NOBEL PRIZE
50 YEARS AGO

As we recall the major contributions of Professor Dennis Gabor that resulted in his Nobel Prize in Physics in 1971 for the invention of holography, it is interesting to put his impact on science, technology, as well as humanity, in a broader context so as to better understand his experiences, and recognize the very significant role that he played in his time.

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▲ Dennis Gabor receiving his 1971 Nobel Prize for Physics from King Gustav Adolf of Sweden.

Born as Günszberg Dénes in Budapest, Hungary, in 1900 into a well-to-do family that had converted to Lutheranism but was nevertheless affected by the air of the times, and decided to change the family surname to the more Hungarian sounding "Gábor" in 1902.

As an adolescent, while receiving an excellent Gymnasium education in his home town, he and his older brother enjoyed a home laboratory to run relatively advanced physics experiments for the time with X-rays or radioactivity.He was also fascinated by the calculus, voraciously reading relatively advanced textbooks. The two drawings that are included in this brief article, show that Dénes was also artistically imaginative and talented.

During the last year of the First World War, Dénes served with the Hungarian artillery against Italy, and after the armistice in 1918 he started his engineering studies at the Technical University of Budapest. He then moved to the Charlottenburg Technical University in Berlin with his parents' support, and graduated with an Engineering degree in 1924.

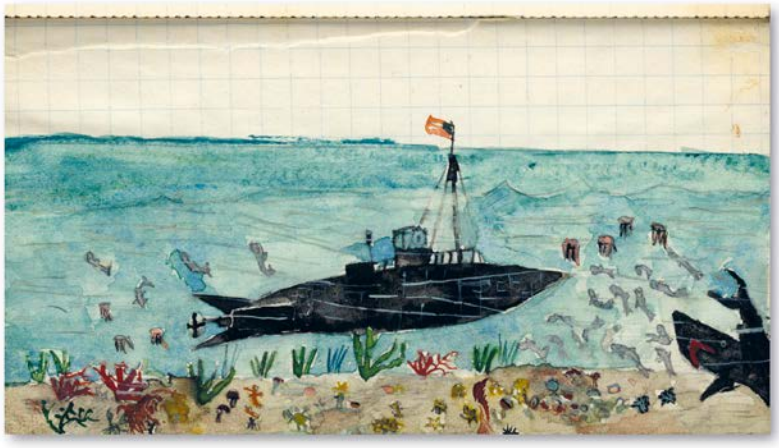
He pursued his studies in Berlin to obtain a doctorate in engineering in 1927 under Professor Ernst Orlich, working on electron optics to design and experiment cathode-beam oscillographs for the analysis of high-voltage electric transmission lines. His PhD thesis focused on the "Recording of Transients in Electric Circuits with the Cathode Ray Oscillograph", and this early work would lead him later to other devices such as electron microscopes and TV tubes. During his years as an engineering PhD student in Berlin, he also pursued his interest in physics by taking advantage of lectures and research groups surrounding the likes of Einstein, von Laue, Max Planck *etc.*

After his PhD, he joined the Siemens & Halske AG company as a research engineer, staying there until 1933. At Siemens he made some inventions such as the high-pressure quartz mercury lamp with superheated vapour with a molybdenum heat-resistant seal, that has been widely used in street lamps. Throughout his career, from 1928 until 1971, he filed no less than 62 patents, and he has often stated that he considered himself more of an inventor and engineer than a physicist.

In 1933-1934 he left Berlin because his contract at Siemens & Halske was not renewed, and briefly moved back to Budapest because of the threats posed for him personally by the rise of the Nazis in Germany. Then he was fortunate enough to be able to join the British Thomson-Houston (BTH) Co., in Rugby (England), on an inventor's contract, since regular employment as a foreigner was very difficult to obtain at the time in the UK (and elsewhere in Europe).

At BTH he initially worked on gas-discharge tubes, and later moved to the BTH Research Department as a regular employee. In Rugby he met his future wife, Marjorie Louise Butler, whom he married in 1936 and with whom he lived till his death in London in 1979. In 1946 he acquired British citizenship and was still at BTH when he invented holography in 1947, experimenting with light from a heavily filtered mercury arc. However, it was the invention of the laser in 1960 that provided the coherent source of light that allowed the creation of the first holograms in 1964, finally making holography commercially available.

Indeed, Dennis Gabor developed the early principles of holographic theory while trying to make improvements to the resolution of the electron microscope by exploiting the phase of the electron beams. However, progress in the field was very slow, and the value of these ideas only became broadly apparent when efficient sources of light, namely the laser, became available. Indeed, to form a simple hologram, or "wave-front reconstruction" as it was initially called, one can exploit the image formed on a sensitive film plate or paper by the interference patterns of two light waves that have different phases.



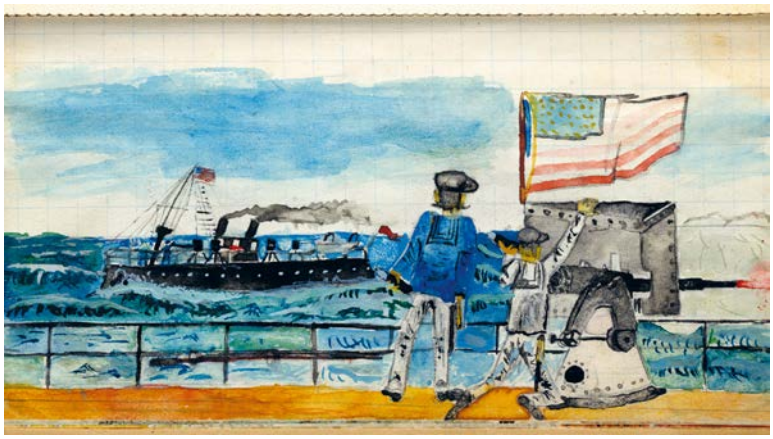
▲ **FIG. 1:** Drawing by Gabor when he was around 10 years old. Provided by courtesy of the Library of the Hungarian Academy of Sciences.

This apparently simple idea has given rise to many applications both in science and for commercial use, such as barcode readers, credit card security, the capture of three dimensional images, for measurements related to particles in physics, *etc.*

In 1949, Dennis Gabor (as he had become known in the UK) finally transferred to academia by accepting an appointment as Reader in Electronics at the Imperial College of Science and Technology in London, in the Department of Electrical and Electronic Engineering. He was then promoted to Professor of Applied Electron Physics only after he was elected a Fellow of the Royal Society in 1956. During his time at Imperial he was also associated for some years, from 1950 to 1953, with the AEI Research Laboratory in Aldermaston, where he worked on holography.

In several respects, he was similar to his predecessor, the great astronomer, physicist, mathematician and philosopher Ḥasan Ibn al Haytham (Latinized as Alhazem, c. 965 – c.1040) of the Islamic Golden Age, who is viewed as the father of modern optics through his "Book of Optics" (Kitab al-Manazir or "Book ● ● ●

As elegantly stated by the distinguished French physicist Edouard Brézin (private communication) and former President of the French Academy of Sciences:
"If Dennis Gabor was awarded the 1971 Nobel prize in physics 'for his invention and development of the holographic method', his contributions to science and electrical engineering span more than half a century. Before the actual implementation of his ideas, he realized early in his career ... that for ideal imaging, one should use not simply the amplitude of the wave, but also its phase. Initially he (Gabor) had in mind holography as a tool for electron microscopy, but after the invention of lasers, it became available and familiar to all with visible light. He had kept all along his life an interest for new technological developments in the fields of electronic optics, information processing and storage. His career is a model of cross-fertilization between very fundamental ideas and major technological developments."



▲ FIG. 2: Drawing by Gabor when he was around 10 years old. Provided by courtesy of the Library of the Hungarian Academy of Sciences.

● ● ● of Views or Landscapes") that survived through its Latin translation.

Indeed, with his curiosity about the role of phase in light, but also in the role of phase in sound signals and speech (*e.g.*, over telephone lines or wireless communications), Dennis Gabor is a precursor of the theory and applications of the mathematics of wavelets. The "Gabor Wavelet" tries to capture the time, phase and frequency nature of signals, as well as the orientation of such signals if we consider small but important spatial features in images. These ideas are now widely used, even for the recent detection of gravitational waves.

Thus Gabor's wavelet representation, first expounded in a paper published in 1946, includes a spatial template modulated by sinusoidal waves of fixed frequency ω_0 that propagate along different directions θ with different phases φ. Anchored in physics through the Uncertainty Principle, these ideas provide a powerful and useful generalization of Fourier series that has endured, and also resulted in the theory of wavelets which has been thoroughly developed by leading contemporary scientists such as the Abel Prize-winning mathematician Yves Meyer who expressed (personal communication) his admiration for Dennis Gabor, both as an individual who stayed on in Europe during the war years, despite his opportunity to emigrate to the USA, and for his precursory work on the time-frequency representation of signals motivated by the theory of communications.

Both Ibn al-Haytham and Gabor were also concerned with societal and philosophic issues, and each of these two "scientists of optics" expressed their interest in manners appropriate for their time: theology for Ibn al-Haytham, and the need to design the future with the help of science and engineering in the case of Dennis Gabor. Thus, Dennis Gabor's persona would be incomplete to the reader if we did not mention his engagement and efforts for the creation of the Club of Rome, which was one of the very first institutions to address the sustainability of our planet, based on ideas expressed by the Turkish-American system scientist Hasan Özbekhan (1921-2007), Professor at the Wharton School of the University of Pennsylvania, in works such as "The Predicament of Mankind" (Report to the Club of Rome), and "Toward a General Theory of Planning" (1968), regarding the need to investigate multiple options and paths into the future, going beyond the "natural" and empirical selection of the "one" pathway into the future that is dictated by events that we do not control.

In addition to Fellowship of the Royal Society (1956), Dennis Gabor was elected Honorary Member of the Hungarian Academy of Sciences (1964). Though he was not awarded a Knighthood, which would have been usual for a British Nobel Prize Winner, he was awarded the UK honour of Commander of the British Empire (CBE) in 1971, as well as several honorary doctorates and prizes including the Institute of Electrical and Electronic Engineers' (New York) Medal of Honor, and the Albert A. Michelson Medal of the Franklin Institute in Philadelphia. ■

Dennis Gabor has the good fortune to be much loved and admired in his home country Hungary, and widely recognized internationally. The NOVOFER Foundation of Budapest has been awarding for more than thirty years annual "Gabor Prizes" to Hungarian born scientists and innovators. The author's Hungarian colleagues, such as Professor Lajos Hanzo of the University of Southampton (private communication), have shared the inspiration they received from Dennis Gabor's example when they were high school and university students. A High School in Budapest is named after him. The International Society of Optical Engineering (SPIE) gives the annual Dennis Gabor Award, and the Royal Society of London awards the Dennis Gabor Medal to commemorate the contributions of this exceptional engineer scientist. Berlin also remembers him with the Dennis Gabor Strasse in Potsdam.

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