Quantum tomography of an electron

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Abstract

The complete knowledge of a quantum state allows the prediction of the probability of all possible measurement outcomes, a crucial step in quantum mechanics. It can be provided by tomographic methods

which have been applied to atomic, molecular, spin and photonic states. For optical or microwave photons, standard tomography is obtained by mixing the unknown state with a large-amplitude coherent photon field. However, for fermions such as electrons in condensed matter, this approach is not applicable because fermionic fields are limited to small amplitudes (at most one particle per state), and so far no determination of an electron wavefunction has been made. Recent proposals involving quantum conductors suggest that the wavefunction can be obtained by measuring the time-dependent current of electronic wave interferometers or the current noise of electronic Hanbury-Brown/Twiss interferometers. Here we show that such measurements are possible despite the extreme noise sensitivity required, and present the reconstructed wavefunction quasiprobability, or Wigner distribution function, of single electrons injected into a ballistic conductor [1]. Many identical electrons are prepared in well-controlled quantum states called levitons by repeatedly applying Lorentzian voltage pulses to a contact on the conductor. After passing through an electron beam splitter, the levitons are mixed with a weak-amplitude fermionic field formed by a coherent superposition of electron–hole pairs generated by a small alternating current with a frequency that is a multiple of the voltage pulse frequency. Antibunching of the electrons and holes with the levitons at the beam splitter changes the leviton partition statistics, and the noise variations provide the energy density matrix elements of the levitons. This demonstration of quantum tomography makes the developing field of electron quantum optics with ballistic conductors a new test-bed for quantum information with fermions.

These results may find direct application in probing the entanglement of electron flying quantum bits, electron decoherence and electron interactions. They could also be applied to cold fermionic atoms.

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