Institute for Physics of Microstructures of RAS

Center for Quantum Technologies of NNSTU

SIS junction as single microwave photon counter for axion search

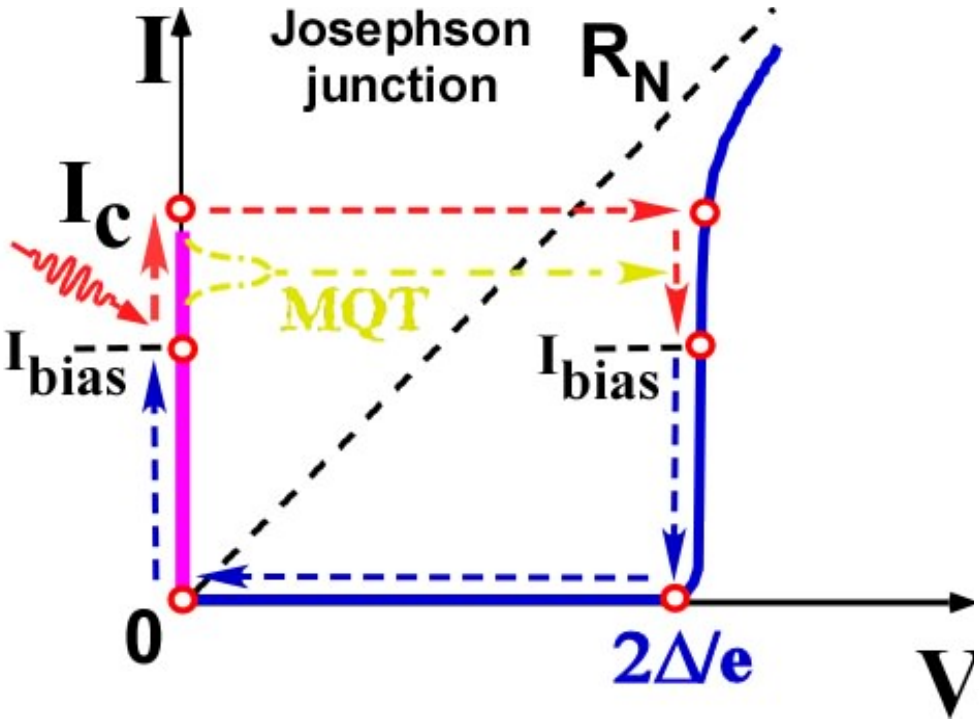
A.L. Pankratov[1,2], A.V. Gordeeva[1,2], L.S. Revin[1,2], A.A. Yablokov[1,2], L.S. Kuzmin[1,3], E.V. Il'ichev[4]

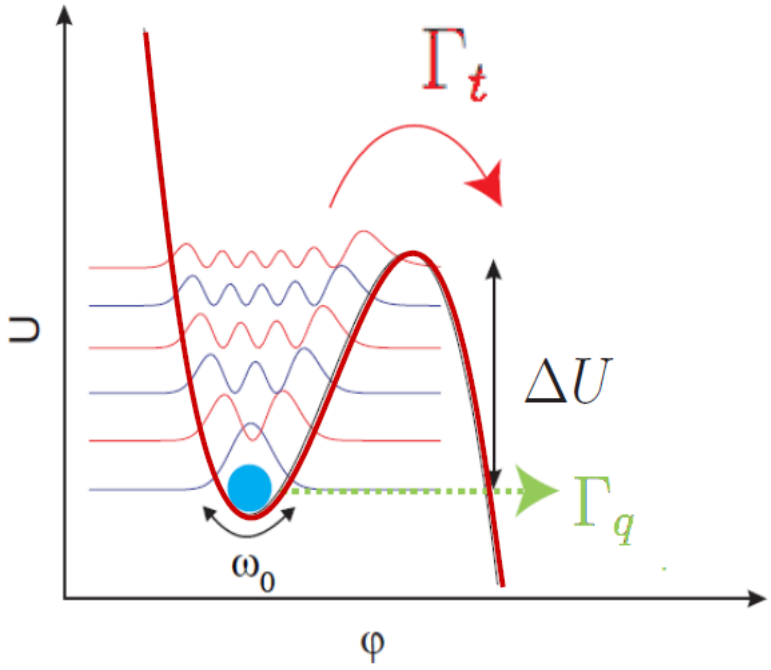
[1]Nizhny Novgorod State Technical University, 603950, Russia
[2]Institute for Physics of Microstructures of RAS, Nizhny Novgorod, 603950, Russia
[3]Chalmers University of Technology, 41296, Gothenburg, Sweden
[4]Leibniz Institute of Photonic Technology, D-07702 Jena, Germany

16th Patras Workshop on Axions, 2021

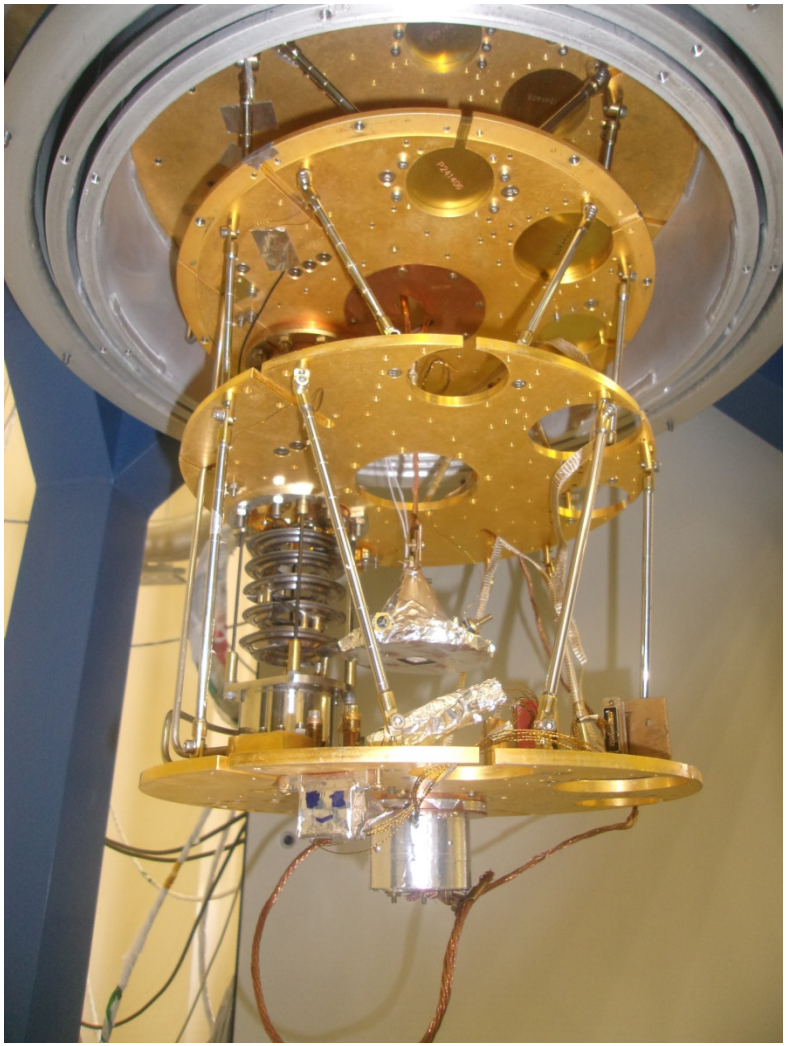
Principle of operation

SIS tunnel junction is a type of Josephson junction with low damping, having hysteretic current-voltage characteristic. It is used as threshold detector – the single photon counter

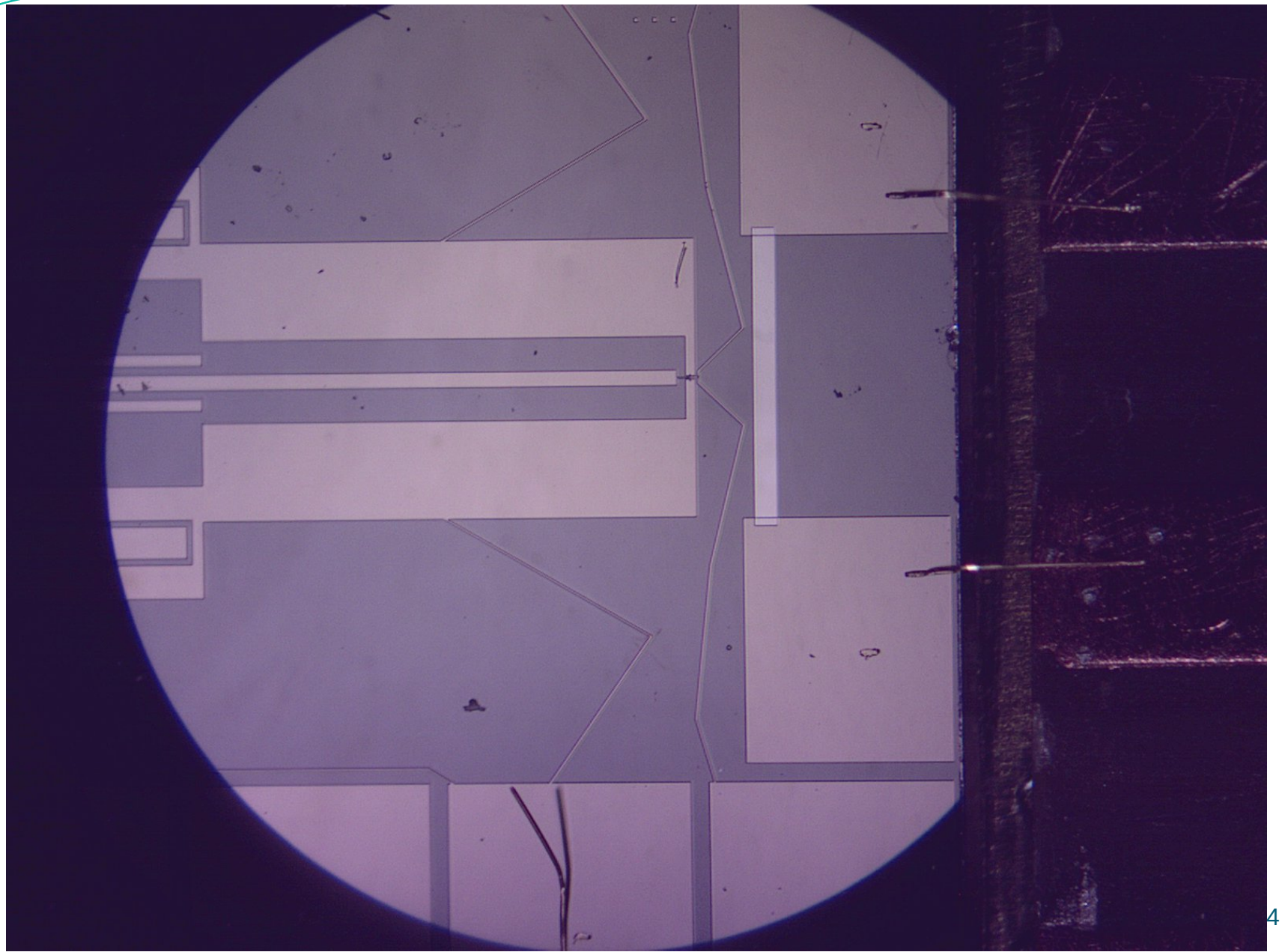




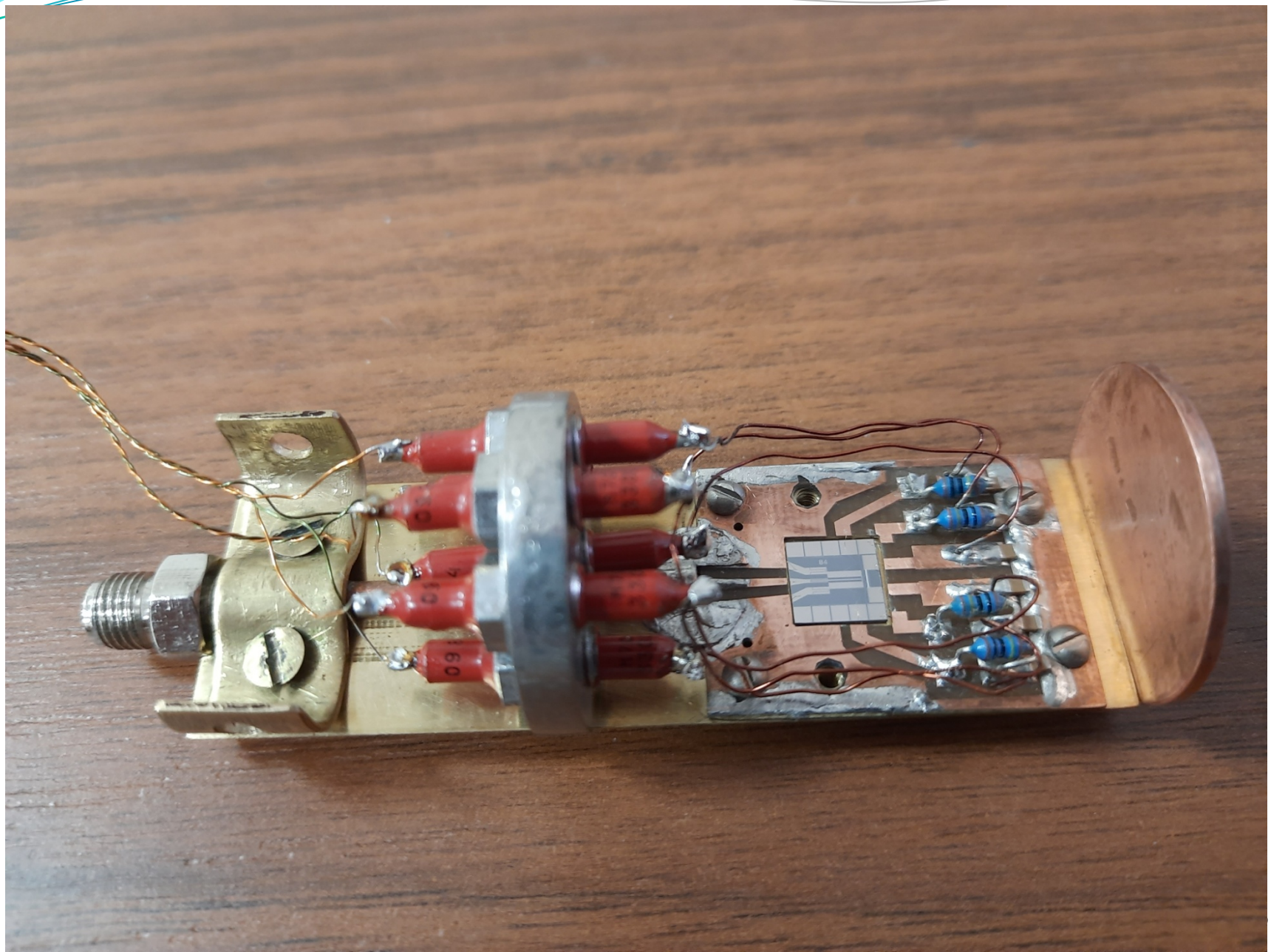
Laboratory of Superconducting Nanoelectronics



Sample photos



Sample photos

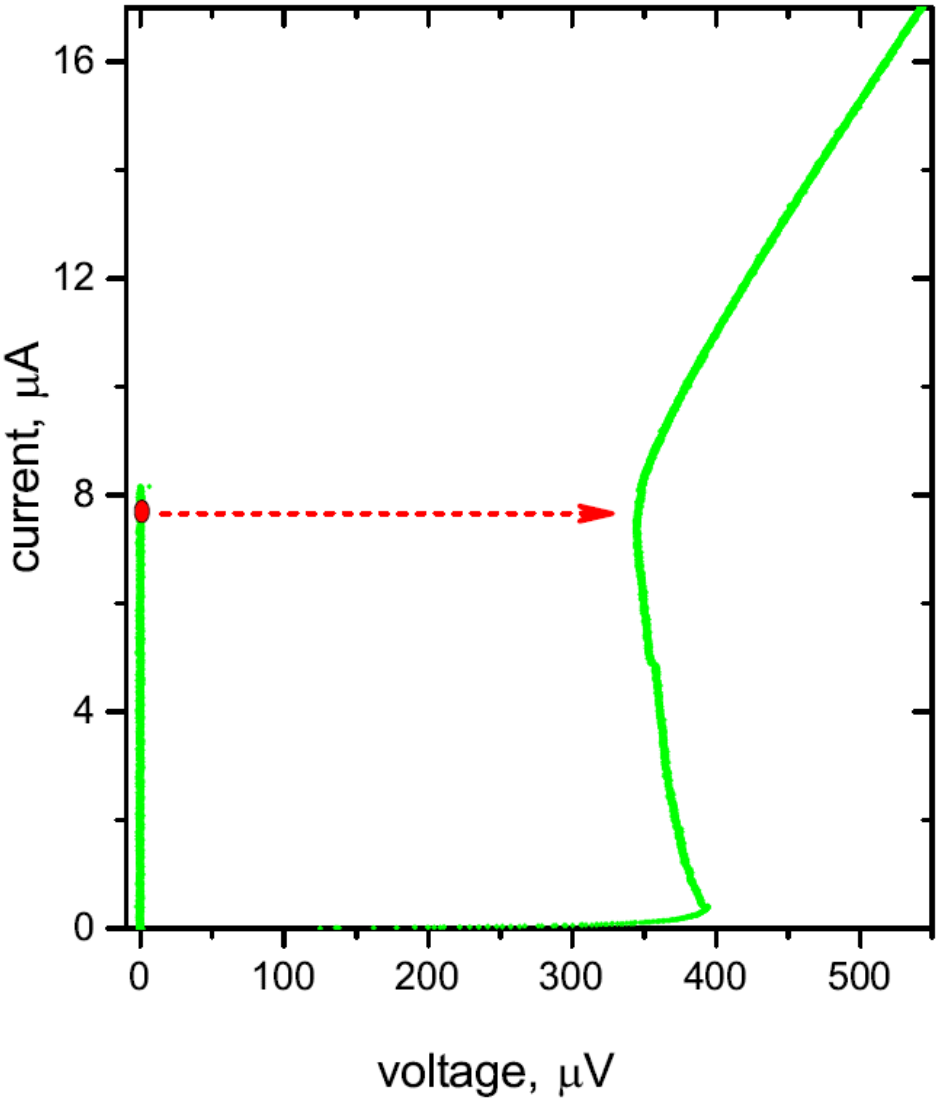


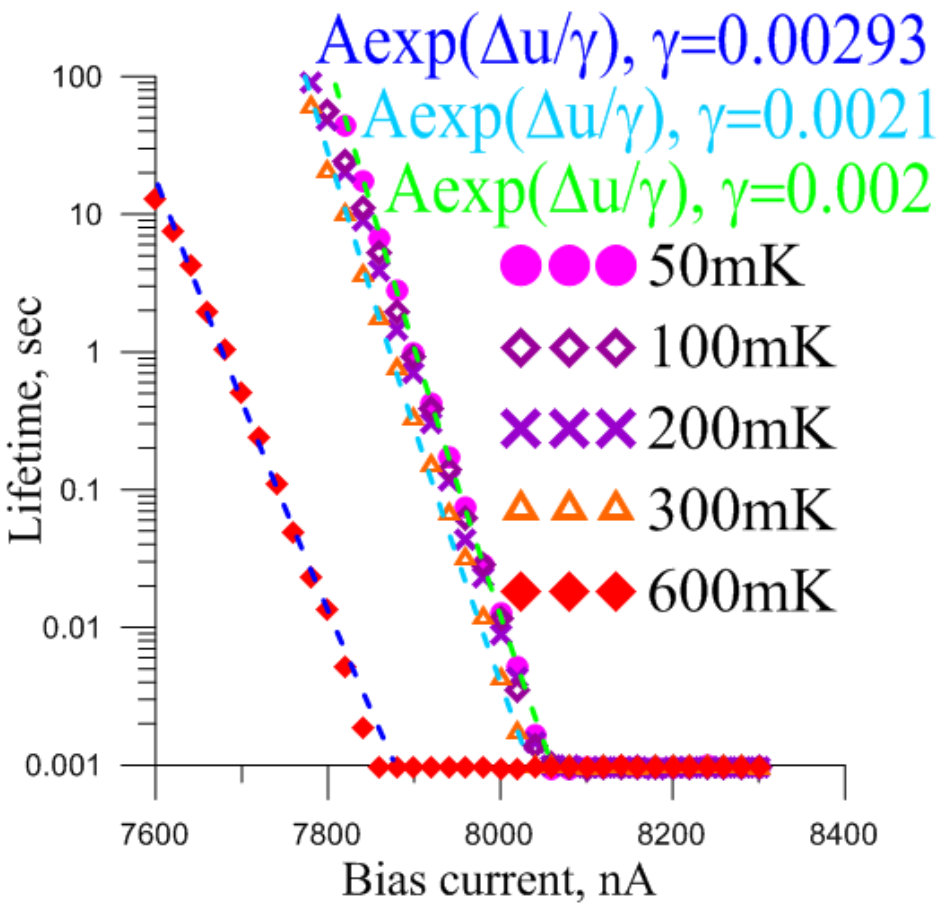
Sample photos

Lifetime (dark count time) for large SIS junctions

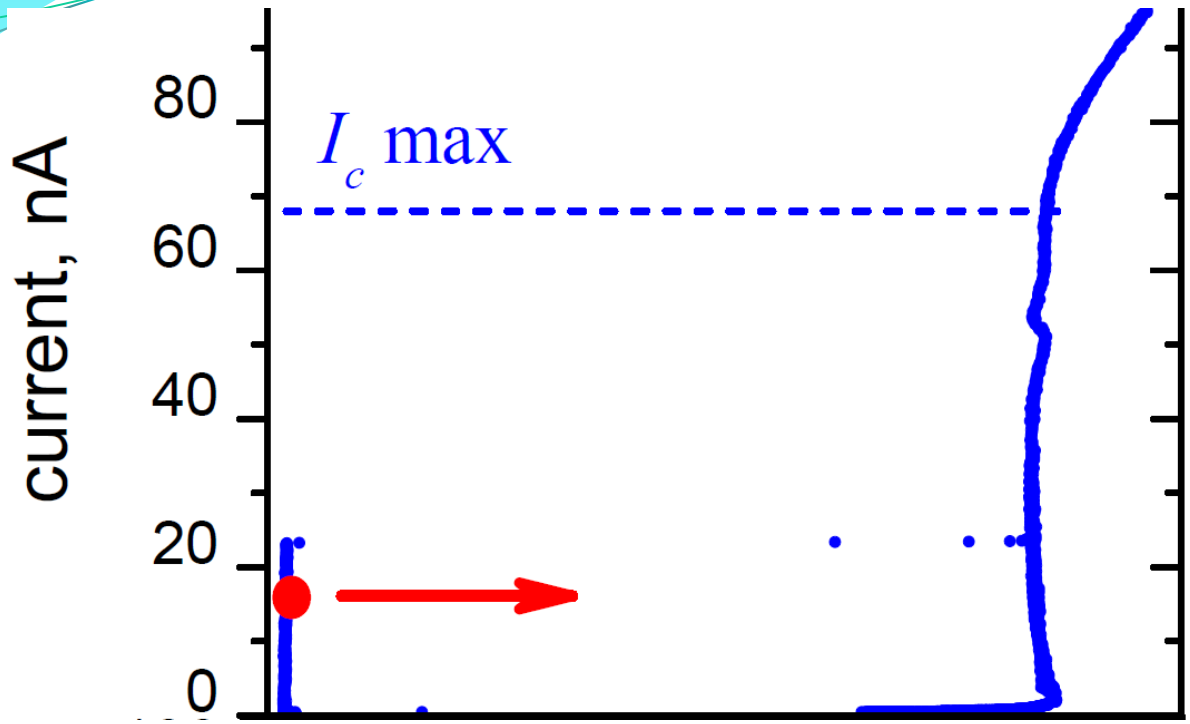
$\gamma = I_T/I_C \qquad I_T\ [\mu A] = 0.042T\ [K]$

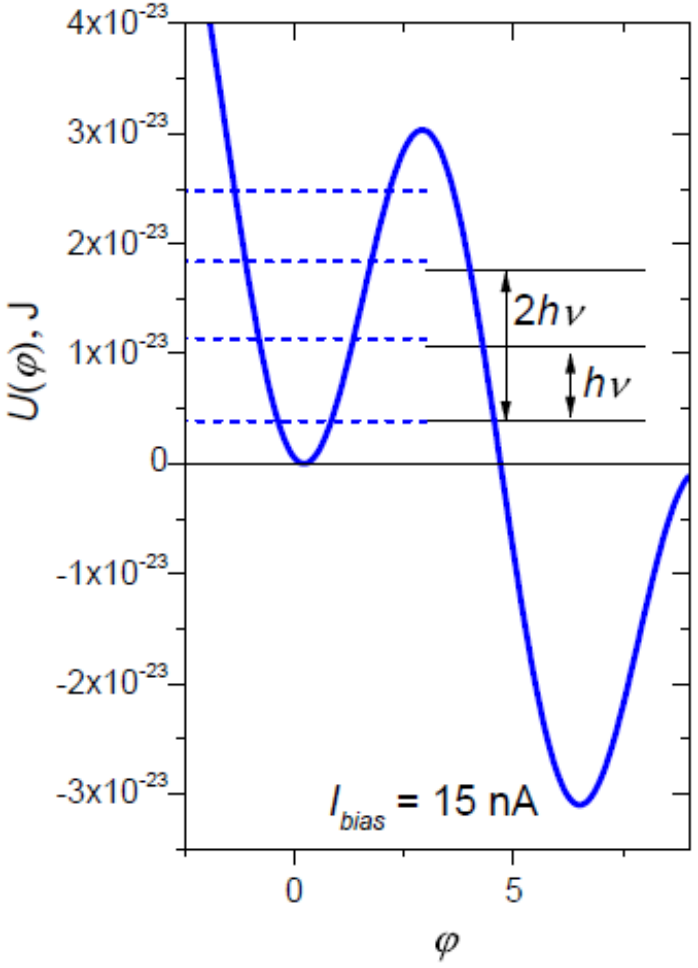
$$\tau = \frac{f(\alpha)\exp(\Delta u/\gamma)}{\sqrt{1-i^2}}$$





Small SIS junctions, 10th nA critical current

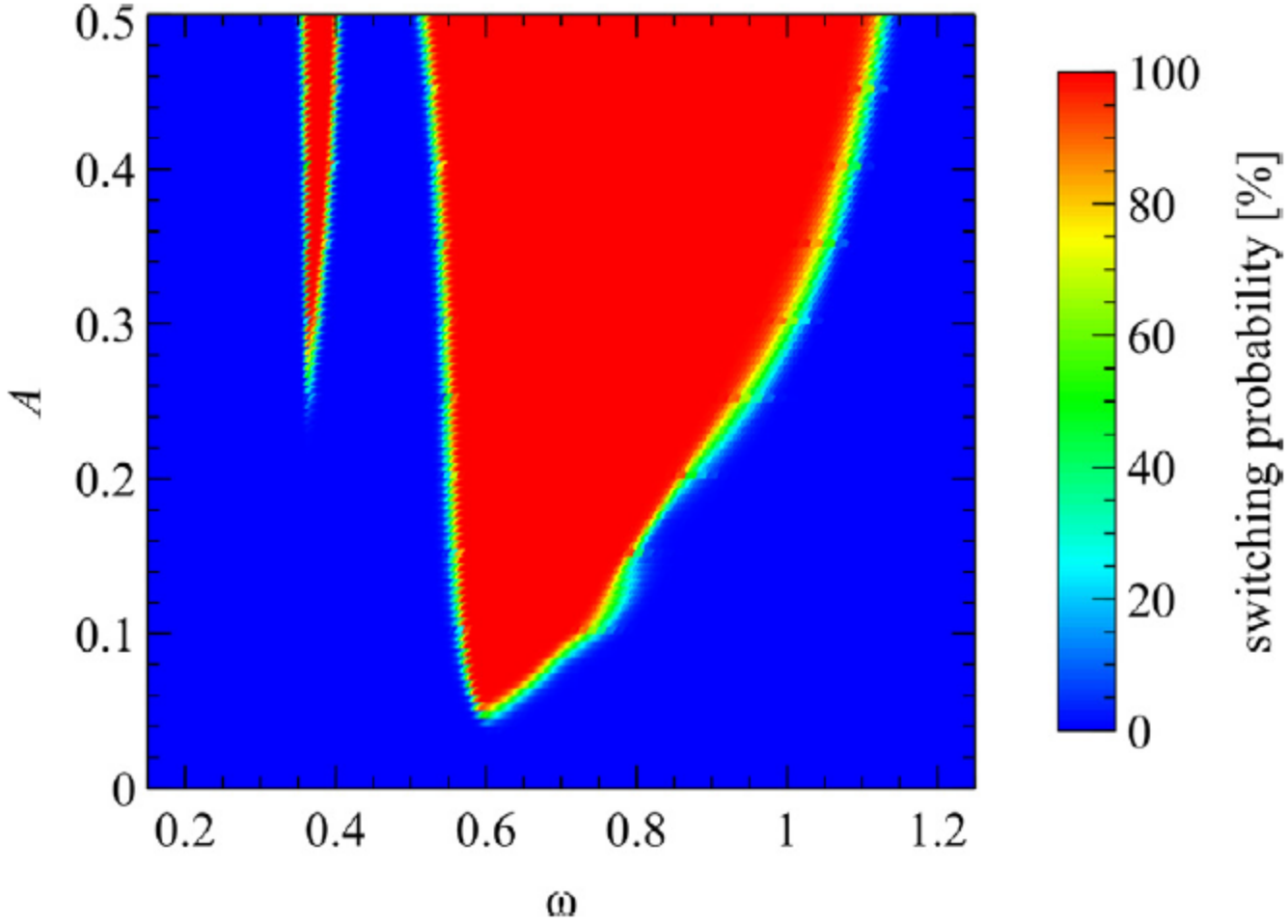




For small junctions critical current is suppressed due to MQT

D.S. Golubev, E.V. Il'ichev, & L.S. Kuzmin, Phys. Rev. Appl. 15, in press (2021).

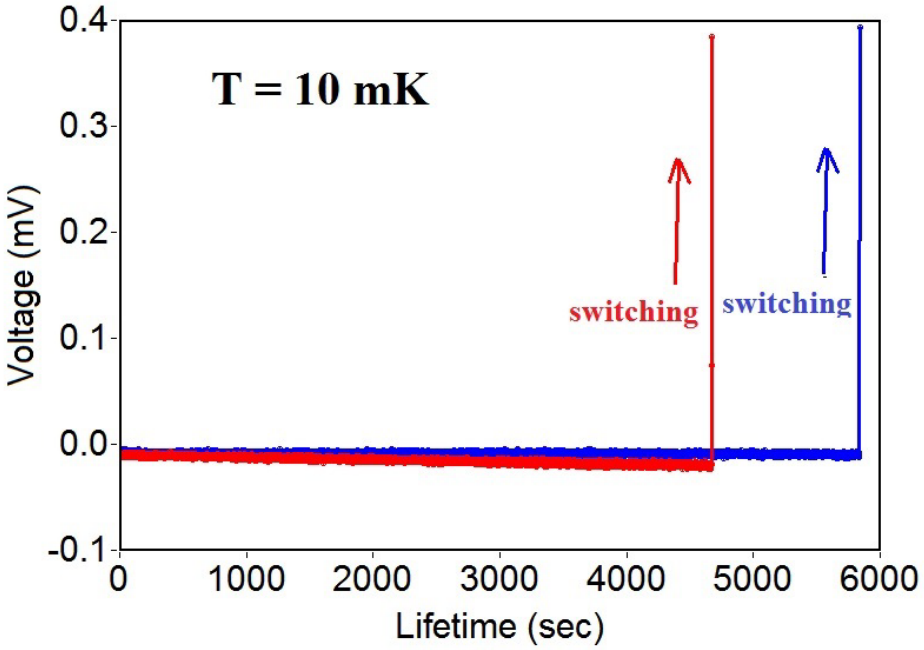
Resonant response drives sensitivity

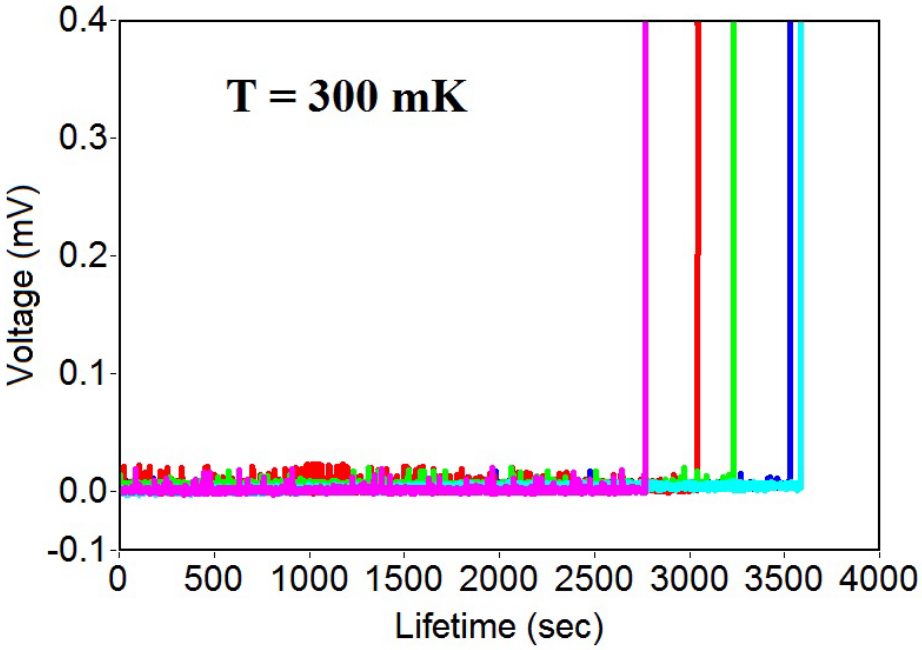


Resonant response drives sensitivity of Josephson Escape Detector

A.A. Yablokov, E.I. Glushkov, A.L. Pankratov, A.V. Gordeeva, L.S. Kuzmin, E.V. Il'ichev, Chaos, Solitons & Fractals 148, 111058 (2021)

Lifetime (dark count time) for small SIS junctions

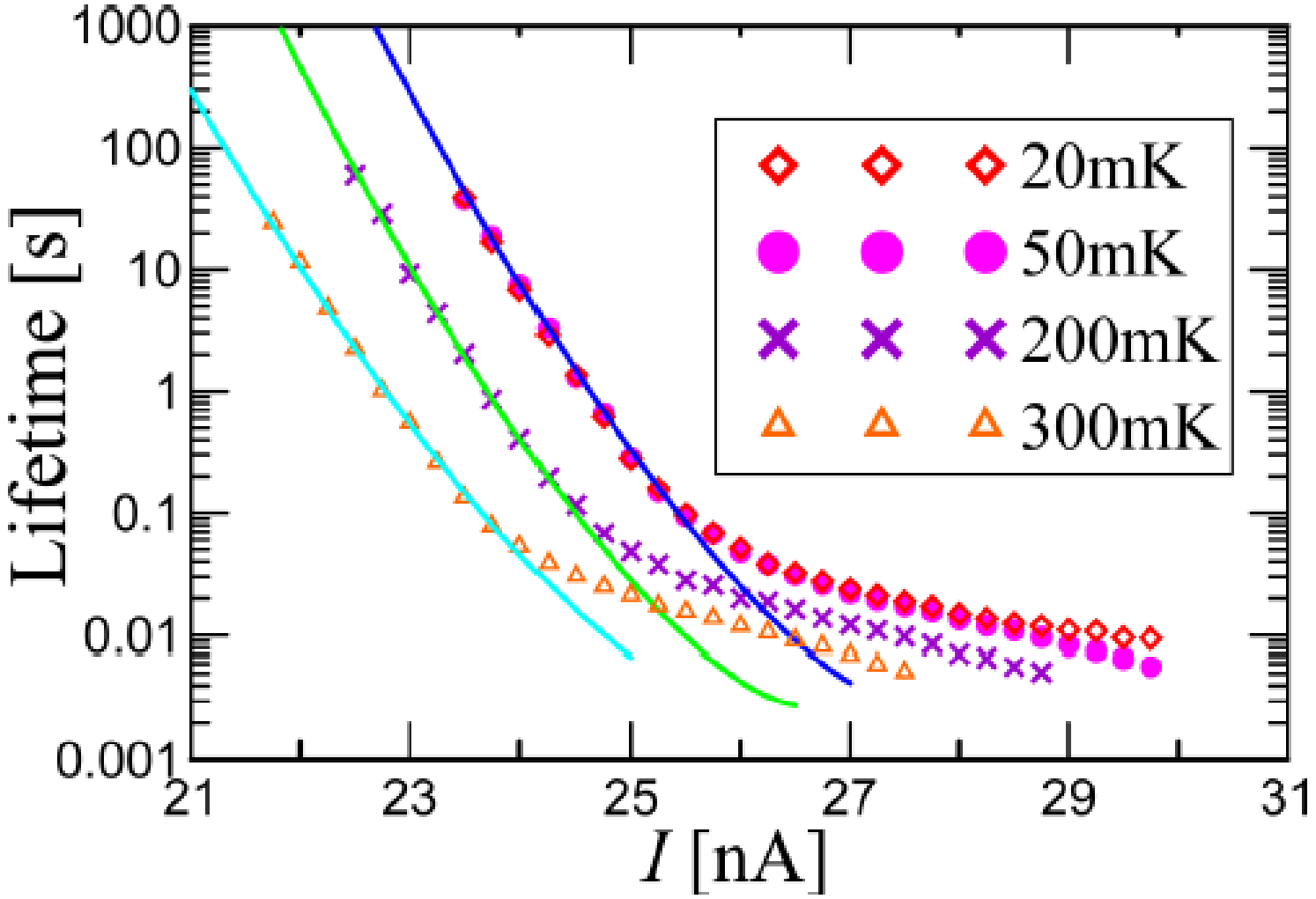




Does Kramers' formula $\tau \sim \exp(\Delta u/\gamma)$ still work ???
Lifetime can be increased by orders of magnitude due to the phase diffusion regime

L.S. Revin, A.L. Pankratov, A.V. Gordeeva, A.A. Yablokov, I.V. Rakut, V.O. Zbrozhek, L.S. Kuzmin, Beilstein J. Nanotechnol. **11,** 960 (2020).

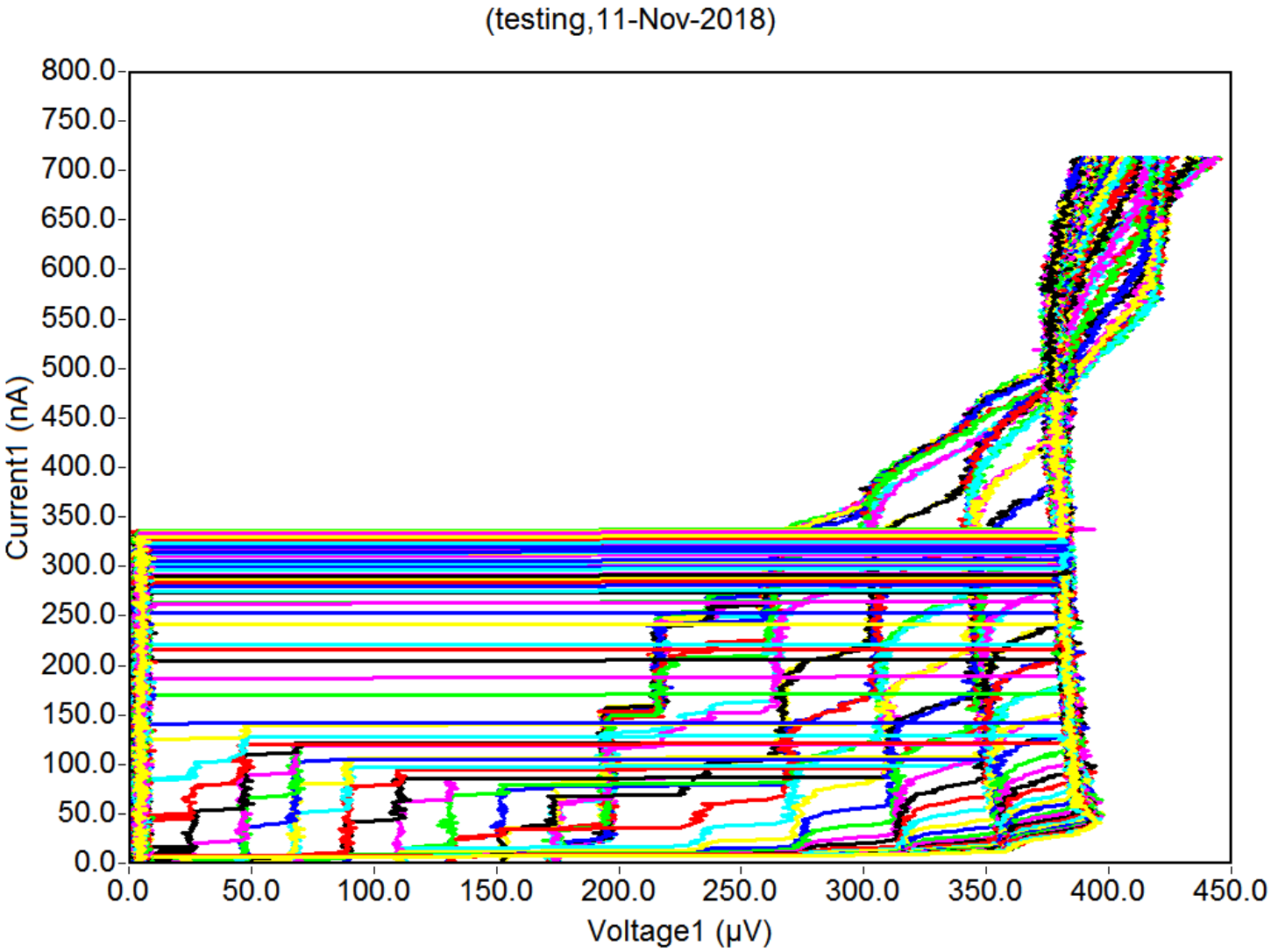
Lifetime (dark count time) for small SIS junctions



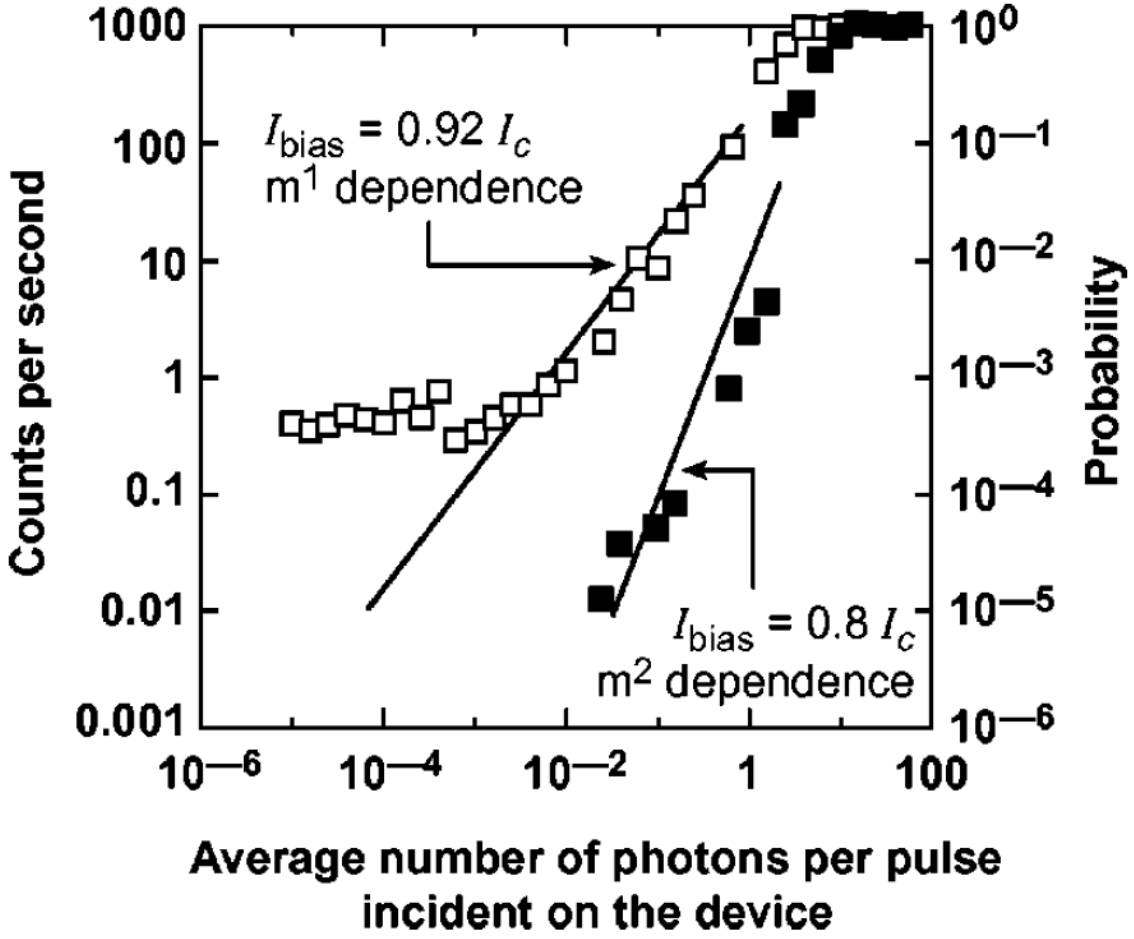
Kramers' formula $\tau \sim \exp(\Delta u/\gamma_{eff})$, but $\gamma_{eff} << \gamma$
Lifetime can be increased by orders of magnitude due to the phase diffusion regime

Calibration of signal power by PAT steps

Problem: absence of microwave single photon sources on-demand
Supplying strongly attenuated harmonic signal



Counting photons by large statistics in IR range

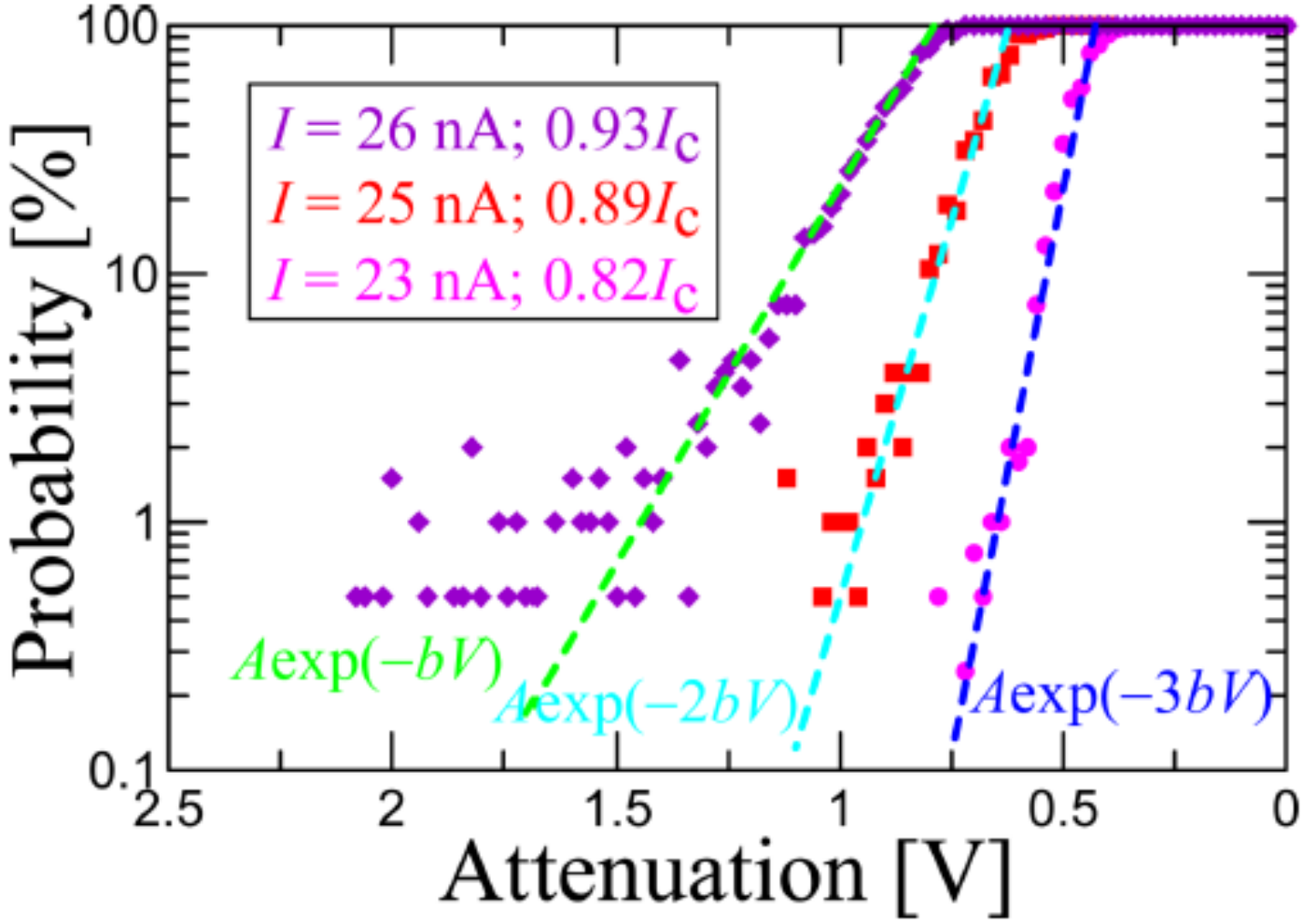


Detection of 140 THz photons at 4 K

G. N. Gol'tsman, O. Okunev, G. Chulkova, A. Lipatov, A. Semenov, K. Smirnov, B. Voronov, and A. Dzardanov, Appl. Phys. Lett., **79**, 705 (2001).

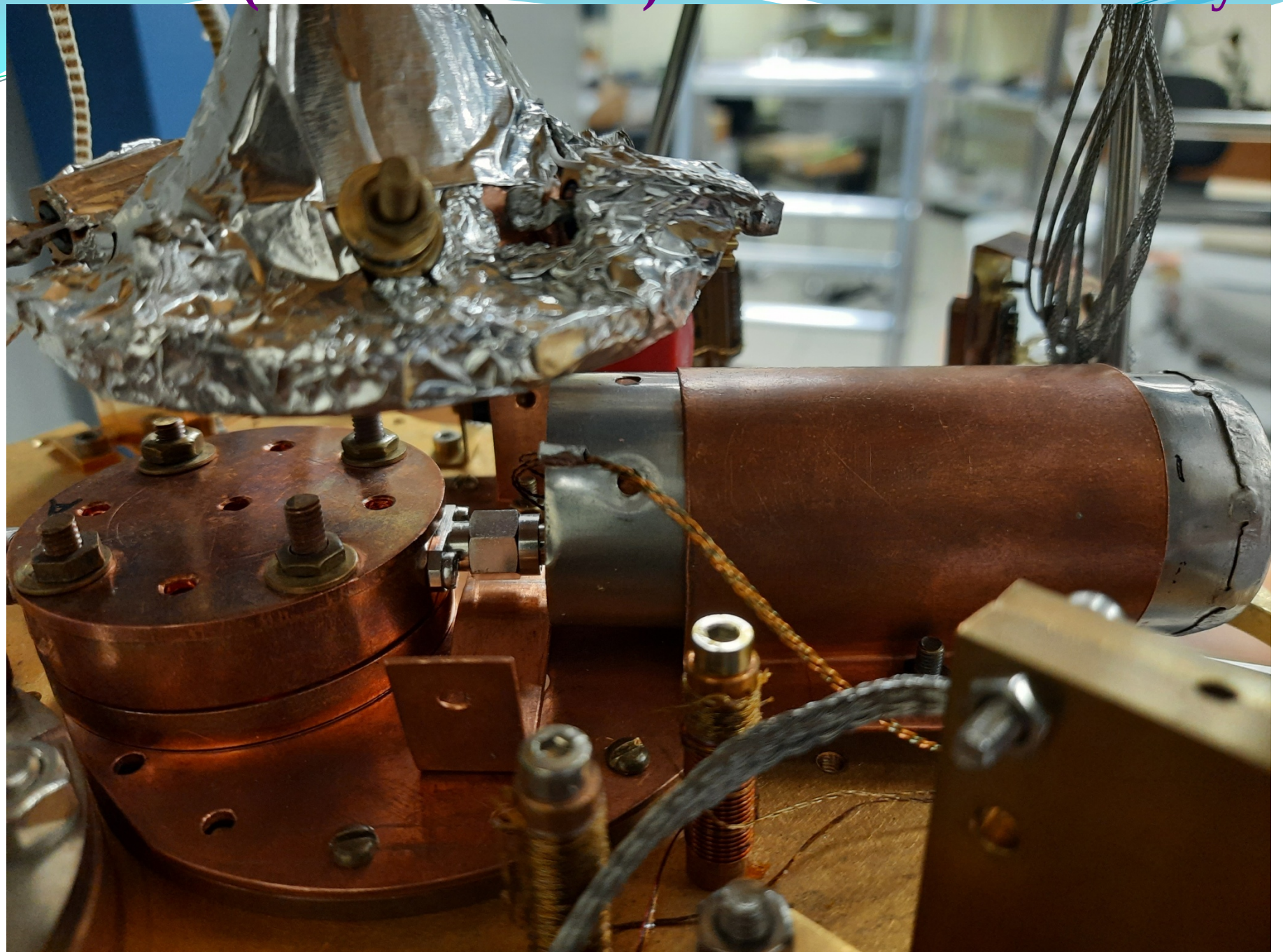
N-photon response to 9 GHz signal at 50 mK

Supplying strongly attenuated harmonic signal giving Poisson distribution of photons

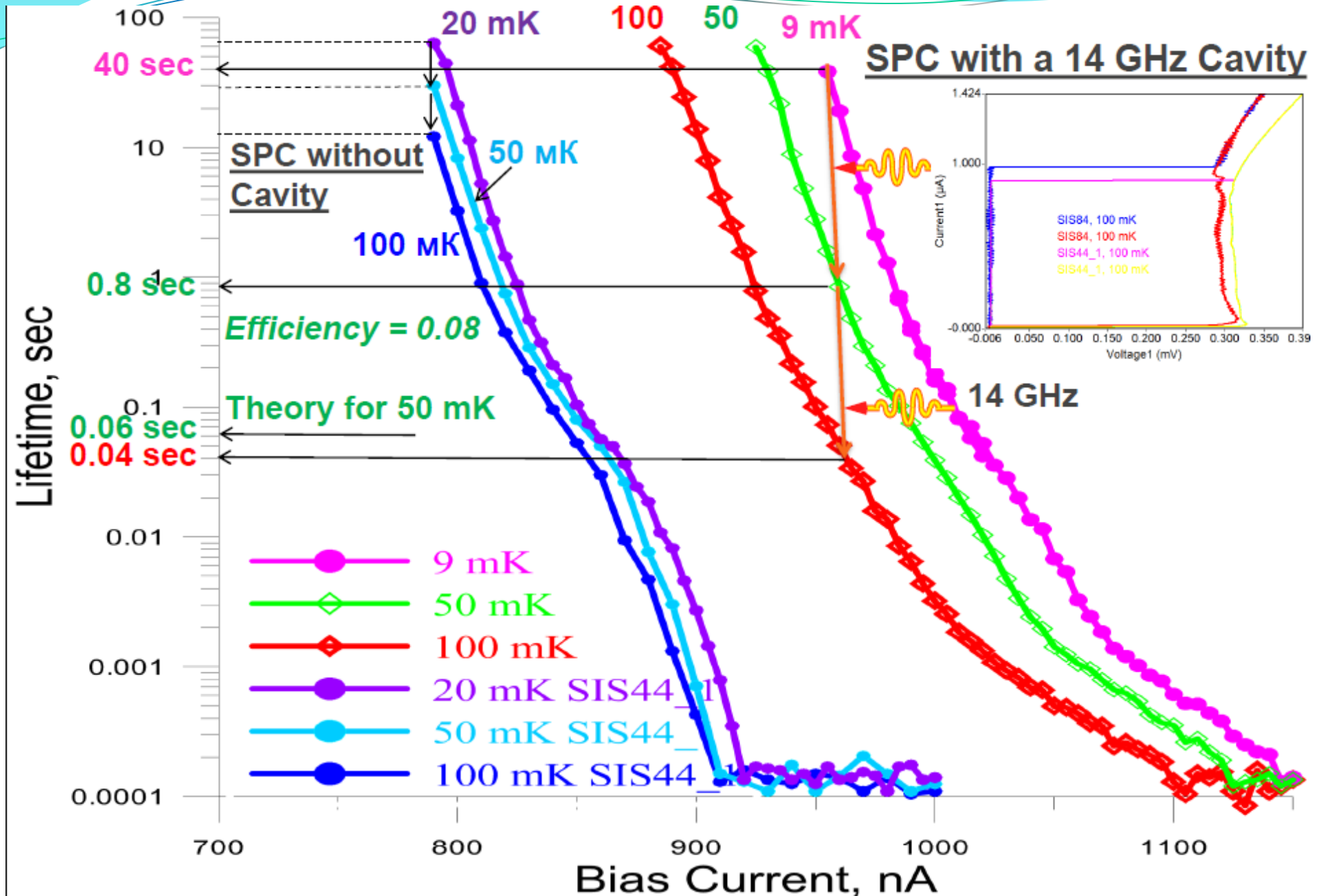


L.S. Revin, A.L. Pankratov, A.V. Gordeeva, A.A. Yablokov, I.V. Rakut, V.O. Zbrozhek, L.S. Kuzmin, Beilstein J. Nanotechnol. **11,** 960 (2020).

Lifetime (dark count time) with and without cavity



Lifetime (dark count time) with and without cavity



Thank you for attention!

Please, send your questions to: alp@ipmras.ru

Here ALP stands for Andrey L. Pankratov