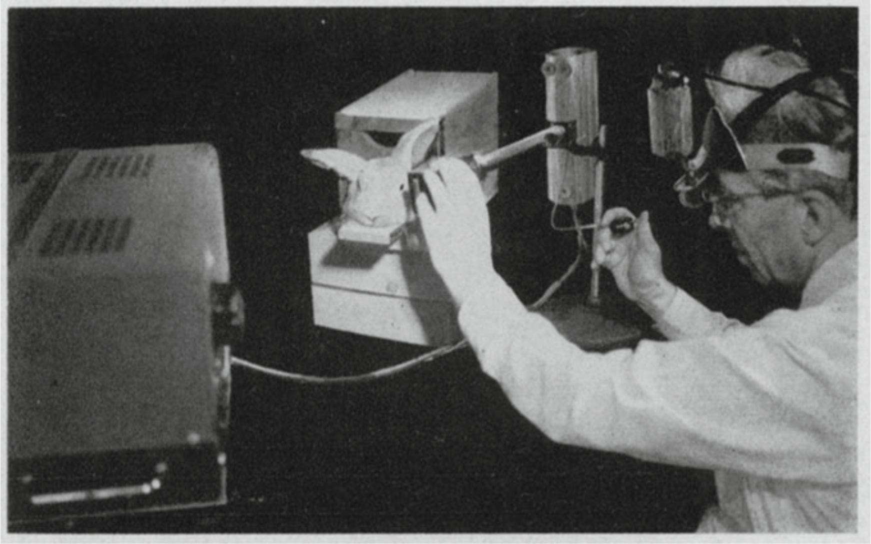


Fig. 2.8 Zeiss photocoagulator with xenon arc

was the author of the first known experience of therapeutic photocoagulation of retina, because he had previously used a similar technique in rabbit and human eyes in 1945 and 1946. These studies were described in his doctoral dissertation, which was defended in 1946, almost three years before Meyer-Schwickerath. He wrote: *"(…) scars produced by sunlight are very variable in intensity, depending on the stational variations, amount of sunlight, moment of the day, atmospheric changes, ophthalmoscopy lens position, (…) pupil size, refractive status of the patient, media transparency, retinal pigmentation, gaze direction, (…)"* [34]. Interestingly, Morón did not publish his results until 1950, when after reading the Meyer-Schwickerath´s reports he decided to share his experiences [35]. Due to the limitations derived from the sunlight variations, he searched for a different light source. All trials with lamps with filament were negative, and he tried with an arc lamp up to 15 amperes. In 1946, he practiced the procedure with an intense white light in four patients with retinal detachment. After pharmacological mydriasis, the patient kept his gaze in the same direction that of the light, Moron placed the voltaic arc in the place of the observer. The exposition time was 5 min. The results were unsatisfactory, the fixation was not good enough and patients complained with heating. Later, he tried the same procedure in two patients with retinal tear without retinal detachment, and the final lesion was not strong enough to close a retinal tear. Morón postulated that ideal conditions to treat a retinal tear with light photocoagulation, include the attached retina, not peripheral tear, dark fundus, clean ocular media, emmetropia and good mydriasis. He noted also that he had never treated a case with such a favorable condition, and remarked that Meyer-Schwickerath was luckier or more perseverant than him, getting what he was looking for, and resolving three retinal detachment cases with that technique.

Fig. 2.9 The Spanish ophthalmologist José Morón Salas (1918–2000) (right) with Dr. Antonio Olivella (left) and Prof. Meyer-Schwickerath (center) in the Retina Symposium celebrated in Sevilla in 1983

Interestingly, Meyer-Schwickerath mentioned in his first articles Morón as one of the precursors in the idea of photocoagulation [29] (Fig. 2.9).

Other Important Contributors

The first successful clinical application of photocoagulation in USA was performed in 1957 by Guerry, Wiesinger and Ham [36]. They photocoagulated a central von Hippel's hemangioma of 2–3 diameters in size with a light beam from an experimental instrument built for retinal burn studies in rabbits. This device employed a 24-inch carbon arc searchlight as light source with an ellipsoidal mirror for reduction of the solid cone of radiation. They reported only a faint macular scar after four years and improvement in visual acuity from 20/200 and large central scotoma to 20/70 with a small scotoma. The same authors presented their clinical and experimental experiences with light coagulation in several subsequent articles. This group, later with W. Geeraets, was very well-prepared for early light coagulation studies since they have worked earlier on the toxicity of light produced by atomic bomb to the eye structures [37–39]. Later, they become the leading groups in photocoagulation in USA [40–42]. In 1958 Guinan presented his observations from his visit to Bonn University to Mayer-Schwickerath [43], and Ten Doesschate reported a few cases

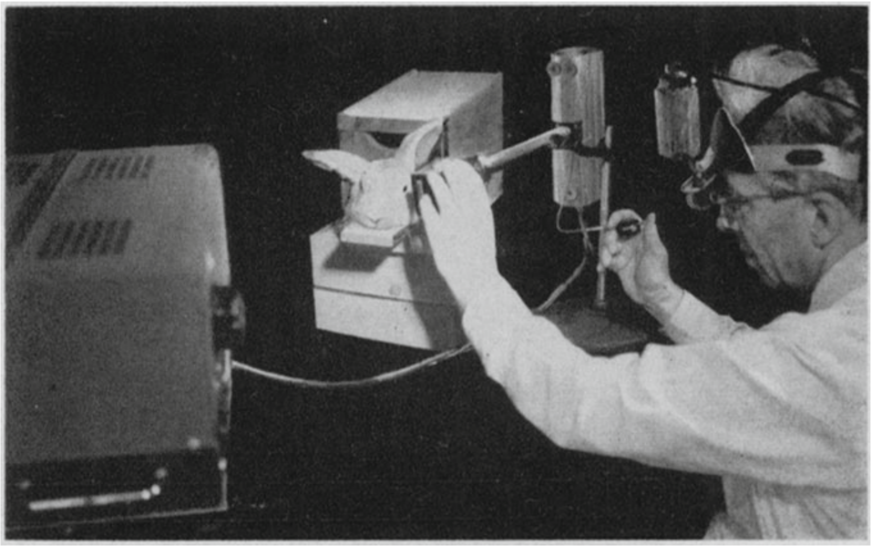


Fig. 2.10 Operator with binocular indirect ophthalmoscope exposing rabbit eye to light coagulation. *Source* Brockhurst RJ, Wolf E, Schepens CL. Light coagulation with indirect ophthalmoscopy. AMA Arch Ophthalmol. 1959 Apr;61(4):528–32

treated with photocoagulation, including choroidal melanoma, peripheral degenerations with retinal holes, flat retinal detachments with retinal holes [44]. In 1959, Heinzen, Ricci, Dubler and DuFour presented a report from 3 Swiss ophthalmology clinics on their experiences with light coagulation [45], and Brockhurst et al. reported on light coagulation with indirect ophthalmology [46] (Fig. 2.10).

In the following years, photocoagulation found application in the prevention and treatment of retinal detachment. One of the first to notice this was Meyer-Schwickerath. This was proposed in 1959 by Linnen, in 1960 by Boecke, Girard, Havener, Murreh, Pischel et al., Nowell et al., and Cibis [47–57]. In the same year, Heinzen published an extensive monograph on the prophylactic treatment of retinal detachment and presented critical discussion of indications and contraindications for the light coagulation for this purpose [58]. This time of enthusiasm and reserve towards the new treatment possibilities, introduced first by light coagulation, and later by lasers, is interestingly described in interview by American Academy of Ophthalmology Oral History Collections with DuPont Guerry III, MD and Dohrmann Kaspar Pischel, MD, two pioneers of these technologies in USA [59, 60].

The Complicated Beginnings of Laser

Max Planck in 1900 showed based on his studies on the radiancy of light that light is a form of electromagnetic radiation. Then, Albert Einstein in 1917 proposed the theory of stimulated emission in his work on *quantum theory of radiation.* This argued that light travels in units of energy called photons, and that most atoms exist in a standard ground energy stage, however, some occur at higher energy levels. Einstein postulated that by adding energy to atoms in a ground energy level they could be excited to a higher energy level. Then, when returning to their ground energy level, atoms emit the energy they acquired spontaneously in the form of photons or electromagnetic wave. In short, this concept led to the stimulated emission that was the fundament of laser development. In 1951, Charles Townes (1915–2015) (Fig. 2.11) conceived a new way to create intense, precise beams of coherent radiation, for which he invented the acronym *maser* (for Microwave Amplification by Stimulated Emission of Radiation). Townes in collaboration with James P. Gordon, and Herbert J. Zeiger built the first ammonia maser that used stimulated emission in a stream of energized ammonia molecules to produce amplification of microwaves at a frequency of about 24.0 gigahertz at Columbia University in New York in 1953. He also received the patent for “microwave oscillator” in 1957. In 1956, Gordon Gould (1920–2005) proposed using optical pumping to excite a maser, and discussed this idea with Townes, who advised him on how to obtain a patent on his innovation, and agreed to act as a witness. In 1957, Gould realized that an appropriate optical resonator can be made by using two mirrors in the form of a Fabry–Pérot interferometer what would produce a narrow, coherent, intense beam. He also coined the name of laser and many possible applications of such a device. Gould had his ideas witnessed and notarized. At the same time Arthur Schawlow and Charles Townes discovered the importance of the Fabry–Pérot cavity and called the resulting device an “optical maser”. They submitted patent application for “masers and maser communication systems” in 1958, and it was issued in 1960. Gould recorded his analysis and suggested applications in a laboratory notebook under the heading “Some rough calculations on the feasibility of a LASER: Light Amplification by Stimulated Emission of Radiation”—the first recorded use of this acronym (Fig. 2.12). Gould’s notebook was the first written prescription for preparing a potentially working laser. Then, the story gets much more complicated, because Gould did not patent nor publish his concept at that time. He believed incorrectly that he needed to build a working laser to do this, he left Columbia University without completing his doctoral degree and joined a private research company TRG (Technical Research Group) that obtained funding for his project from the Advanced Research Projects Agency. The government declared the project classified, which meant that a security clearance was required to work on it, and Gould due to his former participation in communist activities, was unable to obtain a clearance what greatly complicated his participation in the project and extended its duration [61–63].

In 1958 Schawlow and Townes, both later Nobel Prize awardees (Fig. 2.13), were the first to publish the theory of laser design and operation in their seminal 1958

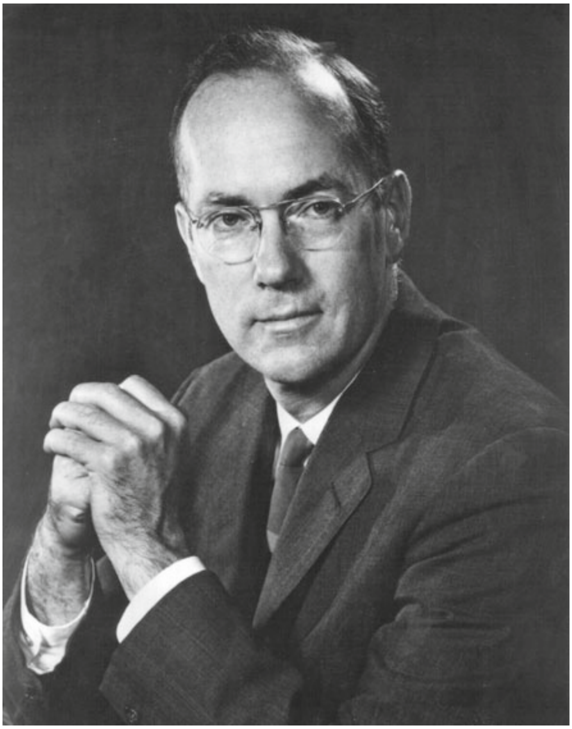
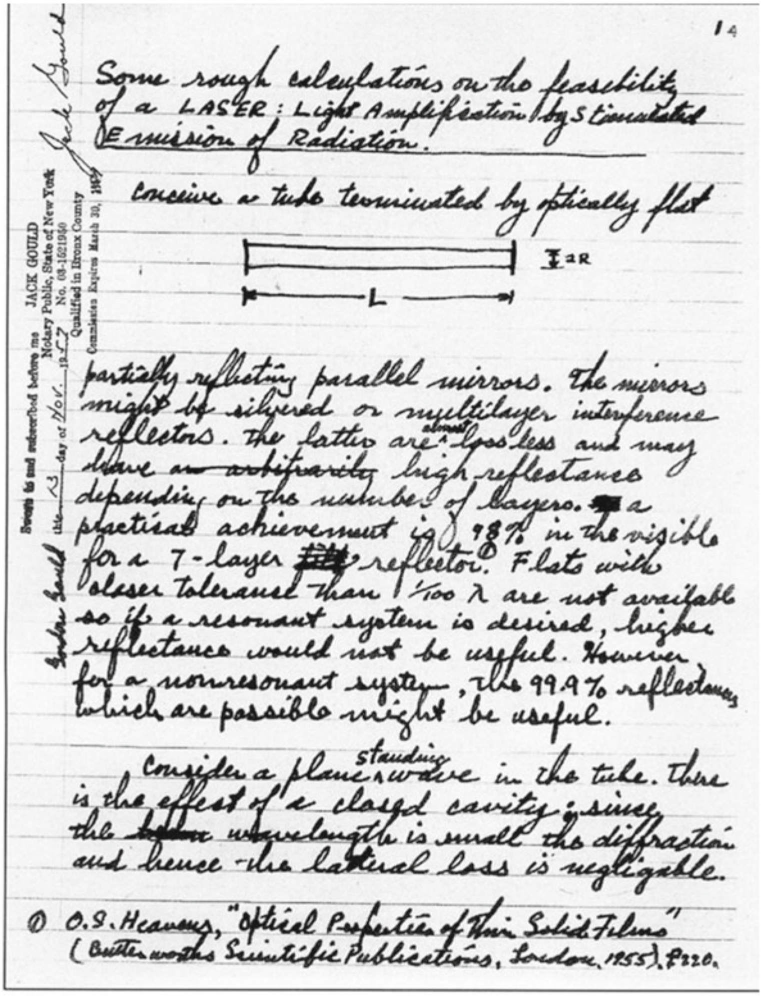


Fig. 2.11 Charles Townes (1915–2015). *Source* https://commons.wikimedia.org/wiki/File:Charles_Townes.jpg

paper on "optical masers" [64]. Townes along with Nikolay Basov and Alexander Prokhorov received the 1964 Nobel Prize in Physics "for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle". Schawlow shared the 1981 Nobel Prize in Physics with Nicolas Bloembergen and Kai Siegbahn for their contributions to the development of laser spectroscopy. On the other hand, Gould is often credited with the "invention" of the laser, due to his unpublished work that predated Schawlow and Townes by a few months. Due to the aforementioned difficulties, TRG and Gould was beaten in the race to build the first working laser by Theodore Maiman (1927–2000) (Fig. 2.14) at Hughes Research Laboratories, who made the first working laser in 1960. After reading the paper by Schawlow and Townes, Maiman turned to the development of a laser based on his own design with a synthetic ruby crystal. On May 16, 1960, his solid-state pink ruby laser emitted mankind's first coherent light, with rays all the same wavelength and fully in phase. Maiman documented his invention in *Nature* [65]. His piece consisted of two simple figures, fewer than 300 words, and the device itself looked surprising in its simplicity. It is known that Maiman had begun conceptualizing a solid-state laser design even before he undertook the maser project at Hughes. Moving the microwave frequency of masers up the electromagnetic spectrum 50,000-fold to the frequency of light would require finding a feasible lasing medium and excitation source and designing the system.



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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. [illegible] a practical achievement is 98% in the visible for a 7-layer [illegible] reflector.① 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 negligible.

① O.S. Heavens, "Optical Properties of Thin Solid Films" (Butterworths Scientific Publications, London, 1955), p.220.

Sworn to and subscribed before me this 13 day of Nov. 1957
JACK GOULD
Notary Public, State of New York
No. 03-1521950
Qualified in Bronx County
Commission Expires March 30, 1959

Jack Gould

Gordon Gould

Fig. 2.12 The first page of the notebook in which Gould coined the acronym LASER and described the essential elements for constructing one

This laser had a wavelength of 694.3 nm. At the same time, other research groups at IBM, Bell Labs, MIT, Westinghouse, Radio Corporation of America, and Columbia University, among others, were also pursuing projects to develop a laser. Maiman submitted patent application for "Ruby laser systems" in 1961, and it was issued in 1967 (Fig. 2.15).

Gould spent next 30 years fighting with the United States Patent and Trademark Office to obtain patents for the laser and related technologies, and with laser manufacturers in court to enforce the patents he subsequently did obtain. Finally, in 1985 Gould won his battle, was issued 48 patents, with the optical pumping, collisional

Fig. 2.13 Charles Townes receiving Noble Prize in 1964. *Source* https://m.facebook.com/nobelprize/photos/a.164901829102/10158808321239103/?type=3

Fig. 2.14 Theodore Maiman (1927–2007) *Source* https://en.wikipedia.org/wiki/Theodore_Maiman#/media/File:Maiman_with_the_first_laser.jpg

Fig. 2.15 Maiman with his laser in July 1960 https://en.wikipedia.org/wiki/Theodore_Maiman#/media/File:Theodore_Maiman_1960.jpg

pumping, and applications patents being the most important, including technologies covering most lasers used at the time, like the first operating laser, a ruby laser. The spread of lasers into many areas of technology meant that the patents were much more valuable than if Gould had won initially, and he made of them several million dollars. Gould was elected to the National Inventors Hall of Fame in 1991 for inventing optically pumped laser amplifier [66, 67].

In conclusion, credit for the invention of the laser is disputed, since Gould conceived the idea, Townes and Schawlow were the first to publish the theory and Maiman was the first to build a working laser.

Beginnings of Lasers in Ophthalmology

Maiman's laser introduced in 1960 opened the ophthalmic world doors to many new applications (Fig. 2.16). In 1961 Zaret started experimentations with ruby laser photocoagulation in the rabbit retina, and in 1962 Campbell and Zweng started using it in human treatment [68–72]. The experimental studies were continued by Kapany, Noyori, Geeraets and Ham, among few more [73–75] (Figs. 2.17 and 2.18). The ruby laser was useful in sealing retinal holes, but not very helpful in the treatment of vascular disorders. Moreover, it was related with instability of the beam and inconvenient pulse duration. In 1961 Ali Javan, William Bennett and Donald Herriott of Bell Laboratories described a different kind of laser, using a mixture of helium and neon as the active medium and producing a continuous beam rather than a series of pulses [76]. Not long afterwards, a laser based on carbon dioxide was proposed. Gas lasers due to their ease of construction, efficiency, and versatility became, both scientifically and commercially a dominant technology in the next decades.

The blue-green argon laser was developed in the Edward Harkness Laboratories in the Columbia Presbyterian Medical Center in 1965, and the first study on humans was conducted by Francis A. L'Esperance in 1968 [71]. He reported that the argon ion laser produced a coherent, monochromatic blue-green beam of intense light energy that is 4.5 times more effectively absorbed by hemoglobin and vascular structures than xenon-arc radiation, and 7–8 times than ruby laser radiation; can be absorbed even more effectively in vascular lesions by the intravenous addition of sodium fluorescein, can deliver more continous wave (cw) power through the ocular medium and produce a greater cw power density at the retina than any other light source. Moreover, he showed that the blue-green beam had greater inherent energy per photon than any laser source considered for photocoagulation therapy, and that the argon laser produced radiation that was more highly absorbed per incident photon at the pigment epithelium than any existing photocoagulation system [71]. In 1969, over

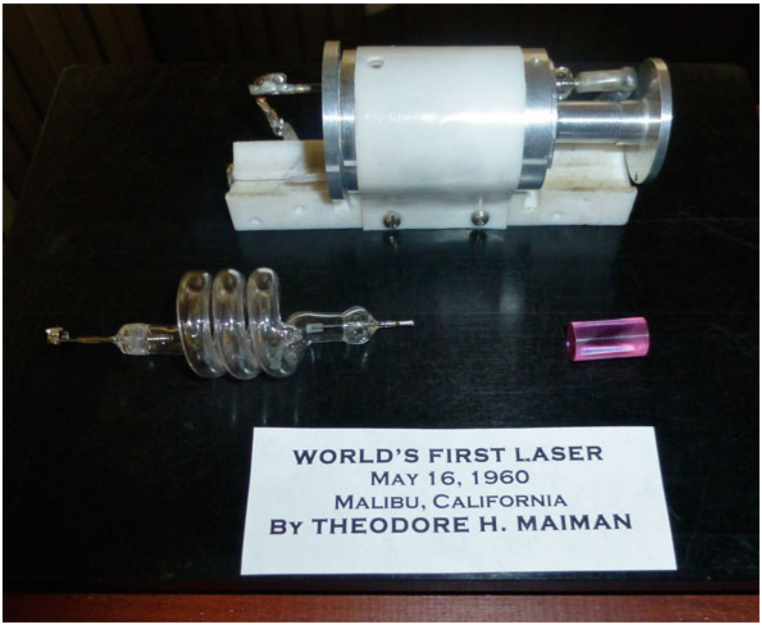

Fig. 2.16 World's first laser https://en.wikipedia.org/wiki/Theodore_Maiman#/media/File:World's_first_laser_out_of_case.jpg

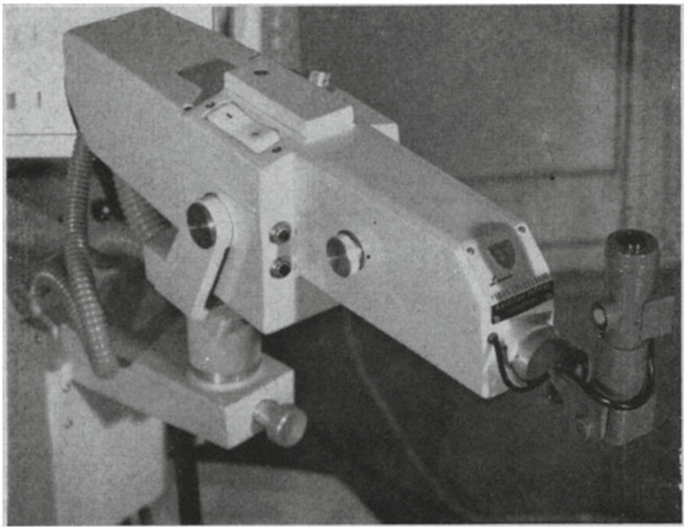

Fig. 2.17 Ruby laser photocoagulator. *Source* Campbell CJ, Koester CJ, Curtice V, Noyori KS, Rittler MC. Clincal studies in laser photocoagulation. Arch Ophthalmol. 1965 Jul;74:57–65

500 human subjects with different disorders were treated by him using argon laser photocoagulation. This has opened a new dimension in photocoagulation therapy. The argon laser permitted precise focusing and the placement of photocoagulation spots as small as 30 to 50 micra in diameter, thus was well suited to the treatment of macular disorders. The continuous gas phase allowed relatively slow release of energy avoiding the "explosive effect" that occurred with the ruby laser. The experimental and human studies by L'Esperance [77, 78], Patz, Little, Zwang, Peabody [79–85] and Behrendt [86] led to the introduction of a commercially available unit in 1971. Patz et al. presented 100 consecutive cases of macular diseases treated with the argon laser photocoagulator. They pointed advantages of this therapy due to the precise focusing qualities of the argon laser beam and the ability to place spots of coagulation as small as 30 to 50 micra [82]. Meanwhile, krypton and YAG laser were used in clinical trials (Fig. 2.19).

In 1990 Pankratov invented a novel laser modality, in which the laser energy was delivered in short pulses or "micro pulses" instead of continuous wave [87]. Micropulsing allowed selective treatment of the retinal pigment epithelium (RPE) and sparing of the neurosensory retina [88, 89]. Micropulsed lasers due to use of high treatment powers and / or micropulse duty cycles reduced the thermal retinal damage. However, the belief that achieving a therapeutic effect is directly related to laser-induced thermal retinal injury was very strong. Further developments in producing shorter microsecond continuous-wave laser pulses, including Birngruber and colleagues in 1992, helped sparing the photoreceptors and other intraretinal cells and selectively target the retinal pigment epithelium (RPE) leading to coin the term "Selective Retina Therapy" [90, 91]. In the beginning of 1990s Journee-de Korver

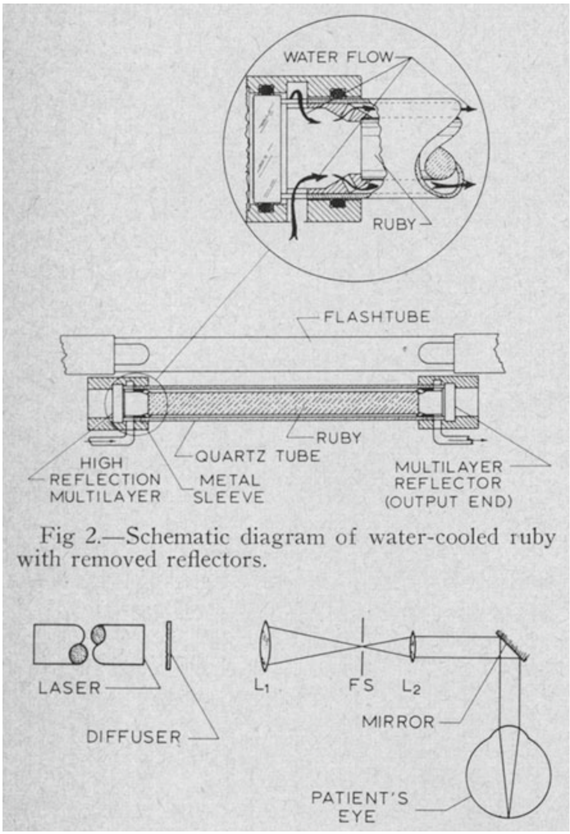

Fig 2.—Schematic diagram of water-cooled ruby with removed reflectors.

Fig. 2.18 Schematic diagram of a portion of the optical system. *Source* Campbell CJ, Koester CJ, Curtice V, Noyori KS, Rittler MC. Clincal studies in laser photocoagulation. Arch Ophthalmol. 1965 Jul;74:57–65

et al. studied the destructive effect of hyperthermia at sub-photocoagulation level of 45–60 °C on melanomas. They performed transpupillary thermotherapy (TTT) with a diode laser at 810 nm in patients with choroidal melanomas prior to enucleation and showed the possible advantages of this approach [92]. Later, the concept that micropulsed laser parameters (high-density/low-intensity "true" Subthreshold Diode Micropulse laser, or "SDM") without any laser-induced retina injury can be clinically effective was confirmed [93].

Conclusions

Light is the source of life on earth for both plants and animals. Since ancient times it has been understood that light can be the source of life and death. The awareness that light is a source of great energy that can be dangerous to health, including vision existed already in antiquity. From antiquity, this knowledge could also be used for military purposes, as evidenced by the history of Archimedes. In the middle of the

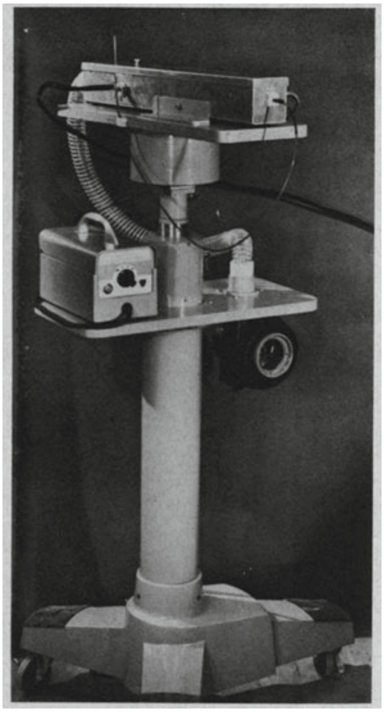

Fig. 2.19 Neodymium fiber laser, fiber optics iluminator, and curved tip for scleral surgery. *Source* Campbell CJ, Noyori KS, Rittler MC, Innis RE, Koester CJ. The application of fiber laser techniques to retinal surgery. Arch Ophthalmol. 1964 Dec;72:850–7

twentieth century, after earlier unsuccessful attempts, Meyer-Schwickerath was able to show that light can be used treat some retinal disorders. This, later supported by lasers led to the introduction of standard laser treatment in ophthalmology. The main weakness of this approach, however, was its disruptive nature, which for years was assumed to be essential and inextricably linked to the potential benefits of treatment.

This, however, has changed in recent years. The concept of subthreashold laser therapy radically changes our current thinking about this form of treatment. According to this concept, it is possible to achieve therapeutic effects in various diseases of the retina without simultaneously destroying the relevant areas of the retina. Although, presently we cannot evaluate all pathophysiology pathways behind this approach in very complicated cellular and molecular environment of the retina, however, the accumulating data shows that this the future of laser therapy. The future experimental studies should help us to better adjust the laser beam characteristics (wavelength, power, size, duration, etc.) to expected outcomes, what should make this approach even more effective than it is nowadays. It might also help to enter new fields for lasers, including early treatment, that was not possible with destructive character of traditional laser therapy. Moreover, new disorders might be treated with a therapy that is safe, and non-destructive. Although we still did not enter the field of known knowns in subthreshold laser therapy, but in recent decades we certainly moved from unknown unknowns to known unknowns.

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