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The Ubiquitous SQUID: From Axions to Cancer[1]

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I briefly review the principles, practical implementation and applications of the dc SQUID (Superconducting QUantum Interference Device), an ultrasensitive detector of magnetic flux. Cosmological observations show that a major constituent of the universe is cold dark matter (CDM). A candidate particle for CDM is the axion which, in the presence of a magnetic field, is predicted to decay into a photon with energy given by the axion mass, ranging from 0.001 to 1 meV. The axion detector constructed at LLNL consists of a cooled, tunable cavity surrounded by a 7-T superconducting magnet. Photons from the axion decay would be detected by a cooled semiconductor amplifier. To search for the axion over an octave of frequency, however, would take two centuries. Now at the University of Washington, Seattle the axion detector will be upgraded by cooling it to 50 mK and installing a near-quantum limited SQUID amplifier. The scan time will be reduced by three orders of magnitude to a few months. In medical physics, we use an ultralow-field magnetic resonance imaging (ULFMRI) system with SQUID detection to obtain images in a magnetic field of 0.132 mT, four orders of magnitude lower than in conventional MRI. An advantage of low fields is that different types of tissue exhibit much greater contrast in the relaxation time T1 than in high fields. We have measured T1 in ex vivo specimens of surgically removed healthy and malignant prostate tissue. The percentage of tumor in each specimen is determined with pathology. The MRI contrast between two specimens from a given patient scales with the difference in the percentage of tumor; in healthy tissue T1 is typically 50 percent higher than in a tumor. These results suggest that ULFMRI with T1-weighted contrast may have clinical applications to imaging prostate cancer and potentially other types of cancer.

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