History Day

Plenary Talks

Wednesday, 21 September 2011

3-H-1 9:25 – 10:00

Kamerlingh Onnes's Notebooks and the Discovery of Superconductivity

Peter H. Kes

Kamerlingh Onnes Laboratory, Leiden Institute of Physics, Leiden University, Netherlands

A century ago Heike Kamerlingh Onnes and his collaborators were the first to observe superconductivity. Although accidental, his retraced notebooks tell us today that this was the result of a well planned research program which was started after liquid helium temperatures were reached [1].

[1] Dirk van Delft and Peter Kes, Physics Today 63, 38 (2010).

3-H-2 10:00 – 10:35

The Early Days of Superconducting Electronics: 1950 to 1970

John M Rowell

Arizona State University. (Bell Telephone Laboratories and Bellcore, 1961 to 1989)

About 50 years after the discovery of superconductivity, major advances were made towards its applications, particularly in magnets and electronics. In this talk, I will trace some of the important predictions, theories, experiments, discoveries, observations and inventions that are the foundation of today's superconducting electronics technology, which will be described in later talks. Bolometers were first proposed in the early 1940s, and the cryotron switching device in 1956. The energy gap in a superconductor's density of states, central to the BCS theory of 1957, was observed directly at much the same time by millimeter wave and infra-red absorption experiments, and most strikingly by Giaever in his newly invented thin film tunnel junctions. With Bill McMillan, our spectroscopy of such junctions revealed in detail the mechanism of superconductivity (now known as low temperature superconductivity). In 1962, Brian Josephson proposed his effects, being due to the tunneling of pairs between two superconductors. I will describe the confirmation of his predictions in my work with Phil Anderson, using some laboratory notebook entries of the time. Shortly afterwards, the interaction of microwaves with the Josephson current were observed at A.D. Little, and the first SQUID at Ford Labs. The Josephson Effect was generalized from tunnel junctions to all weak links by Phil Anderson. I will conclude by mentioning the first patent application based on the Josephson Effect, one later by Phil on the "flux shuttle", and the initial superconducting circuits program at IBM.

3-H-3 11:05 – 11:40

Evolution of practical superconducting materials

H. Kumakura

National Institute for Materials Science

Since the discovery of superconductivity in mercury, huge number of superconducting materials has been found until now. They are metals, ceramics, organic materials, and heavily-doped semicondcutors or insulators. In my talk, I will introduce several interesting superconducting materials from the aspect of practical applications. For electric power applications, important superconductors are type-II superconductors that can maintain zero resistivity current at high magnetic fields. The key properties of type-II superconductors are their superconducting transition temperature (T_c), upper critical field (H_{c2}), and critical current density (J_c). T_c and H_{c2} are inherent to superconductors, while J_c mainly depends on the microstructure of the superconductor. The superconductors that have already been used in practical applications are Nb-Ti and Nb_3Sn. Nb-Ti alloys are currently the most widely used because they have good mechanical workability and can be easily fabricated into wires. Nb_3Sn is an inter-metallic superconductor whose H_{c2} is much higher than that of Nb-Ti. Nb_3Sn is now used for high field superconducting magnets. High-temperature cuprate superconductors with T_c exceeding 77 K (the boiling point of liquid nitrogen at 1 atm.) have been intensively studied since their discovery. Among them, Bi-based cuprates($Bi_2Sr_2CaCu_2O_x$ and $Bi_2Sr_2Ca_2Cu_3O_y$) and Y-based cuprate($YBa_2Cu_3O_z$) are the most promising materials. An inter-metallic superconductor, MgB_2, has many advantages over high-temperature cuprates despite its much lower T_c of 39K, and R & D is now actively in progress. Iron-pnictide superconductors show very high H_{c2} values with their smaller anisotropy than that of high temperature cuprates and are promising for high field applications.

3-H-4 11:40 – 12:15

Conductors from Superconductors

David C Larbalestier and Peter J Lee

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Kamerlingh Onnes came to Chicago in 1913, just two years after discovering superconductivity, with a detailed plan to make a 10 T superconducting magnet! He recognized very clearly the central advantage of superconductors for generating strong magnetic fields – their ability to make compact windings operating at current densities of many hundred A/mm^2 without dissipation. His Hg wires passed 1000 A/mm2 – but sadly only in self-field, and the dream was put away. Fifty years of confusion over the distinction between positive and negative surface energy superconductors ensued that was blown away only in 1961 when, to great surprise, Nb_3Sn was found to superconduct while carrying 1000 A/mm^2 at almost 9 T. Within 2 years, Onnes's dream was fulfilled and, within 10 years, Nb-Ti and Nb_3Sn research superconducting magnets became common, based on sub-divided conductors composed of fine, twisted and decoupled superconducting filaments. At first for science, above all for accelerators, magnet applications pulled the technology powerfully and then in the late 1970's MRI emerged as the anchor of the superconducting wire industry. Today a profitable industry making NbTi and Nb_3Sn conductors exists on multiple continents. MgB_2, $REBa_2Cu_3O_{7-x}$ and the two BSCCO compounds, $Bi_2Sr_2CaCu_2O_{8-x}$ and $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10-x}$ are vying to add to the mix. Some interesting stories of how this technology emerged and how it might still change will be presented to remind us that progress is never smooth and steady, but rather episodic and sometimes disruptive.

3-H-5 14:00 – 14:35

SQUIDs: Then and Now

John Clarke

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Macroscopic quantum interference in a superconducting ring containing two Josephson tunnel junctions was first demonstrated in 1964. Shortly after, the first practical devices emerged, including the point-contact SQUID (Superconducting QUantum Interference Device) and the SLUG (Superconducting Low-inductance Undulatory Galvanometer)—a blob of solder frozen on a piece of niobium wire. Theories for the performance of SQUIDs appeared in the 1970s. Today, the square washer dc SQUID based on niobium thin films is the workhorse design, and is used in a variety of configurations, for example, as magnetometers, gradiometers, low-frequency and microwave amplifiers, and susceptometers. Applications include magnetoencephalography, magnetocardiography, geophysics, nondestructive evaluation, precision gyroscopes, standards, cosmology, nuclear magnetic resonance, reading out superconducting quantum bits, and a myriad of one-of-a-kind experiments in fundamental science. To illustration these applications, a quantum limited amplifier to search for the axion—a candidate for cold dark matter—and magnetic resonance imaging in microtesla magnetic fields are briefly described.

3-H-6 14:35 – 15:10

Superconductor Digital Electronics

Konstantin K. Likharev

Stony Brook University, USA

I will present a brief review of the development of superconducting digital electronics, including such important milestones as cryotrons based on the SN phase transition, latching logic based on voltage switching in Josephson junctions, and single-flux-quantum circuits. Though the history of work in the United States, Europe and Japan will be discussed, an emphasis will be made on the efforts in the former Soviet Union, which have led, in particular, to the invention of reversible parametric-quantron circuits and ultrafast RSFQ logic. In the light of the superconductor electronics history, future prospects of the field will be briefly discussed.

3-H-7 15:40 – 16:15

The Success Story of 50 years of Superconducting Magnets for Physics Research and Medical Applications

Herman ten Kate

CERN, Physics Department, Switzerland; and University of Twente, the Netherlands

It took about 50 years from the discovery of superconductivity in mercury in 1911 to the first technical superconducting wires made of NbTi and Nb3Sn suitable for constructing superconducting magnets that could provide magnetic fields beyond the practical limits of water cooled electromagnets with iron cores.

Ever since we have seen very successful applications of superconductivity in magnets for physics research, medical diagnostics and big science. Fully superconducting laboratory magnets and hybrid magnets up to 25 and 45 tesla respectively serve physics, chemical and biological research. Whole body Magnetic Resonance Imaging magnets provide medical diagnostics in hospital. Synchrotron radiation facilities use photons to resolve the structure of matter and particle accelerators complexes and their huge detectors are key for elementary particle physics. Fusion reactors for electricity production would not be possible without superconducting magnets for plasma confinement.

High field magnets are the most successful applications of superconductivity by far and stand for more than 90% of the 4-5 billion euro market of superconductivity.
Presented are essential achievements in understanding superconductors that enabled most exiting magnet applications as well as an outlook to what the next 100 years may bring………

3-H-8 16:15 – 16:50

History, State-of-the-Art and Perspectives of Superconducting Power Equipment

Mathias Noe

Institute for Technical Physics, KIT, Germany

Shortly after the discovery of superconductivity in 1911 there were first ideas to make use of it in superconducting power equipment like lossless energy transport. Nevertheless, it took until the 60’ and the 70´ of the last century for first large scale demonstrations of cables, current limiters, magnetic energy storage and rotating machines using low temperature superconductors being cooled at 4.5 K (~269°C). Mainly due to the high cooling effort nearly all of this Research and Development (R&D) has been discontinued. With the discovery of high temperature superconductivity with a cooling temperature of 77 K (~196°C) in 1986 R&D in superconducting power equipment regained a very large interest and since that time many large scale demonstrators and prototypes have been successfully built and tested. Some applications like cables and fault current limiters are already close to commercialization.

This presentation summarizes the most important R&D activities of superconducting power equipment in the past, gives an overview on present R&D highlights and tries to give an outlook on future perspectives. Superconducting cables, rotating machines, transformers, magnetic energy storage, fault current limiters and levitation will be considered.