# SIMULATIONS OF A QUANTUM EFFECT BASED ELECTRON WAVE SWITCH OPERATING AT ROOM TEMPERATURE

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One of the earliest and most fundamental discoveries of semiconductor nanostructures was that of the quantum point contact (QPC), a narrow constriction between two terminals with a width of the order of the Fermi wavelength of the electrons. The most prominent feature of a QPC is the quantised conductance, which is an integer multiple of $2e^2/h$. This arises due to electrons having to pass through the constriction in a quantised mode.

In this work we make use of another striking quantum effect associated with QPCs, that of the branched current flow of the ejected electrons, to design a novel quantum effect switching device. The ejected electrons have an angular probability distribution with the number of branches equal to the quantum mode of the electrons as they pass through the QPC. We have performed time domain based simulations of an electron wave packet with a standard deviation of 4 nm, corresponding to a temperature of 330 K, traversing an adiabatic QPC of 10nm width, as shown in Fig. 1.

Compared to the easily observable quantised conductance, this branching effect has not been greatly studied but has recently been imaged using an atomic force microscope (AFM). So far, analysis of this effect has been mainly limited to relatively low temperatures and bias voltages only. Here, our work is based at 330 K and with a range of bias from 0 to 500 mV.

Simulations show that the angular probability of electrons ejected from a QPC varies by only a small amount over the above range of bias when compared with the difference exhibited between different quantum modes. We have therefore proposed and simulated a novel device, as shown in Fig. 2, that makes use of this property by dividing the output reservoir of a QPC into three terminals to selectively channel the wave packets based on their quantum mode. This selectivity is achieved by two insulating dividers of 50nm wide, a width that can be routinely produced by nanolithography.

By increasing the bias across this device, mode 2, which is choked off below about 250 mV, becomes occupied and is selectively channelled into the outer terminals on the output side. As the bias is increased from 250 mV to 450mV, this mode selective channelling leads to an increase in conductance in the outer terminals by a factor of 2.9. At the same time the increase in total current flow through the QPC is only a factor of 2. Over this range of bias all quantum modes above 2 are choked off.

Due to the narrow width of the QPC in the design simulated, the sensitivity to temperature is small. This novel device concept therefore demonstrates that a quantum based switching effect should be observable at room temperature by utilising the branched electron flow from a QPC.

**References:**

**Figures:**

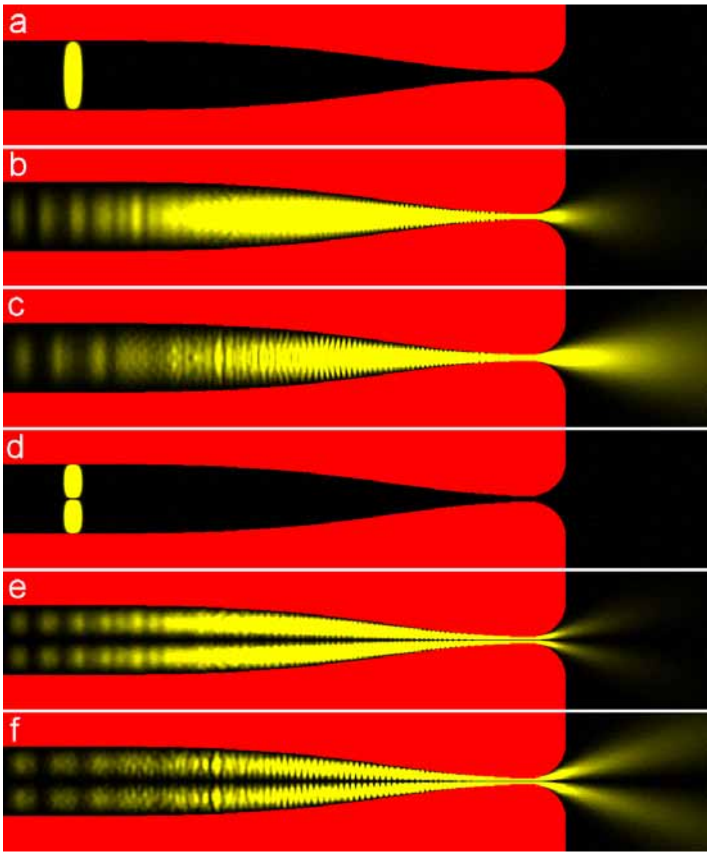


**FIG 1:** Probability density of an electron wave packet traversing an adiabatic quantum point contact of width 10 nm. The wave packet for mode 1 at times of 0, 0.8 and 1 ps are shown respectively in a) and b) and c), while d) and e) and f) show the same for mode 2.

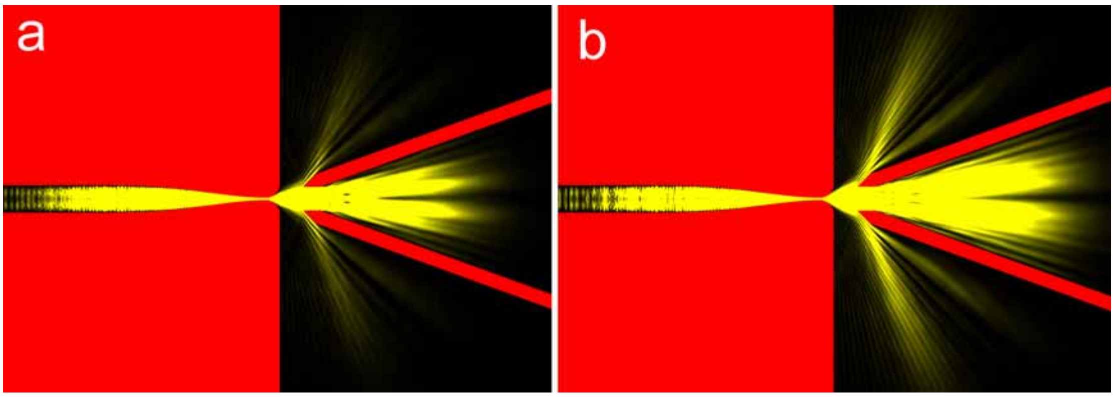


**Fig 2:** Wave packet probability densities for electrons traversing a QPC with an applied bias when the output reservoir is divided into three terminals by insulating lines. Mode 1 and 2 are summed together to show the overall probability density of ejected electrons. The lines are 50nm wide, start at a radius of 200 nm from the QPC exit and extend out at an angle of 20 degrees. The bias across the QPC is a) 240mV and b) 450mV.