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MODERN NOBEL LAUREATES

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Charles K. Kao

Born 4 November 1933 is a pioneer in the development and use of fiber optics in telecommunications. Kao, widely regarded as the "Father of Fiber Optics" or "Father of Fiber Optic Communications", was awarded half of the 2009 Nobel Prize in Physics for "groundbreaking achievements concerning the transmission of light in fibers for optical communication".

In early 1960s at STL, Kao did his pioneering work in the realisation of fiber optics as a telecommunications medium, by demonstrating that the high-loss of existing fiber optics arose from impurities in the glass, rather than from an underlying problem with the technology itself. Kao was pointed to the head of the electro-optics research group at STL in 1963; he took over the whole optical communication program of STL in December 1964 and decided to overall change their research direction. Kao not only considered the optical physics but also the material properties. The results were first presented by Kao in January 1966 in London, and further published in July with his former colleague George Hockham (1964-1965). This study first theorized and proposed to use glass fibers to implement optical communication, the ideas (especially structural features and materials) described largely are the basis of today's optical fiber communication.

In 1965, Kao concluded that the fundamental limitation for glass light attenuation is below 20 dB/km (Decibels per Kilometer, is a measure of the attenuation of a signal over a distance), which is a key threshold value for optical communications (it was first reported by Kao to IEE in London in January 1966). However, at the time of this determination, optical fibers commonly exhibited light loss as high as 1,000 db/km and even more. This conclusion opened the intense race to find low-loss materials and suitable fibers for reaching such criteria.

Kao, together with his new team (members including T.W. Davies, M.W. Jones, and C.R. Wright), pursued this goal by testing various materials. They precisely measured the attenuation of light with different wavelengths in glasses and other materials. During this period, Kao pointed out that the high purity of fused silica (SiO2) made it an ideal candidate for optical communication. Kao also stated that the impurity of glass material is the main cause for the dramatic decay of light transmission inside glass fiber, rather than fundamental physical effects such as scattering as many physicists thought at that time, and such impurity could be removed. This led to a worldwide study and production of high-purity glass fibers. Theatrically, when Kao first proposed that such glass fiber could be used for long-distance information transfer and replace copper wires which were used for telecommunication during that era, his ideas were widely disbelieved; later people realized that Kao's ideas revolutionized the whole communication technology and industry.

In 1968, Kao with M.W. Jones measured the intrinsic loss of bulk-fused silica at 4 dB/km, which is the first evidence of ultra-transparent glass. Bell Laboratories started considering fiber optics seriously.

Willard Boyle

Willard Sterling Boyle (born August 19, 1924) is a Canadian physicist and co-inventor of the charge-coupled device. On October 6, 2009 it was announced that he would share the 2009 Nobel Prize in Physics for "the invention of an imaging semiconductor circuit—the CCD sensor".

In 1969, Boyle and George E. Smith invented the charge-coupled device (CCD), for which they have jointly received the Franklin Institute's Stuart Ballantine Medal in 1973, the 1974 IEEE Morris N. Liebmann Memorial Award, the 2006 Charles Stark Draper Prize, and the 2009 Nobel Prize in Physics.

Charge-coupled device

A charge-coupled device (CCD) is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated, for example conversion into a digital value. This is achieved by "shifting" the signals between stages within the device one at a time. Technically, CCDs are implemented as shift registers that move charge between capacitive bins in the device, with the shift allowing for the transfer of charge between bins.

Often the device is integrated with a sensor, such as a photoelectric device to produce the charge that is being read, thus making the CCD a major technology where the conversion of images into a digital signal is required. Although CCDs are not the only technology to allow for light detection, CCDs are widely used in professional, medical, and scientific applications where high-quality image data is required.

In a CCD for capturing images, there is a photoactive region (an epitaxial layer of silicon), and a transmission region made out of a shift register (the CCD, properly speaking).

An image is projected through a lens onto the capacitor array (the photoactive region), causing each capacitor to accumulate an electric charge proportional to the light intensity at that location. A one-dimensional array, used in line-scan cameras, captures a single slice of the image, while a two-dimensional array, used in video and still cameras, captures a two-dimensional picture corresponding to the scene projected onto the focal plane of the sensor. Once the array has been exposed to the image, a control circuit causes each capacitor to transfer its contents to its neighbor (operating as a shift register). The last capacitor in the array dumps its charge into a charge amplifier, which converts the charge into a voltage. By repeating this process, the controlling circuit converts the entire contents of the array in the semiconductor to a sequence of voltages, which it samples, digitizes, and stores in memory.

George Smoot, John C. Mather

George Fitzgerald Smoot III (born February 20, 1945) is an American astrophysicist, cosmologist, Nobel laureate, and $1 million TV quiz show prize winner. He won the Nobel Prize in Physics in 2006 for his work on COBE with John C. Mather that led to the measurement "of the black body form and anisotropy of the cosmic microwave background radiation."

This work helped further the big-bang theory of the universe using the Cosmic Background Explorer Satellite (COBE). According to the Nobel Prize committee, "the COBE project can also be regarded as the starting point for cosmology as a precision science." Smoot donated his share of the Nobel Prize money, less travel costs, to a charitable foundation.

George Smoot switched to cosmology and began work at Lawrence Berkeley National Laboratory, collaborating with Luis Walter Alvarez on the HAPPE (High Altitude Particle Physics Experiment), a stratospheric weather balloon designed to detect antimatter in Earth's upper atmosphere, the presence of which was predicted by the now obscure steady state theory of cosmology.

He then took up an interest in cosmic microwave background radiation (CMB), previously discovered by Arno Allan Penzias and Robert Woodrow Wilson in 1964. There were, at that time, several open questions about this topic, relating directly to fundamental questions about the structure of the universe. Certain models predicted the universe as a whole was rotating, which would have an effect on the CMB: its temperature would depend on the direction of observation. With the help of Alvarez and Richard A. Muller, Smoot developed a differential radiometer which measured the difference in temperature of the CMB between two directions 60 degrees apart. The instrument, which was mounted on a Lockheed U-2 plane, made it possible to determine that the overall rotation of the universe was zero, which was within the limits of accuracy of the instrument. It did, however, detect a variation in the temperature of the CMB of a different sort. That the CMB appears to be at a higher temperature on one side of the sky than on the opposite side, referred to as a dipole pattern, has been explained as a Doppler effect of the Earth's motion relative to the area of CMB emission, which is called the last scattering surface. Such a Doppler effect arises because the Sun, and in fact the Milky Way as a whole, is not stationary, but rather is moving at nearly 600 km/s with respect to the last scattering surface. This is probably due to the gravitational attraction between our galaxy and a concentration of mass like the Great Attractor.

COBE

At that time, the CMB appeared to be perfectly uniform excluding the distortion caused by the Doppler effect as mentioned above. This result contradicted observations of the universe, with various structures such as galaxies and galaxy clusters indicating that the universe was relatively heterogeneous on a small scale. However, these structures formed slowly. Thus, if the universe is heterogeneous today, it would have been heterogeneous at the time of the emission of the CMB as well, and observable today through weak variations in the temperature of the CMB. It was the detection of these anisotropies that Smoot was working on in the late 1970s. He then proposed to NASA a project involving a satellite equipped with a detector that was similar to the one mounted on the U-2 but was more sensitive and not influenced by air pollution. The proposal was accepted and gave rise to the satellite COBE, which cost US$160 million. COBE was launched on November 18, 1989, after a delay owing to the destruction of the Space Shuttle Challenger. After more than two years of observation and analysis, the COBE research team announced on 23 April 1992 that the satellite had detected tiny fluctuations in the CMB, a breakthrough in the study of the early universe. The observations were "evidence for the birth of the universe" and led Smoot to say regarding the importance of his discovery that "if you're religious, it's like looking at God."

The success of COBE was the outcome of prodigious teamwork involving more than 1,000 researchers, engineers and other participants. John Mather coordinated the entire process and also had primary responsibility for the experiment that revealed the blackbody form of the CMB measured by COBE. George Smoot had main responsibility for measuring the small variations in the temperature of the radiation.

Peter Grünberg, Albert Fert

Peter Andreas Grünberg (born 18 May 1939) is a German physicist, and Nobel Prize in Physics laureate for his discovery with Albert Fert of giant magnetoresistance which brought about a breakthrough in gigabyte hard disk drives.

In 1986 he discovered the antiparallel exchange coupling between ferromagnetic layers separated by a thin non-ferromagnetic layer, and in 1988 he discovered the Giant magnetoresistive effect (GMR). GMR was simultaneously and independently discovered by Albert Fert from the Université de Paris Sud. It has been used extensively in read heads of modern hard drives. Another application of the GMR effect is non-volatile, magnetic random access memory.

GMR was discovered in 1988 in Fe/Cr/Fe trilayers by a research team led by Peter Grünberg of the Jülich Research Centre (DE), who owns the patent. It was also simultaneously but independently discovered in Fe/Cr multilayers by the group of Albert Fert of the University of Paris-Sud (FR). The Fert group first saw the large effect in multilayers that led to its naming, and first correctly explained the underlying physics. The discovery of GMR is considered the birth of spintronics. Grünberg and Fert have received a number of prestigious prizes and awards for their discovery and contributions to the field of spintronics including the 2007 Nobel Prize in Physics.

Giant magnetoresistance

Giant magnetoresistance (GMR) is a quantum mechanical magnetoresistance effect observed in thin film structures composed of alternating ferromagnetic and nonmagnetic layers.

The effect manifests itself as a significant decrease (typically 10–80%) in electrical resistance in the presence of a magnetic field. In the absence of an external magnetic field, the direction of magnetization of adjacent ferromagnetic layers is antiparallel due to a weak anti-ferromagnetic coupling between layers. The result is high-resistance magnetic scattering as a result of electron spin.

When an external magnetic field is applied, the magnetization of the adjacent ferromagnetic layers is parallel. The result is lower magnetic scattering, and lower resistance.

Spin valve GMR

In spin valve GMR two ferromagnetic layers are separated by a thin non-ferromagnetic spacer (~3 nm), but without RKKY coupling. If the coercive fields of the two ferromagnetic electrodes are different it is possible to switch them independently. Therefore, parallel and anti-parallel alignment can be achieved, and normally the resistance is again higher in the anti-parallel case. This device is sometimes also called a spin valve.

Research to improve spin valves is intensely focused on increasing the MR ratio by practical methods such as increasing the resistance between individual layers interfacial resistance, or by inserting half metallic layers into the spin valve stack. These work by increasing the distances over which an electron will retain its spin (the spin relaxation length), and by enhancing the polarization effect on electrons by the ferromagnetic layers and the interface. The magnetic properties of nanostructures (and all properties) are dominated by surface and interface effects due to the high local ratio of atoms as compared to the bulk.

Current perpendicular to plane (CPP) Spin valve GMR is the configuration that currently yields the highest GMR and thus is the configuration used in hard drives. Research is ongoing in the older current-in-plane configuration, and in the tunneling magnetoresistance (TMR) spin valves which enable disk drive densities exceeding 1 Terabyte per square inch.

GMR has been used extensively in the read heads in modern hard drives and magnetic sensors. An application of the TMR effect, which is closely related to the GMR effect, is in magnetoresistive random access memory (MRAM), a type of non-volatile semiconductor memory. GMR has triggered the rise of a new field of electronics called spintronics.