Time-resolved detection of single-electron wave packets

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The recent development of on-demand semiconductor single-electron sources such as mesoscopic capacitors [1] and leviton excitations [2] has enabled an electronic analogy of quantum optics experiments. This allows the detailed studies of electron emission dynamics [1] and fermion quantum statistics [2,3] using shot-noise or ac-current measurements. However, some of the electron dynamics occur at such short timescales that they are often inaccessible due experimental bandwidth limitations.

In this talk, we present an experimental method to detect electron arrival-time distribution with resolutions as small as 1 picosecond. Our electrons are emitted from a GaAs quantum-dot pump as hot electrons at energies ~100 meV above the Fermi energy [4]. These electrons travel through quantum-Hall edge states acting as electron waveguides. A fast-rising detector potential barrier, driven by an rf signal synchronised to the pump, acts as a shutter for incoming electrons. The measurements of transmitted electron current provides the information on the arrival-time distribution as the time delay of detector barrier rise is shifted against the timing of electron emission [4,5]. Electron arrival-time distribution as small as 4 ps has been detected. We demonstrate how this technique can be used to study ultra-fast dynamics of single-electron wave packet transport such as time-of-flight measurements for deducing edge-state velocity [6].

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