Response and sensitivity of a normal-metal RF-SET

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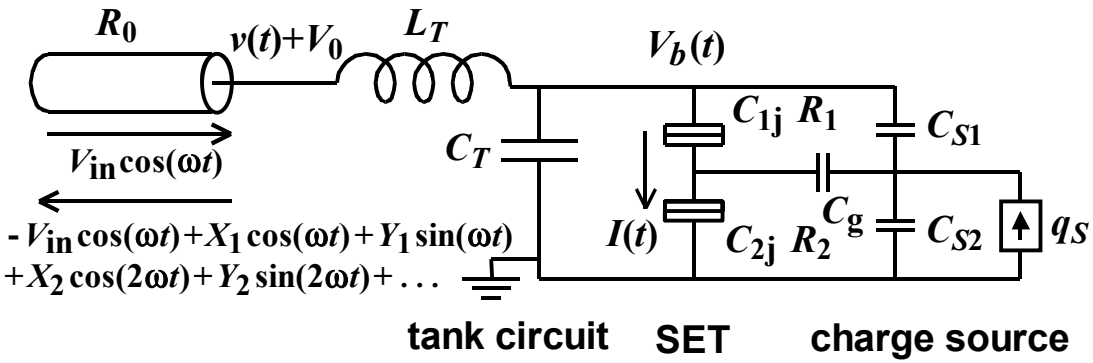
Abstract

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.



$$Q_L = (1/Q + 1/Q_{SET})^{-1}$$

$$Q = \sqrt{L_T / C_T} / R_0$$

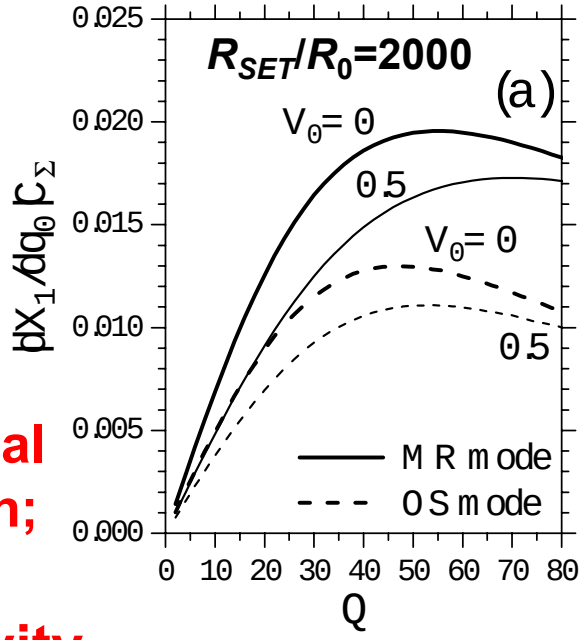
Matching: $Q \approx \sqrt{R_{SET} / R_0}$

Previous theoretical papers:

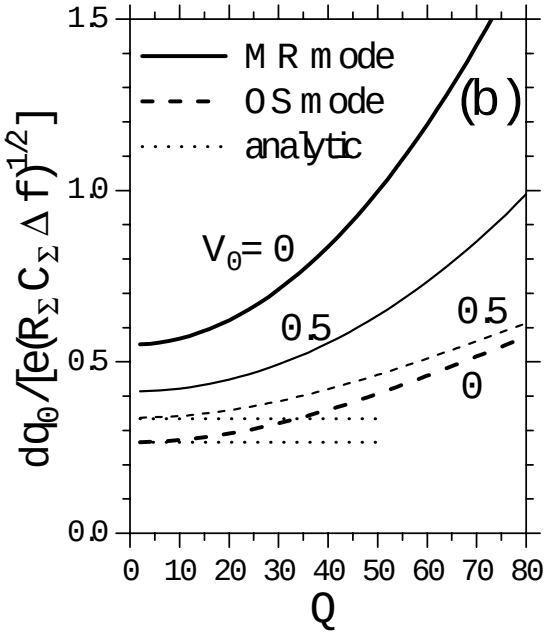
- **Korotkov-Paalanen, 1999**
- **Blencowe-Wybourne, 2000**
- **Zhang-Blencowe, 2002**

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

response



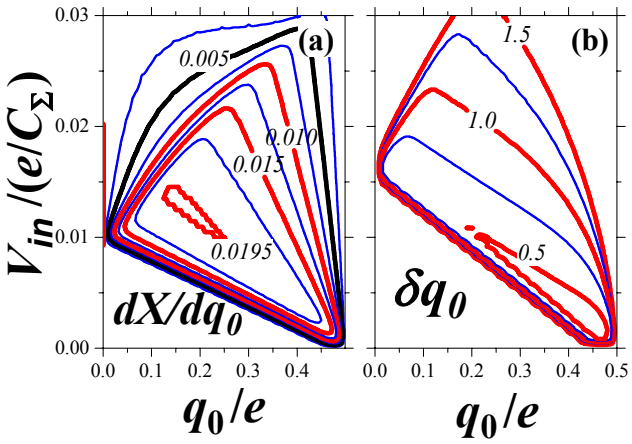
sensitivity



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

MR – maximum response mode
OS – optimized sensitivity mode

response sensitivity



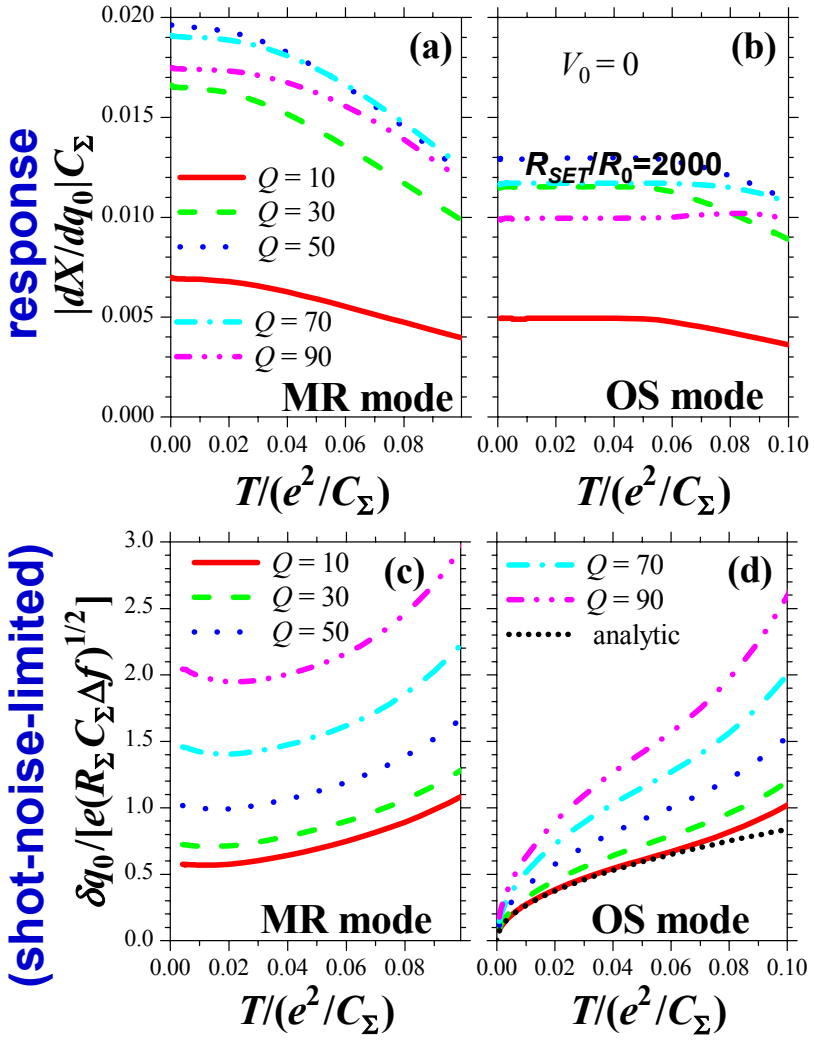
Optimizations of response and sensitivity are different (rf amplitude is much smaller for optimal sensitivity)

Model:

- full nonlinear analysis
- several overtones

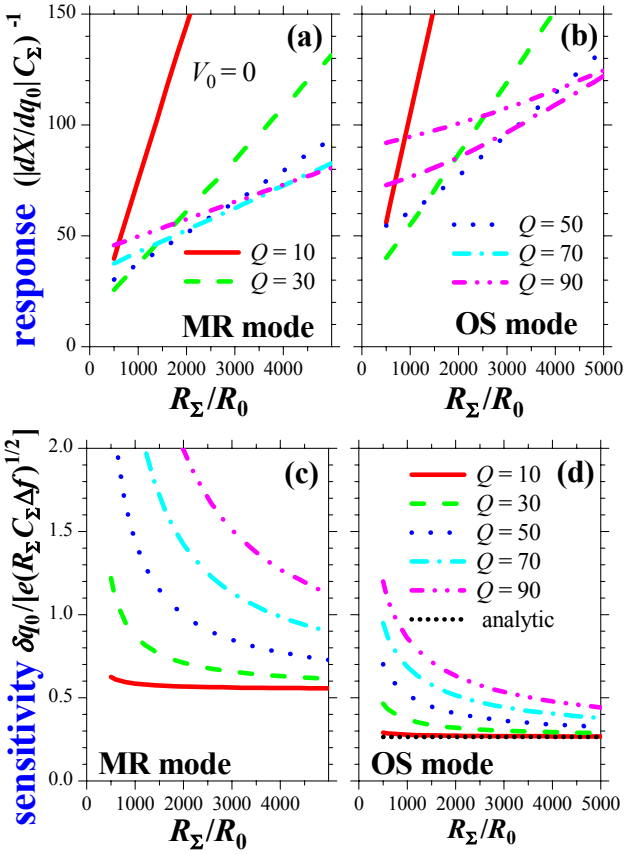
- normal metal SET only
- no cotunneling
- low frequency signal
- no backaction analyzed

Temperature dependence



MR – maximum response mode
OS – optimized sensitivity mode

Dependence on SET resistance



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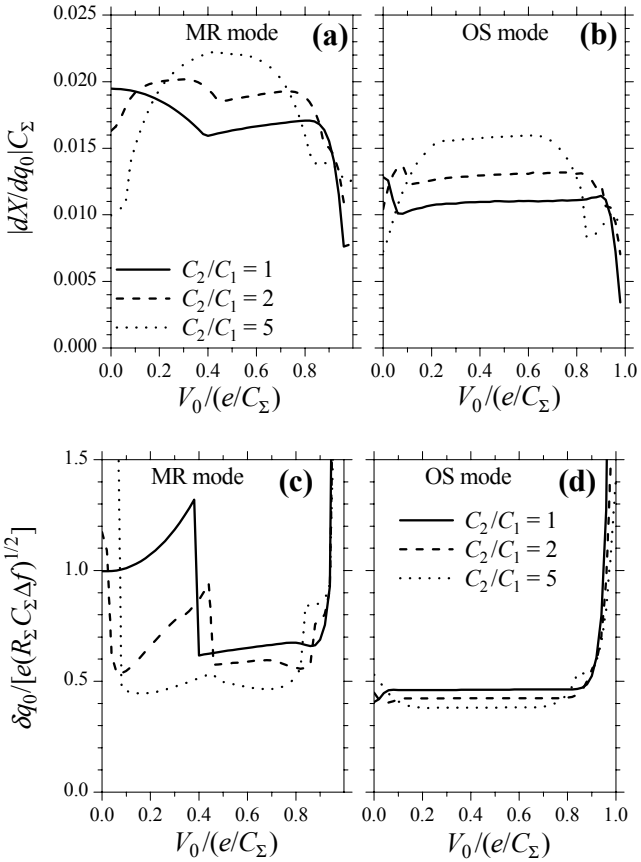
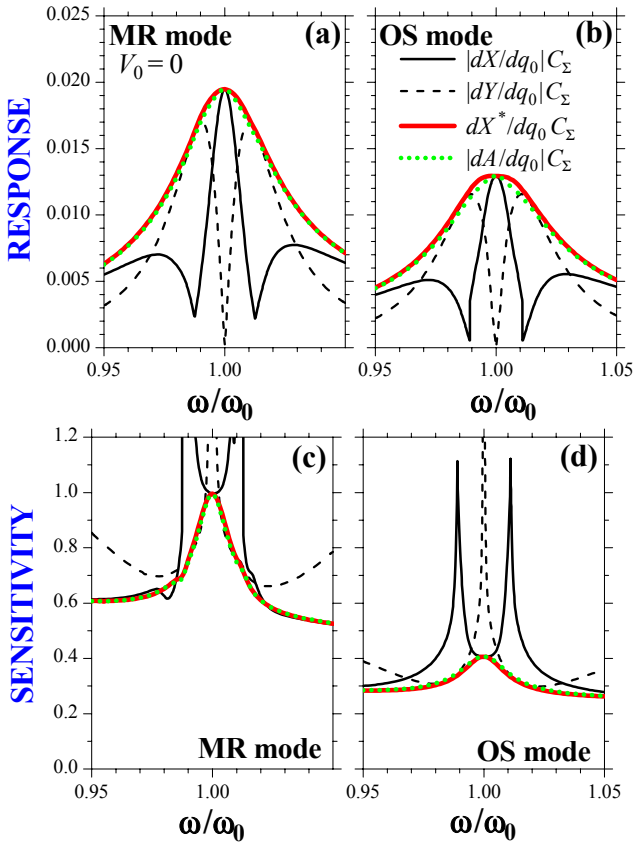
Effect of asymmetric rf biasing



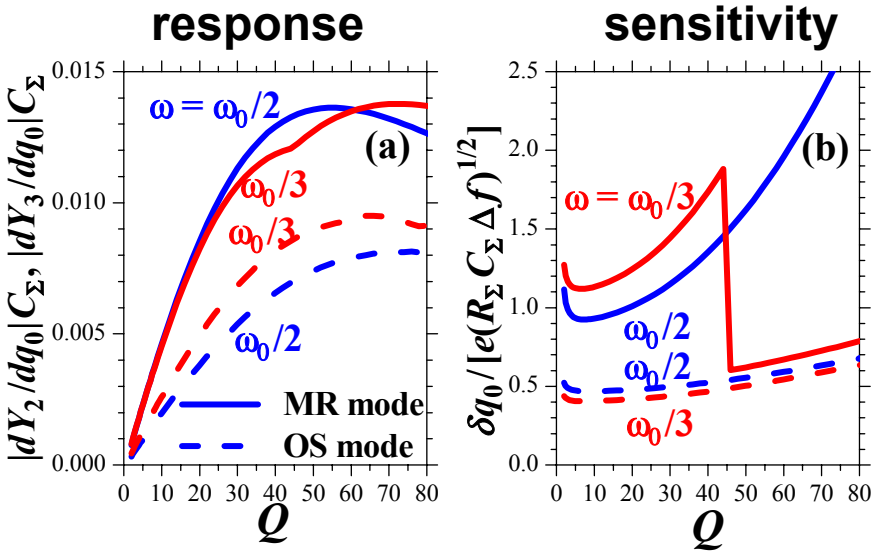
Asymmetric rf biasing does not worsen the RF-SET performance

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