February 2, 2017
Colloquium

Development of Cryogenic Memory for Superconducting Computers

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Large-scale computing facilities and data centers are using electrical power at an ever increasing rate. Current projections suggest that a future "exoscale" computer will require the power output of a typical nuclear power plant – clearly an untenable situation. One approach to addressing this problem is to build a computer out of all superconducting elements, which dissipate very little power. Such a computer would have to be cooled to cryogenic temperatures, so it must be extremely energy-efficient to justify the added complexity and cost associated with cooling.

Superconducting logic circuits based on manipulating single flux quanta have existed since 1991; what has been missing is a high-density, fast, and energy-efficient cryogenic memory. This talk will focus on proposals to use Josephson junctions containing ferromagnetic materials as the basic memory element for such a memory. In our approach, a Josephson junction contains two ferromagnetic layers whose magnetization directions can be switched between being parallel or antiparallel to each other, just as in a conventional spin valve. We have demonstrated successful switching of such a junction between the "0" phase state and the "π" phase state, from measurements of two junctions in a SQUID geometry. If there is time, we will also discuss other possible types of Josephson junction memory elements, such as those that carry spin-triplet supercurrent rather than the conventional spin-singlet supercurrent.