# Physics Nobel Prize 2009

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## 1 Introduction

To Charles K. Kao for groundbreaking achievements concerning the transmission of light in fibers for optical communication.

Willard S. Boyle and George E. Smith for the invention of an imaging semiconductor circuit the CCD sensor. Bell Laboratory.

Charles K. Kao 1/2 of the prize
Willard S. Boyle 1/4 of the prize
George E. Smith 1/4 of the prize

## 2 Charles K. Kao

In 1965, Charles K. Kao and George A. Hockham of the British company Standard Telephones and Cables (STC) were the first to promote the idea

that the attenuation in optical fibers could be reduced below 20 decibels per kilometer (dB/km), allowing fibers to be a practical medium for communication.[7] They proposed that the attenuation in fibers available at the time was caused by impurities, which could be removed, rather than fundamental physical effects such as scattering. This discovery led to Kao being awarded the Nobel Prize in physics in 2009.[8]

The crucial attenuation level of 20 dB/km was first achieved in 1970, by researchers Robert D. Maurer, Donald Keck, Peter C. Schultz, and Frank Zimar working for American glass maker Corning Glass Works, now Corning Incorporated. They demonstrated a fiber with 17 dB/km attenuation by doping silica glass with titanium. A few years later they produced a fiber with only 4 dB/km attenuation using germanium dioxide as the core dopant. Such low attenuations ushered in optical fiber telecommunications and enabled the Internet. In 1981, General Electric produced fused quartz ingots that could be drawn into fiber optic strands 25 miles (40 km) long.[9]

# 3 Willard S. Boyle

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.

Boyle was Executive Director of Research for Bell Labs from 1975 until his retirement in 1979. In retirement, he settled in Wallace, Nova Scotia, and helped launch an art gallery with his wife Betty, a landscape artist.[5] He has been married to Betty since 1947, and has four children, 10 grandchildren and one great-grandchild.[3] In 2009, he and his wife live in Halifax.

# 4 George E. Smith

He was awarded a one-quarter share in the 2009 Nobel Prize in Physics for "the invention of an imaging semiconductor circuit, the CCD sensor".

Smith was born in White Plains, New York. Smith served in the US Navy, attained his BSc at the University of Pennsylvania in 1955 and his PhD from the University of Chicago in 1959 with a dissertation of only

three pages.[2] He worked at Bell Labs in Murray Hill, New Jersey from 1959 to his retirement in 1986, where he led research into novel lasers and semiconductor devices. During his tenure, Smith was awarded dozens of patents and eventually headed the VLSI device department.[3]

In 1969, Smith and Willard Boyle invented the Charge-Coupled Device (CCD)[4], 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.

Both Boyle and Smith were avid sailors who took many trips together. After retirement Smith sailed around the world with his wife, Janet, for five years, eventually giving up his hobby in 2001 to "spare his 'creaky bones' from further storms."

# 5 IEEE Spectrum 8 Ocober 2009

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Corrected 8 Ocober 2009.

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Willard Boyle and George Smith, formerly of Bell Telephone Laboratories, in Murray Hill, N.J., will share half of this years Nobel Prize in Physics "for the invention of an imaging semiconductor circuit-the CCD," the basis for digital imagery in everything from pocket cameras to the Hubble Space Telescope. (The "imaging" part of the citation is in dispute, as the first imaging CCD was developed by IEEE Fellow Michael F. Tompsett, a colleague of Boyle and Smith.) In announcing the awards, the Royal Swedish Academy of Sciences called Boyle and Smith masters of light and said that, with fellow winner and optical-fiber pioneer Charles Kuen Kao, they helped to shape the foundations of todays networked societies.

Boyle and Smith came up with the idea for the CCD during a brief meeting in 1969. The two were working on semiconductor integrated circuits, and Smith had been involved with trying to create an imaging chip for the Picturephone, which consisted of an array of silicon diodes. At the time, Bell Labs was also working on a new type of computer memory that relied on tiny bubbles of magnetism. As the two recalled in a 1976 article in IEEE Transactions on Electronic Devices , their boss, Jack Morton, urged them to look at whether it was possible to make a form of bubble memory using

semiconductors.

The idea is fairly simple. You start with a layer of silicon, doped so that its deficient in electrons and oxidized at the surface. Atop the oxide, add an array of metal electrodes as gates, creating capacitors that can store charge. Then apply a voltage to the gate, which repels the silicons positive carriersthe holesand creates a potential well at the surface of the silicon. When a photon strikes the silicon, it creates an electron-hole pair, and the electron moves toward an electrode into the well. Electrons accumulate in the interface between the silicon and the oxide. When you apply a sequence of high and low voltages to adjacent gates, the electrons move from one gate to the next, like water being poured from one bucket to another, until they reach the edge of the chip, where the level of charge can be read as a measure of light intensity.

Essentially, this was the invention, Smith recalled in a 2001 interview with the IEEE History Center. Lets not have any circuit in between. Lets just put these things close together. If charge is stored here, just put a voltage over here thats bigger than the voltage over there, and the charge will fall over. This voltage is then reset, and you repeat the process.

Though their aim was to invent memory, Smith says it was obvious that the technology would work for imaging as well. And when random access memory (RAM) came along, attempts to create bubble memory were abandoned.

James Janesick, director of sensor development at Sarnoff Corp., says hes long thought the two should receive a Nobel. Besides seeing the edge of the universe, which is how I applied the technology at the time, it made billions and billions of dollars.

Janesick was a young researcher at NASAs Jet Propulsion Laboratory, in Pasadena, Calif., in the early 1970s, where he worked on the imaging system for the Hubble. At the time, engineers were actually considering putting film in the telescopes cameras and sending astronauts to retrieve it, or using old-fashioned vidicon camera tubes. The fact that CCDs were 100 times as sensitive as either film or camera tubes, Janesick says, led them to quickly sweep through the field of astronomy and completely dominate scientific imaging today.

Carlo Sequin, a professor of electrical engineering and computer science at the University of California, Berkeley, joined Smiths group to work on CCDs after the initial invention. He helped build the first CCDs that were compatible with the U.S. television format, thus reducing the size of TV

cameras. It was very exciting, because there was this very new principle that at the beginning seemed to be very simple, Sequin says. In practice, he says, there were a lot of design issues to solve to make the device practical.

What used to be this incredibly simple principle is one of the most complex devices being built today, yet for 100 dollars you find it in every camera, Sequin says.

Imagers based on complementary metal-oxide-semiconductor (CMOS) technology are starting to take over in some areas, particularly in low-end cameras, where price is a greater issue than performance. These sensors are still not quite as sensitive as CCDs, but the same advances in lithography that have propelled microprocessors are improving CMOS sensors, and its widely agreed theyll eventually displace CCDs.