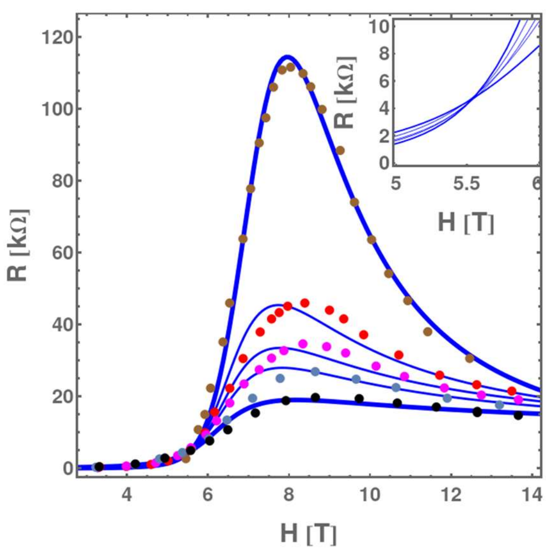
Abstracts of active research areas

Field-Induced Superconductor-Insulator Transition in Disordered 2D Electron systems: The case of amorphous Indium-Oxide thin films

The phenomenon of field-induced superconductor-insulator transition (SIT) in disordered two-dimensional (2D) electron systems has been a subject of both great interest and controversy since its discovery in the early 1990s. Its commanding paradigm has been the boson-vortex duality introduced by M. P. A. Fisher in 1990. However, in 2000 Gantmakher et al. reported on parallel magnetic field-induced SIT in amorphous Indium Oxide thin films, similar to what used to be observed under perpendicular field, calling this paradigm into question.

In this article we present an alternative paradigm in which superconductivity is destroyed, and an insulating state is created at low temperatures due to condensation and localization of Cooper-pair-fluctuation (CPF) bosons in real-space mesoscopic puddles upon increasing magnetic field.

Within a new hybrid microscopic-phenomenological approach, introducing quantum tunneling of CPFs and their pair breaking into fermionic quasi-particle excitations, the theory accounts well (see the figure below) for the field-induced SIT observed experimentally in amorphous Indium-Oxide thin films, including the presence of a single crossing (quantum critical) point of the sheet resistance isotherms (as shown in the inset below).

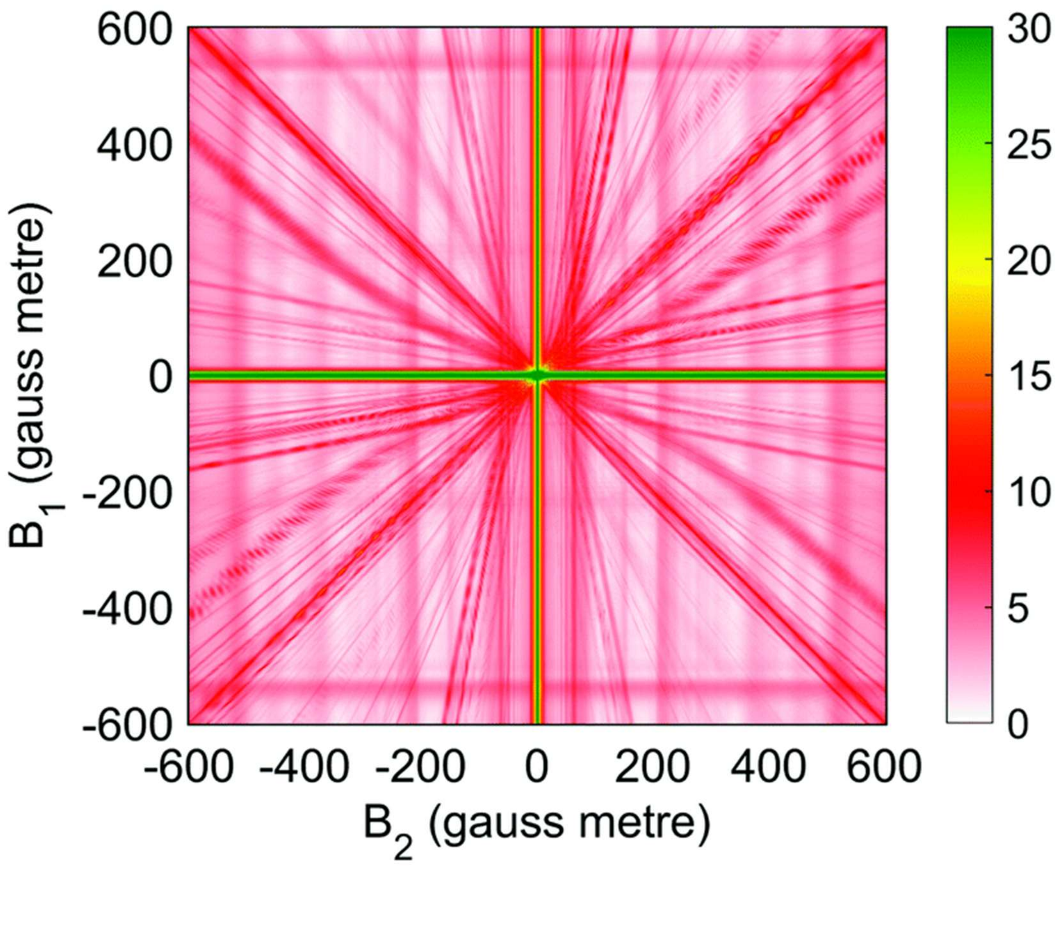


The theory seems also to be applicable to the 2D electron gas formed in the perovskite-oxide SrTiO3/LaAlO3 (111) interface, for which SIT has been observed experimentally under both parallel and perpendicular magnetic fields.

See Ref.1 in the list of selected publications.

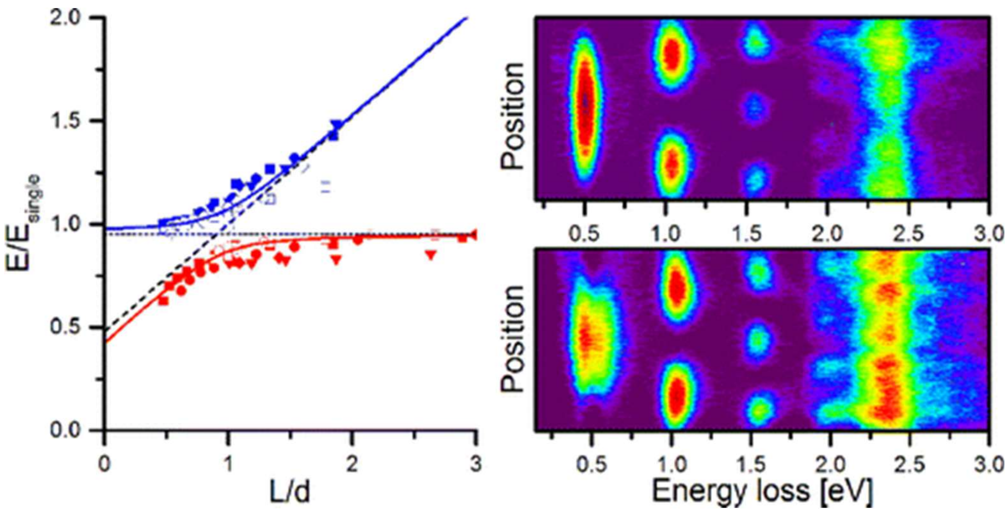
Molecular spin echoes; multiple magnetic coherences in molecule surface scattering experiments

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.