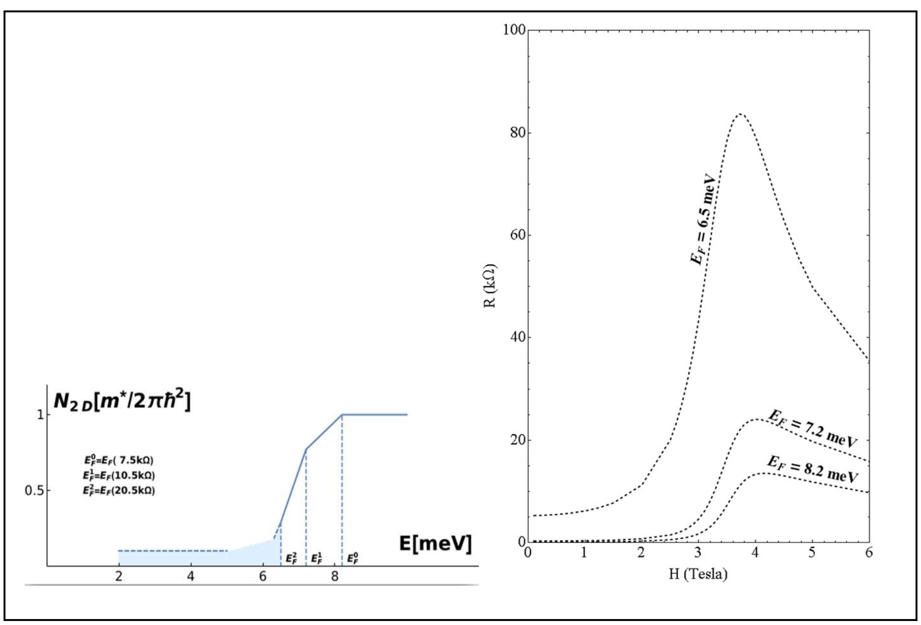
# Abstracts of active research areas

## Superconducting fluctuations and giant negative magnetoresistance in a gate-voltage tuned two-dimensional electron system with strong spin-orbit impurity scattering

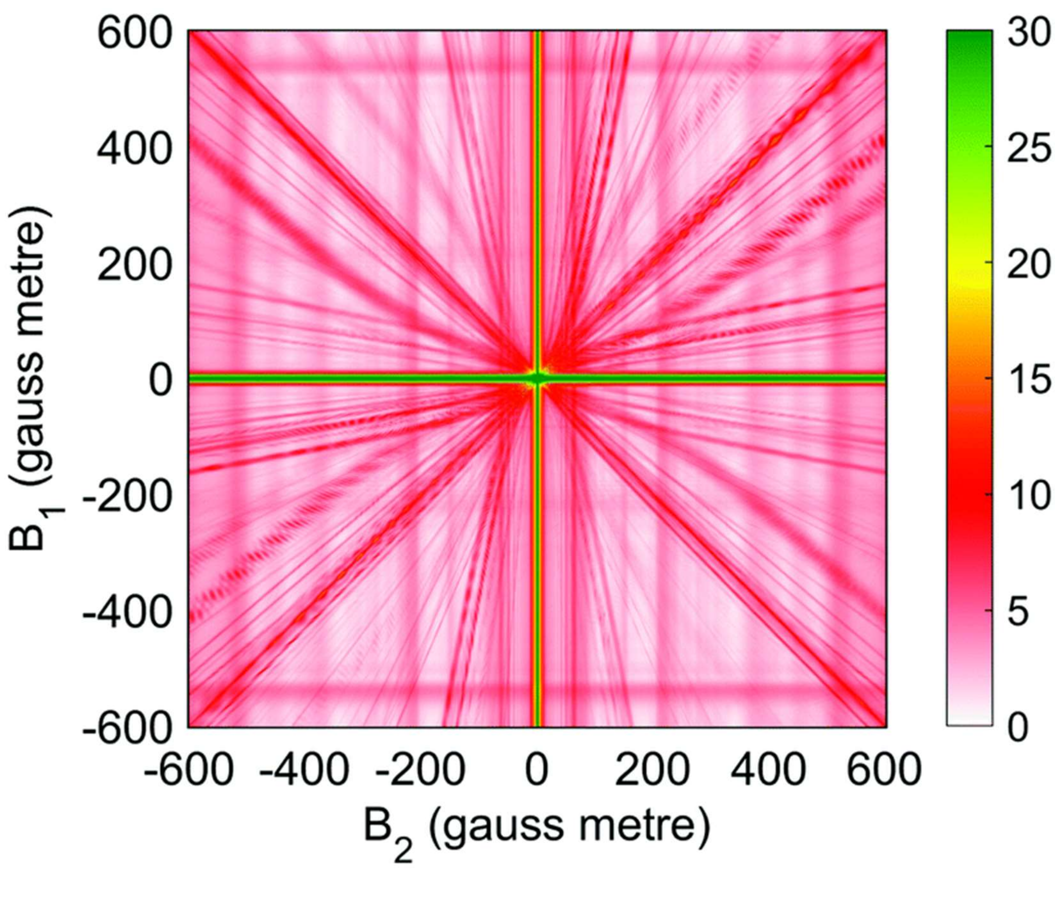
The electron-doped perovskite oxide interface LaAlO3/SrTiO3 is known to support two-dimensional high mobility electron systems with exotic transport properties, which can be smoothly tuned by gate bias. Here we present a quantitative theory of gate-voltage tuned superconductor-to-insulator transitions, observed experimentally in LaAlO3/SrTiO3 interfaces, in which the entire landscape of states, varying from superconducting to insulating states, originates in Cooper-pair fluctuations forming mesoscopic puddles. The theory predicts great sensitivity of the fluctuation-induced magnetoresistance peaks, observed at high fields, to variation of the electronic interface density of states in the transition region of strong spin-orbit induced band-mixing. This feature is exploited for extracting the mobile electrons states-density (see, e.g. the left panel of the figure below) from the experimental sheet-resistance data (right panel) just by varying the gate voltage.




See Ref.1-2 in the list of selected publications

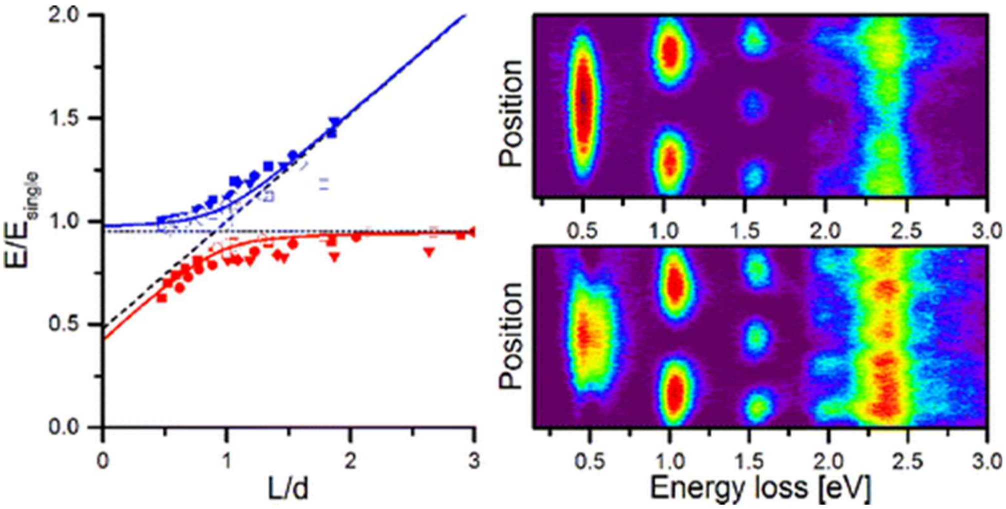
## Molecular spin echoes; multiple magnetic coherences in molecule surface scattering experiments

In this research we have developed a theory for coherent propagation and scattering of molecules from solid surfaces in a magnetically controlled molecular beam experiment. We demonstrate that a molecular beam of hydrogen molecules can be magnetically manipulated to produce multiple coherences in the molecular interference pattern. Unlike spin 1/2 magnetic beam experiments, *i.e.*, neutron and helium spin echo, the nuclear and rotational magnetic moments in a molecule are strongly coupled. We show experimentally and theoretically that this coupling leads to multiple magnetic field conditions under which the magnetic moment of molecules travelling with different speeds can be coherently refocused (see the figure below). We also demonstrate that these multiple coherence signals are extremely sensitive to the scattering event, opening up new possibilities for measuring molecule–surface interactions.




See Refs.3-6 in the list of selected publications.

# Coupling of Surface-Plasmon-Polariton-Hybridized Cavity Modes between Submicron Slits in a Thin Gold Film




In this research Electron Energy Loss Spectroscopy (EELS) in a Scanning Transmission Electron Microscope (STEM) is applied to probe extraordinary photon transmission through submicron slits in a thin gold film. Coupling of standing-wave-like cavity modes, hybridized with surface plasmon polaritons (SPP), between two adjacent slits, which strongly influences the transmission of light through the slits, is studied by systematically varying the width of the metal bar *d* that separates the slits.

Measurements on two-slit systems with different slit lengths *L* and fixed width reveal energy shifts and mode splitting of the fundamental SPP cavity mode which can be generally described as a function of a dimensionless scaling parameter *L*/*d*. A simple analytical model of mode coupling, supported by numerical simulations, agrees well with the experimental data and reveals insights into the underlying complex coupling mechanisms.

See Refs.9,10 in the list of selected publications.