Mesoscopic Superconductivity

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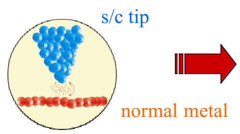
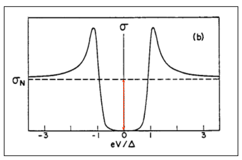
Motivation

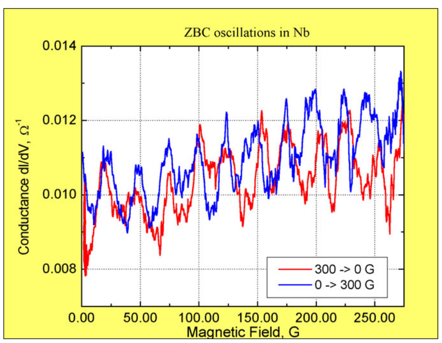
In type II superconductors the magnetic field penetrates in forms of vortices. By tuning the magnetic field, giant vortices that form in mesoscopic type II s/c structures split into molecules and the density of states rings split into maxima. Theoretical predictions for the density of states distribution in mesoscopic superconductors have not been confirmed yet.

Results

Vortices in confined mesoscopic structures



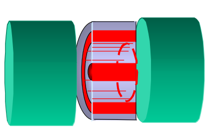


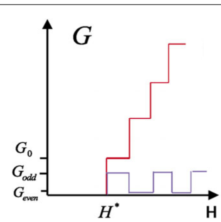


Tunneling conductance oscillations in a mesoscopic superconductor due to vortex penetration.
S-I-N tunneling conductance at zero bias changes if tunneling occurs into a vortex core (suppressed s/c order parameter) or superconducting region. Periodic oscillations show how a single magnetic flux quantum penetrates the superconductor.

Impact

Vortex Quantum Switch



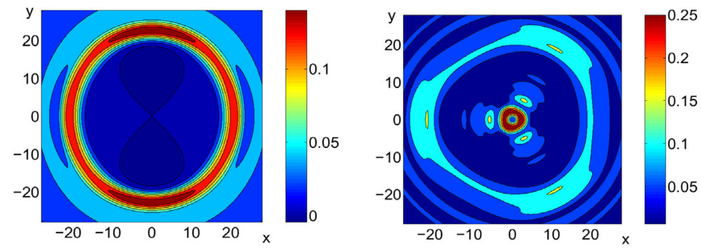


Mesoscopic superconducting disk placed between two normal metal contacts

$$G \propto \frac{e^2}{\hbar} T \times \frac{\xi^2}{L^2} \times \text{Number of channels}$$

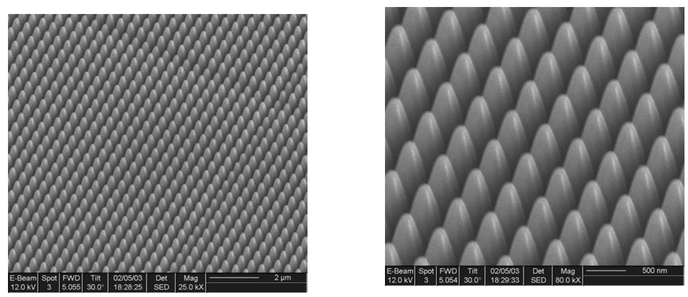
A.S. Mel'nikov, V.M. Vinokur Nature 415, 60 (2002)

Vortex Molecules in Mesoscopic Superconductors



$2\phi_0$-vortex $3\phi_0$-vortex

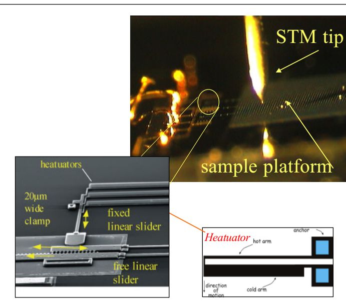
Mesoscopic Structure in single crystalline $NbSe_2$ by FIB



SEM micrograph of NbSe2 disks fabricated using a Focused Ion Beam at the University of Illinois at Urbana Champaign

Nanoscale Instrumentation

The development of MEMS-based basic science research tools will enable the characterization of materials down to the mesoscopic scale. A wide range of MEMS-based characterization tools can be developed, including μ-calorimeters, μ-magnetometers, and μ-mass spectrometers. Since MEMS are mass produced in a batch process, hundreds of metrology devices can be fabricated on a single wafer, allowing for combinatorial based parallel sample characterization.



MEMS based coarse positioning for low temperature STM

Future Directions

We will investigate, both theoretically and experimentally, the new physical phenomena which occur at small length scales and research a viable design of a novel type of current switch based on this effect. This research will open new routes for future design of a new class of superconductor-based switching and memory elements, quantum transport and spin-transmitters that are central to the problem of quantum computing and quantum telecommunications.

BES - DOE

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