Scanning Tunneling Spectroscopy and Vortex Imaging on $NbSe_2$ with attoAFM III / STM I at 315 mK

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Scanning Tunneling Spectroscopy (STS) is a useful tool to characterize material properties, especially on superconductors at ultra low temperatures. In a series of experiments STS measurements as well as vortex imaging on $NbSe_2$ have been performed at a temperature of only 315 mK. The tests show excellent stability of the combined attoAFM/STM microscope setup as well as the possibility to apply stable voltages in the micro-Volt range.

An etched Platinum/Iridium tip was mounted on a tuning fork, thus allowing shear force measurements as well as STM type measurements. The setup including a small low temperature compatible trans-impedance amplifier was integrated in a 300 mK attoliquid3000 cryostat system (sample in vacuum) equipped with a 9 T magnet. To achieve the low noise and high stability required, the ANC250 voltage amplifier was used in combination with the ASC500 scan controller.

Typically, STS measurements involve the local measurement of the tunneling current versus the tip-sample bias voltage (see Figure 1) and measurements of the tunneling conductance *dI/dV* versus the bias voltage (as shown in Figure 2). In both experiments the superconducting gap can be clearly identified with 2 Δ being 2.8 mV.

Additionally, an external field of 1 T was applied to generate a vortex pattern in the superconductor. Setting the bias voltage to a fixed value of ~1.4 mV, the typical hexagonal Abrikosov flux pattern (see Figure 3) was resolved. By analyzing the achieved image, the distance of the vortex centers were determined, in excellent agreement with the expected value for a magnetic field of 1 T.

These measurements prove the excellent mechanical and thermal stability of the setup. Hence, the combined tuning fork based attoAFM III /attoSTM I microscope system is the ideal instrument for analyzing and spatially mapping materials properties at low temperatures.

The sample was generously provided by of R. Kramer, Katholieke Universiteit Leuven. The measurements were performed in the attocube application labs.

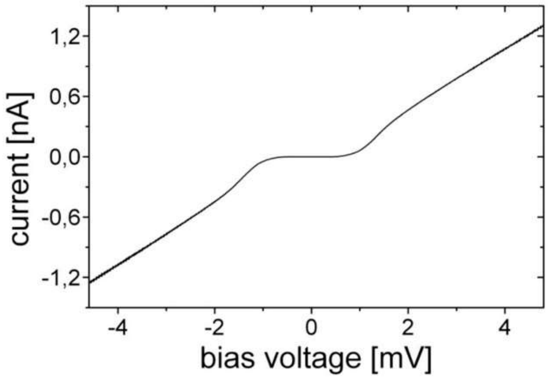

Figure 1: *Current-Voltage image of the superconducting $NbSe_2$ at 315 mK. The graph clearly shows the superconducting gap.*

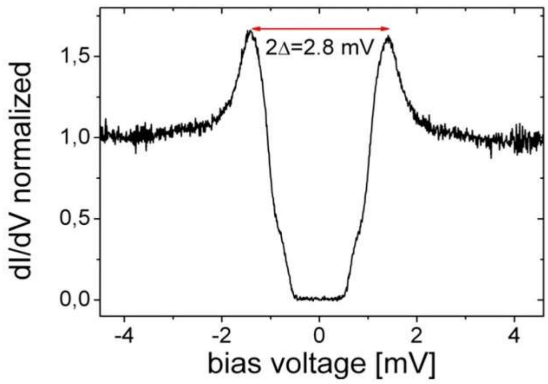

Figure 2: *dI/dV image of the superconducting gap. A fine structure of unknown origin at the side walls of the gap can be seen.*

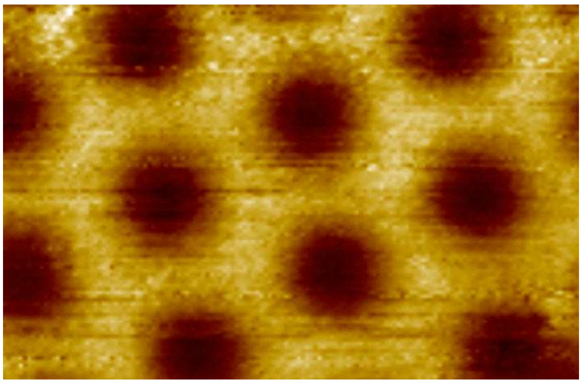

Figure 3: *Vortex imaging on NbSe2 at 315 mK and 1 T external field. The image was taken at a bias voltage of 1.4 mV.*