The Nobels and light

John DUDLEY[1,*]
[1] Université de Franche-Comté, Besançon, France
***john.dudley@univ-fcomte.fr**

Milestones such as the 40th anniversary of the French Optical Society are an ideal time to reflect on historical achievements, and there is no shortage of major highlights to celebrate in photonics. What is not always appreciated, however, is just how many different areas of light-related science have been recognized by perhaps the most prestigious scientific celebration of all - the award of the Nobel Prize !

https://doi.org/10.1051/photon/202311921

The second week in October every year is eagerly awaited by scientists around the world. For a very select few, they may be hoping for a phone call from a representative of the Royal Swedish Academy of Sciences, but for most of us, we are just waiting impatiently to learn which specific areas of science have been recognized by the tremendous honour of the Nobel Prize. However, the decision of who receives the call is the result of a process that actually begins 12 months before.

According to the Nobel Prize website, the details depend on the particular subject of the prize but for physics at least, the procedure begins when thousands of invitations are sent out to scientists around the world to submit nominations.

Figure 1. It is not unusual to find several Nobel laureates in the same discipline coming from the same laboratory, and this is usually indicative of a scientific environment that encourages basic science and support for fundamental and long-term research. Examples include Bell Labs and Berkeley in the United States, and another example is the celebrated École Normale Supérieure (ENS) in Paris where Kastler, Cohen-Tannoudji, and Haroche all performed their prize-winning work. This remarkable photo taken around 1966 shows Kastler (centre) with Cohen-Tannoudji (left) and Haroche (right.) © Archives LKB - Photothèque ENS, 1966.

1964	Townes, Basov, Prokhorov Laser-Maser Principle	Physics
1966	Kastler Precision studies of optical resonances	Physics
1967	Granit, Hartline, Wald Physiological and chemical visual processes in the eye	Physiology or Medicine
1967	Eigen, Norrish, Porter Flashlamp Pump-Probe Studies of Chemical Reactions (µs)	Chemistry
1971	Gabor Holography	Physics
1981	Bloembergen & Schawlow Laser Spectroscopy	Physics
1981	Hubel & Wiesel Information Processing in the Visual System	Physiology or Medicine
1989	Ramsey, Dehmelt, Paul Atomic Clocks, the Ion Trap	Physics
1997	Chu, Cohen-Tannoudji, Phillips Laser Cooling and Trapping	Physics
1999	Zewail Femtochemistry	Chemistry
2000	Alferov & Kroemer Optoelectronics, Semiconductor Heterostructures	Physics
2001	Cornell, Ketterle, Wieman Bose Einstein Condensation	Physics
2005	Glauber, Hall, Haensch Quantum Optics, Spectroscopy, Optical Frequency Comb	Physics
2008	Shimomura, Chalfie, Tsien Green Fluorescent Protein GFP	Chemistry
2009	Kao, Boyle and Smith Optical Fiber Communications ; Imaging and the CCD	Physics
2012	Haroche & Wineland Individual Quantum Systems	Physics
2014	Akasaki, Amano, Nakamura The Blue LED and Energy-Saving White Light Sources	Physics
2014	Betzig, Hell, Moerner Super-resolution microscopy	Chemistry
2018	Ashkin, Mourou, Strickland Optical Tweezers & Biophotonics Chirped Pulse Amplification	Physics
2022	Aspect, Clauser, Zeilinger Entangled photons and quantum information	Physics

Table 1. A selection of Nobel Prizes related to the physics of light dating from the invention of the laser in 1960. The descriptions are highly abridged from the formal citation, and this is only a partial list; many other Nobel Prizes have been related to light science in some way or another especially in areas of astronomy and crystallography. © Archives LKB - Photothèque ENS, 1966.

Typically around 250–350 individuals are nominated before the deadline of 31 January, and then the difficult task begins of assessing their work. As might be expected, this takes several months, and the assessment is followed by the preparation of a formal report by the Nobel Committee, which is submitted together with recommendations to the Academy. The final decision on who the laureates will be is then made in October.

The first Nobel Prizes were awarded in 1901, and according to the Testament of Alfred Nobel, the prizes were intended to be awarded for work performed during the year preceding the award. However, it was soon realized that such a strict criterion did not reflect the realistic timescale on which the impact of scientific research can actually be determined. As a result, this restriction was relaxed and the rules now allow for the recognition of research performed many years ago in cases where its significance has been appreciated only recently.

Importantly, the rules also state clearly that the prize is not a lifetime achievement or career award. Rather it is for a particular body of work or result ("invention or discovery" in physics for example) that has had impact on science, or shown the usefulness of science to society. Indeed, societal significance is a key part of the Nobel Prize, and Nobel's testament explicitly states his intention to recognize work that has led to "the greatest benefit to humankind."

Understanding these rules gives us insight into how Nobel prizes recognize both fundamental long-term conceptual advances, as well as work that has had more direct or short-term societal relevance. This dual aspect of the Nobel Prize becomes especially clear when we consider the many awards related to optics and photonics. And indeed, one particular example dates right back to the very first Nobel prizes. Specifically, although not widely appreciated, the early studies of black body radiation (that led to the development of quantum mechanics) were stimulated by a very practical and economic question: Berlin was deciding between gas and electric lighting for its urban environment, and making the best choice required standardization of the spectral efficiency of the different light sources. This practical question led to precision measurements, and although Wein was able to successfully develop a model relating source temperature to peak emission wavelength, understanding the detailed form of the full emission curve was only possible after Max Planck introduced the quantum hypothesis in 1900.

The 1921 Nobel Prize was awarded to Einstein, and one can imagine how difficult it must have been for the committee to decide which amongst his many discoveries would be the focus of the award. In the end, the official citation recognizes "services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect." Now given Einstein's immense contributions to special and general relativity, this can seem a little unusual to us now, but the wording was very carefully chosen to circumvent controversy that still surrounded relativity at the time. The presentation speech by Arrhenius mentioned relativity briefly, but focused more on Einstein's studies of Brownian motion, specific heat, photoluminescence, the photoelectric effect, as well as applications in fields such as photochemistry. In photonics, it is Einstein's prediction of stimulated emission from 1917 that is widely cited as being at the foundation of the development of the laser. Indeed, Einstein's insights here were tremendous: as well as developing the now familiar rate equation theory of emission and absorption, he realized that stimulated emission would be associated with directionality. It is this particular characteristic that allows for amplification, and whilst Einstein did not actually foresee any form of practical laser, his work is justifiably seen as central to everything that followed.

The following decades saw extensive international work extending both theory and experiment in atomic physics and light-matter interactions. This was an exciting period, and it paved the path to the first demonstration of the maser in 1953 by Charles Townes and his PhD student Jim Gordon. Townes and Arthur Schawlow wrote a theoretical proposal for the optical maser in 1958, yet it was Ted Maiman at Hughes Research Laboratories who first saw laser oscillation. Maiman had deliberately avoided complex pumping approaches that seemed to require cryogenics, and by building on his intuition that flashlamp pumping would yield a dynamic population inversion sufficient to reach threshold, he observed pulsed laser oscillation at 694.3 nm on May 16th, 1960. This date is now recognized by UNESCO as the International Day of Light. There are many excellent surveys of the diverse international contributions in quantum electronics leading to the laser.

The maser and laser were recognized in 1964 with the award of the Nobel Prize to Charles Townes, Nicolay • • •

HAMAMATSU
PHOTON IS OUR BUSINESS

ADVERTORIAL

LEADING SCIENTIFIC CAMERA FOR PHOTON COUNTING

Photon counting is a technique to detect the absolute minimum amount of light, namely a single photon.
Traditionally, photon-counting cameras were implemented using different methods of signal amplification by electron multiplication, such as impact ionization or secondary emission. This solution provided the advantage of a very high low-light sensitivity when only single photons were available. However, this was at the cost of a complex system and other performance parameters.

Last year, Hamamatsu Photonics, a world leader in scientific cameras released the first camera equipped with a qCMOS® (quantitative CMOS) sensor. This groundbreaking technology has revolutionized the approach to photon counting. Named the ORCA®-Quest, this ultra-sensitive camera offers the best in the market in terms of quantitative imaging. This is primarily due to its extremely low noise performance of 0.27 electrons.
When comparing qCMOS with EM-CCD cameras, one of the key advantages is their versatility. qCMOS cameras combine the advantages of conventional sCMOS cameras with extremely low noise, challenging and partially exceeding the performance of electron multiplication cameras.
Hamamatsu offers a whole series of scientific cameras each with its own unique features. Their customizable OEM cameras also cover imaging in the visible light region and invisible spectral regions such as X-ray and infrared.

Contact Hamamatsu Photonics France
infos@hamamatsu.fr
01 69 53 71 00

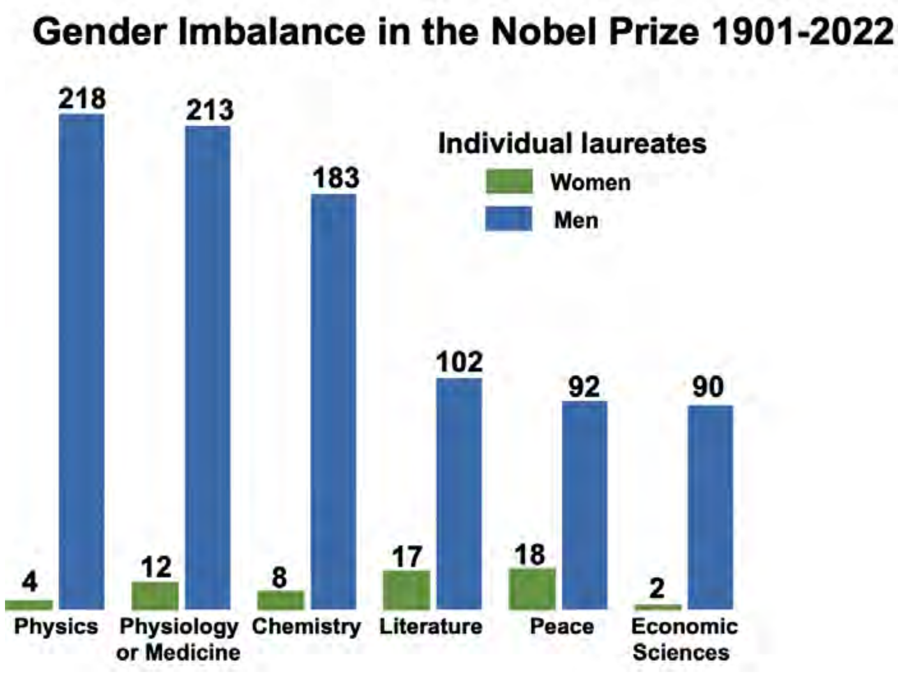

Figure 2. Plotting the public data from the Nobel prize website clearly shows the gender imbalance amongst Nobel laureates across all categories of the award. Although one reason for this imbalance is the fact that women have historically been underrepresented in some of the fields that the Nobel Prizes are awarded in (such as physics and chemistry) it is almost certain that systemic biases also play a role. For example, women are often excluded from academic and scientific networks, which can limit their opportunities for nomination and recognition. Data from nobelprize.org . Figure design adapted from 2020 infographic by Felix Richter (www.statista.com/chart/2805/nobel-prize-winners-by-gender/) CCBY 3.0

Basov, and Aleksandr Prokhorov. Two years later in 1966, Albert Kastler received the Nobel Prize for his work on optical pumping, and Bloembergen and Schawlow shared the 1981 Nobel Prize for laser applications in spectroscopy. Absent from the list of Nobel laureates are Gordon and Maiman, but we can understand this when we learn that they simply were not frequently nominated. From the Nobel archives (which are now openly accessible up until 1971) we find that Maiman was actually nominated only twice (1964 and 1969) and Gordon only once (1963). In contrast, Charles Townes received 30 nominations in the year in which he won, and had in fact been nominated a total of 75 times since 1958 (where Kastler was amongst the first of his nominators!). Clearly winning a Nobel Prize requires a strong and persistent network of supporters!

The development of the laser opened up the field of photonics with its many multidisciplinary applications, and led to the many advances in both fundamental and applied physics that members of the international optical physics community have been privileged to witness at first hand. Lasers and their impact have been recognized in many Nobel Prizes since 1960, and Table 1 highlights a selection since the invention of the laser.

However, this figure is necessarily incomplete, and we know that lasers and other photonics-related instrumentation have been central to prizes such as gravitational wave astronomy, the imaging of black holes, and no doubt many other Nobel prizes in Chemistry or Medicine or Physiology. It is highly recommended to explore the Nobel Prize website to learn more, not only about the themes that have been recognized, but also about the inspiring stories of the laureates themselves.

Considering the history of the laser is an opportunity to think about the tremendous economic and societal benefits that can arise from basic curiosity-driven scientific research. As Charles Townes himself remarked, the laser is "a textbook example of broadly applicable technology growing unexpectedly out of basic research." Anniversaries provide the chance to look to the past in order to improve the future, and as science seems to be directed more and more to short-term goal-driven objectives, the lesson of the laser is something we all need to remember.

REFERENCES

[1] Nobel Prizes in all fields and the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel have been awarded to a total of 954 individuals and 27 organisations since 1901. Laureates, nomination archives, and transcripts of the Presentation Speeches, can be seen at www.nobelprize.org

[2] H. Kubbinga, *Europhysics News* **49/4** 27-33 (2018)

[3] C. H. Townes, *How the Laser Happened: Adventures of a Scientist*, Oxford University Press (1999)

[4] T. H. Maiman, *The Laser Inventor: Memoirs of Theodore H. Maiman*, Springer (2018)

[5] M. Bertolotti, *Optica Acta: International Journal of Optics* **32**, 961-980 (1985)

[6] J. M. Dudley, *Advanced Photonics* **2**, 050501 (2020)