DEVELOPMENT OF A NEW PHYSICAL LABORATORY FOR STUDIES ON QUANTUM SPIN DYNAMICS IN MOLECULAR MAGNETS

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Overview

This new laboratory will allow investigation of various quantum effects on the mesoscopic scale. We aim towards a highly sensitive and time-resolved detection of the quantum dynamics of molecular spins in the presence of variable magnetic fields. The goal is to achieve coherent control of the total spin of a molecular magnet and implement quantum computing schemes in such materials. The challenge is the same for all existing qubit proposals: managing the main decoherence sources that can be intrinsic (phonon bath, nuclear bath, paramagnetic impurities, defects, etc) or extrinsic (current fluctuations, magnetic field noise, mechanical vibrations, etc). Understanding how decoherence acts on a qubit will constitute an essential component of our research and it will be assessed in parallel with developing qubit and readout fabrication and control techniques.

Experimental

By using the clean room facilities in MARTECH we can elaborate micrometer sized Nb SQUIDs (Fig.1). First transport measurements at 4K of Nb sputtered structures were done together with Charles Stein (REU program – summer '05) who assisted in the fabrication of low-pass filters. The SQUID will detect the magnetic moment of a thin film (even a monolayer) of magnetic molecules synthesized on the same chip in the Department of Chemistry (collaboration with Prof. N. Dalal). Integrated on the same chip, microwave lines (waveguides) will allow the excitation and the coherent control of the molecular spin while being observed by the SQUID. We propose to use short microwave pulses in resonance with the energy levels of the spin (qubit) to induce Rabi rotations. Also, we will investigate a second method consisting in applying fast, non-adiabatic variations of the external bias of a qubit. Quantum oscillations between the two levels of the qubit should be observable in both cases. To achieve control on the quantum state of the spin, the samples will be cooled at ~10 mK in a top loading dilution refrigerator (Fig. 1). The dilution refrigerator is currently in tests at the manufacturer site and it will be RF wired shortly after that. The insert will slide in the bore of a vector magnet at the bottom of a He dewar (Fig. 1). Such magnet is required to tune *in-situ* the natural magnetic anisotropy of the molecules. In this magnetic configuration we can achieve d.c. control on both diagonal and off-diagonal terms of the spin Hamiltonian. The entire setup is sustained by a non-magnetic vibration isolated frame located below ground level. RF equipments allow generation of sub-ns microwave and dc pulses to control the dynamics of the spin.

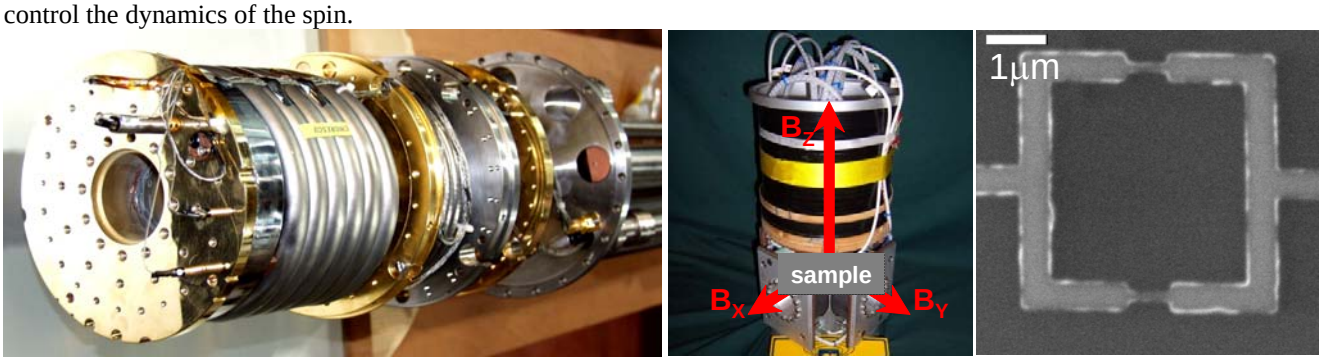

Fig. 1. (left) The dilution refrigerator to be installed in the C-120 area. The mixing chamber shows a 50 mm bore to accommodate the loading probe. **(middle)** The vector magnet (bore 50.8 mm, B_z=7T, B_x=B_y=1T) is located at the bottom of the He dewar that will host the dilution refrigerator. The entire installation is suspended by a non-magnetic frame with vibration isolators. **(right)** Scanning electron micrograph of a Nb-SQUID fabricated at MARTECH.

Conclusions

We are developing a new facility that will perform sensitive detection of spins in variable magnetic fields, at very low temperatures. We estimate the first results for the first half of 2006. As a side note, we remark that superconducting qubits and magnetic molecules are two level systems characterized by measurable magnetic moments and consequently the physics and the necessary equipment are relatively similar. Thus, there is a strong potential for studying both kind of systems in this future physics laboratory.