Unconventional quantum oscillations in complex oxide interfaces

K. Rubi[1], D. R. Candido[2], M. Dumen[3], S. Zeng[4], E. Ammerlaan[5], F. Bangma[5], M. Chan[1], M. Goiran[6], A. Ariando[4], S. Chakraverty[3], W. Escoffier[6], U. Zeitler[5], N.Harrison[1]
1. National High Magnetic Field laboratory, Los Alamos National laboratory; 2. University of Iowa; 3. Institute of Nano Science and Technology, India; 4. National University of Singapore, Singapore; 5. HFML-EMFL, Radboud University Netherlands; 6. LNCMI-EMFL, Toulouse France.
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The interface between two insulating oxides (e.g., $SrTiO_3$ and $LaAlO_3$) becomes conducting. These interfaces also host superconductivity, magnetism, and spin-orbit interaction—making them promising for next-generation spintronics and quantum computing. However, to harness their potential in technology, a deep understanding of the electronic bands responsible for conduction is essential.

In this study, we explore the electronic states of oxide interfaces through quantum oscillations in three different interfaces: $LaAlO_3/SrTiO_3$, $EuO/KTaO_3$, and $LaAlO_3/KTaO_3$. To accurately resolve quantum oscillations, we conducted resistivity measurements in high magnetic fields up to 60 T.

Contrary to the conventional theory of Landau quantization, the observed quantum oscillations are not periodic in inverse magnetic field (1/*B*). Instead, both the oscillations frequency and cyclotron mass increase progressively with magnetic field for all three studied interfaces. We attribute these universal and intriguing findings to the nontrivial electronic bands, for which the energy-momentum dispersion incorporates both linear and parabolic relations.

The observed unconventional quantum oscillations, with a frequency that varies quadratically with magnetic field, established a new paradigm for two-dimensional electron systems in complex oxides. Our experimental findings and versatile theoretical model also hold promise for comprehending similar observations in other materials with strong spin-orbit coupling, including Dirac and Weyl semimetals.

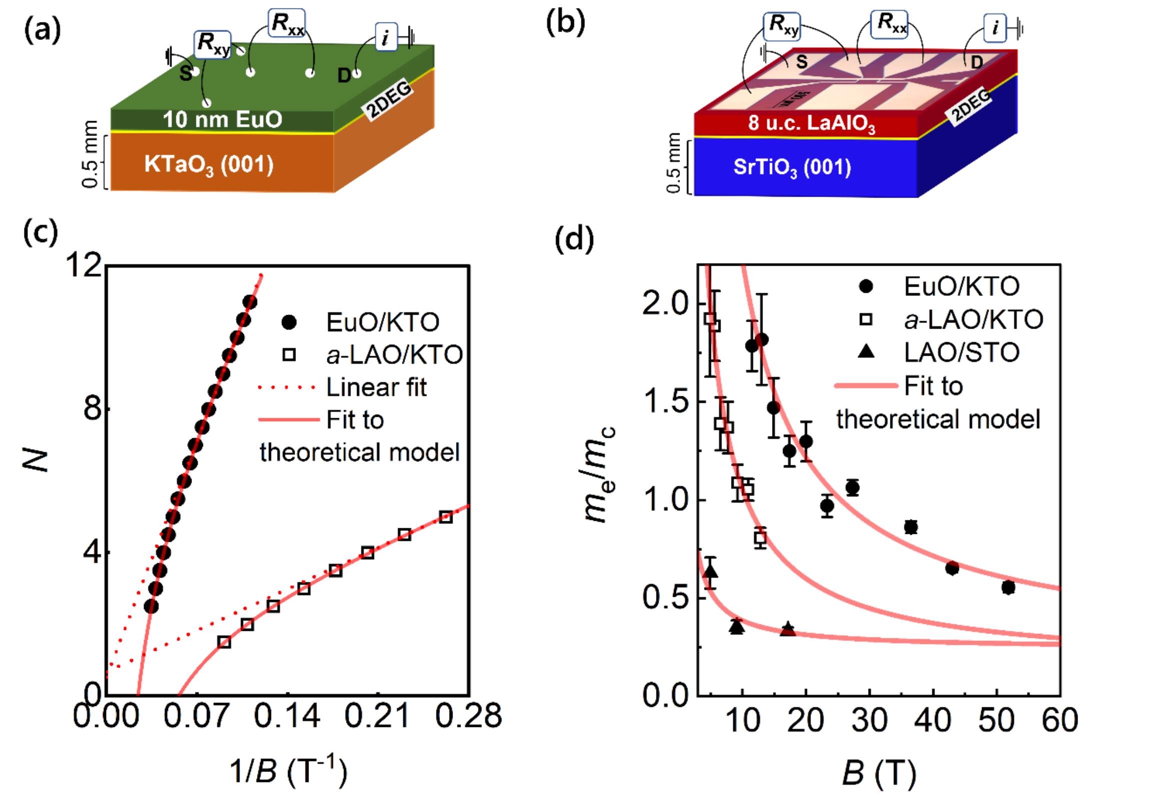

Figure: Schematics of two heterostructures (a) $EuO/KTaO_3$ (EuO/KTO) and (b) $LaAlO_3/SrTiO_3$ (LAO/STO). (c) Noxideson-linear Landau plots constructed from quantum oscillations and (d) cyclotron mass enhancement with field, fitted with the theoretical model which suggest the existence of non-trivial electronic states in both $SrTiO_3$- and $KTaO_3$-based interfaces.

Facilities and instrumentation used: 65 T short-pulse magnet at pulsed field facility.

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