Response and sensitivity of a normal-metal RF-SET

V.O. Turin and A.N. Korotkov

UC, Riverside
Abstract

We have analyzed the response and noise-limited sensitivity of the radio-frequency single-electron transistor (RF-SET), extending the previously developed theory to the case of arbitrary large quality factor $Q$ of the RF-SET tank circuit.

It is shown that while the RF-SET response reaches the maximum at $Q$ roughly corresponding to the impedance matching condition, the RF-SET sensitivity monotonically worsens with the increase of $Q$.

Also, we propose an operation mode, in which an overtone of the incident rf wave is in resonance with the tank circuit.
\[ Q_L = (1/Q + 1/Q_{SET})^{-1} \]

\[ Q = \sqrt{\frac{L_T}{C_T}/R_0} \]

Matching: \[ Q \approx \sqrt{\frac{R_{SET}}{R_0}} \]

Previous theoretical papers:
- Korotkov-Paalanen, 1999
- Blencowe-Wybourne, 2000
- Zhang-Blencowe, 2002

All of them assumed low Q-factor (<< matching)

RF-SET response is maximal close to matching condition; however, large Q-factor worsens RF-SET sensitivity (shot-noise-limited)
Temperature dependence

Model:
- full nonlinear analysis
- several overtones
- normal metal SET only
- no cotunneling
- low frequency signal
- no backaction analyzed

Optimizations of response and sensitivity are different (rf amplitude is much smaller for optimal sensitivity)

MR – maximum response mode
OS – optimized sensitivity mode
Dependence on SET resistance

Effect of asymmetric rf biasing

Asymmetric rf biasing does not worsen the RF-SET performance

MR – maximum response mode
OS – optimized sensitivity mode
Dependence on rf detuning

- sensitivity does not worsen with detuning
- monitoring by rectification is as good as homodyne detection

Proposal of resonant overtone mode

- $\omega = \omega_0/n$, reflected wave due to SET nonlinearity, in resonance with tank
- Advantage: different frequencies of incident and reflected waves
- RF-SET performance in the mode of resonant overtone is comparable to performance in the usual regime
- Recent experimental realization: Keith Schwab, similar performance in the proposed and usual modes