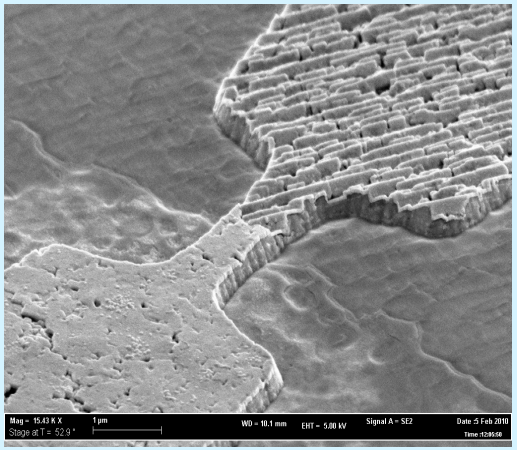
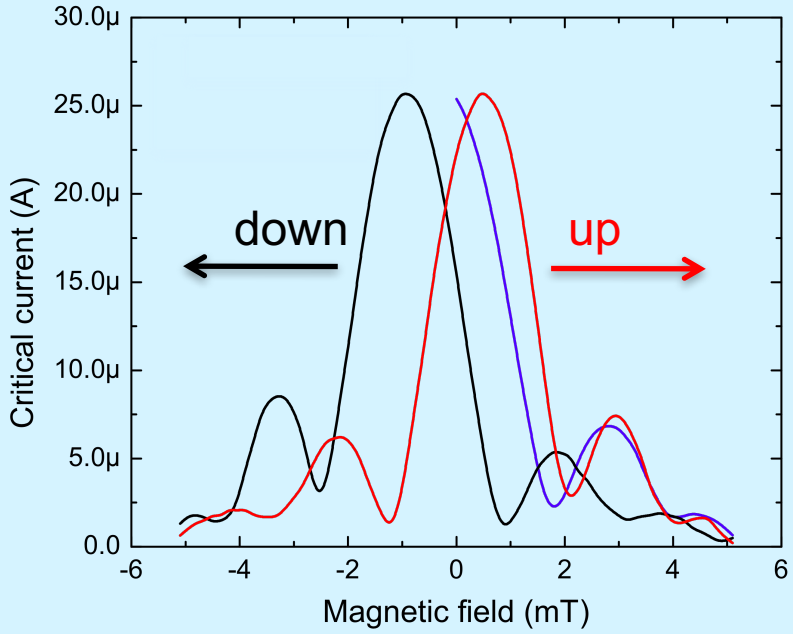
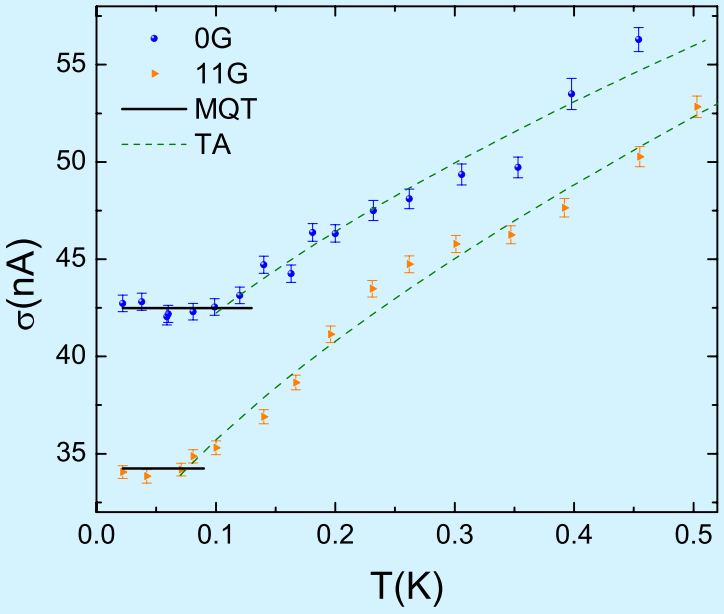
Phase dynamics and macroscopic quantum phenomena in hybrid Josephson junctions







Davide Massarotti

13th European Conference on Applied Superconductivity

September 19, Geneva

D. Massarotti, R. Caruso, D. Stornaiuolo, P. Lucignano, G. Rotoli, L. Longobardi, G. P. Pepe, A. Tagliacozzo, F. Tafuri

Dipartimento di Fisica, Università degli Studi di Napoli Federico II & CNR-SPIN UOS Napoli, Italy

A. Pal, M. G. Blamire

Department of Materials Science and Metallurgy, University of Cambridge, UK

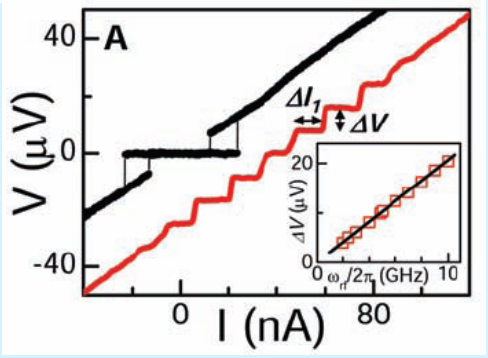
T. Bauch, F. Lombardi

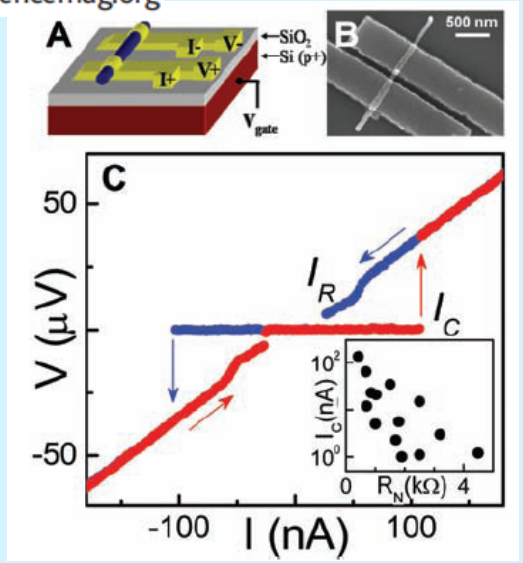
Chalmers University of Technology, Goteborg, Sweden

8 JULY 2005 VOL 309 SCIENCE www.sciencemag.org

Tunable Supercurrent Through Semiconductor Nanowires

Yong-Joo Doh,[1*] Jorden A. van Dam,[1*] Aarnoud L. Roest,[1,2] Erik P. A. M. Bakkers,[2] Leo P. Kouwenhoven,[1] Silvano De Franceschi[1†]





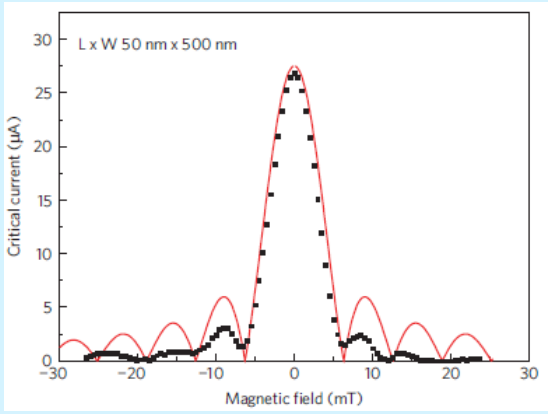
nature materials

LETTERS

PUBLISHED ONLINE: 19 FEBRUARY 2012 | DOI: 10.1038/NMAT3255

Josephson supercurrent through a topological insulator surface state

M. Veldhorst[1], M. Snelder[1], M. Hoek[1], T. Gang[1], V. K. Guduru[2], X. L. Wang[3], U. Zeitler[2], W. G. v. d. Wiel[1], A. A. Golubov[1], H. Hilgenkamp[1,4] and A. Brinkman[1]*

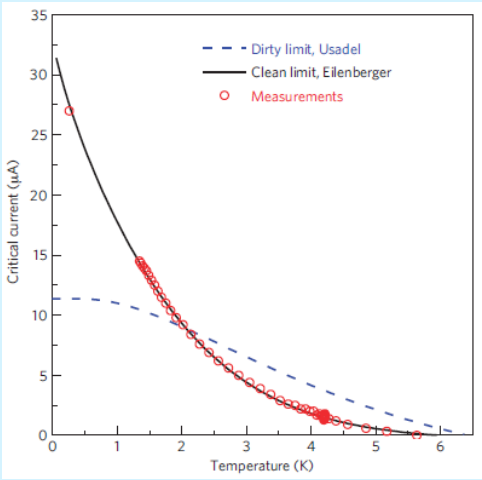


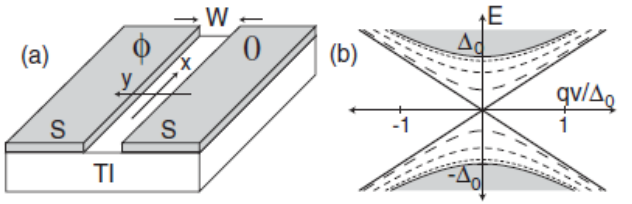
PRL 100, 096407 (2008) PHYSICAL REVIEW LETTERS week ending 7 MARCH 2008

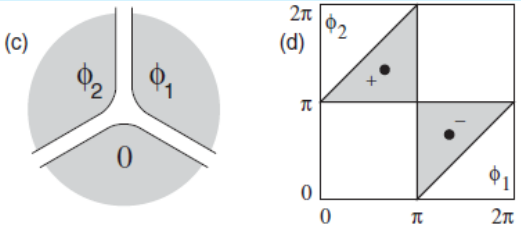
Superconducting Proximity Effect and Majorana Fermions at the Surface of a Topological Insulator

Liang Fu and C. L. Kane

We study the proximity effect between an s-wave superconductor and the surface states of a strong topological insulator. The resulting two-dimensional state resembles a spinless $p_x + ip_y$ superconductor, but does not break time reversal symmetry. This state supports Majorana bound states at vortices. We show that linear junctions between superconductors mediated by the topological insulator form a nonchiral one-dimensional wire for Majorana fermions, and that circuits formed from these junctions provide a method for creating, manipulating, and fusing Majorana bound states.



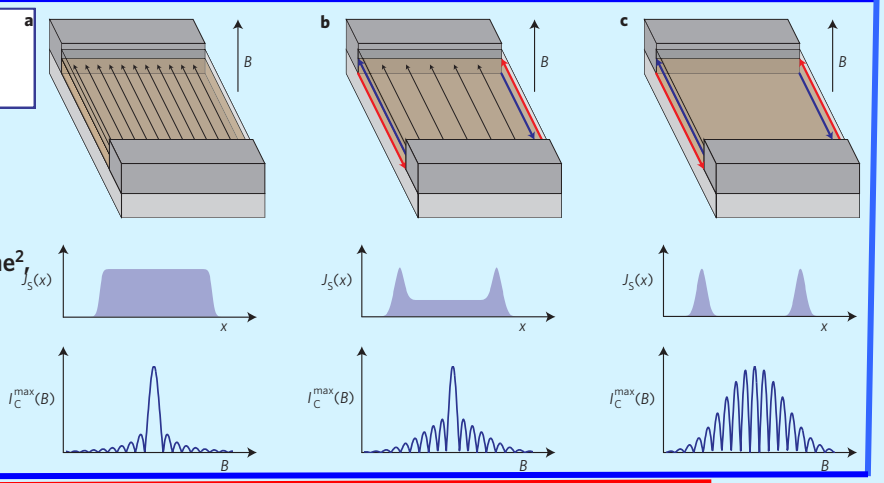




LETTERS
PUBLISHED ONLINE: 3 AUGUST 2014 | DOI: 10.1038/NPHYS3036
nature physics

Induced superconductivity in the quantum spin Hall edge

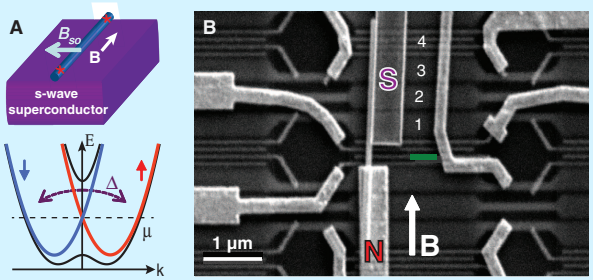
Sean Hart[1†], Hechen Ren[1†], Timo Wagner[1], Philipp Leubner[2], Mathias Mühlbauer[2], Christoph Brüne[2], Hartmut Buhmann[2], Laurens W. Molenkamp[2] and Amir Yacoby[1*]

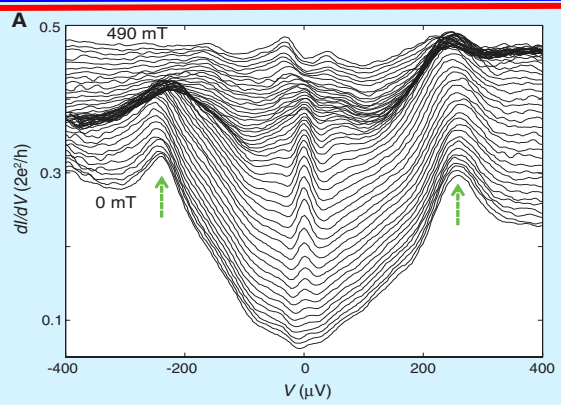


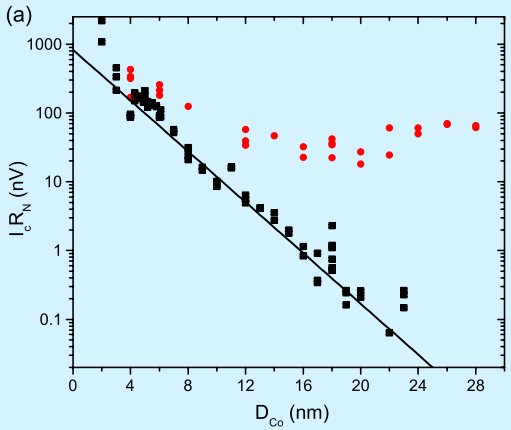
REPORTS www.sciencemag.org SCIENCE VOL 336 25 MAY 2012

Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices

V. Mourik,[1*] K. Zuo,[1*] S. M. Frolov,[1] S. R. Plissard,[2] E. P. A. M. Bakkers,[1,2] L. P. Kouwenhoven[1†]







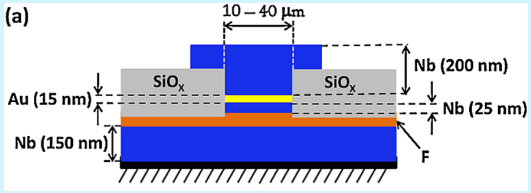
PRL 104, 137002 (2010) PHYSICAL REVIEW LETTERS week ending 2 APRIL 2010

Observation of Spin-Triplet Superconductivity in Co-Based Josephson Junctions

Trupti S. Khaire, Mazin A. Khasawneh, W. P. Pratt, Jr., and Norman O. Birge*

Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824-2320, USA

(Received 1 December 2009; published 29 March 2010)

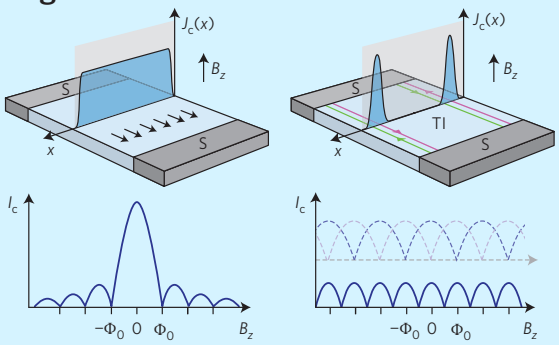


Dissipation in hybrid JJs

nature nanotechnology
LETTERS
PUBLISHED ONLINE: 11 MAY 2015 | DOI: 10.1038/NNANO.2015.86

Edge-mode superconductivity in a two-dimensional topological insulator

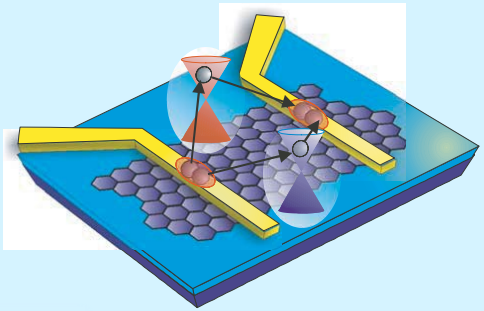
Vlad S. Pribiag[1†‡], Arjan J. A. Beukman[1‡], Fanming Qu[1‡], Maja C. Cassidy[1], Christophe Charpentier[2], Werner Wegscheider[2] and Leo P. Kouwenhoven[1*]



LETTERS
nature Vol 446|1 March 2007|doi:10.1038/nature05555

Bipolar supercurrent in graphene

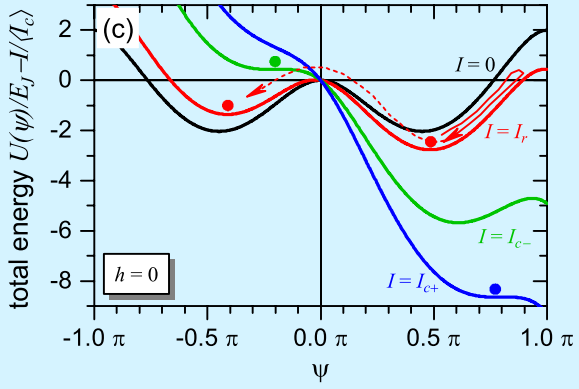
Hubert B. Heersche[1*], Pablo Jarillo-Herrero[1*], Jeroen B. Oostinga[1], Lieven M. K. Vandersypen[1] & Alberto F. Morpurgo[1]

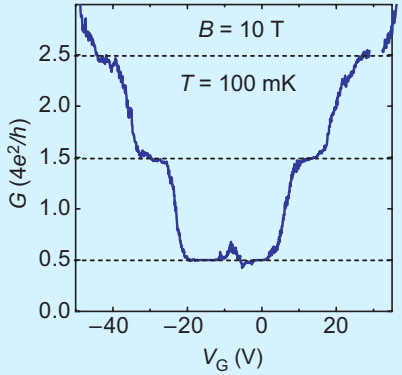


PRL 109, 107002 (2012) PHYSICAL REVIEW LETTERS week ending 7 SEPTEMBER 2012

Experimental Evidence of a φ Josephson Junction

H. Sickinger,[1] A. Lipman,[2] M. Weides,[3] R. G. Mints,[2] H. Kohlstedt,[4] D. Koelle,[1] R. Kleiner,[1] and E. Goldobin[1]





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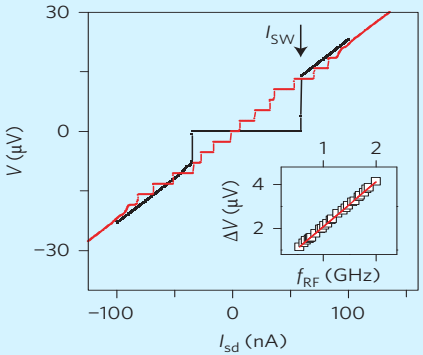

PRL 109, 107002 (2012) PHYSICAL REVIEW LETTERS week ending 7 SEPTEMBER 2012

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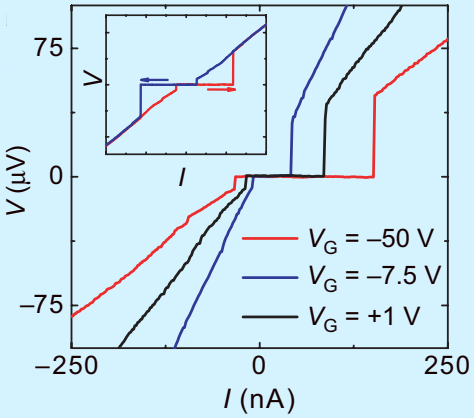

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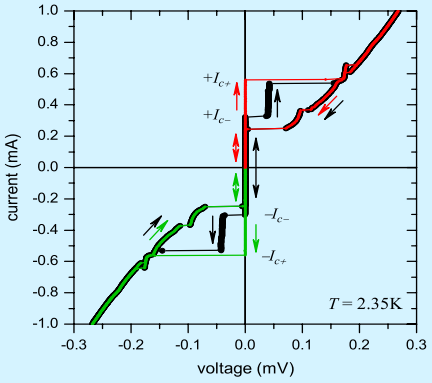

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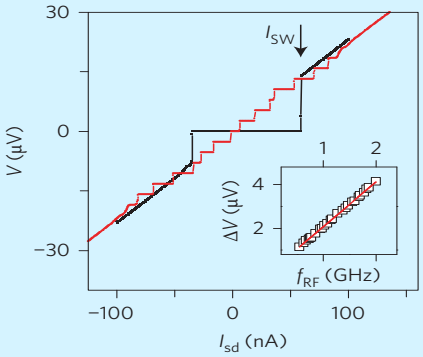

LETTERS
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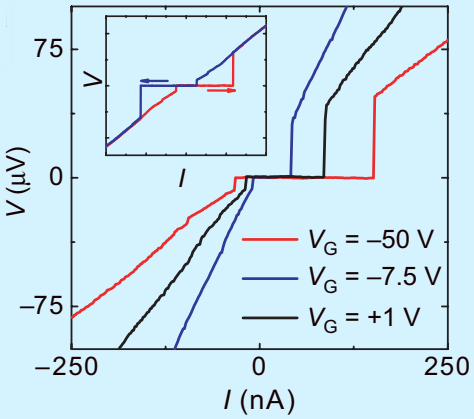
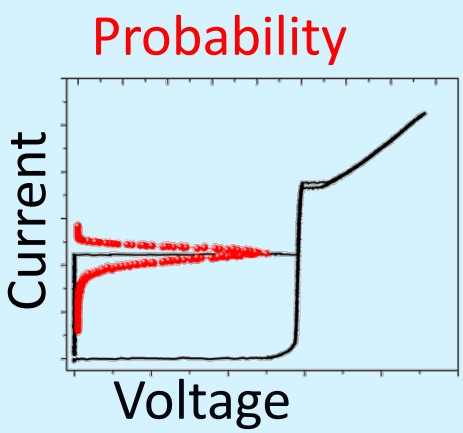
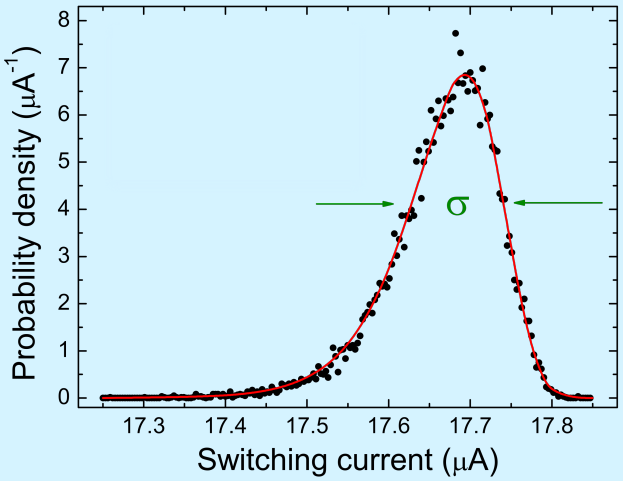
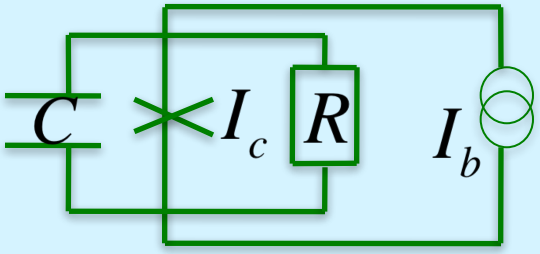






Phase dynamics of current biased JJ

RCSJ model



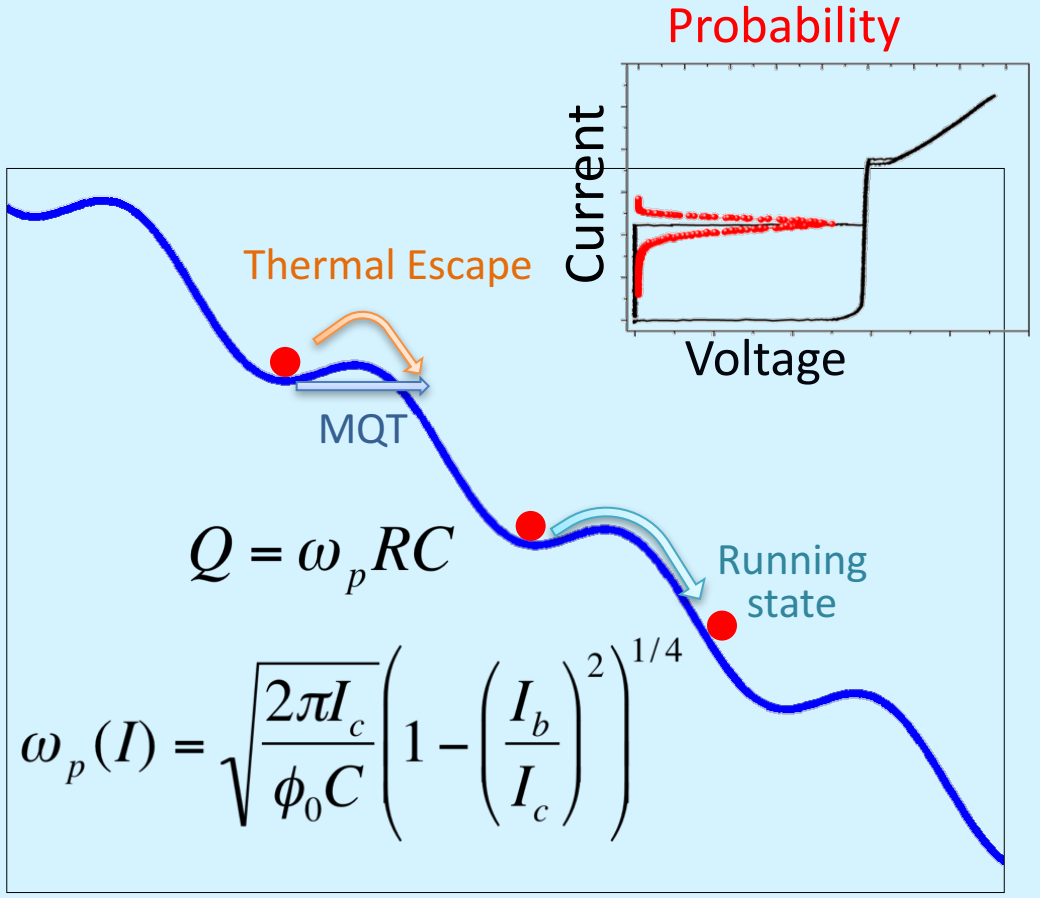
$$C\left(\frac{\phi_0}{2\pi}\right)^2\frac{\partial^2\varphi}{\partial t^2}+\frac{1}{R}\left(\frac{\phi_0}{2\pi}\right)^2\frac{\partial\varphi}{\partial t}+\frac{\partial U}{\partial t}=0$$

Washboard potential

$$U=-E_J\left(\cos\varphi+\frac{I_b}{I_c}\varphi\right)$$

$$\phi_0=h/2e$$

$$E_J=\phi_0 I_c/2\pi$$



Phase dynamics of current biased JJ

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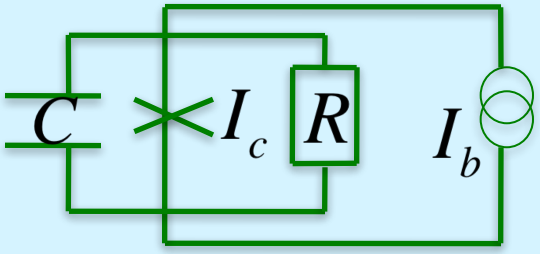


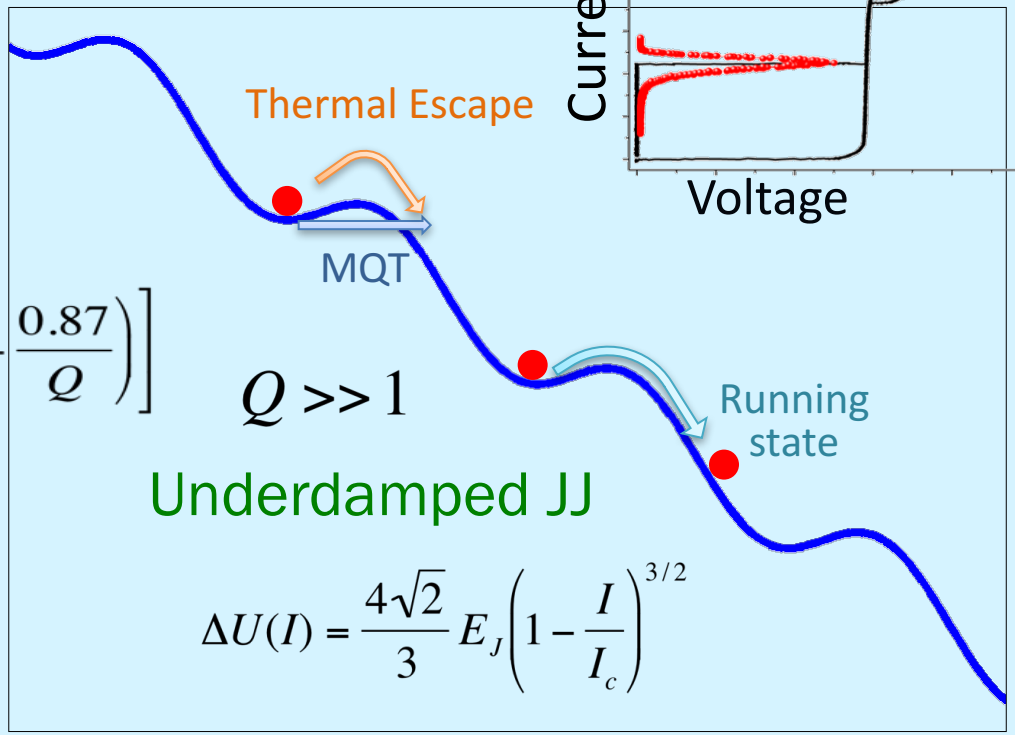
Probability density of switching

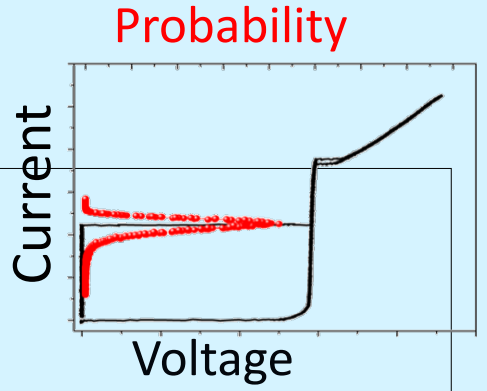
$$P(I) = \frac{\Gamma(I)}{\Delta I/\Delta t} e^{-\int_0^I \frac{\Gamma(I)}{\Delta I/\Delta t} dI}$$

Escape rates

$$\Gamma_T(I) = a_T(I)\frac{\omega_p(I)}{2\pi}\exp\left[-\frac{\Delta U(I)}{k_B T}\right]$$

$$\Gamma_Q(I) = a_q(I)\frac{\omega_p(I)}{2\pi}\exp\left[-7.2\frac{\Delta U(I)}{\hbar\omega_p(I)}\left(1+\frac{0.87}{Q}\right)\right]$$





Macroscopic quantum tunneling

VOLUME 55, NUMBER 18 PHYSICAL REVIEW LETTERS 28 OCTOBER 1985

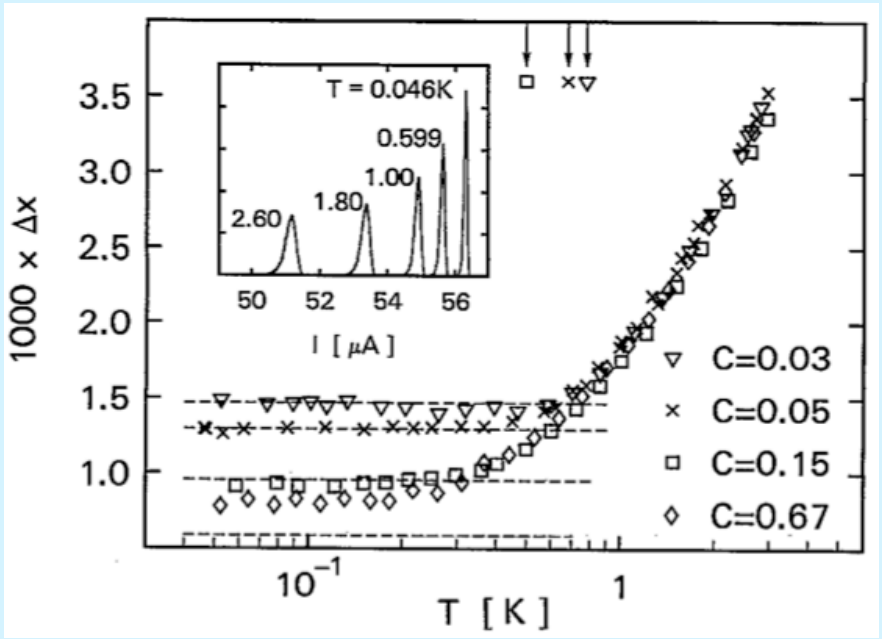
Measurements of Macroscopic Quantum Tunneling out of the Zero-Voltage State of a Current-Biased Josephson Junction

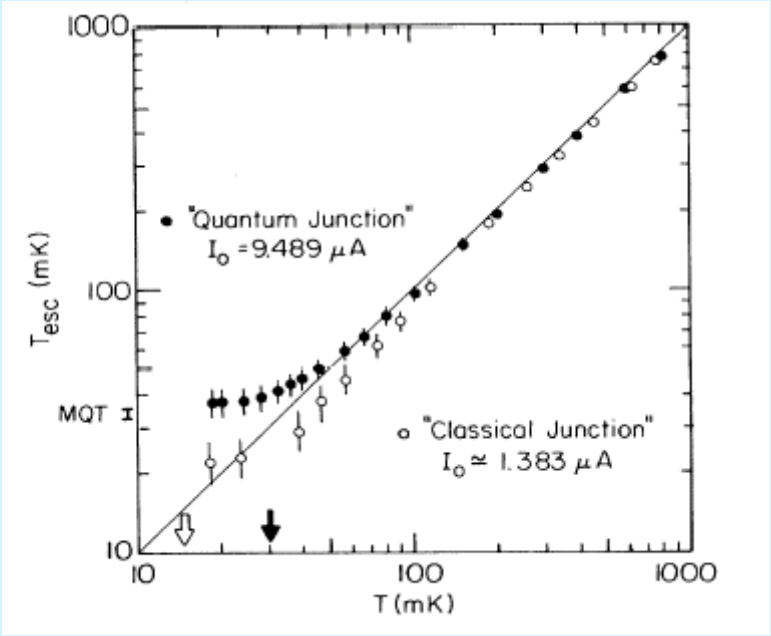
Michel H. Devoret,[a] John M. Martinis, and John Clarke
Department of Physics, University of California, Berkeley, California 94720, and Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, California 94720
(Received 26 July 1985)

VOLUME 54, NUMBER 25 PHYSICAL REVIEW LETTERS 24 JUNE 1985

Effects of Dissipation and Temperature on Macroscopic Quantum Tunneling

S. Washburn, R. A. Webb, R. F. Voss, and S. M. Faris[a]
IBM T. J. Watson Research Center, Yorktown Heights, New York 10598
(Received 26 December 1984)





$$T_{cross} = \frac{\hbar\omega_p}{2\pi k_B}\left[\left(1+\frac{1}{4Q^2}\right)^{1/2} - \frac{1}{2Q}\right]$$

Macroscopic quantum tunneling

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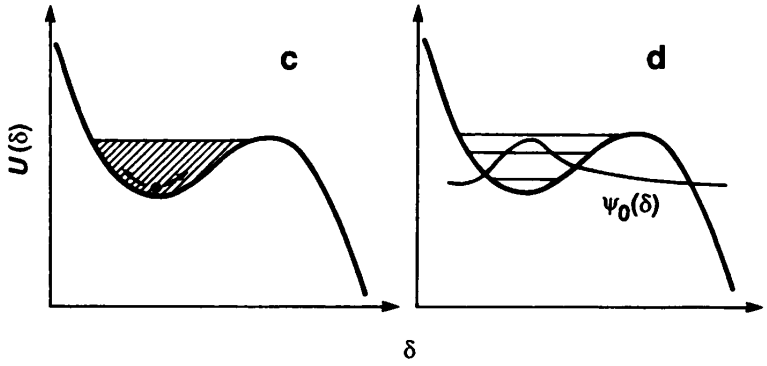
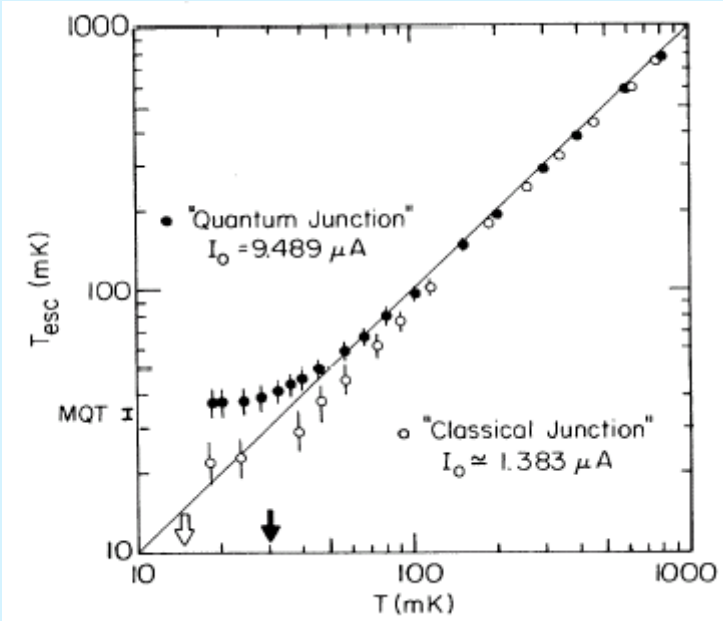
SCIENCE, VOL. 239 26 FEBRUARY 1988

Quantum Mechanics of a Macroscopic Variable: The Phase Difference of a Josephson Junction

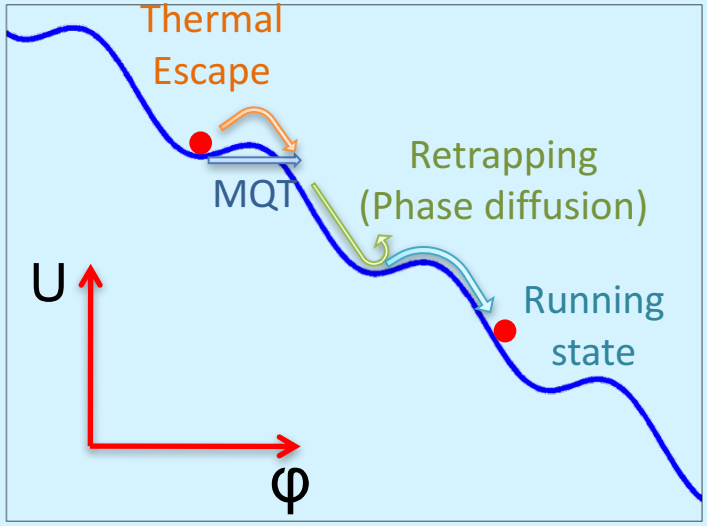
JOHN CLARKE, ANDREW N. CLELAND, MICHEL H. DEVORET, DANIEL ESTEVE, JOHN M. MARTINIS





$$T_{cross} = \frac{\hbar\omega_p}{2\pi k_B}\left[\left(1+\frac{1}{4Q^2}\right)^{1/2} - \frac{1}{2Q}\right]$$

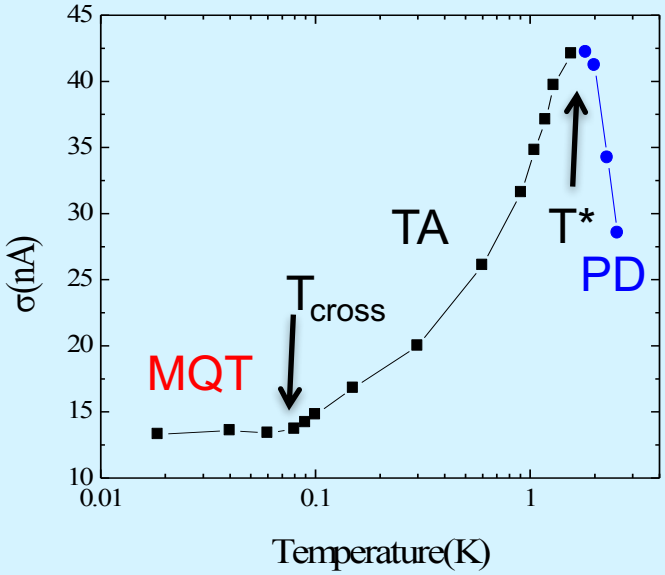
Moderately damped JJs

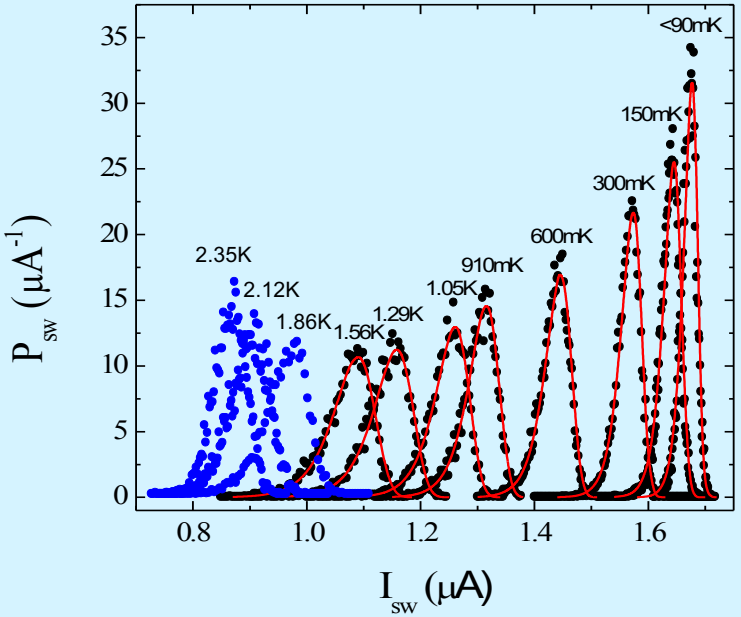


In a **'nano-world'**, reduction of I_c leads to a reduction of Q

increase in dissipation

$$Q \geq 1$$





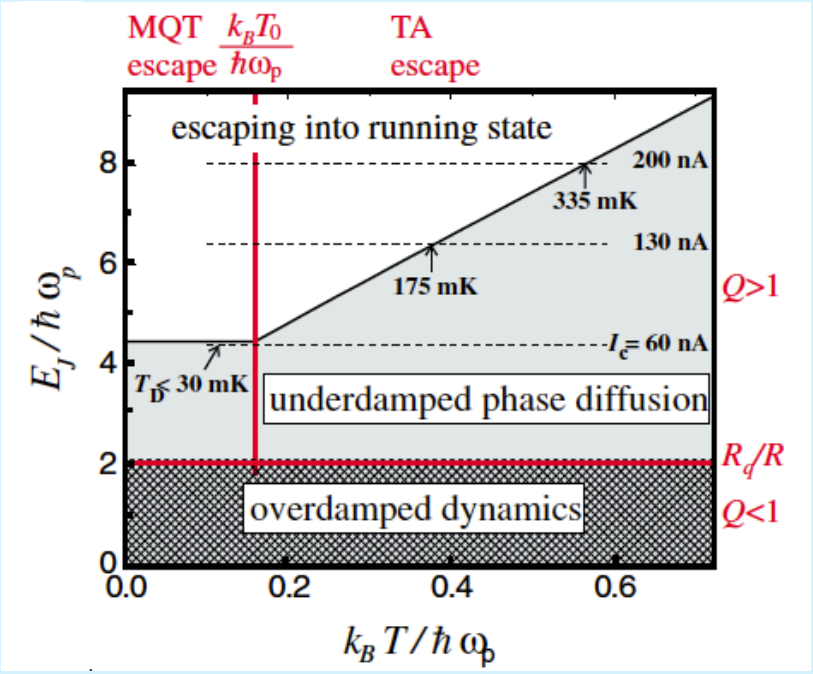
L. Longobardi, D. Massarotti et al. Appl. Phys. Lett. ***99****, 062510 (2011)*

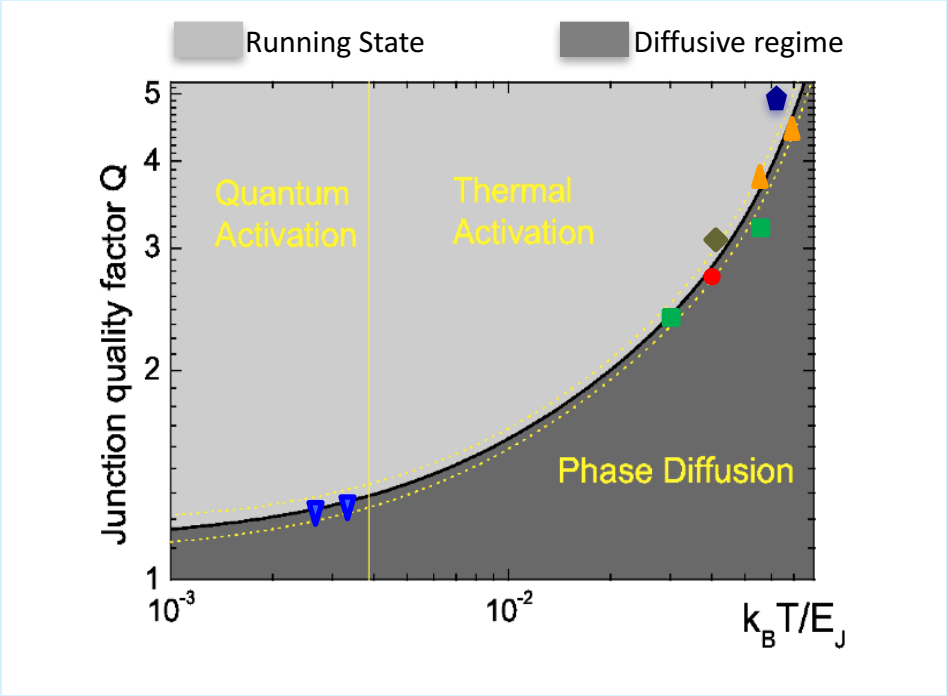
L. Longobardi, D. Massarotti et al. Phys. Rev. B ***84****, 184504 (2011)*

Moderately damped JJs

L. Longobardi, D. Massarotti et al. Phys. Rev. Lett. ***109****, 050601 (2012).*
D. Stornaiuolo, G. Rotoli, D. Massarotti et al. Phys. Rev. B ***87****, 134517 (2013)*

Kivioja et al. PRL 94, 247002 (2005)

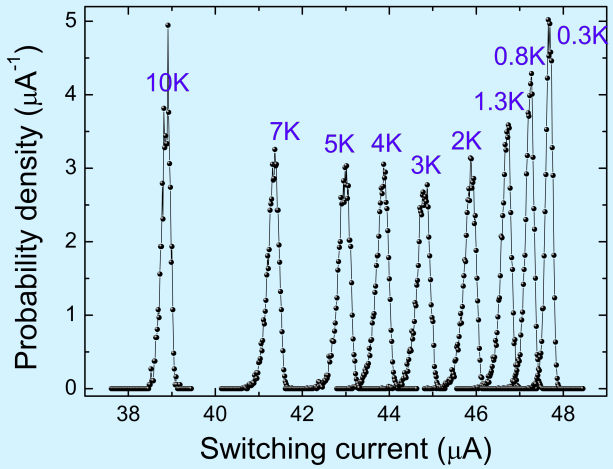




$J_c \leq 10^2$ A/cm^2

- Mannik et al. PRB 71 (2005) – Nb/AlOx/Nb
- Kivioja et al. PRL 94 (2005) – Al/AlOx/Al
- Krasnov et al. PRL 95 (2005) – BSCCO IJJ
- Longobardi et al. PRB 84 (2011) – NbN/MgO/NbN
- Yu et al. PRL 107 (2011) – Nb/AlOx/Nb
- Longobardi et al. PRL (2012) – GB YBCO

Switching dynamics in high Jc JJs

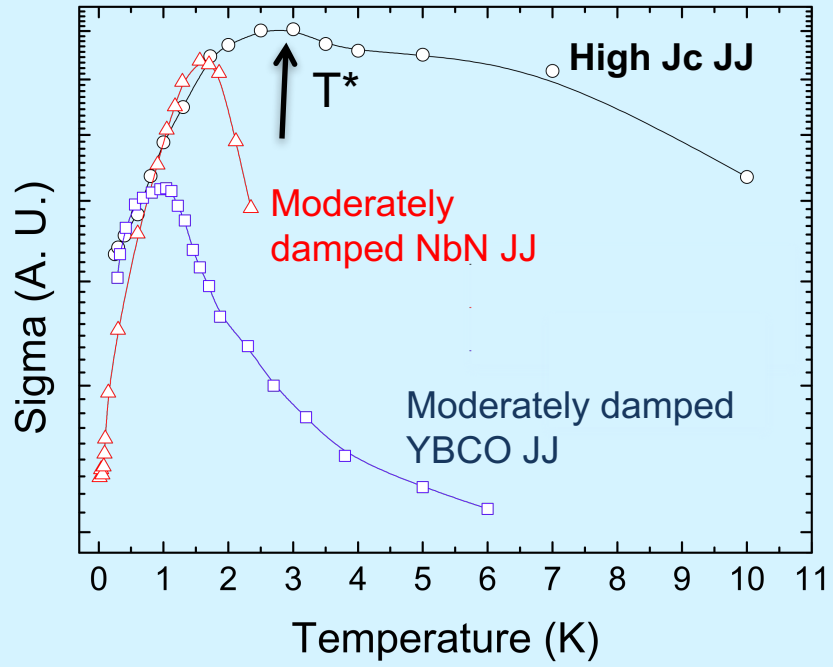


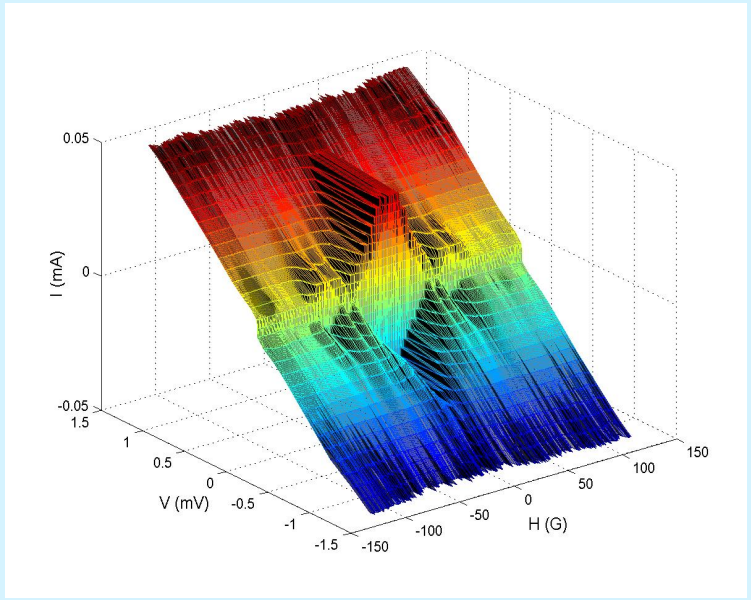
PHYSICAL REVIEW B **92**, 054501 (2015)

Breakdown of the escape dynamics in Josephson junctions

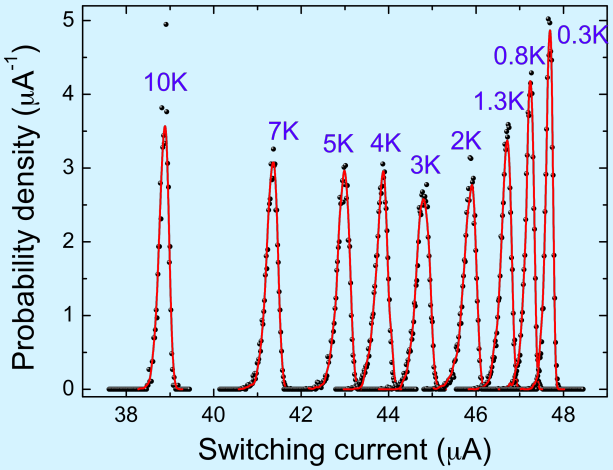
D. Massarotti,[1,2,*] D. Stornaiuolo,[1,2] P. Lucignano,[2] L. Galletti,[1,2] D. Born,[3] G. Rotoli,[4] F. Lombardi,[5] L. Longobardi,[4,6] A. Tagliacozzo,[1,2] and F. Tafuri[2,4]

Sample	I_c (μA)	W (μm)	J_c (A/cm^2)
JCT C	50	0.2	10^5





Switching dynamics in high Jc JJs



PHYSICAL REVIEW B **92**, 054501 (2015)

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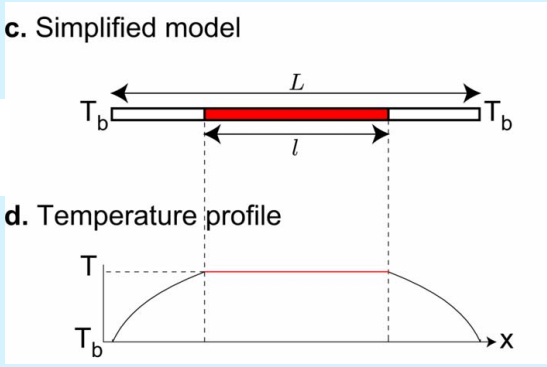
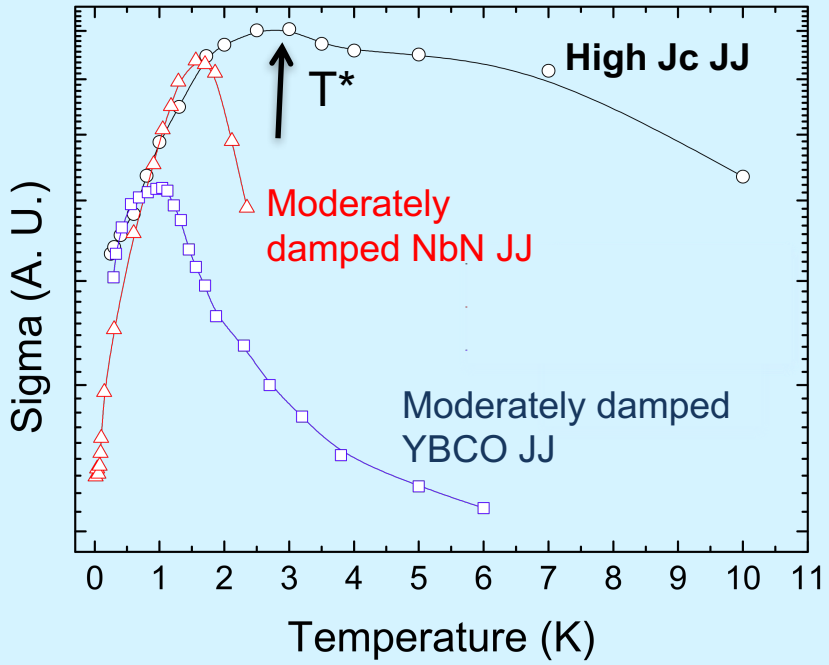
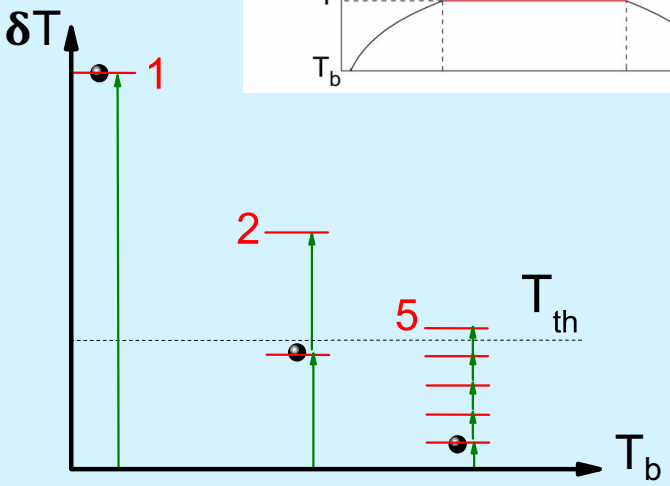
$$\Gamma_{\mathrm{TAPS}}(T, I) = \Omega_{\mathrm{TAPS}} \exp\left(\frac{-F(T, I)}{k_B T}\right)$$

$$\frac{dT}{dt} = -\alpha(T, T_b)(T - T_b) + \eta(T, I)\sum_i \delta(t - t_i).$$







- Distinctive switching phenomena
- Local heating processes drive the transition to the resistive state

Phase dynamics of hybrid JJs

SFS JJs

nature COMMUNICATIONS

ARTICLE

Received 12 Dec 2014 | Accepted 1 May 2015 | Published 9 Jun 2015

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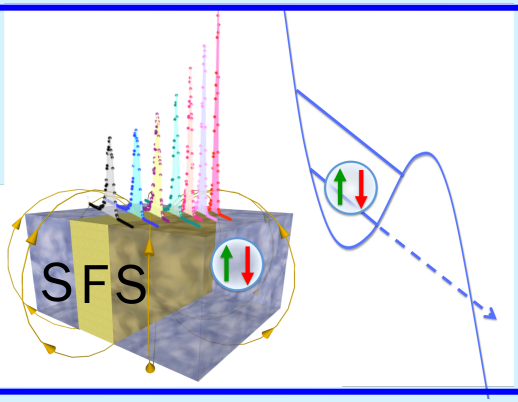
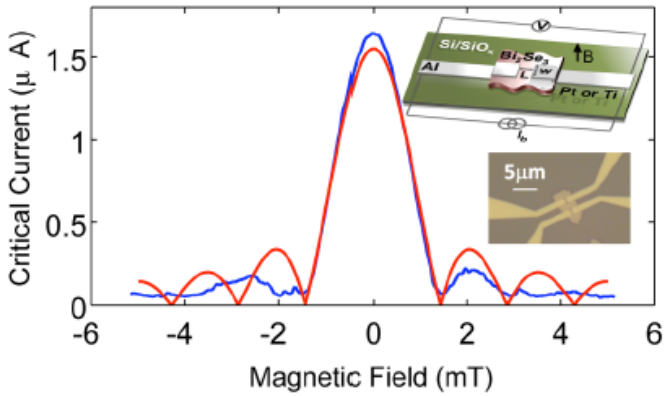


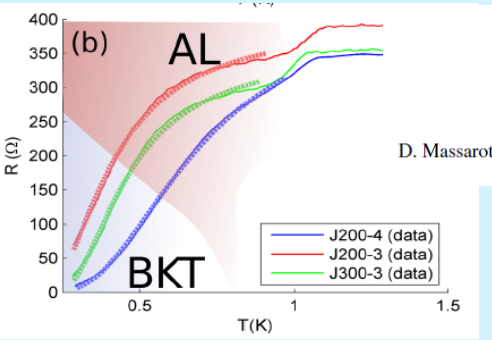


PHYSICAL REVIEW B 89, 134512 (2014)

Influence of topological edge states on the properties of Al/Bi_2Se_3/Al hybrid Josephson devices

L. Galletti,[1,2,*] S. Charpentier,[3] M. Iavarone,[4] P. Lucignano,[1,2] D. Massarotti,[1,2] R. Arpaia,[2,1,3] Y. Suzuki,[5] K. Kadowaki,[5] T. Bauch,[3] A. Tagliacozzo,[1] F. Tafuri,[2,6] and F. Lombardi[3]

Al/Bi_2Se_3/Al JJs

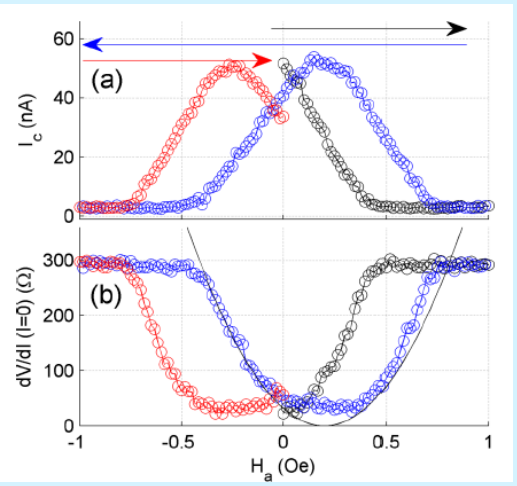


PHYSICAL REVIEW B 94, 054525 (2016)

Incipient Berezinskii-Kosterlitz-Thouless transition in two-dimensional coplanar Josephson junctions

D. Massarotti,[1,2,*] B. Jouault,[3] V. Rouco,[4] S. Charpentier,[5] T. Bauch,[5] A. Michon,[6] A. De Candia,[2,4] P. Lucignano,[2,4] F. Lombardi,[5] F. Tafuri,[1,2] and A. Tagliacozzo[2,4,7]

Al/Graphene/Al JJs



Spin filter NbN/GdN/NbN JJs

nature materials

LETTERS

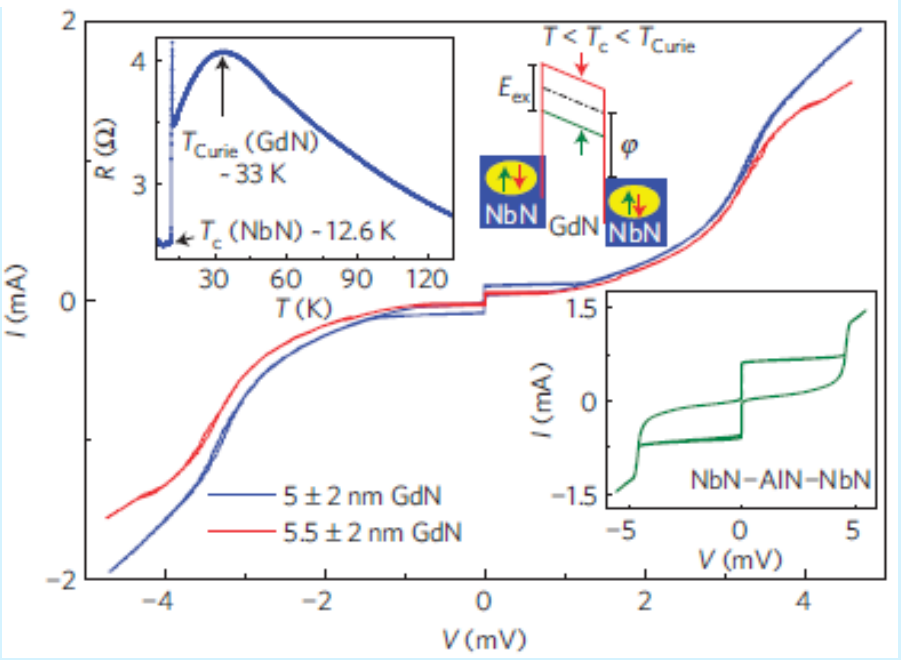
PUBLISHED ONLINE: 11 SEPTEMBER 2011 | DOI: 10.1038/NMAT3116

Spin-filter Josephson junctions

Kartik Senapati*†, Mark G. Blamire and Zoe H. Barber

$$P = \left|(\gamma_{\uparrow} - \gamma_{\downarrow})/(\gamma_{\uparrow} + \gamma_{\downarrow})\right|$$

$$P = \tanh\left[\cosh^{-1}(R*/R)\right]$$



Sample	Spin filter efficiency P	Barrier thickness t (nm)	Ic (μA)
1	Very low (0-20%)	1.5	820
2	Low (10-30%)	1.7	280
3	High (60%)	2.0	130
4	Very high (90%)	3.0	30

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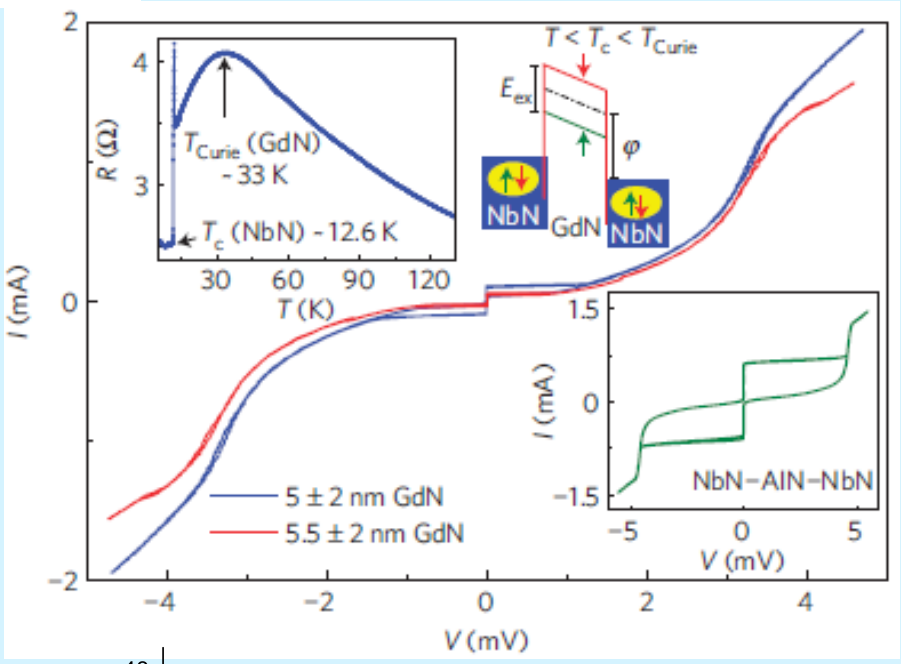
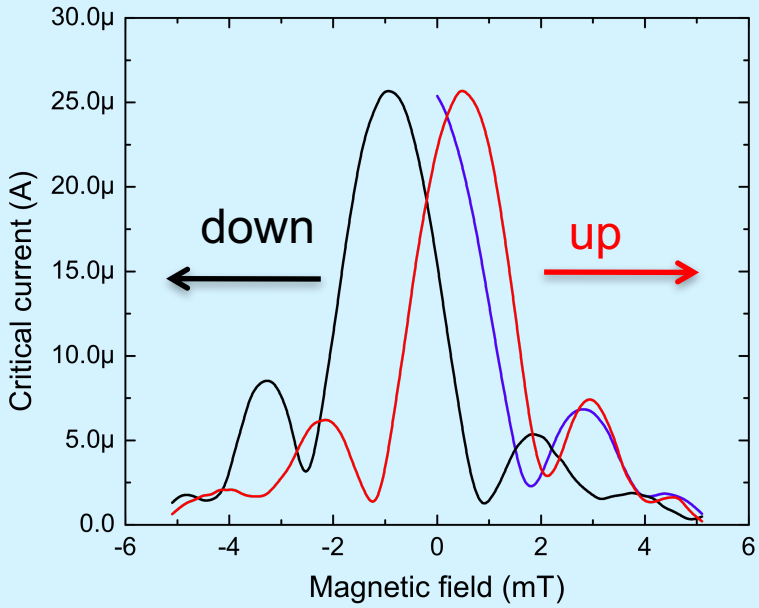
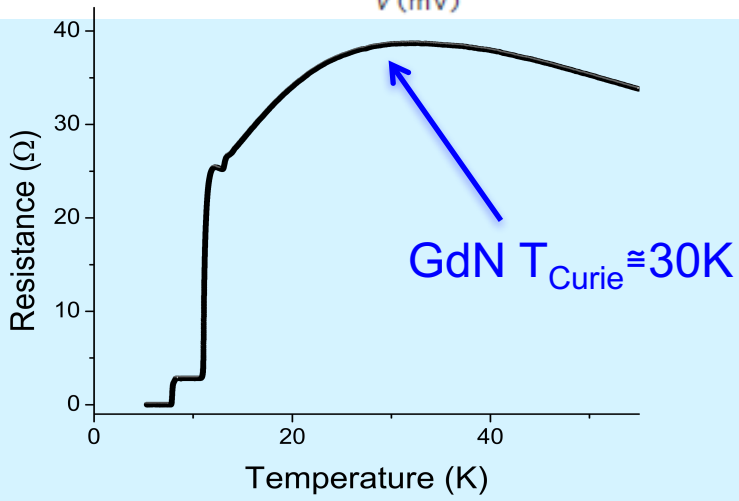






IV characteristics

VOLUME 86, NUMBER 11 PHYSICAL REVIEW LETTERS 12 MARCH 2001

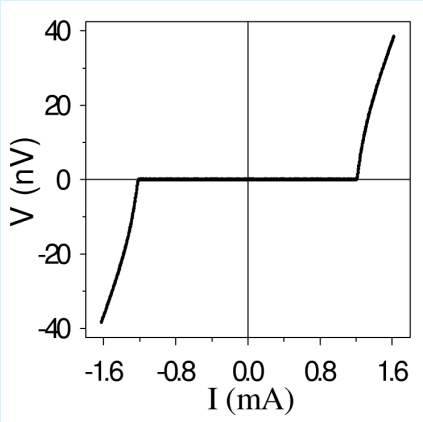
Coupling of Two Superconductors through a Ferromagnet: Evidence for a π Junction

V. V. Ryazanov,[1] V. A. Oboznov,[1] A. Yu. Rusanov,[1] A. V. Veretennikov,[1] A. A. Golubov,[2] and J. Aarts[3]

[1]*Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, 142432, Russia*

[2]*University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands*

[3]*Kamerlingh Onnes Laboratory, Leiden University, P.O. Box 9504, 2300 RA Leiden, The Netherlands*



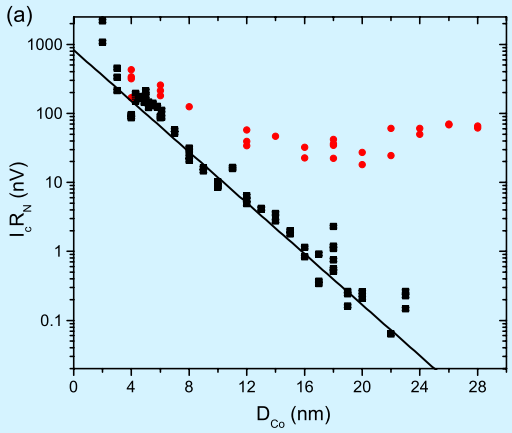
PRL **104,** 137002 (2010) PHYSICAL REVIEW LETTERS week ending 2 APRIL 2010

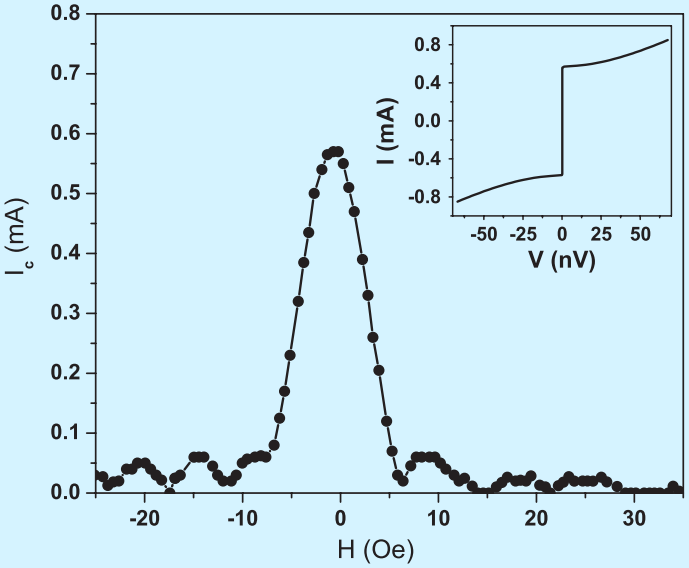
Observation of Spin-Triplet Superconductivity in Co-Based Josephson Junctions

Trupti S. Khaire, Mazin A. Khasawneh, W. P. Pratt, Jr., and Norman O. Birge*

Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824-2320, USA

(Received 1 December 2009; published 29 March 2010)





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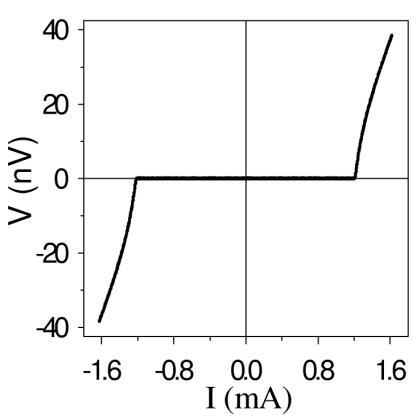
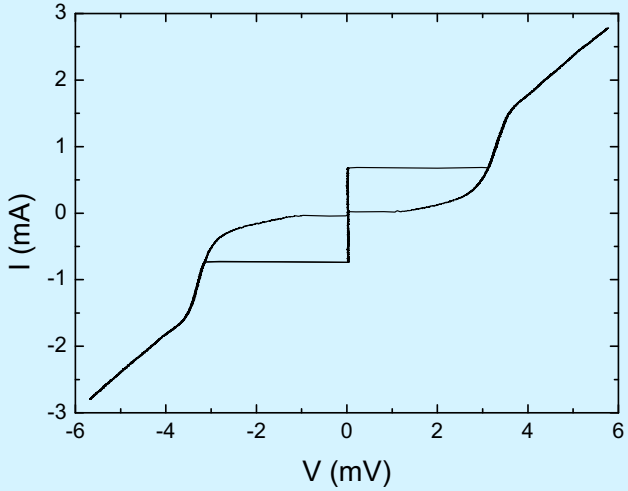
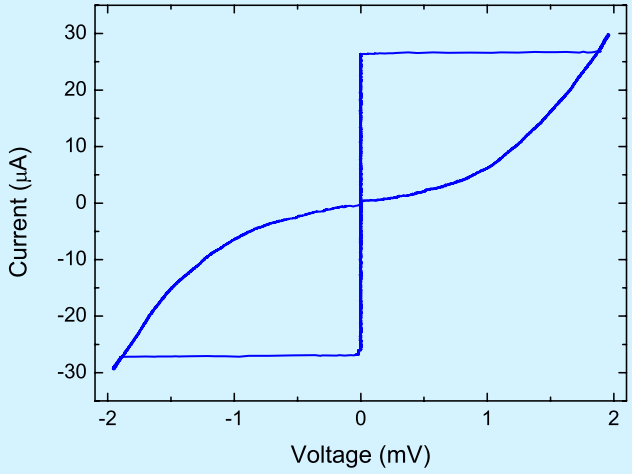


Spin filter JJs





MQT in spin filter JJs

nature COMMUNICATIONS

ARTICLE

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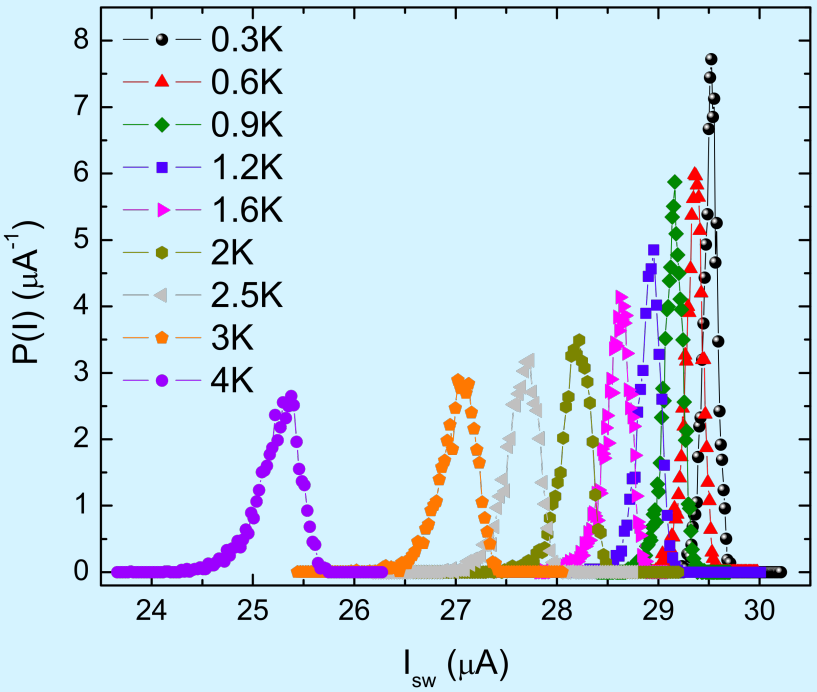
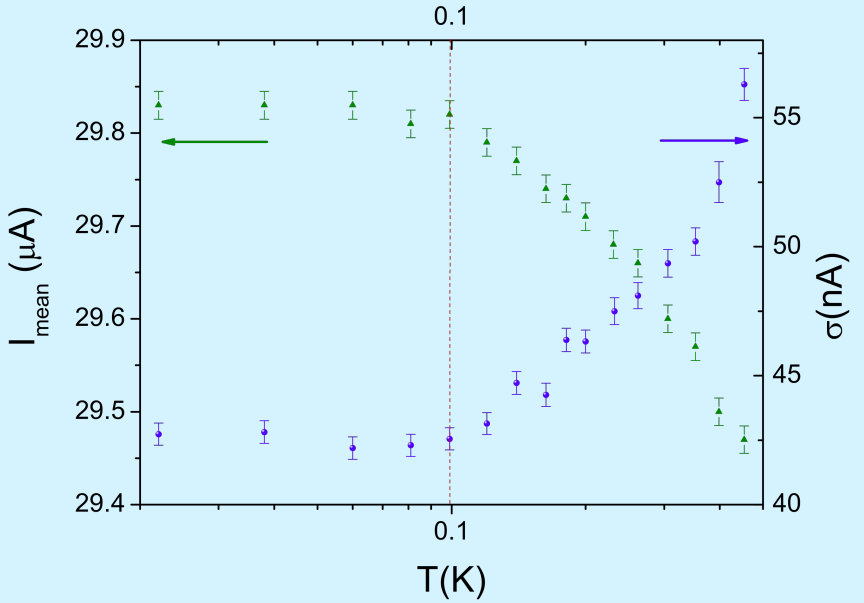
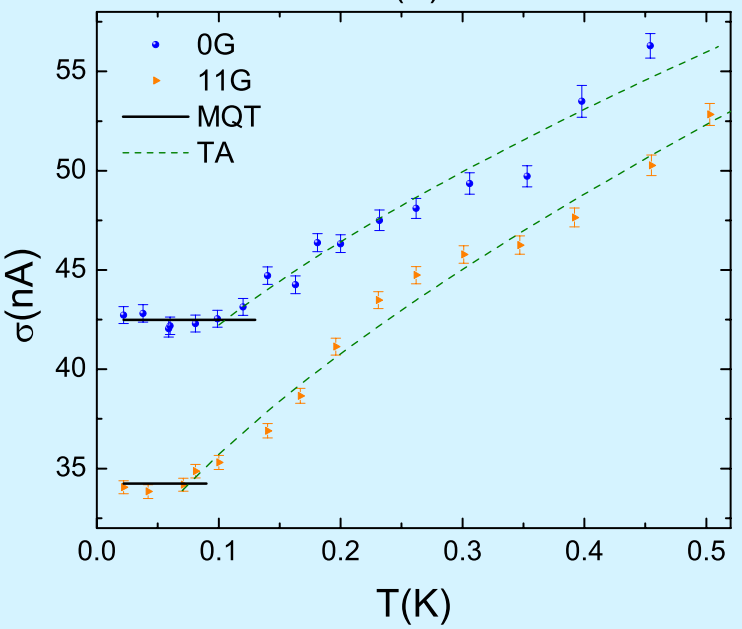
90% SFE JJ Jc ≅ 60 A/cm^2







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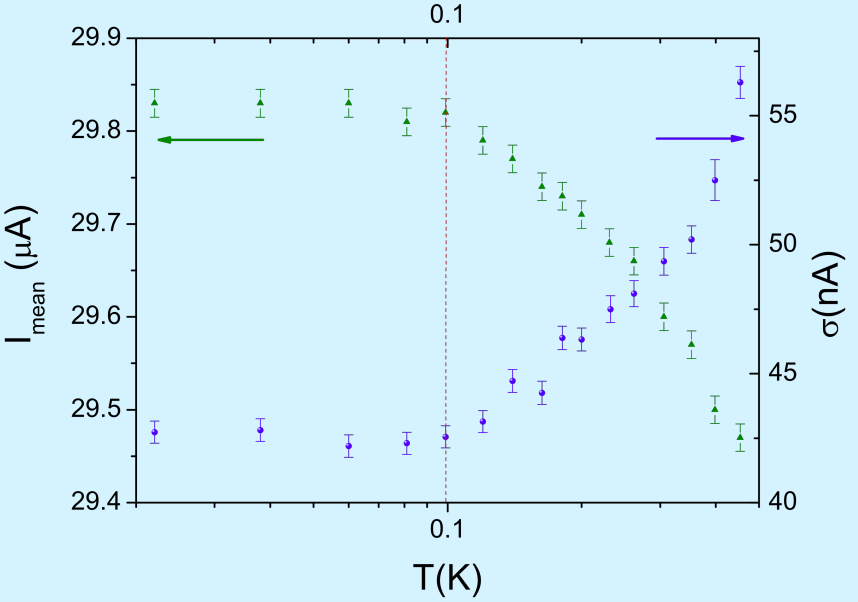

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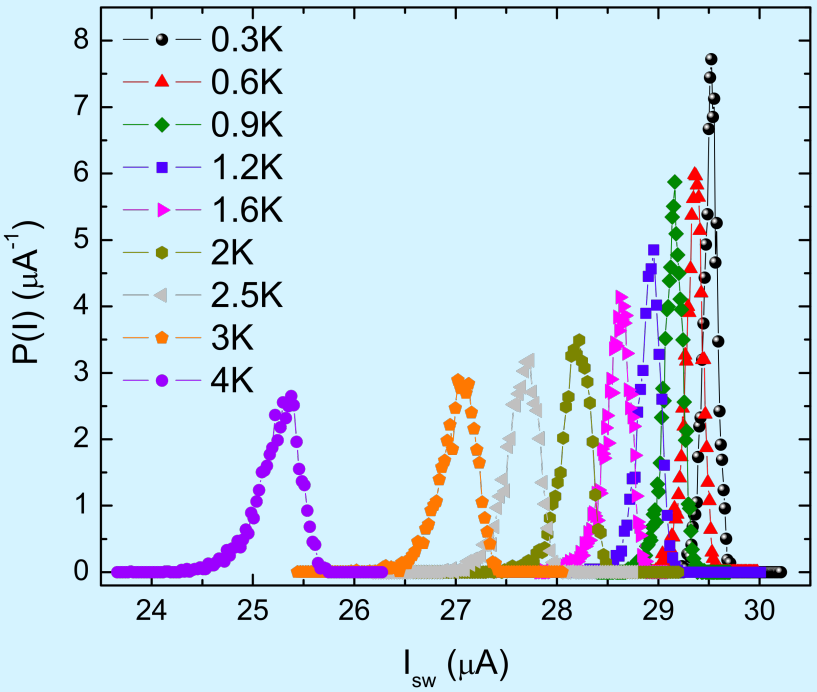
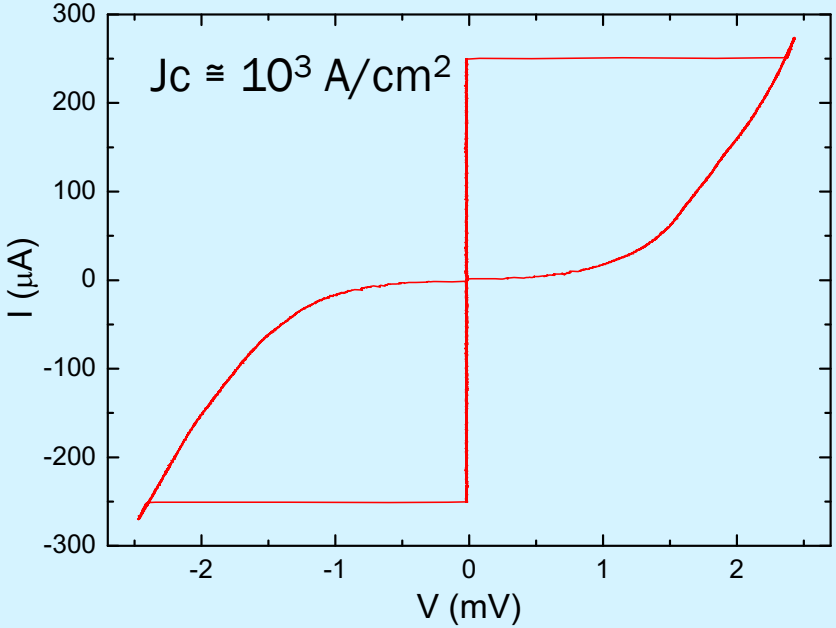
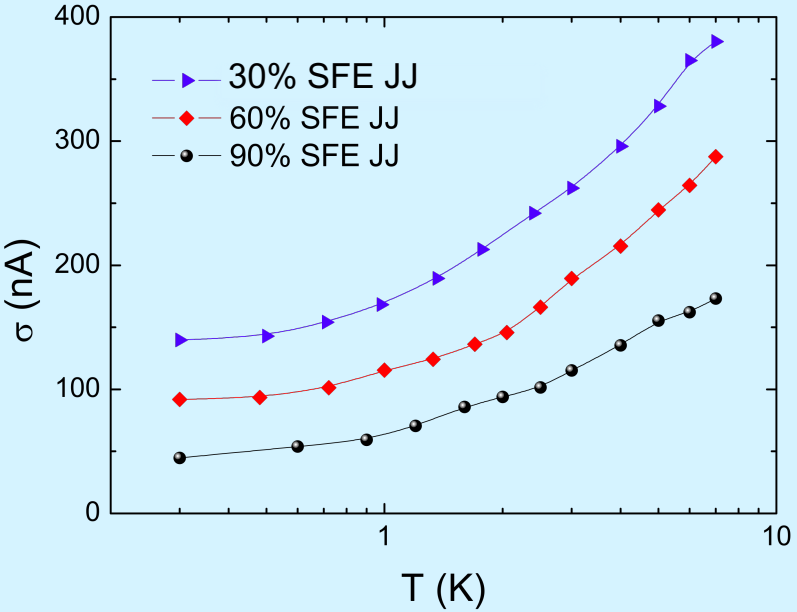


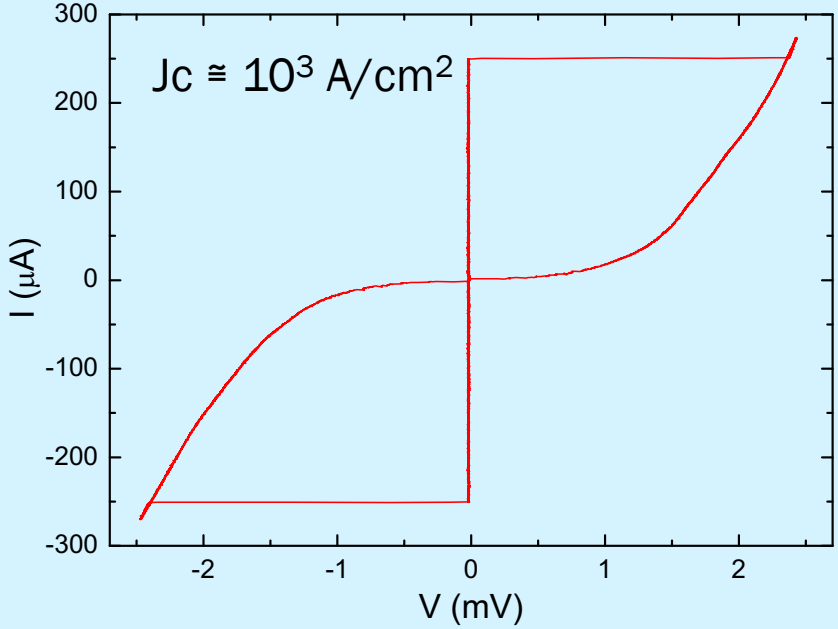
- Ferromagnetic-insulator barrier
- Hysteretic magnetic field behavior
- Underdamped regime
- High IcRn product
- MQT

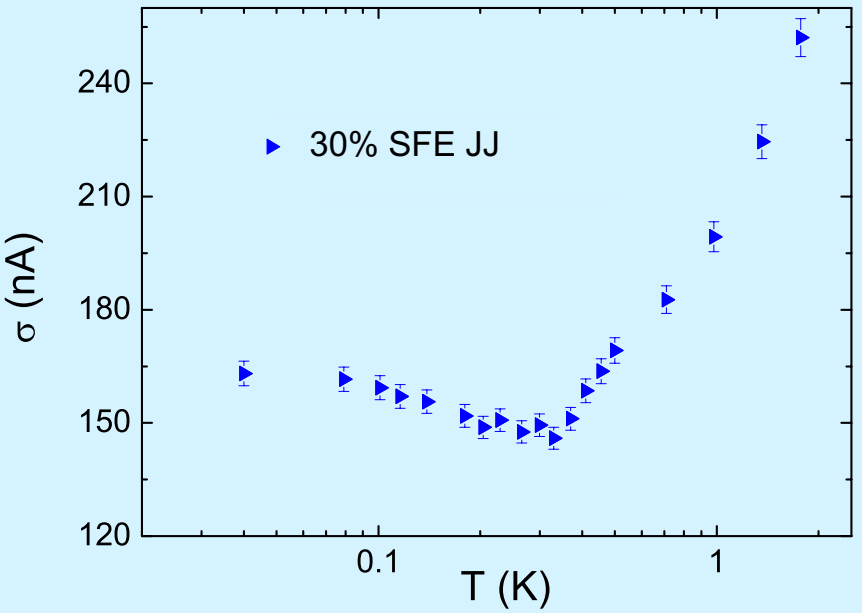
High Jc spin filter JJs





High Jc spin filter JJs





Work in progress

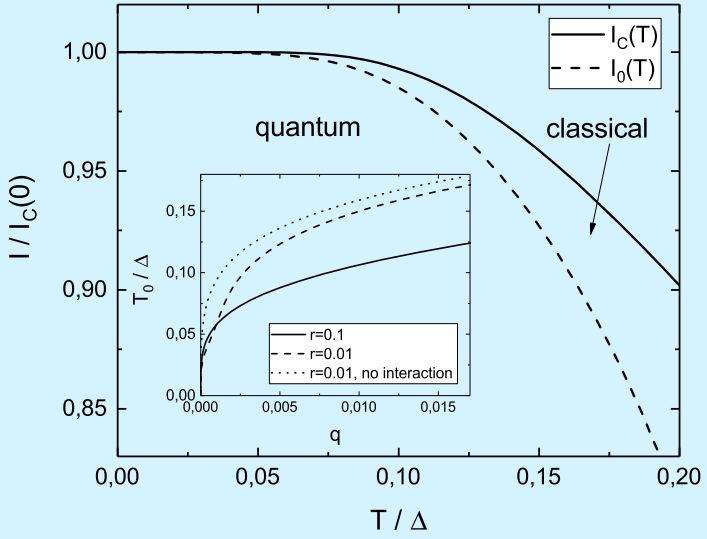
Andreev levels as a quantum dissipative environment

Artem V. Galaktionov[1], Dmitry S. Golubev[2] and Andrei D. Zaikin[3,1]

[1] *I.E.Tamm Department of Theoretical Physics, P.N.Lebedev Physical Institute, 119991 Moscow, Russia*

[2] *Low Temperature Laboratory, Department of Applied Physics, Aalto University, Espoo, Finland*

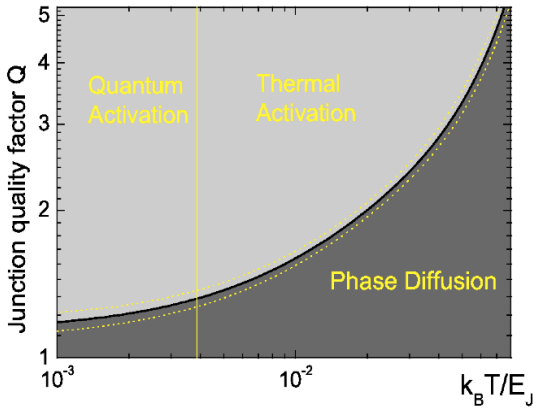
[3] *Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany*



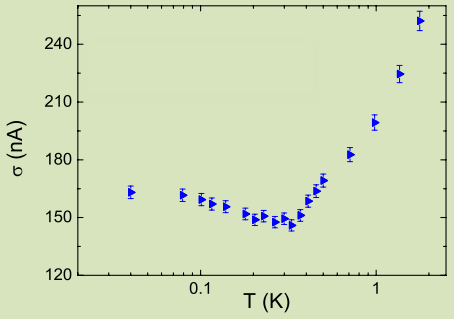
Conclusions

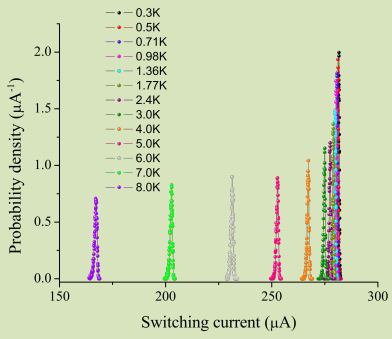
- First evidence of macroscopic quantum tunneling in spin filter ferromagnetic JJs characterized by low values of Jc
- Phase dynamics of unconventional JJs: fingerprints of different sources of dissipation
- Critical current density as the third axis of the phase diagram

$1\text{-}10^2$ A/cm^2

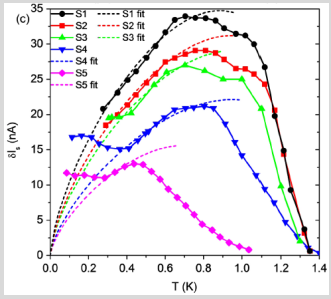


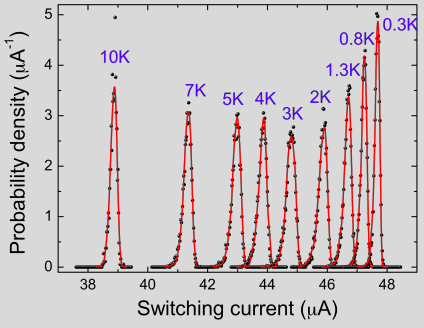
$10^2\text{-}10^4$ A/cm^2





10^5 A/cm^2

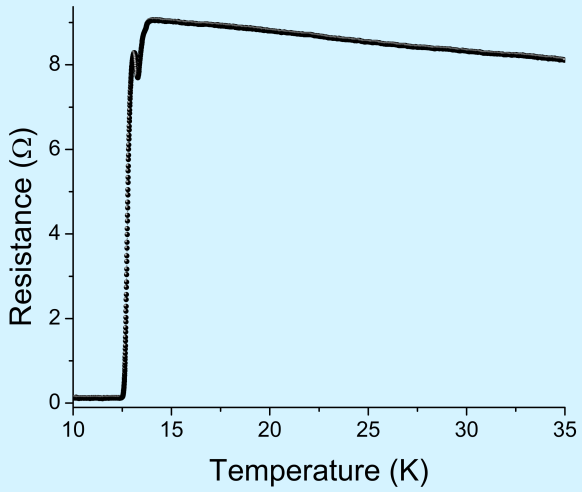




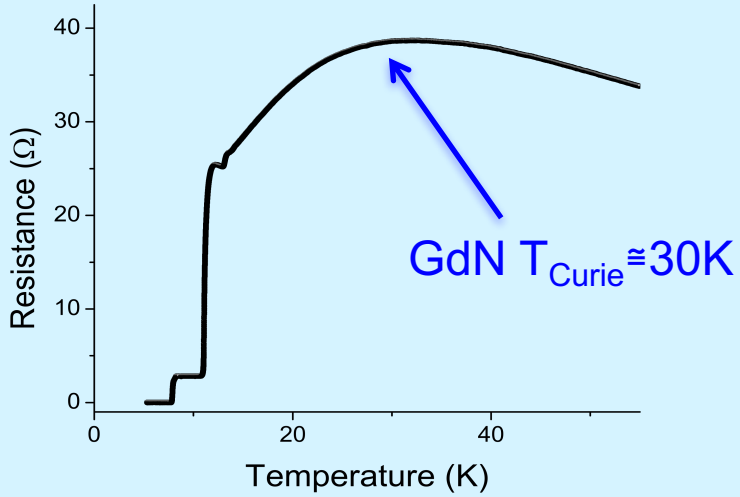
Jc

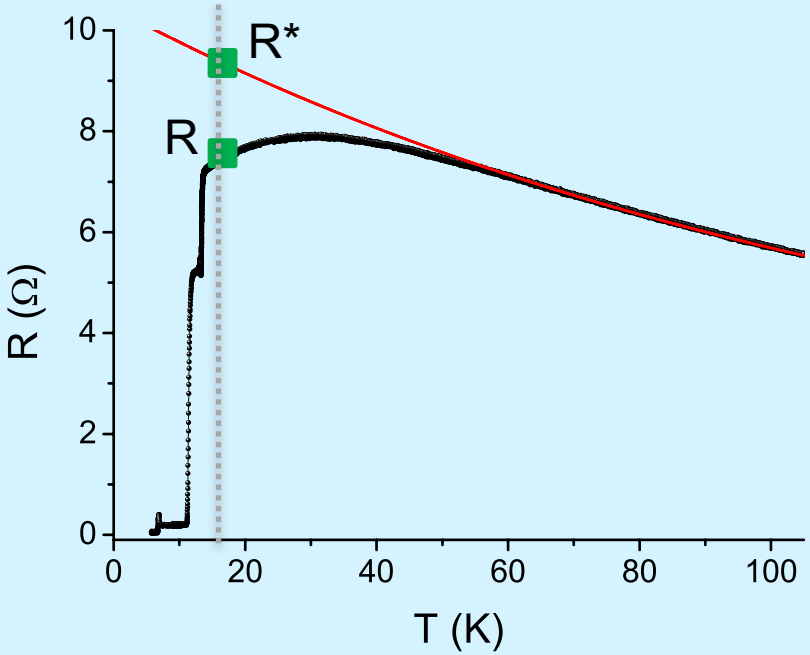
Spin filter efficiency

Non spin filter JJs



Spin filter JJs





$$P = \left|(\gamma_{\uparrow} - \gamma_{\downarrow})/(\gamma_{\uparrow} + \gamma_{\downarrow})\right|$$

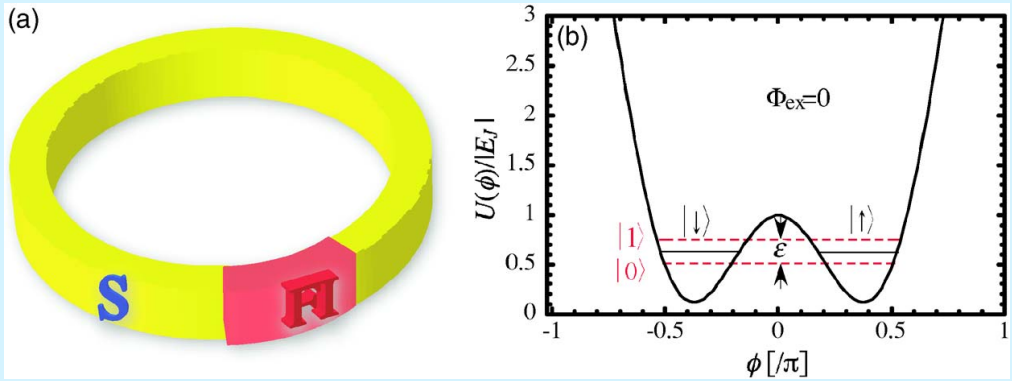
$$P = \tanh\left[\cosh^{-1}(R*/R)\right]$$

PHYSICAL REVIEW B **74**, 180502(R) (2006)

Macroscopic quantum dynamics of π junctions with ferromagnetic insulators

Shiro Kawabata,[1,2] Satoshi Kashiwaya,[3] Yasuhiro Asano,[4] Yukio Tanaka,[5] and Alexander A. Golubov[1]

As proposed by Bulaevskii *et al.*,[2] a superconducting ring with a π junction [a π superconducting quantum interference device (SQUID)] exhibits a spontaneous current without an external magnetic field and the corresponding magnetic flux is half a flux quantum Φ_0 in the ground state. Therefore it is expected that a S-FM-S π SQUID system becomes a *quiet* qubit that can be efficiently decoupled from the fluctuation of the external field.[11–14] From the viewpoint of quantum dissipation, however, the structure of S-FM-S junctions is inherently identical with S-N-S junctions (where N is a normal nonmagnetic metal). Therefore a gapless quasiparticle excitation in the FM layer is inevitable. This feature gives a strong Ohmic dissipation[15,16] and the coherence time of S-FM-S qubits is bound to be very short. In practice the current-voltage characteristic of a S-FM-S junction shows nonhysteretic and overdamped behaviors.[8] On the other hand, as was shown by Tanaka and Kashiwaya,[17] a π junction can also be formed in Josephson junctions with a ferromagnetic insulator (FI). In S-FI-S junctions, the influence of the quasiparticle excitation in the FI is expected to be very weak as in the case of S-I-S junctions[18] (where I is a nonmagnetic insulator).



Switching dynamics in high Jc JJs

Appl. Phys. Lett. 63 (10), 6 September 1993

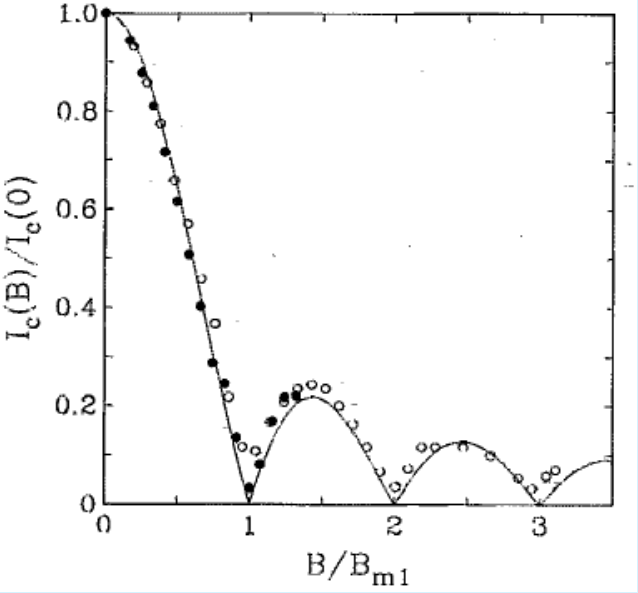
Niobium trilayer Josephson tunnel junctions with ultrahigh critical current densities

R. E. Miller and W. H. Mallison
AT&T Bell Laboratories, Murray Hill, New Jersey 07974

A. W. Kleinsasser
IBM Research Division, T. J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York 10598

K. A. Delin and E. M. Macedo
Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Massachusetts 02173

(Received 24 March 1993; accepted for publication 27 June 1993)



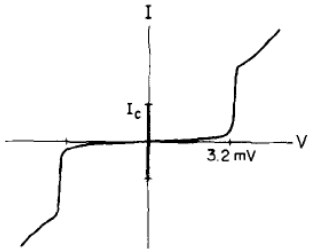


FIG. 3. *I-V* characteristic of a low-current-density (10^3 A/cm^2) junction.

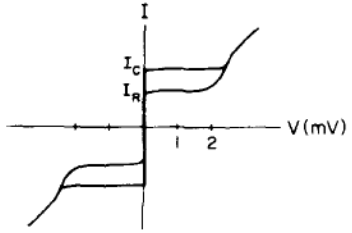
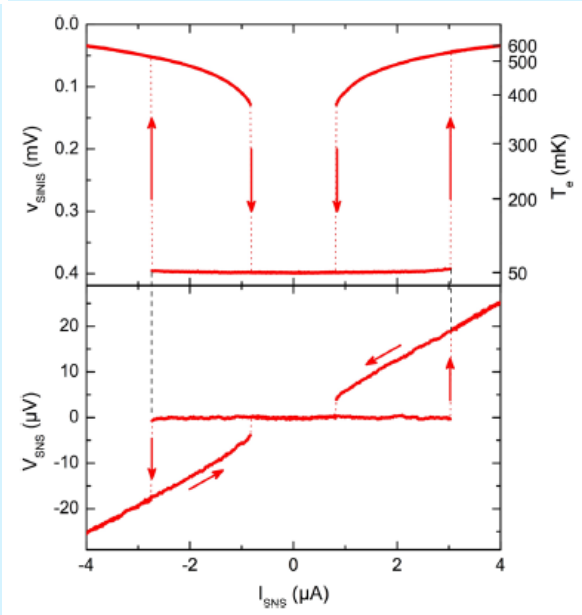


FIG. 4. *I-V* characteristic of a high-current-density (4×10^5 A/cm^2) junction.

PRL 101, 067002 (2008) PHYSICAL REVIEW LETTERS week ending 8 AUGUST 2008

Origin of Hysteresis in a Proximity Josephson Junction

H. Courtois,[1,2] M. Meschke,[1] J. T. Peltonen,[1] and J. P. Pekola[1]



Switching dynamics in nanobridges

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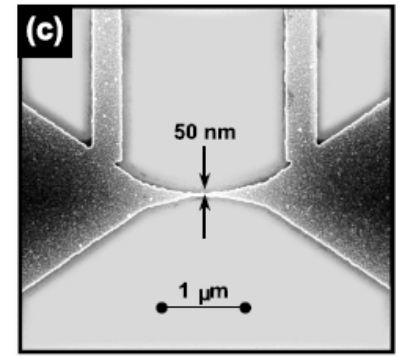
Accepted: 09 February 2017
Published: 16 March 2017

SCIENTIFIC REPORTS

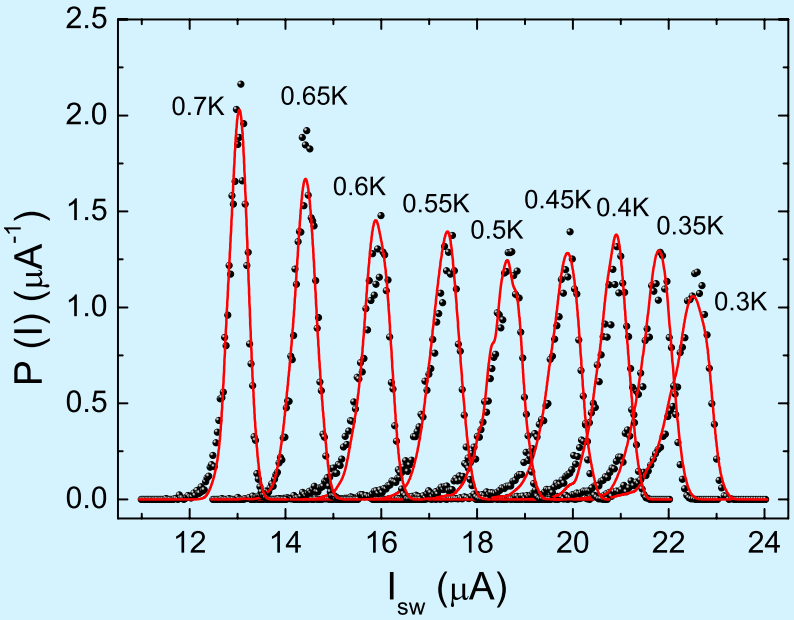
OPEN

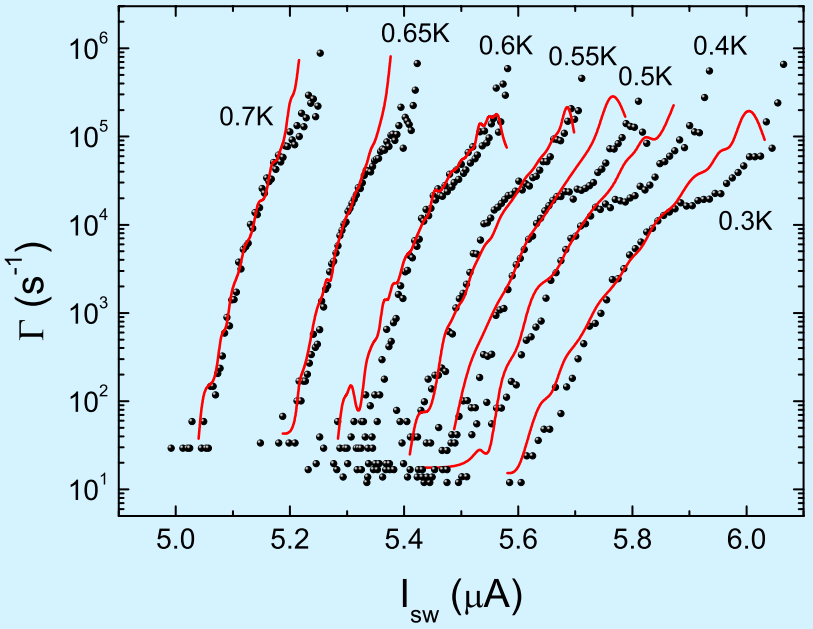
Statistics of localized phase slips in tunable width planar point contacts

Xavier D.A. Baumans[1], Vyacheslav S. Zharinov[2], Eline Raymenants[2], Sylvain Blanco Alvarez[1], Jeroen E. Scheerder[2], Jérémy Brisbois[1], Davide Massarotti[3,4], Roberta Caruso[4,5], Francesco Tafuri[4,5], Ewald Janssens[6], Victor V. Moshchalkov[2], Joris Van de Vondel[2] & Alejandro V. Silhanek[1]

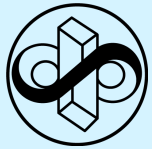


- Highly localized phase slip events in a point contact connecting two Al superconducting electrodes
- The main dissipative mechanisms can be ascribed to a train of thermally driven phase slip events

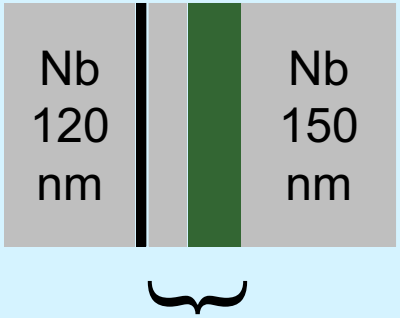




MJJs for memory applications



HYPRES

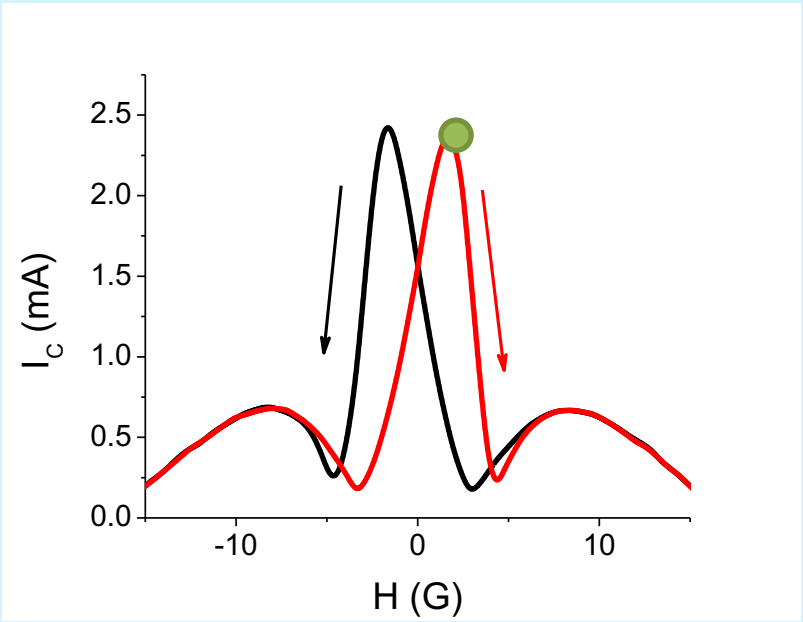


APPLIED PHYSICS LETTERS **100**, 222601 (2012)

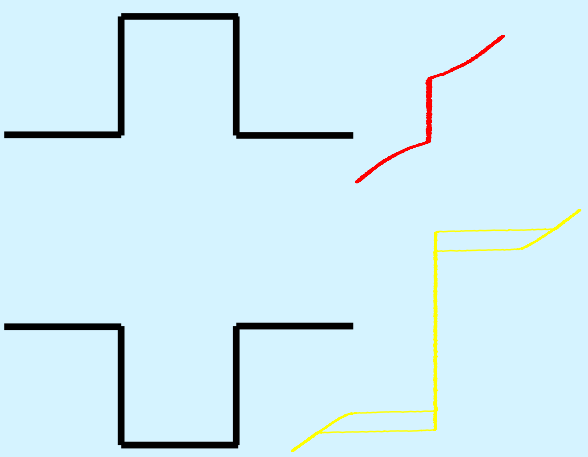
Ferromagnetic Josephson switching device with high characteristic voltage

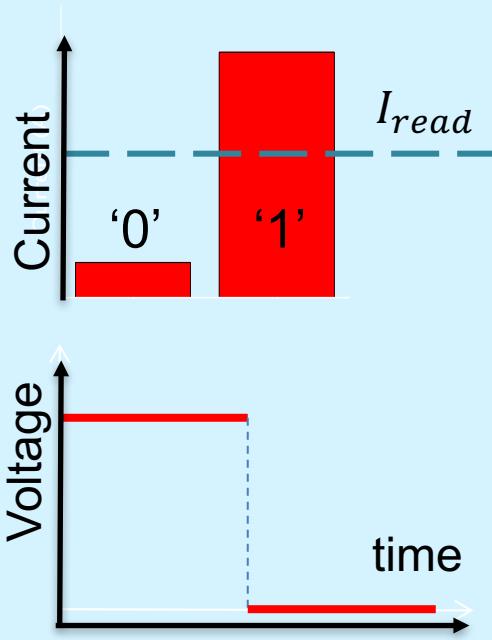
Timofei I. Larkin,[1] Vitaly V. Bol'ginov,[1] Vasily S. Stolyarov,[1] Valery V. Ryazanov,[1,a)]
Igor V. Vernik,[2,b)] Sergey K. Tolpygo,[2] and Oleg A. Mukhanov[2]
[1]*Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka 142432, Russia*
[2]*HYPRES, Inc., 175 Clearbrook Road, Elmsford, New York 10523, USA*

$Pd_{0.99}Fe_{0.01}/Nb/Al_{1-x}AlO_x$
(14/10/2)nm

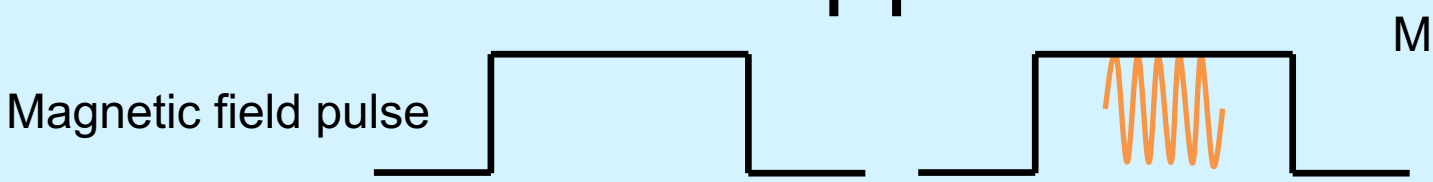


External magnetic field pulse





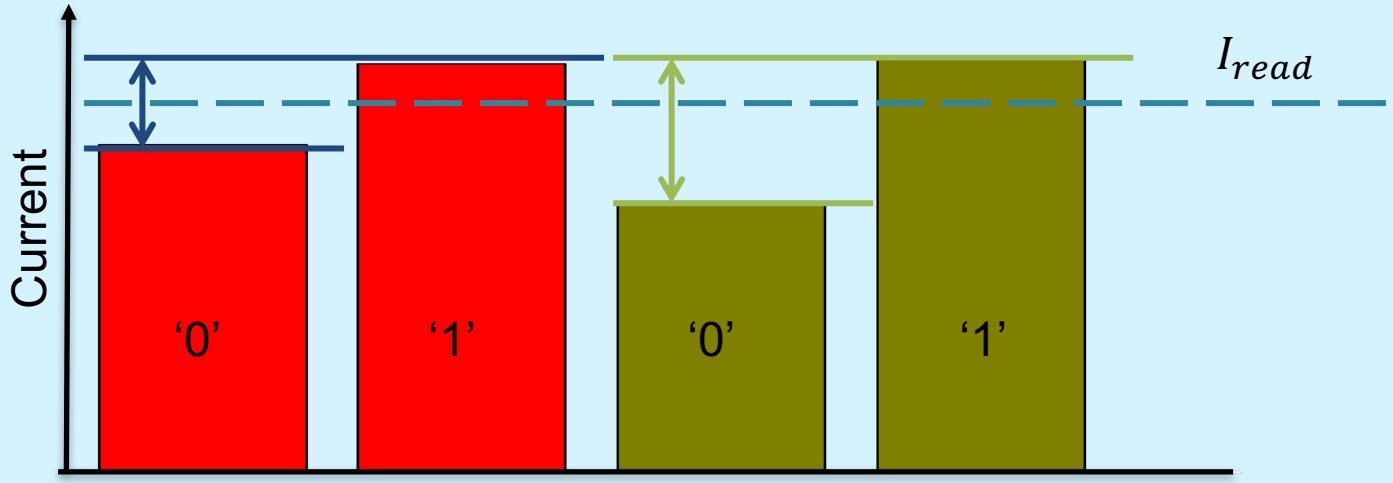
Our approach

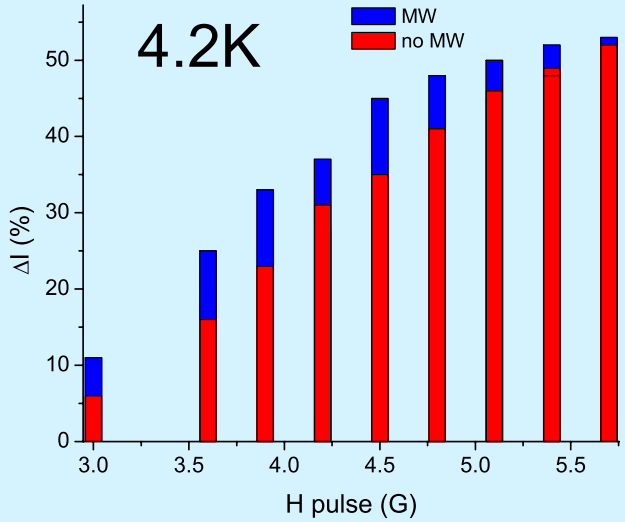


Magnetic field pulse

+

RF field





R. Caruso, D. Massarotti et al.
submitted to Applied Physics Letters

Current level separation is enhanced in a wide range of magnetic pulse amplitudes

Current-phase relation

$$I = I_{c1} \sin\varphi + I_{c2} \sin 2\varphi$$

nature COMMUNICATIONS

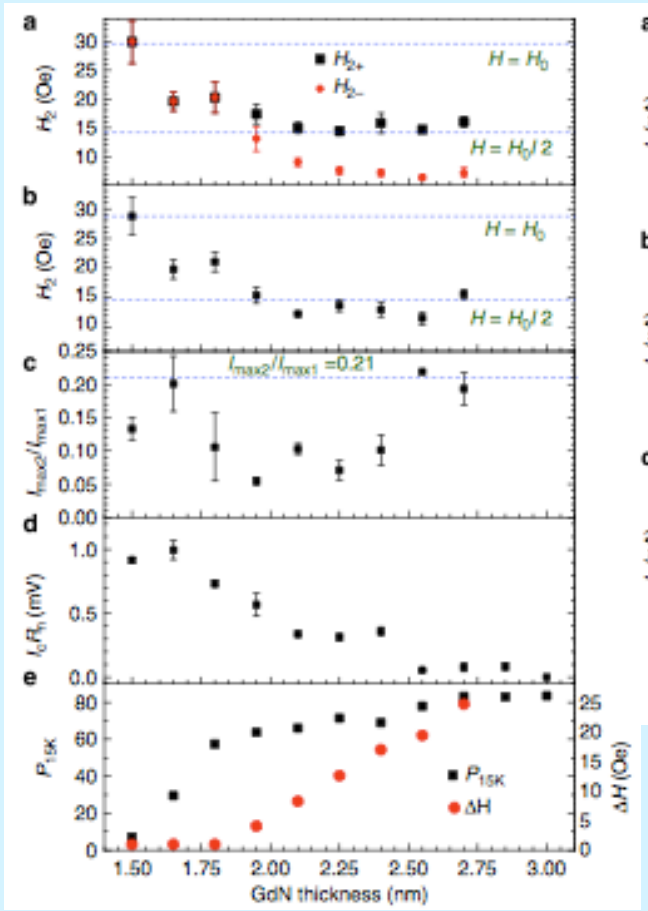
ARTICLE

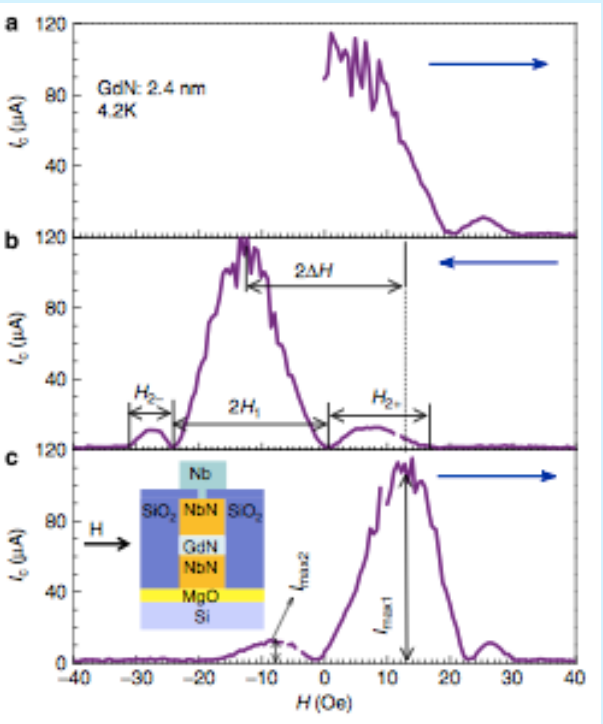
Received 10 Nov 2013 | Accepted 29 Jan 2014 | Published 18 Feb 2014

DOI: 10.1038/ncomms4340

Pure second harmonic current-phase relation in spin-filter Josephson junctions

Avradeep Pal[1], Z.H. Barber[1], J.W.A. Robinson[1] & M.G. Blamire[1]





Current-phase relation

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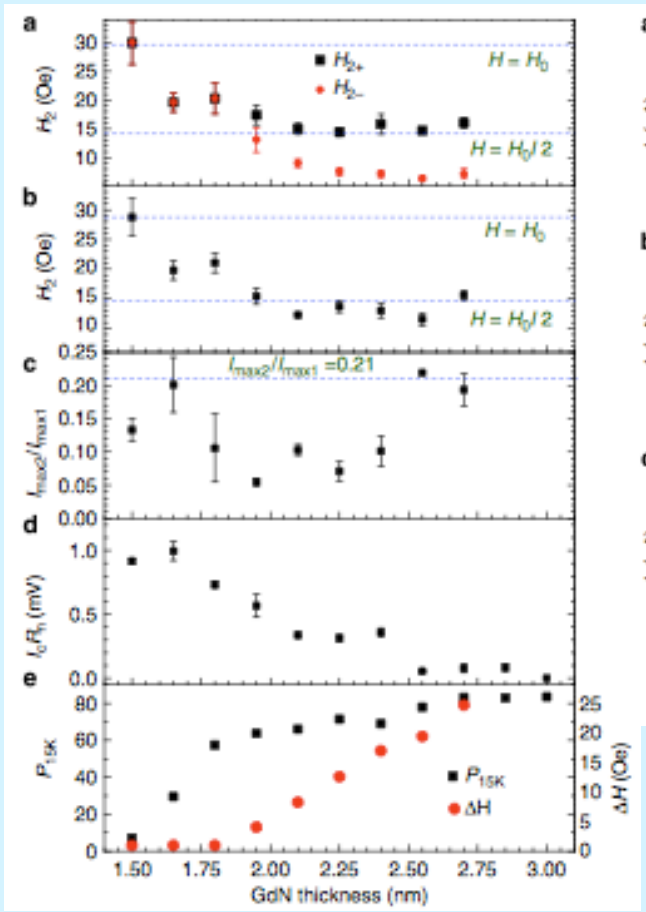
Pure second harmonic current-phase relation in spin-filter Josephson junctions

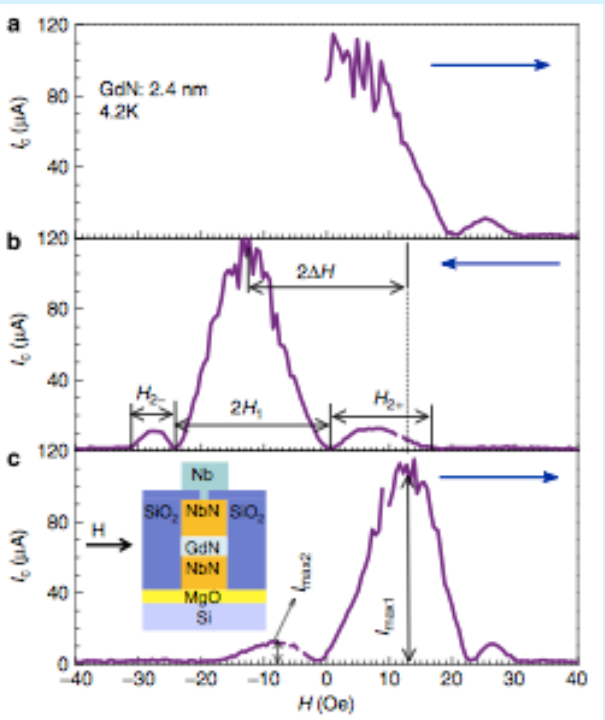
Avradeep Pal[1], Z.H. Barber[1], J.W.A. Robinson[1] & M.G. Blamire[1]

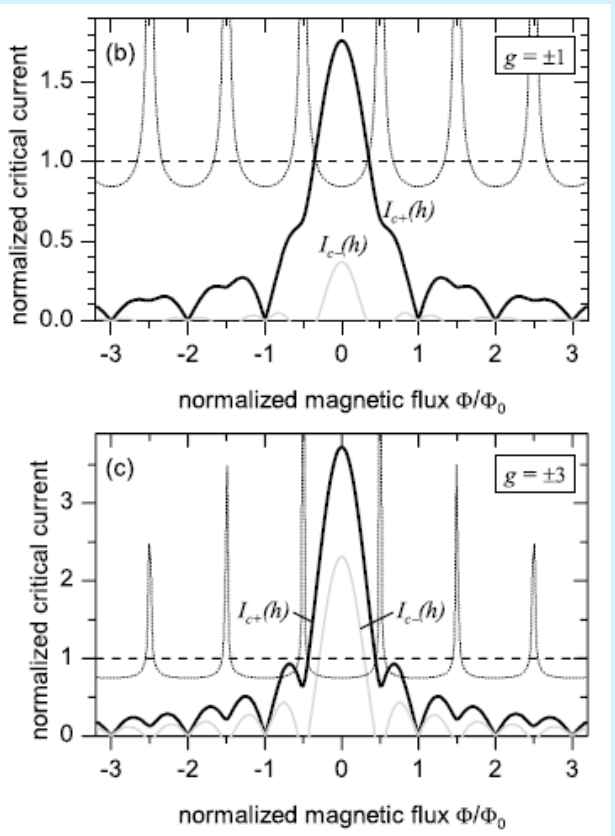
PHYSICAL REVIEW B 76, 224523 (2007)

Josephson junctions with second harmonic in the current-phase relation: Properties of φ junctions

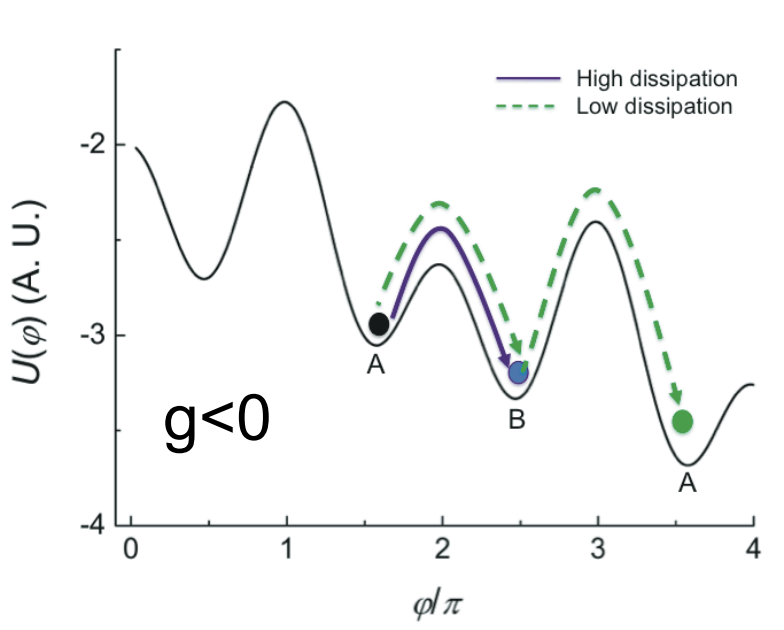
E. Goldobin,[1,*] D. Koelle,[1] R. Kleiner,[1] and A. Buzdin[2]

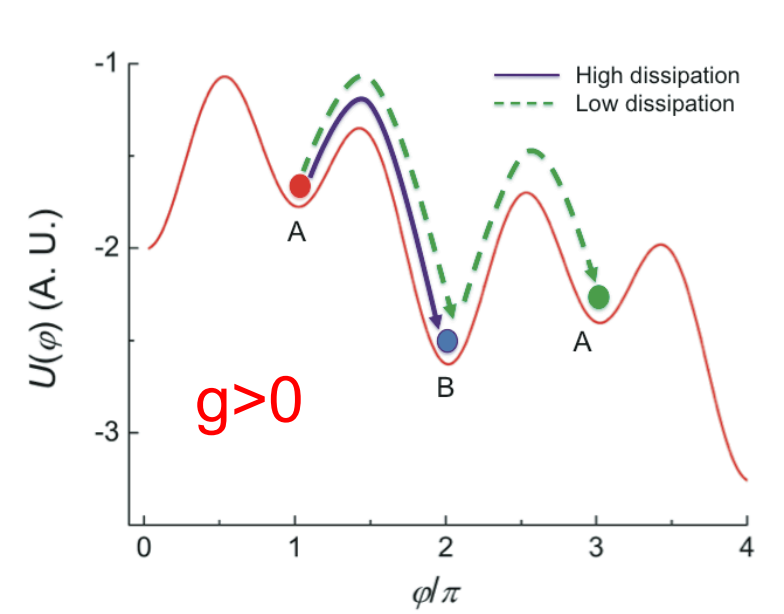






Second harmonic component

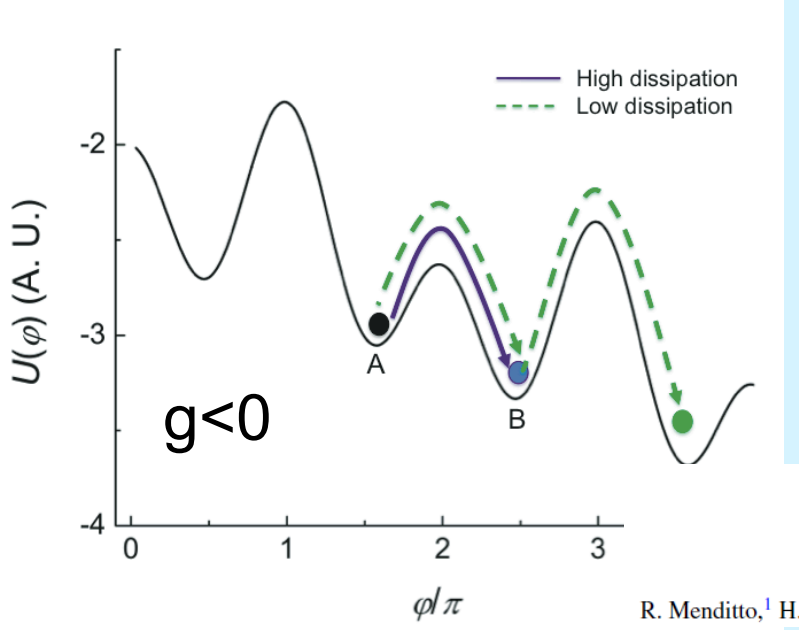




$$U(\varphi) = -E_1(\cos\varphi + g\cos 2\varphi)$$

$$E_1 = \frac{\hbar I_{c1}}{2e} \qquad g = \frac{I_{c2}}{I_{c1}}$$

Second harmonic component



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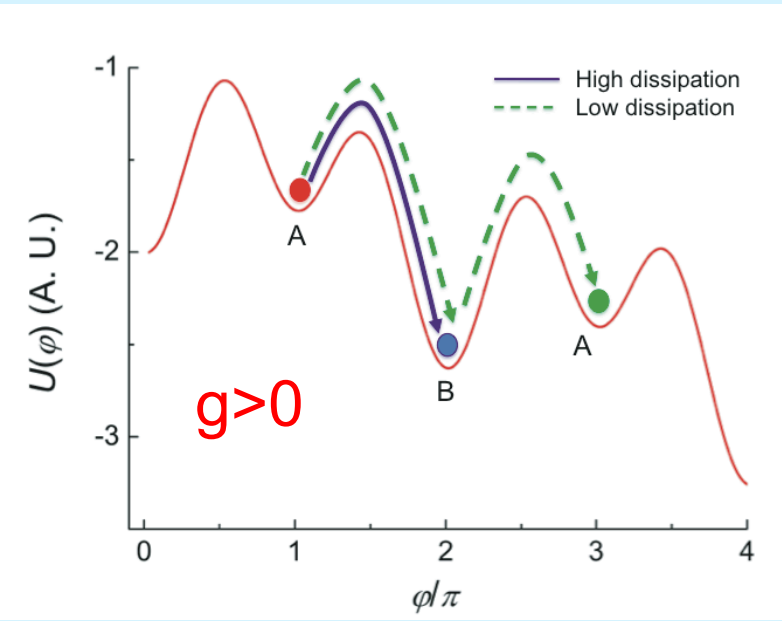
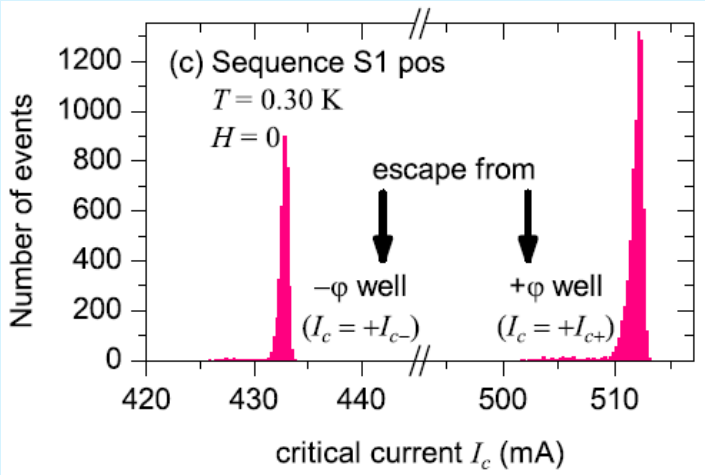
PHYSICAL REVIEW B 93, 174506 (2016)

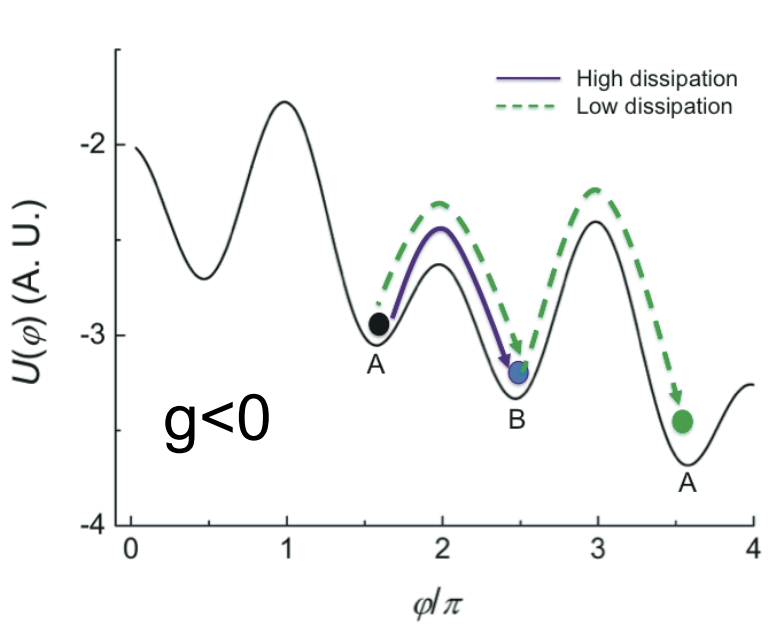
Phase retrapping in a φ Josephson junction: Onset of the butterfly effect

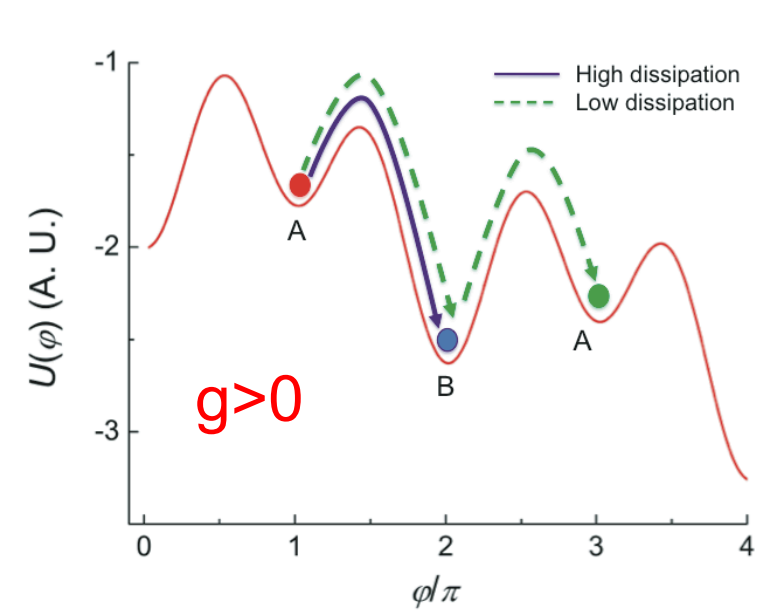
R. Menditto,[1] H. Sickinger,[2] M. Weides,[3,*] H. Kohlstedt,[4] M. Žonda,[5] T. Novotný,[5] D. Koelle,[2] R. Kleiner,[2] and E. Goldobin[2]





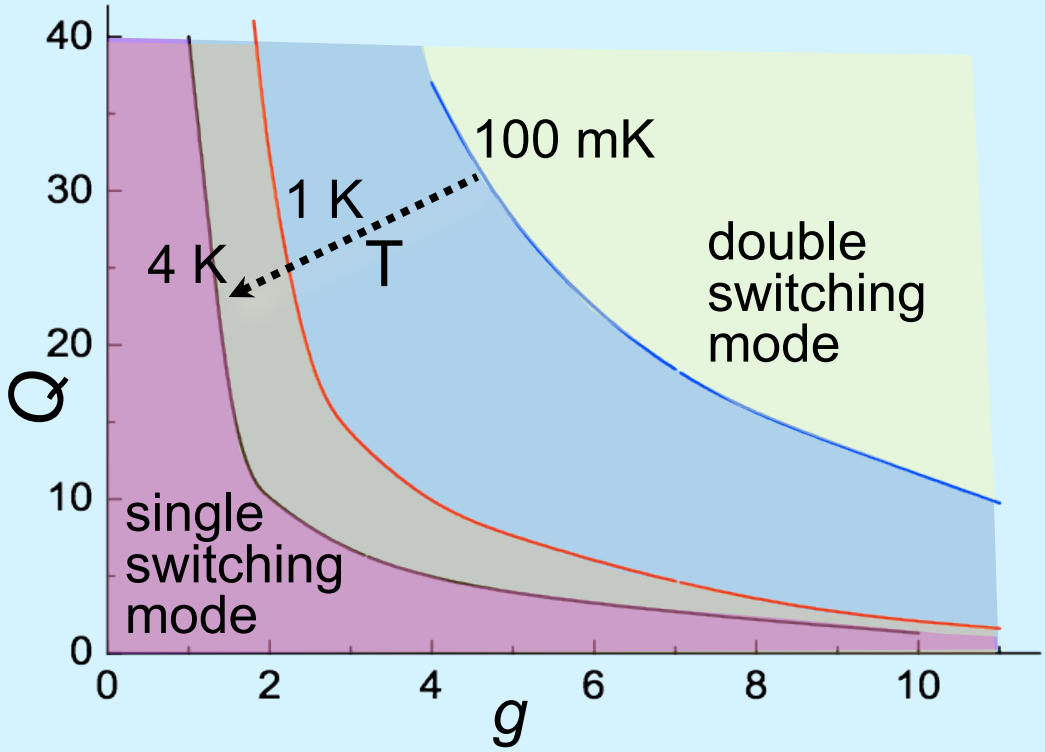
Second harmonic component



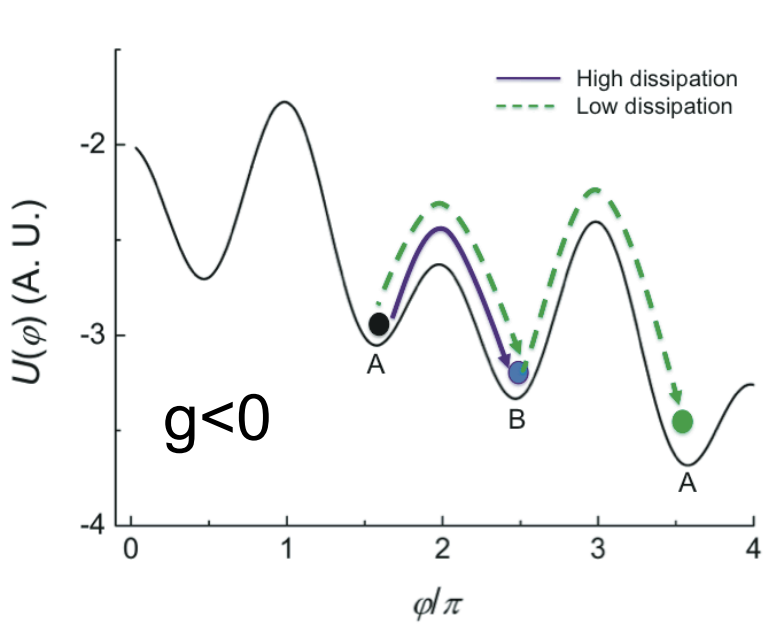


$$U(\varphi) = -E_1(\cos\varphi + g\cos 2\varphi)$$

$$E_1 = \frac{\hbar I_{c1}}{2e} \qquad g = \frac{I_{c2}}{I_{c1}}$$



Second harmonic component



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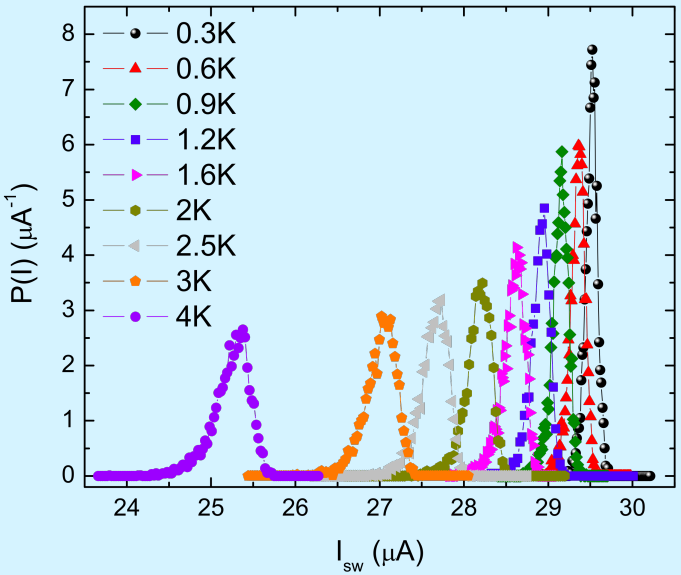
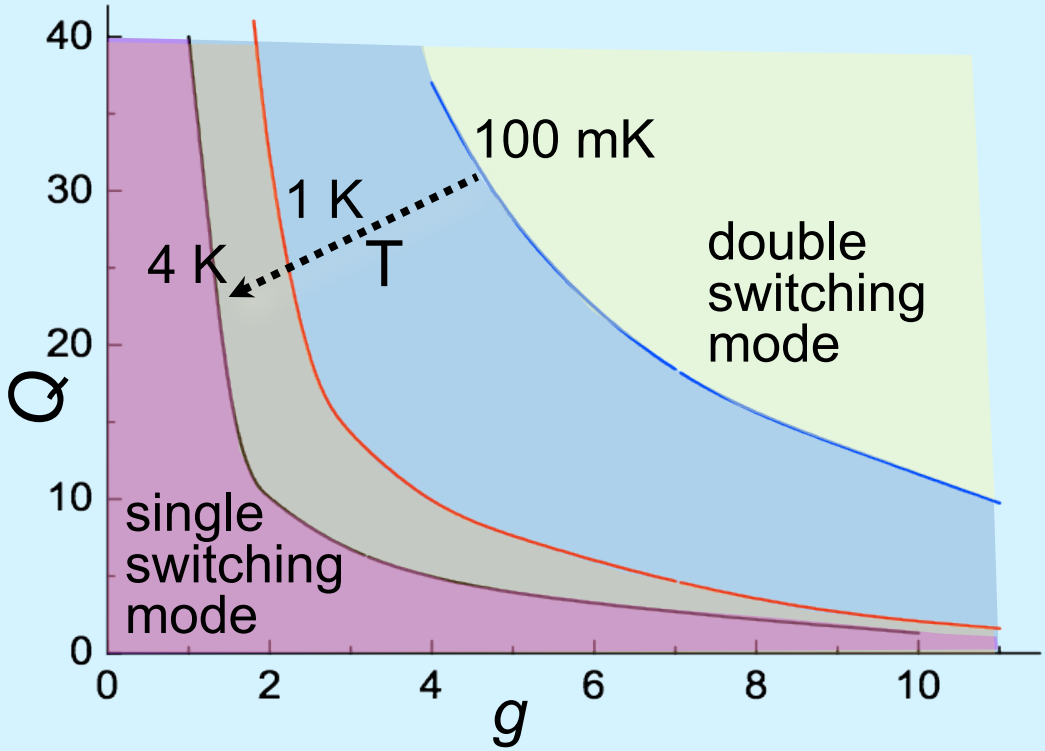
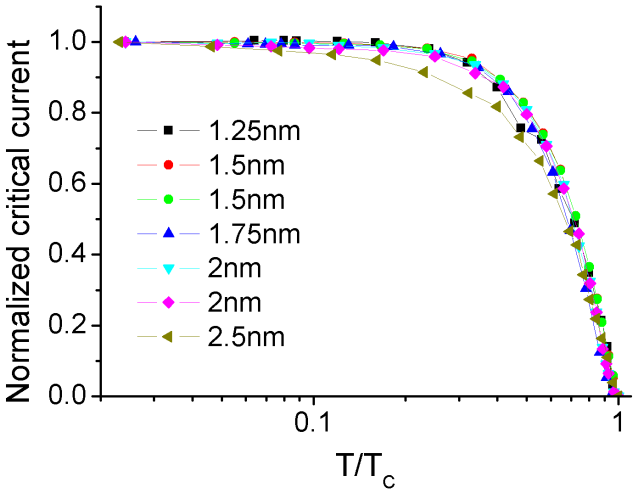
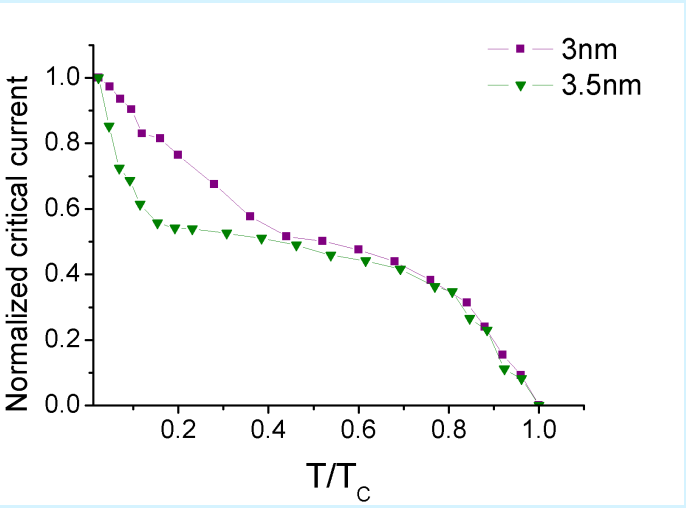




Ic(T) curves



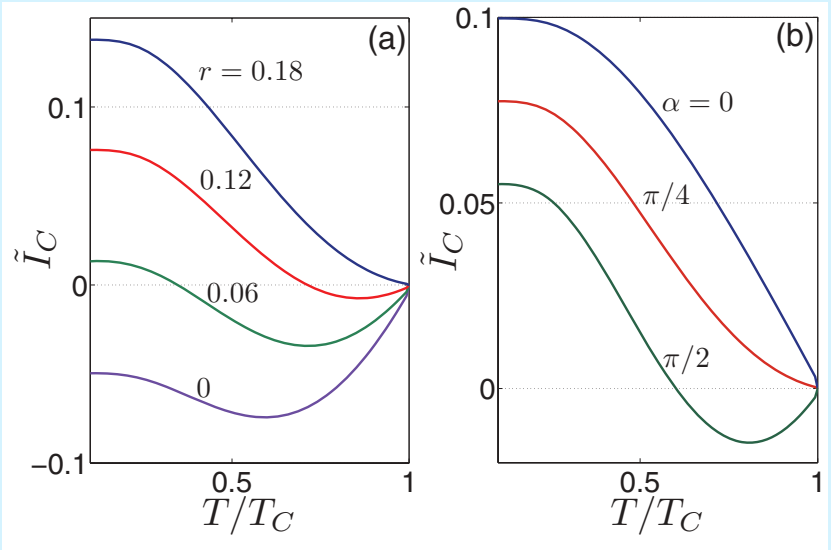


PHYSICAL REVIEW B **86**, 060506(R) (2012)

Spin-polarized Josephson and quasiparticle currents in superconducting spin-filter tunnel junctions

F. Sebastian Bergeret,[1,2,*] Alvise Verso,[2] and Anatoly F. Volkov[2,3]
[1]*Centro de Física de Materiales (CFM-MPC), Centro Mixto CSIC-UPV/EHU, Manuel de Lardizabal 4, E-20018 San Sebastián, Spain*
[2]*Donostia International Physics Center (DIPC), Manuel de Lardizabal 5, E-20018 San Sebastián, Spain*
[3]*Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany*

$$eR_N I_c = 2\pi T \sum_{\omega_n>0} \left\{ r\left[f_s^2 + f_t^2 \cos\alpha \cos\beta \right] + f_t^2 \sin\alpha \sin\beta \right\},$$

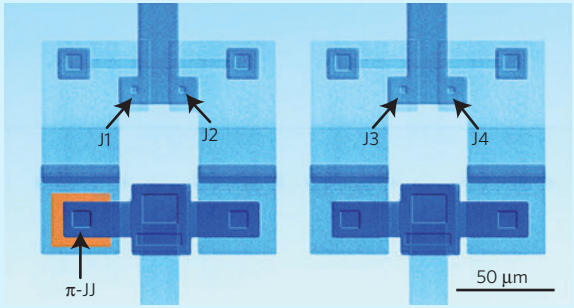


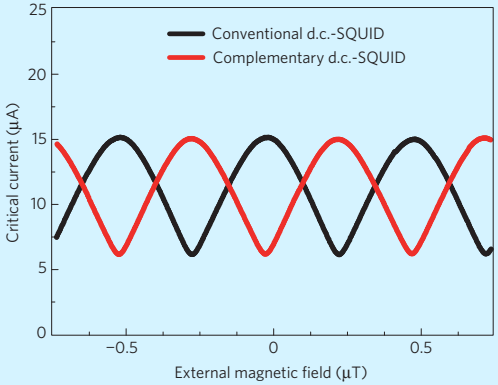
Hybrid qubit

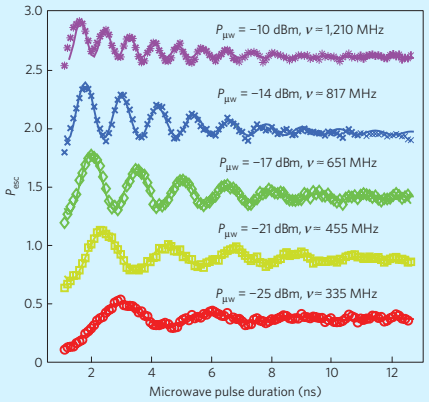
nature physics
LETTERS
PUBLISHED ONLINE: 20 JUNE 2010 | DOI: 10.1038/NPHYS1700

Implementation of superconductor/ferromagnet/superconductor π-shifters in superconducting digital and quantum circuits

A. K. Feofanov[1], V. A. Oboznov[2], V. V. Bol'ginov[2], J. Lisenfeld[1], S. Poletto[1], V. V. Ryazanov[2], A. N. Rossolenko[2], M. Khabipov[3], D. Balashov[3], A. B. Zorin[3], P. N. Dmitriev[4], V. P. Koshelets[4] and A. V. Ustinov[1]*



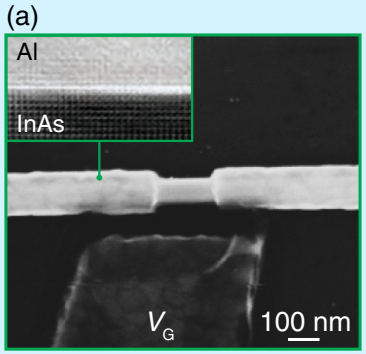


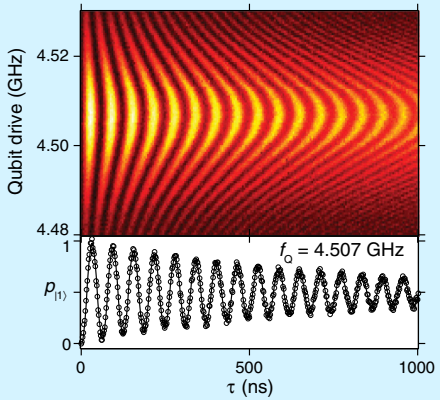


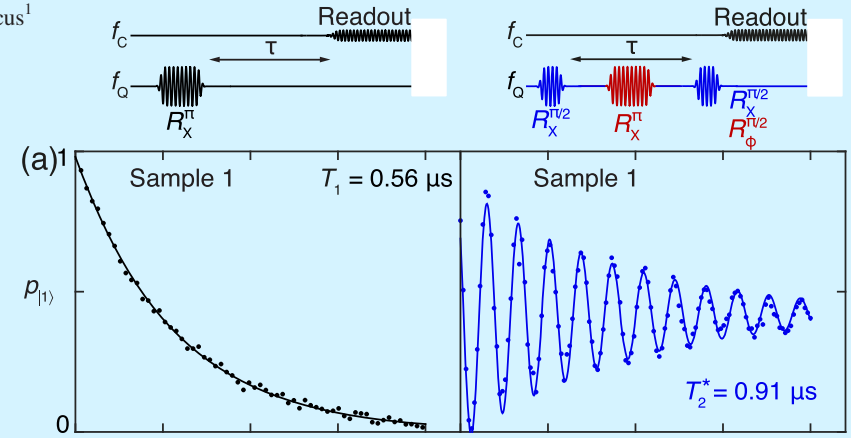
PRL 115, 127001 (2015)
Selected for a Viewpoint in *Physics*
PHYSICAL REVIEW LETTERS
week ending
18 SEPTEMBER 2015

Semiconductor-Nanowire-Based Superconducting Qubit

T. W. Larsen,[1] K. D. Petersson,[1] F. Kuemmeth,[1] T. S. Jespersen,[1] P. Krogstrup,[1] J. Nygård,[1,2] and C. M. Marcus[1]
[1]*Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Copenhagen 2100, Denmark*
[2]*Nano-Science Center, Niels Bohr Institute, University of Copenhagen, Copenhagen 2100, Denmark*





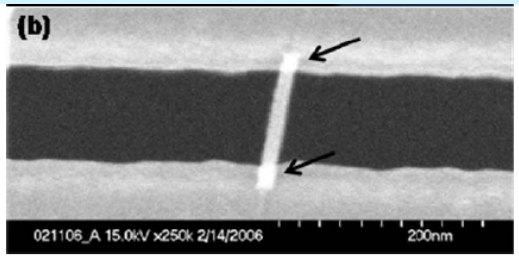


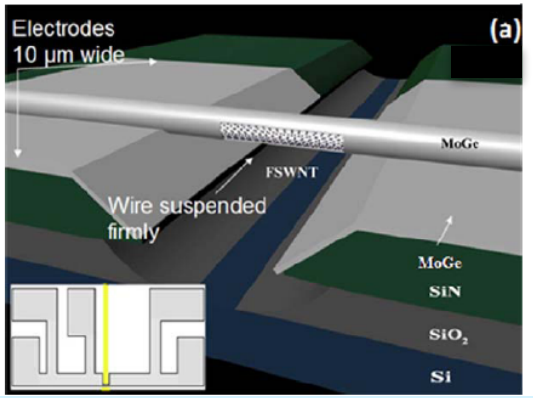
Switching dynamics in nanowires

nature physics
ARTICLES
PUBLISHED ONLINE: 17 MAY 2009 | DOI:10.1038/NPHYS1276

Individual topological tunnelling events of a quantum field probed through their macroscopic consequences

Mitrabhanu Sahu[1]*, Myung-Ho Bae[1], Andrey Rogachev[1,2], David Pekker[1,3], Tzu-Chieh Wei[1,4], Nayana Shah[1], Paul M. Goldbart[1] and Alexey Bezryadin[1]

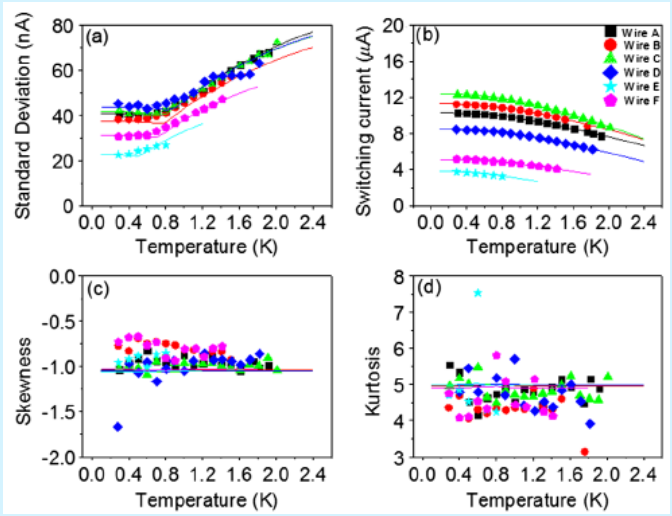




PRL 110, 247001 (2013) PHYSICAL REVIEW LETTERS week ending 14 JUNE 2013

Universal Features of Counting Statistics of Thermal and Quantum Phase Slips in Nanosize Superconducting Circuits

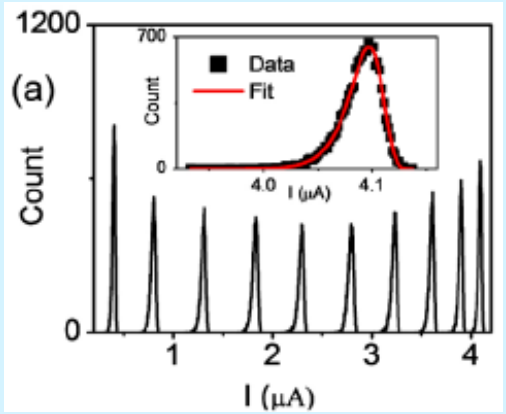
A. Murphy,[1] P. Weinberg,[2] T. Aref,[1,*] U.C. Coskun,[1] V. Vakaryuk,[3] A. Levchenko,[2] and A. Bezryadin[1,†]

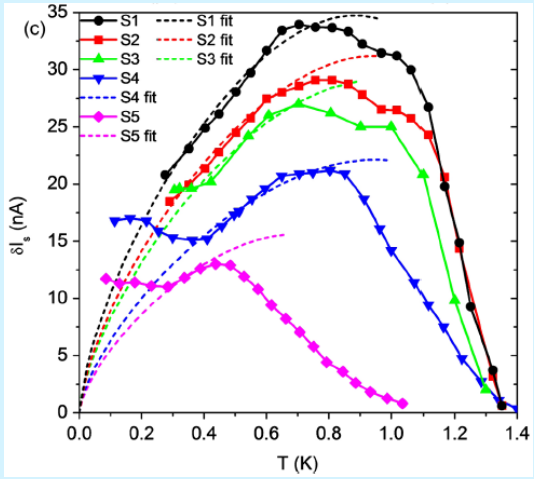


PRL 107, 137004 (2011) PHYSICAL REVIEW LETTERS week ending 23 SEPTEMBER 2011

Switching Currents Limited by Single Phase Slips in One-Dimensional Superconducting Al Nanowires

Peng Li, Phillip M. Wu, Yuriy Bomze, Ivan V. Borzenets, Gleb Finkelstein, and A.M. Chang*





Numerical simulations

PRL 101, 207001 (2008) PHYSICAL REVIEW LETTERS week ending 14 NOVEMBER 2008

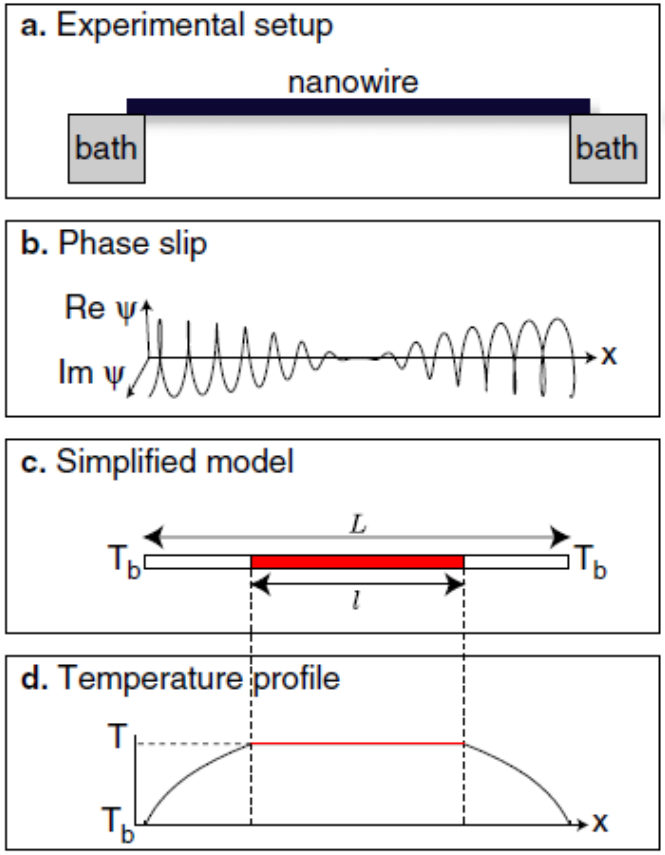
Inherent Stochasticity of Superconductor-Resistor Switching Behavior in Nanowires

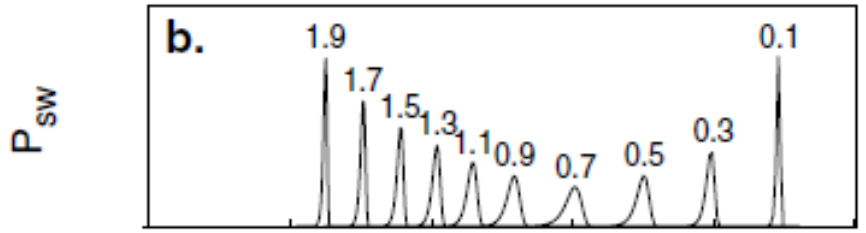
Nayana Shah, David Pekker, and Paul M. Goldbart

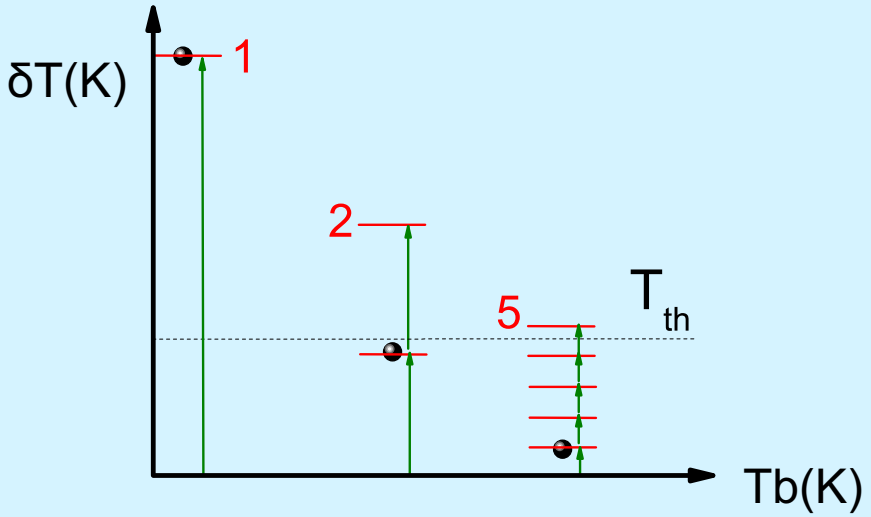
$$\Gamma_{\mathrm{TAPS}}(T, I) = \Omega_{\mathrm{TAPS}} \exp\left(\frac{-F(T, I)}{k_B T}\right)$$

$$\frac{dT}{dt} = -\alpha(T, T_b)(T - T_b) + \eta(T, I)\sum_i \delta(t - t_i).$$

$$\alpha(T, T_b) \equiv \frac{4}{l(L - l)C_v(T)} \frac{1}{T - T_b} \int_{T_b}^{T} dT' K_s(T').$$





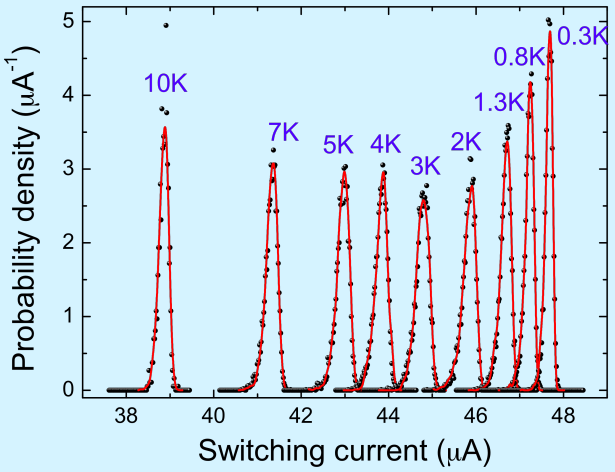


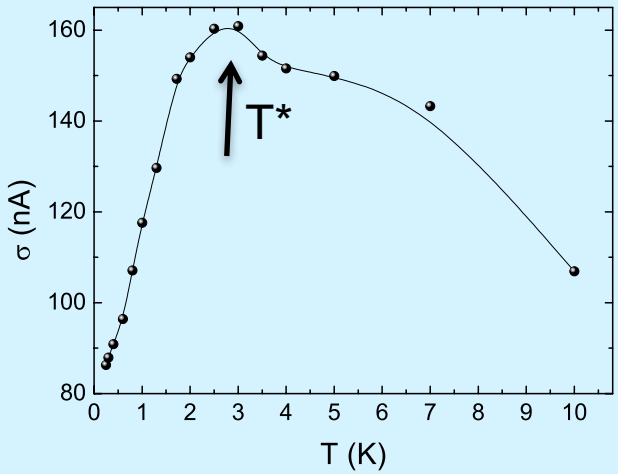
Numerical simulations

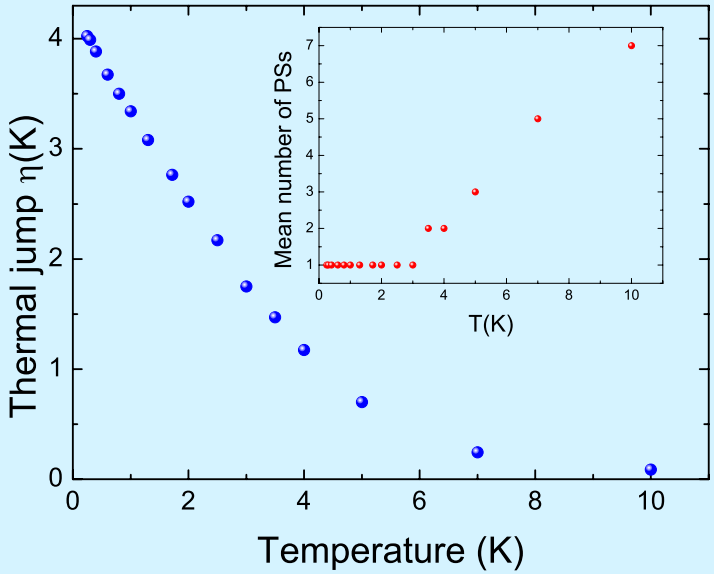
PHYSICAL REVIEW B **92**, 054501 (2015)

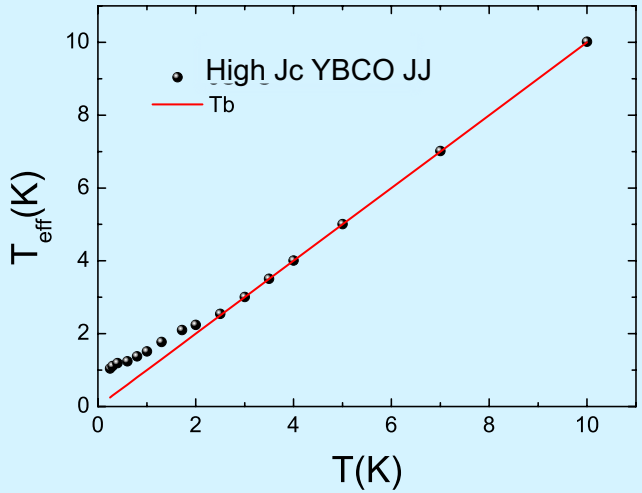
Breakdown of the escape dynamics in Josephson junctions

D. Massarotti,[1,2,*] D. Stornaiuolo,[1,2] P. Lucignano,[2] L. Galletti,[1,2] D. Born,[3] G. Rotoli,[4] F. Lombardi,[5] L. Longobardi,[4,6] A. Tagliacozzo,[1,2] and F. Tafuri[2,4]







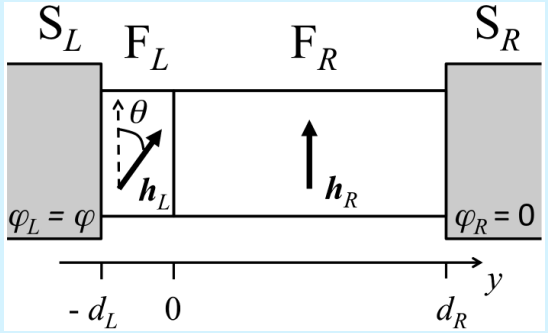


Superharmonic Long-Range Triplet Current in a Diffusive Josephson Junction

Caroline Richard, Manuel Houzet, and Julia S. Meyer

SPSMS, UMR-E 9001 CEA/UJF-Grenoble 1, INAC, Grenoble F-38054, France

(Received 5 March 2013; published 21 May 2013)



Long-Range Superharmonic Josephson Current

Luka Trifunovic

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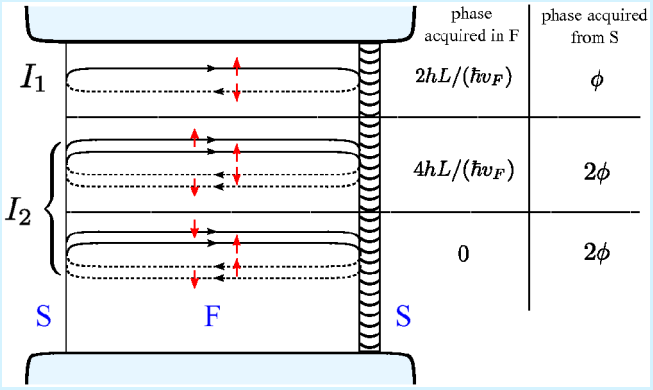
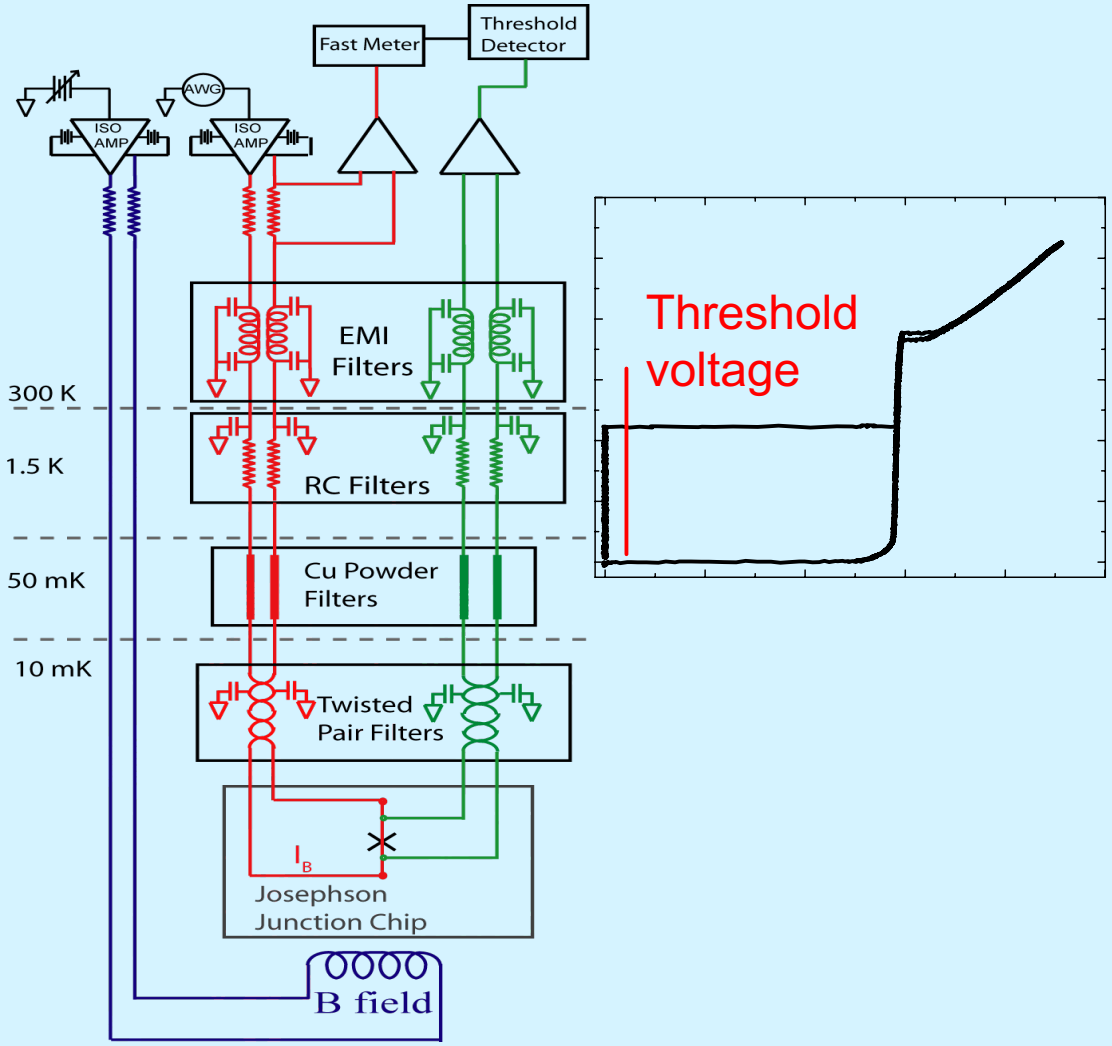
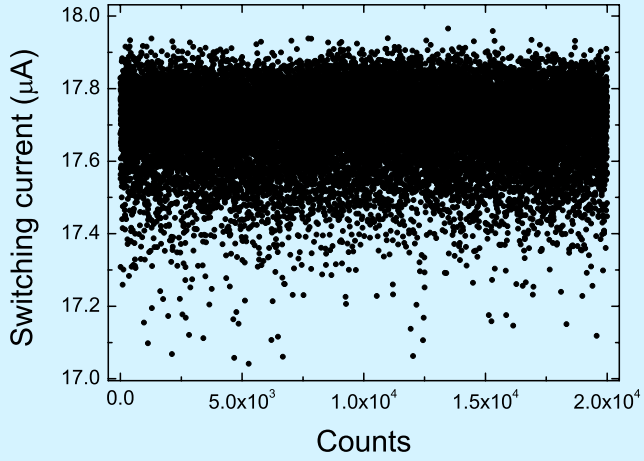
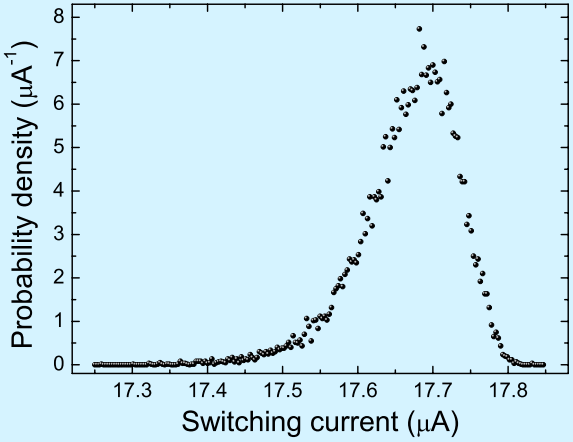
(Received 27 January 2011; published 18 July 2011)



Low temperature measurements

Measurement setup