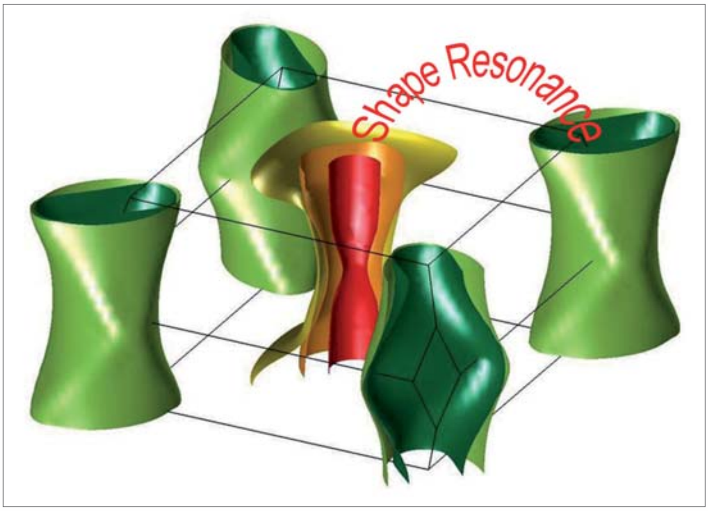
SUPERSTRIPES 2015



edited by

Antonio Bianconi

superstripes press

Superstripes Press

science series

SUPERSTRIPES 2015

Quantum in Complex Matter
Superconductivity, Magnetism & Ferroelectricity

edited by

Antonio Bianconi

superstripes press

science series

Science Series No.6

Title: Superstripes 2015

Published on June 2015
by Superstripes Press, Rome, Italy

http://www.superstripes.net/science/science.htm

ISBN 978-88-6683-038-2
ISBN-A 10.978.886683/0382

Quantum fluctuations in low-dimensional superconductors

K. Yu. Arutyunov[1,2], * J. S. Lehtinen[3] and T. Rantala[3]
[1]*National Research University Higher School of Economics, 101000, Moscow, Russia*
[2]*Kapitza Institute of Physical Problems, Moscow, 119334, Russia*
[3] *Department of Physics, University of Jyvaskyla, PB 35, FI-40014 Jyvaskyla, Finland*

**karutyunov@hse.ru*

Keywords : mesoscopic superconductivity, quantum fluctuations, quantum phase slips

The topic of quantum fluctuations in quasi-1D superconductors, also called *quantum phase slips* (QPS), has recently attracted the significant attention. It has been shown that the phenomenon is capable to suppress the zero resistivity of ultra-narrow superconducting nanowires at low temperatures $T<<T_c$ [1-3] and quench persistent currents in tiny nanorings [4]. The coherent QPS effect enables fabrication of the new generation of quantum logic devices – qubits [5]. It has been predicted that a superconducting nanowire in the regime of QPS is dual to a Josephson junction [6]. In particular case of an extremely narrow superconducting nanowire imbedded in high-impedance environment the duality leads to an intuitively controversial result: the superconductor should enter an insulating state. Here we experimentally demonstrate that the I-V characteristic of such a wire indeed shows Coulomb blockade which disappears with application of a critical magnetic field and/or above the critical temperature proving that the effect is related to superconductivity [7]. Such system can be considered as a junctionless single electron transistor (with charge *2e*), where the QPS provide the dynamic equivalent of weak links in conventional devices containing static (in space and time) tunnel junctions. Application of external RF radiation can be synchronized with the internal Bloch oscillations of charge. The phenomenon is dual to the well-known Shapiro effect: the voltage steps for a Josephson junction are substituted by the current steps for a QPS wire: the proof-of-principle demonstration of the long-awaited metrological application - the quantum standard of electric current [8]. We will also discuss our latest results demonstrating finite noise below the 'residual' critical current and temperature due to the same QPS effect. In ultra-narrow nanowires the quantum fluctuations of the amplitude of the order parameter result in smearing of the energy gap edge, which has been measured in tunneling experiments. **This study (research grant No** 15-01-0153**) was supported by The National Research University–Higher School of Economics' Academic Fund Program in 2015-2016**.

References

1. N. Giordano, **Phys. Rev. Lett**. 61, 2137 (1988); N. Giordano and E. R. Schuler, **Phys. Rev. Lett.** 63, 2417 (1989); N. Giordano, **Physica B** 43, 460 (1994).
2. A. Bezryadin, C. N. Lau, and M. Tinkham, **Nature** 404, 971 (2000); C. N. Lau, N. Markovic, M. Bockrath, A. Bezryadin, and M. Tinkham, **Phys. Rev. Lett**. 87, 217003 (2001).
3. M. Zgirski, K.-P. Riikonen, V. Touboltsev, and K. Yu. Arutyunov, **NanoLett**. 5, 1029 (2005); M. Zgirski, K.-P. Riikonen, V. Touboltsev and K.Yu. Arutyunov, **Phys. Rev. B**. **77**, 054508 (2008); J. S. Lehtinen, T. Sajavaara, K. Yu. Arutyunov, M. Yu. Presnjakov and A. Vasiliev, **Phys. Rev. B** 85, 094508 (2012).
4. K. Yu. Arutyunov, T. T. Hongisto, J. S. Lehtinen, L. I. Leino, and A. L. Vasiliev. **Nature: Sci. Rep.** 2, 293 (2012).
5. O. V. Astafiev, L. B. Ioffe, S. Kafanov, Yu. A. Pashkin, K. Yu. Arutyunov, D. Shahar, O. Cohen, & J. S. Tsai, **Nature** 484, 355 (2012).
6. J. E. Mooij and Yu. V. Nazarov, **Nature Physics** 2, 169 (2006).
7. J. S. Lehtinen, T. Rantala and K. Yu. Arutyunov, **arXiv.1311.3202** (2013).
8. J. Lehtinen, K. Zakharov and K. Arutyunov, **Phys. Rev. Lett.** 109, 187001 (2012).

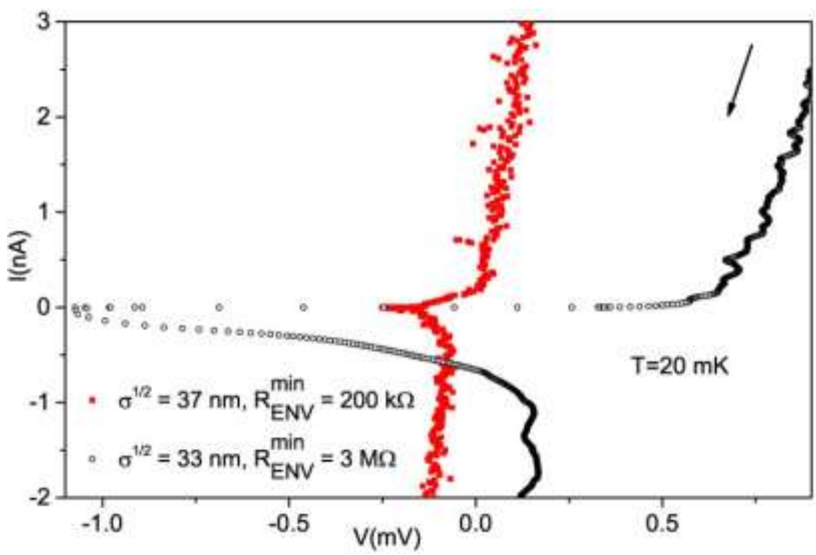


Figure 1: Coulomb blockade of two titanium nanowires with close values of cross section and significantly different impedance of the environment. Arrow indicates the direction of data recording.