ED6-1-INV

The SQUID and its Applications in the Past 30 Years

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The introduction of the superconducting quantum interference device (SQUID) in the 1960's improved the sensitivity of magnetic sensing by several orders of magnitude. The SQUID enabled unprecedented sensitivity in measurements of electric current, voltage, temperature, susceptibility, and many other physical quantities. It allowed new ways for nondestructive evaluation of critical structures, for example, in airplanes or nuclear plants. Magnetic or conductivity anomalies below the earth's surface could be accurately revealed by measuring magnetic fields from above the ground. The SQUID has been used as detector in NMR, in MRI, bolometers, and accelerometers. One of the most notable applications of the SQUID is biomagnetism, where signals from the heart and brain or other organs are measured. The SQUID has enabled high-quality recordings of cardiac activity, spontaneous brain rhythms as well as evoked neuromagnetic fields, these fields being in the femto- to picotesla range. During the last 30 years, SQUIDs have been made more reliable and more sensitive. Large sensor arrays have been built in particular for biomagnetic applications. SQUID microscopy with tiny sensors have allowed submicron-resolution scanning of susceptibility, characterization of magnetic structures such as magnetic nanoparticles, and testing the quality of microcircuits. The discovery of high-transition-temperature superconductors motivated much work to develop devices that work in liquid-nitrogen temperatures. Several commercial companies now sell SQUID sensors for multiple applications. Here, the development of SQUID sensors and their use during the past 30 years will be described, the emphasis being in neuromagnetic applications.

Keywords: Magnetometer, Magnetoencephalography, Magnetocardiography, Ultra-low-field MRI

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Superconducting Detectors: the Past 30 Years and Future Prospects

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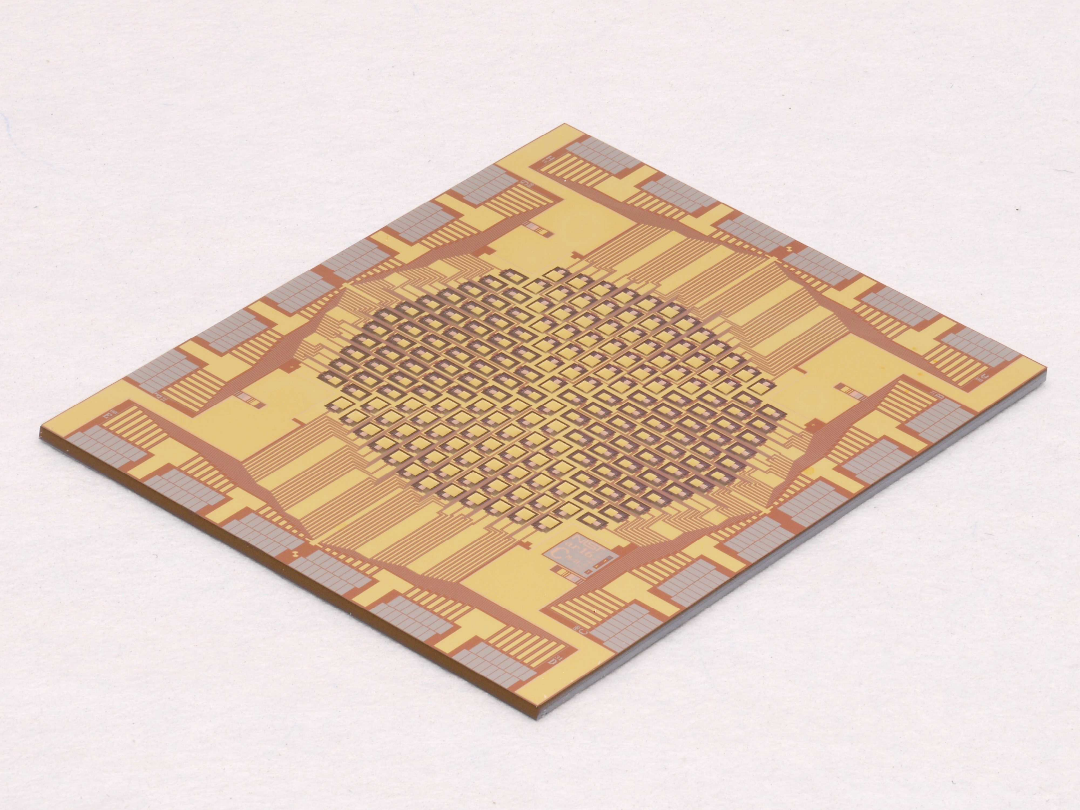
Superconducting detectors are increasingly used to measure photons across the electromagnetic spectrum, as well as for particle detection and searches for exotic particles. In this presentation, we discuss the physical principles that have motivated the study of superconducting detectors, in particular, the potential for sensitivities far surpassing those of more conventional detectors. Then, we review the past 30 years of development in the area of superconducting detectors. Over this period, the use of some technologies, such as transition-edge and kinetic inductance detectors, has steadily grown such that large format arrays (like the one pictured below) are now found in applications as diverse as x-ray materials analysis and millimeter-wave astrophysics. The growing capability of superconducting detectors has produced a virtuous circle wherein the successful entry of superconducting detectors into new application areas has spurred further investment and improvement in the technology. We also discuss the crucial enabling role played by several supporting technologies including convenient cryogenics and superconducting readout circuitry. We then describe the state-of-the-art in superconducting detector technology and some of its many applications. Finally, we discuss potential developments in the years to come.



Keywords: superconducting sensors, transition-edge sensors, microwave kinetic inductance sensors, low temperature sensors

ED6-3-INV

A Thirty History of Superconducting Microwave Devices and Fundamental Studies Thereof

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Thirty years have passed since the discovery of high-temperature superconductors (HTS), and practical applications of HTS equipment and devices are moving into full-swing. From the beginning of their discovery, the use of HTS in microwave devices has been recognized as one of their most practical applications. This is because the microwave surface resistance of HTS is less than 1/1000 of that of pure copper and from early on researchers recognized that high performance of microwave passive devices could be realized by utilizing the characteristics of HTS. In addition, the size of HTS microwave devices is relatively small, and they can be cooled by a small cryocooler. Furthermore, we could establish high-quality HTS thin-film fabrication technology essential for producing high performance microwave devices in a short period of time. In view of the above, I would like to present an overview of the past thirty years of superconducting microwave devices and fundamental studies thereof covering following topics.

(1) HTS film conditions required for highly efficient microwave devices [1]
(2) Superconducting bandpass filters[2,3]
(3) Other prospective superconducting microwave devices[4]

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Keywords: superconducting microwave device, superconducting filter, HTS, NMR superconducting probe

ED6-4-INV

Cryogenic Digital Electronics – Challenges for Practical Use –

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Superconductor-based cryogenic digital electronics has advanced much in the last decade. Single flux quantum (SFQ) circuits, in which an SFQ works as an information carrier, evolves from the rapid single flux quantum (RSFQ) logic circuit into several types of energy-efficient circuits such as the energy-efficient RSFQ circuit (ERSFQ, Hypres), the reciprocal quantum logic circuit (RQL, Northrop Grumman), the adiabatic quantum flux parametron circuit (AQFP, Yokohama Nat'l Univ.). The power consumption of these circuits is 1/10 or less compared to that of the RSFQ circuit with no or small reduction of operating frequencies. Our group has demonstrated an 8-bit-parallel RSFQ arithmetic logic unit (ALU) at 50 GHz by introducing the gate-level pipelining technique proposed by Kyushu University based on the Nb-based integrated circuit (IC) technology of the CRAVITY, AIST. The ALU has shown better performance in both the computing power defined as the number of million instructions per second (MIPS) and the power efficiency (MIPS/W) than the best semiconductor ALU, even if the cooling penalty is considered.

It is often said that difficulty of realization in large capacity cryogenic memories is an obstacle to practical applications of the SFQ ICs. However, nano-cryotrons (nTrons) invented by the MIT group showed a large output voltage up to 1 V. This device opened the way for directly driving a large capacity cryo-CMOS memory or other cryogenic memories including magnetic-Josephson-junction-based memories. Presently, we are struggling to drive a cryo-CMOS memory with an RSFQ decoder through NbN-based nTrons.

We already have a solution to all the obstacles. We believe that superconductor cryogenic digital electronics edges closer to practical use.

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Keywords: single flux quantum, integrated circuit

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Coherent superconducting circuits and quantum information – 30 years' advancements

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In this talk, three decades' progresses in the field of superconducting circuits that exhibit macroscopic quantum coherence, as well as their application to quantum information processing is reviewed.