THE LASER: SIXTY YEARS

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1. Introduction

After 60 years since its invention, the laser continues to create around itself a mixed atmosphere of curiosity and wonder. Curiosity mostly comes from the fact that new lasers are still being invented and new, quite fascinating, applications are continuously developed. Wonder essentially comes from the pervasive character of the laser: there is, in fact, no field of science and technology which has not been influenced, often fundamentally, by this revolutionary invention.

To celebrate the 60th anniversary of this invention, we will here review the early beginning of laser developments, with anecdotes and curiosities derived by the author's personal experience.

2. The Race to Make the first laser

Race started after the publication, in the middle of 1958, of a, by now, very famous paper by A.L. Schawlow and C.H. Townes [1]. In this paper, the two authors proposed to extend the idea of the MASER[1], already demonstrated by H.J. Zeiger, J.P. Gordon and C.H. Townes in 1953, to the infrared or even to the optical range of the electromagnetic spectrum. Several laboratories got involved in this race, mostly in the USA. Among them, we should mention: Bell Laboratories at Murray Hill, Columbia University, IBM Research Laboratories at Yorktown Heights, TRG Laboratories, American Optical and Hughes Laboratories at Malibu. Outside USA, there was a strong activity in former Soviet Union, particularly at Lebedev Institute in Moscow and at Moscow Power Institute. In Europe some early activity started particularly at Oxford University [2]. The incentive for this race was due not only to the envisioned potentialities of this revolutionary source but also for the feeling that, whoever would have achieved first laser action could soon get the Nobel Prize!

Despite the large amount of money invested by some big and prestigious laboratories such as Bell Labs or TRG Labs, the winner of the race turned out to be a young (by then) physicist at Hughes Laboratories, Theodore H. Maiman, spending a reportedly little amount of money (i.e. about 30 k$ against about 1 M$ spent by some other contender!). The fact is that Maiman had the right idea, namely to use a flashlamp to excite, as the active medium, a rod made of (synthetic) Ruby (Cr^{3+}:Al_2O_3). **This happened on May 16 1960**. When the result was announced, the scientific community remained astounded for at least three reasons: (a) The simplicity of the components used. Indeed, as already mentioned, the laser was simply made of a Ruby rod inserted at the center of a helical flashlamp. The system was then surrounded by a cylindrical aluminum cover to reflect back to the rod the light emitted by the lamp toward the outside. People were really shocked because, on account of the fact that the laser had not invented before, general feeling was that its realization would necessarily be very difficult.

[1] MASER is an acronym standing for "Microwave Amplification by Stimulated Emission of Radiation" while LASER, as perhaps well known, stands for "Light Amplification by Stimulated Emission of Radiation". Therefore, the MASER is to be considered as the precursor of the LASER in the microwave field.

(b) The 3-level nature of the laser transition in Ruby. This is a more scientific argument which has to do with the Physics of the Laser [4]. But, it was just this property of Ruby which lead some authoritative scientist of that time to predict that Ruby could never work as a laser active material! (c) The type of laser excitation (pulsed by a flashlamp). As mentioned above, this was the really winning idea of Maiman. And so it happened that, on May 16 1960, i.e., just sixty years ago, first laser action was achieved. In this regard, it is worthwhile to report the account of this happening using just the own words of the author [4]:

"It was in the afternoon of May 16, 1960; it was time to confirm or deny all the fears of why the "ruby can't work" or why "lasers can't be made to work". No more calculations, no more diversionary experiments. This was the moment of truth…We turned up the power supply to 500 volts. We fired the flashtube. Indeed, we observed a trace on the Memoscope! The trace was a recording of the red ruby fluorescence. The decay in the trace was about three milliseconds, the lifetime of the upper possible level…But when we got past 950 volts on the power supply, everything changed! The output trace started to shoot up in the peak intensity and ***the initial decay rapidly decreased. Voilà. This was it! The laser was born!"***

After this revolutionary event, other important laser demonstrations occurred in the second half of 1960. In the fall, P. Sorokin and M. Stevenson at IBM Laboratories, following Maiman's suggestion to use a flashlamp for exciting the laser medium[2], made to operate active rods made of U^{3+} ions in a CaF_2 crystal (at the 2,5 μm wavelength) [5] or Sm^{2+} ions again in a CaF_2 crystal (around at 700 nm wavelength) [6]. Although these lasers are not used any more, since they both require the laser crystal to be cooled at liquid nitrogen temperature (77 K), they still retain their historical importance being the second and third laser of the history. Furthermore, they represent the first two examples of lasers operating on a four-level scheme [3], a much more efficient scheme compared to the three-level one of Ruby laser. This kind of scheme will, in fact, be used for most of the lasers developed in successive years. Lastly, Sm^{2+} represented the first example of an active medium made of a rare-earth ion, which are widely used in nowadays solid-state lasers. To conclude the panorama of laser inventions of the same year, on December 1960 Ali Javan and coworkers at Bell Labs operated a He-Ne laser at its 1.15 μm wavelength [7]. This laser, also, showed a few notable cases of first achievements: it represented, in fact, the first example of an electrically pumped laser, the first example of a gas laser and the first example of a laser operating in a continuous way.

So, by the end of 1960, quite different kinds of lasers were made to operate by most participants to the race. This situation, from one side, established the end of that race and, from the other side, opened the door to all developments in laser physics and in corresponding applications which have been occurring during last sixty years.

3. The Laser during last 60 years

What happened during the successive 60 years up to today is a complete different and very long story which is well beyond the scope of this paper. It suffices, here, to say that new kind of lasers have continuously been developed and still are developed. Furthermore, new applications have by now been

[2] Interestingly enough, P. Sorokin and coworkers have been trying without success, in several months before, to get laser action out of the same crystals upon optical excitation by the most intense continuous-wave lamps.

well established and new ones are still pursued. They span several fields from Information Technologies (e.g. optical-fiber communications, CD and DVD readers, laser printers, bar-code scanners), to Manufacturing (e.g. cutting, welding, marking, micro- nano-machining, precise optical measurements), to Medicine (e.g. ophthalmology, dermatology, micro-surgery, endoscopic treatments), to end up with Space and Homeland security (e.g. space communications, laser ranging, target designators). Thus, applications are so vast and diversified to have lead past US President Barak Obama to state: "*Laser has changed the way we live*"[3].

But what it appears to be even more striking is the large number of scientific applications of the laser. They in fact represent the basic starting point from were all industrial applications considered above actually originated. Here, we can generally state that there is no field in Science (from Physics, to Chemistry, to Biology and Medicine) which has not been influenced, often in a very important way, by this revolutionary invention. In this respect, it suffices to say in the economy of this paper, that 33 scientists have, so far, been awarded the Nobel Prize for researches on the laser or made by the laser (29 in Physics and 4 in Chemistry)[4].

4. Conclusions

To properly conclude this short celebration of the 60th anniversary, we can say that the laser can be considered to represent one of the most important (if not the most important) invention of last century. Indeed, it already played there a very important role in both Science and Technology. Due, however, to the large amount of research and development which are still being pursued in this field all around the word, we can easily predict that this invention will play an even more important role in this century. **So, the most unpredictable surprises are, perhaps, still to come**.

References

[1] A.L. Schawlow and C.H. Townes, Phys. Rev., **112**, 1940 (1958)

[2] For more details about this race see: Jeff Hecht, *Beam: The Race to Make the Laser*, Oxford Univ. Press, Oxford (2005)

[3] Orazio Svelto, *Principles of Lasers*, Fifth Ed. Springer, N.Y. (2010)

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[6] P. Sorokin and M. Stevenson, IBM J. Res. Developm., **5**, 56 (1961)

[7] A. Javan, W.R. Bennet and D.R. Herriott, Phys. Rev. Letts, **6**, 106 (1961)

[3] From the greeting message to the 50th anniversary of the laser, sent by Barak Obama during the special Symposium "Retrospectives on the Invention of the Laser" (Conference CLEO/QELS San Diego, CA, May 16, 2010).

[4] Interestingly enough, despite this large number of Nobel laureates in laser field, the inventor of the first laser, namely Theodore H. Maiman, never got this most prestigious award. But this, by itself, would require a complete different story.