Stick-slip Phenomena and Memory Effects in Moving Vortex Matter

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Elastic deformations of 3D objects in a viscous medium directly impact many different systems such as polymers, Fermi gases, glass-forming liquids and plasma crystals. In the case of superconducting condensates, the defects intrinsically present in natural or artificial materials substantially modify the elastic moduli of the vortex lattice. The theoretical and experimental efforts done on the topics were intense in the 90's but they were performed quasi exclusively on high-Tc superconductors using global techniques, consequently revealing specific vortex dynamics and pinning with discrepancy. However, Auslaender et al. succeeded in moving vortices one by one by means of a magnetic tip in the cuprate YBaCuO and proved that the *anisotropy* in the vortex displacement is determined by the chains of oxygen vacancy like the anisotropy of superconducting gap. In the conventional superconductor NbSe2, scanning tunneling microscopy (STM) was used to directly image moving vortex lattices, confirming the *peak effect* analysis as a *melting transition* from an *elastic phase* to a *plastic phase*. These experiments are ones of the few carried with individually-probed vortex techniques necessary to validate the microscopic theories.

Recently, we have developed a new operating mode of the conventional STM technique to observe periodic vortex core trajectories with spatial and temporal resolution. A periodic motion is probed using an extended version of the so-called "Lazy fisherman method", in which a fisherman (STM tip) waits at a fixed position for a fish (vortex) to pass by. This method synchronized to the external excitation gives access to the *individual trajectory in real-time* and is applicable to virtually any scanning probe microscopy.

Here, we use this new technique to explore the vortex dynamics in interplay with the natural weak pinning landscape in NbSe2. We evidence at low drive the linear and collective motion of a Bragg vortex glass in the so-called Campbell regime, while at high drives the trajectories present striking nonlinear trajectories with a pinning-depinning process unrelated to local defects. Performing three-dimensional Langevin dynamics simulations, we demonstrate that the specific nonlinearity of the second regime is a *stick-slip motion* related to the collective pinning and the periodicity of the lattice. We additionally explore the impact of initial conditions at the transition between the two regimes and reveal an enhancement of the long-range correlations with the ac magnetic field cooling procedure.

The success of this work opens new possibilities to solve issues such as the dynamical channels related to the wave density charge in Nbse2 or the memory effects in high-Tc superconductors.

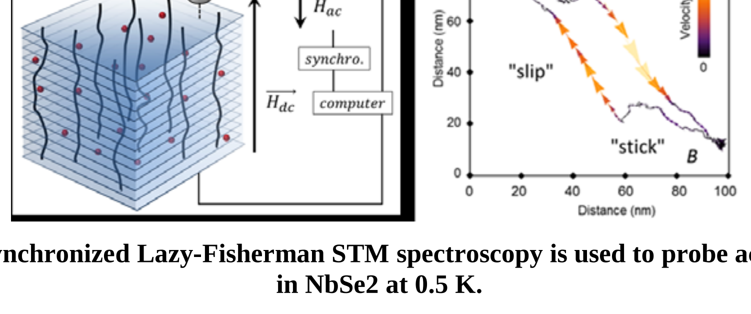

Figure 1| The synchronized Lazy-Fisherman STM spectroscopy is used to probe ac-driven vortices in NbSe2 at 0.5 K.