Potentials for Single Electron State Processing

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Entangletronics, as an emerging research area, aims at manipulating and controlling electron coherence for device operations. Most famously, the Young double-slit setup or the Aharonov-Bohm ring are fundamental structures to control the interference pattern of electrons. Both provide theoretical insights [1] and foundations for advanced applications, e.g., information processing [2]. Alternatively, electron control can be established by specifically shaped electric potentials, called lenses, which can split [3] or focus a single electron state, e.g., for improving the device performance [4]. Recently, it has been observed that the operation of such lenses can be emulated by two potential wells, such as the potentials of two attractive dopants [5]. A well-pronounced interference pattern can be observed. The process has been further investigated regarding the effect of different physical settings, such as the distance between the wells, their potential, and the parameters of the initial electron state. Here, we report the indicative case of a double dopant structure acting as a lense. The well potentials, the injected electron kinetic energy, and the initial condition k_{0y} are the same as in [5], however, reflecting boundary conditions are imposed. Fig. 1 shows the details of the geometry and the initial condition. The classical density (left) spreads evenly across the wire in the bottom part and is concentrated towards the central axis of the wire by the attractive potentials. This illustrates that (i) the effect of the boundaries can be controlled by the potential and the distance between the wells. The quantum evolution (right) demonstrates (ii) a well-pronounced interference effect. Notably, the interference pattern shown on a screen (i.e. a crosscut at a certain y-position) placed at $y = 16\text{nm}$ (iii) gradually transforms to a strong central peak for screen positions beyond $y = 19\text{nm}$. Fig. 2 (left) shows the effect of reducing the left well potential by 50%. This result suggests that (iv) the lense focus can be gradually adjusted with respect to the cross section of the wire by a corresponding variation of the potential difference between the wells. In Fig. 2 (right), the interference patterns of the symmetric and asymmetric cases are compared in the $y = 16\text{nm}$ screen (red). The peak of the focused electron density and its shift caused by the asymmetry is well-pronounced in the $y = 26\text{nm}$ screen (blue). The results (i)-(iv) suggest alternative approaches for a coherent manipulation of the electron state.

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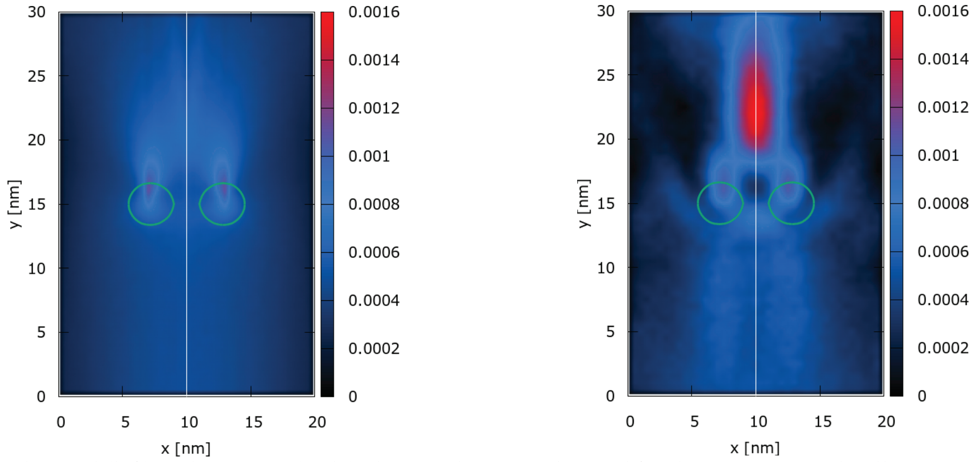

Fig.1: Classical (left) and quantum (right) electron densities obtained for the same – periodically injected (every $1fs$*) and centered at the bottom – initial condition, i.e., a minimum uncertainty Wigner packet with the standard deviation* $\sigma = 8nm$ *and the central wave vector* $(k_{0x}, k_{0y}) = (0, 0.837/nm)$ *corresponding to an energy of* $0.14eV$*. The initial condition's classical interpretation is a distribution function comprising two Gaussian functions in space and momentum. Green isolines at* $0.175eV$ *indicate the places of the potentials.*

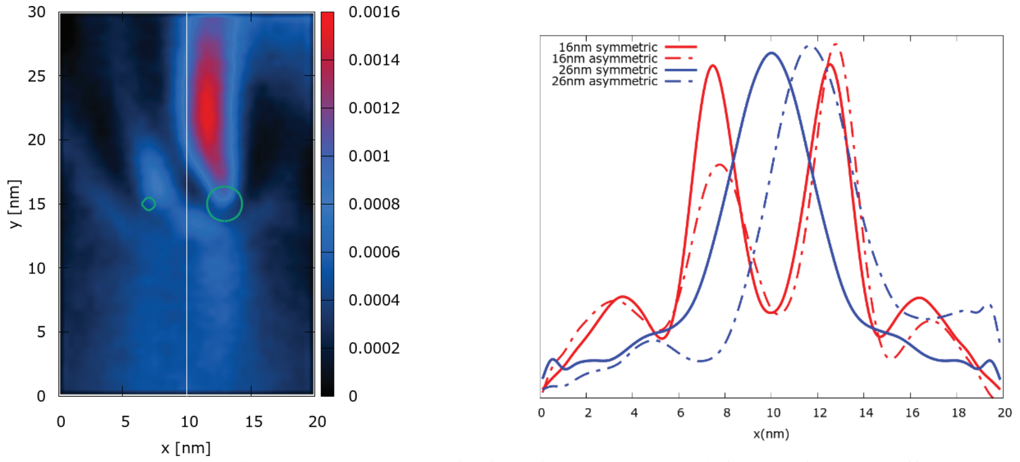

Fig.2: The reduced potential (by 50%) causes a shift of the focused density (left). The focusing effect as well as the effect of the potential asymmetry is well visible on screens at different positions (right).