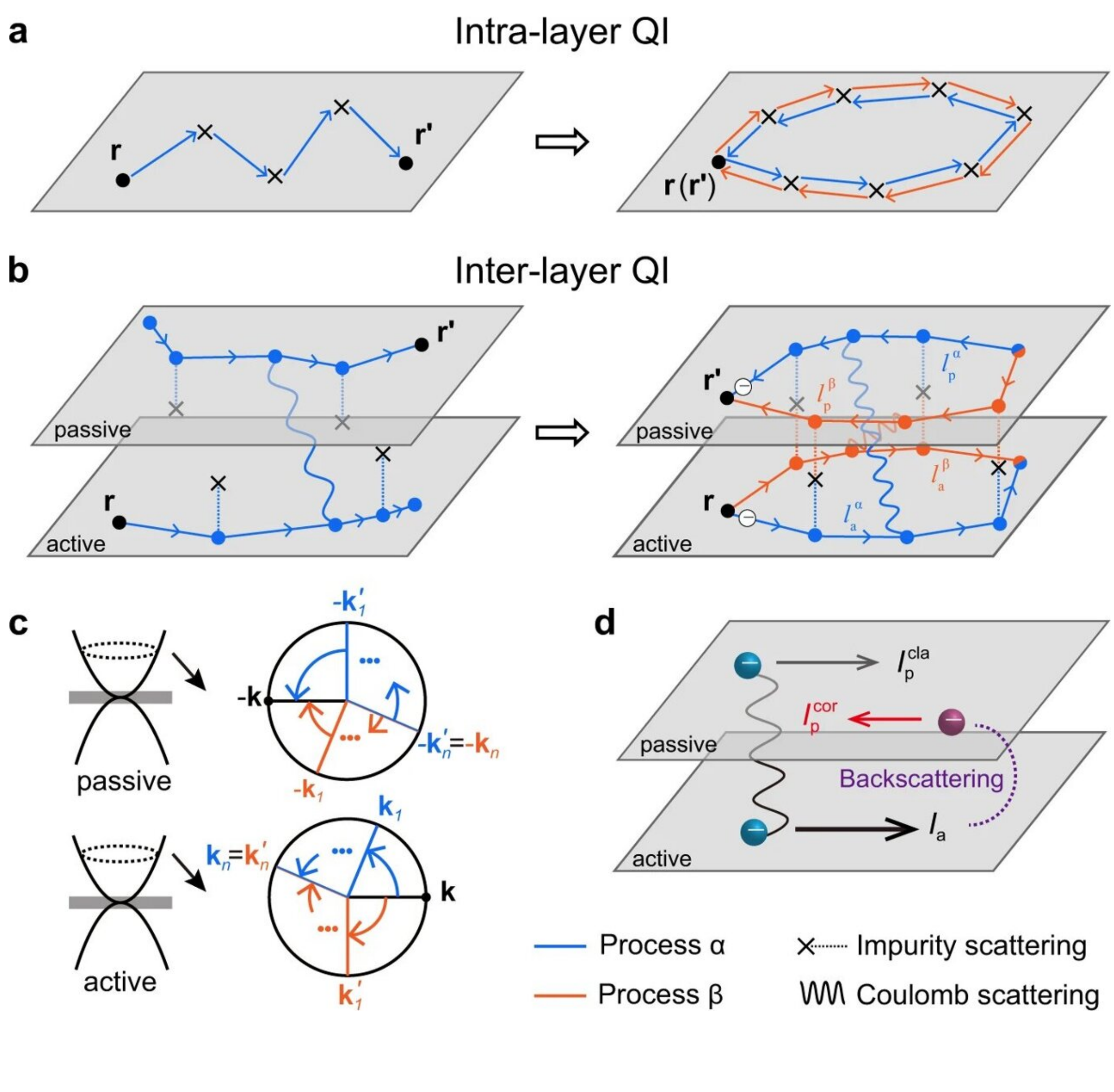
PHYS.ORG

Researchers reveal quantum interference in inter-layer Coulomb drag

April 12 2023



Schematics for intra-layer and inter-layer quantum interference. Credit: Zhu Lijun et al.

A team led by Prof. Zeng Changgan and Associate Researcher Li Lin from the University of Science and Technology (USTC) / Chinese Academy of Sciences (CAS) Key Laboratory of Strongly-Coupled Quantum Matter Physics, collaborating with Prof. Feng Ji's team from Peking University, revealed significant quantum interference effect in inter-layer transport process for the first time using graphene-based electronic double-layer systems. Their work was published in *Nature Communications*.

Coulomb drag is an effect that occurs between two conductive layers in proximity but insulated from each other, wherein moving carriers in one layer (active layer) induces the transport of carriers in the other layer (passive layer), thereby generating an open-circuit voltage in the passive layer.

Coulomb drag has been widely applied in previous studies of long-range interactions between carriers, such as the Bose-Einstein condensation of indirect excitons. However, there is a lack of research on the external field response and possible quantum effects of the Coulomb drag.

As a two-dimensional electron gas, graphene has highly adjustable carrier types and density, and using boron nitride (hBN) as an insulating layer, the distance between two layers of graphene can be reduced to a few nanometers, providing an ideal platform for studying the characteristics of inter-layer Coulomb drag.

On this account, the team constructed multiple graphene-based electronic double-layer systems such as double layers of bilayer graphene (BLG/BLG) with hBN as the insulating spacer, double layers of monolayer graphene (MLG/MLG) and MLG/BLG. By applying an external magnetic field on the graphene-based double-layer systems, the team observed that in a wide range of temperature and carrier density, the magneto-drag resistance deviates significantly from classical drag resistance in the low-field regime.

This low-field correction is sensitive to the band topology of the graphene layers. For example, a peak feature was observed in the low-field correction of BLG/BLG and MLG/MLG, while the BLG/MLG correction showed a valley feature.

By analyzing the transport process, the team found that the observed low-field correction can be well attributed to the quantum interference in the Coulomb drag between two layers that are interrelated by time reversal and mirror reflection. The emergence of such quantum interference relies on the formation of superimposing inter-layer diffusion paths, wherein the impurity potential scatterings from the intermediate insulating layer play a crucial role.

The discovery of this new quantum interference extended the quantum interference in solid materials from the single-particle transport process in single conductor to the multi-particle interactions between multiple conductors. Furthermore, compared with magnetoresistance correction in intralayer quantum interference, the magneto-drag resistance correction is significantly larger, providing a candidate for the future development of new-principle magnetic memory devices.

More information: Lijun Zhu et al, Signature of quantum interference effect in inter-layer Coulomb drag in graphene-based electronic double-layer systems, *Nature Communications* (2023). DOI: 10.1038/s41467-023-37197-2

Provided by University of Science and Technology of China