Quantum Shot Noise Measurements in Single C$_{60}$ Transistors

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The discreteness of electrical charges leads to unavoidable current fluctuations called “shot noise.” Shot noise measurements reveal more detailed information about the electron transport of a system than conventional electrical measurements. Shot noise is measured as the spectral density, $S$, of current fluctuations per unit bandwidth. For classical uncorrelated electrons, Poisson statistics predicts $S = 2eI$, where $e$ is the electronic charge and $I$ is the average DC current. The Fano factor, $F$, in a general system is defined as, $S(f) = 2eIF$. The Fano factor has been investigated in a number of systems, theoretically and experimentally, and it changes depending on the channel properties. A recent theoretical prediction suggests that in the presence of electronic coupling to local vibrational modes, a large Fano factor would be observed. Such a system cannot be realized until recent creation of single molecular devices. In these devices, molecules vibrate as electrons transport through them. Therefore this is the ideal system to study shot noise in vibrating channels.

Here, we present preliminary measurements of shot noise in single C$_{60}$ devices at low temperature down to 4.2K using a high frequency approach coincident with DC measurements.
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Introduction

Quantum conductance

- When the constriction approach the Fermi wavelength of electrons (~40 nm), the conductance $G$ becomes quantized as a function of the number of metal atoms.

Landauer formula: 

$$G = \frac{2e^2}{h} \sum_n T_n$$

Piezo

“The noise is the signal”


What is noise?

- Noise is fluctuations in electrical current.
- Noise is described as spectral density, $S$, which is the mean of the squared current fluctuation per unit bandwidth.

Purpose

Giant Fano factor in single molecule transistors

- Recent theoretical prediction: in the presence of electronic coupling to local vibrational modes, a large Fano factor would be observed.
- Single molecule devices are the ideal systems to study shot noise in vibrating channels.
- Here, we present preliminary measurements of shot noise in single C_{60} devices using a high frequency approach coincident with DC measurements.

Fabrication & Experimental Set Up

Fabrication of metal nanojunctions

- Using shadow evaporation technique, the narrowest nanojunctions can be fabricated.
- Electromigration, the following process, will occur at the constriction, then we can get quantum point contacts, and single molecule junctions, if molecules are coated on the junctions.

Electromigration & Noise power measurement

For electromigration

- Voltage pulse

- Voltage square wave train

- Voltage pulse

Expected Slope of microscopic junction $= 1/3$

Fano factor $= 8.08 \times 10^{-2}$

- Quantum shot noise is slightly measured even at room temperature. This is because channels are transmitting.
- Noise of power is due to large thermal energy and instability of atomic junction.

Conclusion & Future Work

- Quantum Point Contacts were realized by using feedback controlled electromigration.
- Noise measurement at $G = 10G_0$, which means junction consists of 10 metal atoms.
- Fano factor is calculated as $8.08 \times 10^{-2}$, which is very small considered in microscopic junctions.

Acknowledgement

This material is based upon work supported by the NSF’s Partnerships for International Research & Education Program (OISE-9958405).