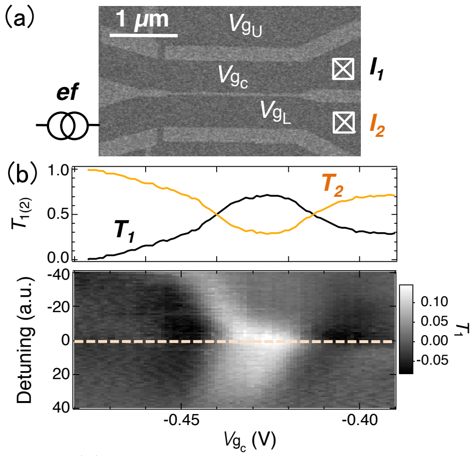
Coherent control of a single electron in a tunnel-coupled wire driven by a surface acoustic wave

S. Takada[1], M. Yamamoto[1,2], S. Nakamura[1], K. Watanabe[1], C. Bäuerle[3], A. D. Wieck[4] and S. Tarucha[1]

[1] *Department of Applied Physics, Univ. of Tokyo, Bunkyo-ku, Tokyo 113-8656, Japan*
[2] *ERATO-JST, Kawaguchi-shi, Saitama 331-0012, Japan*
[3] *Institut Néel - CNRS and Université Joseph Fourier, 38042 Grenoble, France*
[4] *Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany*

Quantum electron optics is an attractive platform for building up coherent quantum systems in solid-state devices. In particular, flying electrons in depleted channels driven by surface acoustic waves (SAWs) are promising because quantum states of the electrons are decoupled from decoherence sources in their environment. Recent experiments have shown that single electrons are transferred as flying electrons trapped by SAWs and detected on demand [1, 2]. To realize quantum optics experiments with the single flying electrons, basic elements such as beam splitters and controllers of phase and interactions are required. Here we report on the realization of a coherent single electron beam splitter as well as coherent manipulation of the single electron charge states in a depleted tunnel-coupled wire driven by SAWs.

The device was defined in a GaAs /AlGaAs heterostructure by Schottky gates. An interdigital transducer (IDT) to generate SAWs is placed at the left side, about 1.2 mm apart from the beam splitter (Fig.1a). Electrons are injected one by one into the lower part of the depleted tunnel-coupled wire by the moving SAW potential. We tuned both tunnel-coupling energy and energy detuning between the upper and lower part of the wire by applying gate voltages Vg_c, Vg_U and Vg_L. We observed coherent oscillation of single electrons between the upper and lower part of the wire as a function of the tunnel-coupling energy or Vg_c (Fig.1b). The visibility was about 40% at the zero-energy detuning, which is most probably limited due to the geometry at the edges of the wire. As the detuning is increased, the oscillation period decreases with decreasing amplitude, which is a clear manifestation of the coherent charge oscillation (Fig.1b). Furthermore the visibility of the oscillation was almost constant from 0.3 K to 1 K. This implies that electrons transported by SAWs through a depleted quantum channel hardly decohere by the phonon bath. Our demonstration paves the way to perform various quantum electron-optical experiments and to realize coherent quantum systems.



: Fig.1(a) A SEM picture of the relevant device. (b) Upper panel shows tunnel-coupling dependence of transmission probability $T_{1(2)} = I_{1(2)}/(I_1 + I_2)$ along the dashed line in the lower panel. Lower panel shows an intensity plot of T_1 as a function of tunnel-coupling energy (Vg_c) and energy detuning ($Vg_U - Vg_L$), where smoothed background is subtracted from raw data.

[1] S. Hermelin et al., Nature. **477**, 435 (2011).
[2] R. P. G. McNeil et al., Nature. **477**, 439 (2011).