Electron quantum optics for electrical metrology

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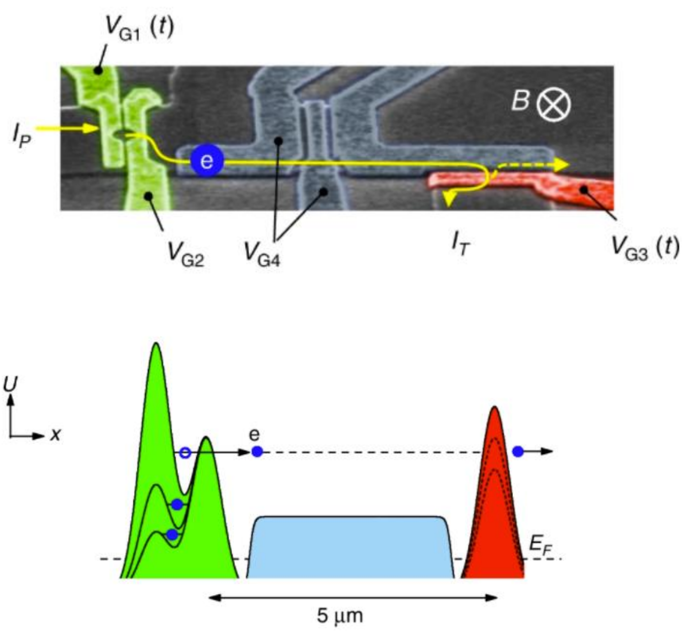
After the redefinition of SI units in 2019, electrical units such as ampere, volt, and ohm, are defined in terms of the fixed value of fundamental constants. This move has made the Josephson effect and the quantum Hall effects as direct methods for the realisation of volt and ohm. A missing element is a quantum current standard that requires accurate control of single-electron transport [1]. Such a standard is required, not just for the direct realisation of ampere, but also for a consistency test of three quantum standards, so-called quantum metrological triangle.

In this talk, I will present our research activities on so-called electron quantum optics at NPL, motivated to achieve accurate single-electron transport [2]. Electron quantum optics is a field analogous to photonics or atomic quantum optics, in which quantum mechanical nature of beams of electrons are exploited in experiments. Progress in nanodevice fabrication and cryogenic electrical measurement techniques has enabled such experiments in semiconductor material, allowing us to probe fundamental behaviour of electrons. I will discuss in particular our recent experimental results on two-electron collision experiment in Hong-Ou-Mandel geometry. While anti-bunching behaviour due to fermionic statistics has been observed in previous studies [3], we observe the effect of Coulomb repulsion in our unscreened system, leading to an understanding of the effect of electron-electron interaction on the paths that electrons take.

[1] B. Kaestner and V. Kashcheyevs, Rep. Prog. Phys. **78**, 103901 (2015).
[2] J. D. Fletcher *et al*., Nature Communications **10**, 5298 (2019).
[3] E. Bocquillon *et al*., Science **339**, 1054 (2013); J. Dubois *et al*., Nature **502**, 659 (2013).



From Fig. 1 of Ref. [2]: (Top) False-colour scanning electron micrograph of device identical to that measured. The electron pump (left, green) injects pump current I_p. The barrier (right, red) selectively blocks electrons giving transmitted current $I_T \leq I_P$. The path between these is indicated with a line. The gates along the path (controlled by V_{G4}) depletes the underlying electron gas but do not block the high energy electrons. (Bottom) Electron potential U(x) along the electron path between source and probe barrier at three representative stages for pumping (left) and blocking (right).