Shot noise and squeezing in the conduction channel of a Field Effect Transistor at ultra-low temperature

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Measurements of electronic noise at ultra-low temperature is often performed on devices that are specifically designed for the experiment. In particular, since inelastic processes have the tendency to kill shot noise, the latter is usually studied in small structures such as tunnel junctions, hybrid superconductor / normal metal junctions, nanowires, chaotic cavities, etc. Much less is known on the noise in more conventional structures such as field effect- or bipolar transistors at ultra-low temperature. However, elastic transport can be achieved in such structures provided they are small enough and put at low enough temperature.

Fig. 1. Low frequency Noise of the conducting channel of the FET as a function of the dc bias current. The noise is measured at low frequency (400kHz) for a channel of resistance 10kΩ. The gate voltage is adjusted for each value of the drain-source voltage to keep the differential resistance of the channel constant.

We present two measurements of the shot noise generated by the conducting channel of a commercial FET (pHEMT ATF-35143 from Avago Technologies) placed at ultra-low temperature $T = 30\text{mK}$. In a first experiment we measure the low frequency noise ($f < 1\text{MHz}$) in the regime of high impedance channel ($R > 10\text{kΩ}$). This measurement is performed using a cryogenic tank circuit and room temperature amplifier. We demonstrate the existence of shot noise with a Fano factor of 0.31, indicating that transport is elastic and close to diffusive, see Fig.1.

In a second experiment we perform a phase-sensitive detection of high frequency quantum shot noise (at $f = 7.2\text{GHz}$) with a low impedance channel ($R = 50\text{Ω}$). We clearly observe that the noise increases only when the bias voltage is greater than $hf/e$, demonstrating that transport is elastic (with a Fano factor of 0.21) and that the FET generates quantum noise, see Fig.2 (black symbols). In the presence of a microwave excitation, we observe photo-assisted noise (green symbols) as well as squeezing of the microwave generated by the FET (red and blue symbols), i.e. the ability to generate voltage fluctuations below that of vacuum on one quadrature.

Our result show that existing commercial technology of micro-electronics could be used to generate quantum states of microwave radiation such as squeezed vacuum. We discuss the possibility of using another mechanism, the high frequency modulation of the gate voltage.

Fig. 2. High frequency noise of the conducting channel of a FET vs. dc bias current. The noise is normalized to its value in vacuum. Black symbols: no ac excitation. Green triangles: photon-assisted noise for an excitation of 18µV at 14.4GHz. Red and blue symbols: phase sensitive noise on the two quadratures. Dashed lines correspond to theoretical expectations. The shaded region corresponds to vacuum squeezing.

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