Time-resolved sensing of electromagnetic fields with single-electron interferometry

Giacomo REBORA
H. Bartolomei, E. Frigerio, M. Ruelle, Y. Jin, U. Gennser, A. Cavanna, E. Baudin, J.-M. Berroir, I. Safi, P. Degiovanni, G. Ménard, G. Fève.

ENS de Lyon, CNRS, Laboratoire de Physique, F-69342 Lyon, France

giacomo.rebora@ens-lyon.fr

Abstract

Characterizing quantum states of the electromagnetic field at microwave frequencies demands fast and sensitive detectors capable of simultaneously probing both the field's time-dependent amplitude and its quantum fluctuations. In this presentation, we explore the potential of single-electron excitations propagating in electronic interferometers, such as Mach-Zehnder and Fabry-Perot, as probes of quantum radiation with sub-nanosecond precision. By leveraging electronic interferometry, we demonstrate a quantum sensor [1] that exploits the phase of a single-electron wavefunction to detect a classical time-dependent electromagnetic field with a resolution of a few microwave photons. The time resolution, dictated by the electronic wavepacket's temporal width, reaches a few tens of picoseconds [2]. Importantly, our approach allows for simultaneous access to both the amplitude of the electromagnetic field, encoded in the phase of the interference pattern, and its fluctuations, extracted from the interference contrast. We illustrate how single-electron wave packets can detect sub-vacuum fluctuations [3], such as squeezing, of microwave radiation. These findings pave the way for on-chip detection of quantum radiation, including non-classical states like squeezed [4] and Fock states, offering new avenues for quantum metrology and information processing.

References

[1] H. Bartolomei et al., accepted in Nature Nanotechnology (2025).
[2] N. Johnson et al., Applied Phys. Lett. 110 (2017) 102105.
[3] H. Souquet-Basiège et al., arXiv:2405 (2024).
[4] H. Bartolomei et al., Phys. Rev. Lett., 130 (2023) 106201.

Figures

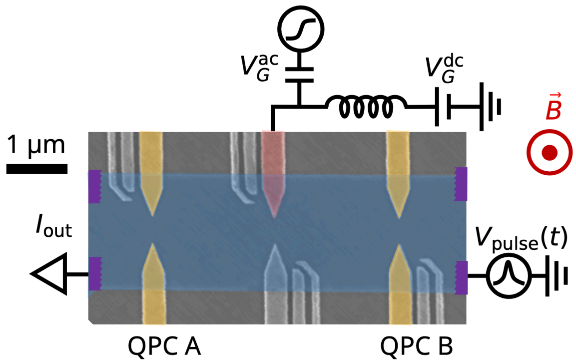

Figure 1: Schematic of the sample. A single electron pulse, sent into the Fabry-Perot interferometer, probes the voltage applied on the red metallic gate.

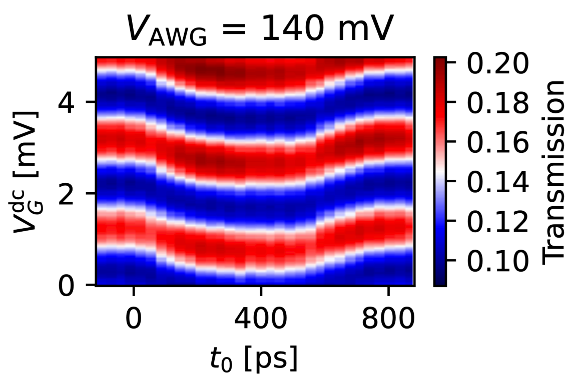

Figure 2: Sensing of a time-dependent voltage with single-electron interferometry.