Anomalous Voltage drop along disordered superconducting InO_x nanowires

Shachaf Poran and Aviad Frydman

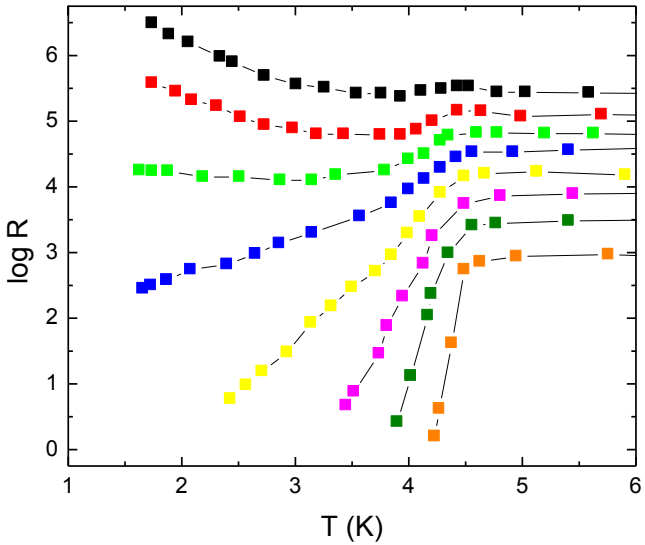
Bar Ilan University

Quench condensed films

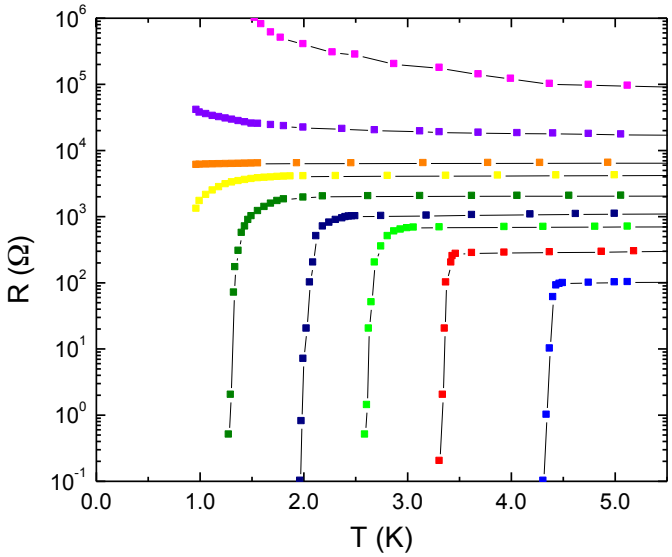
“Granular”

“Uniform”

Granular Sn

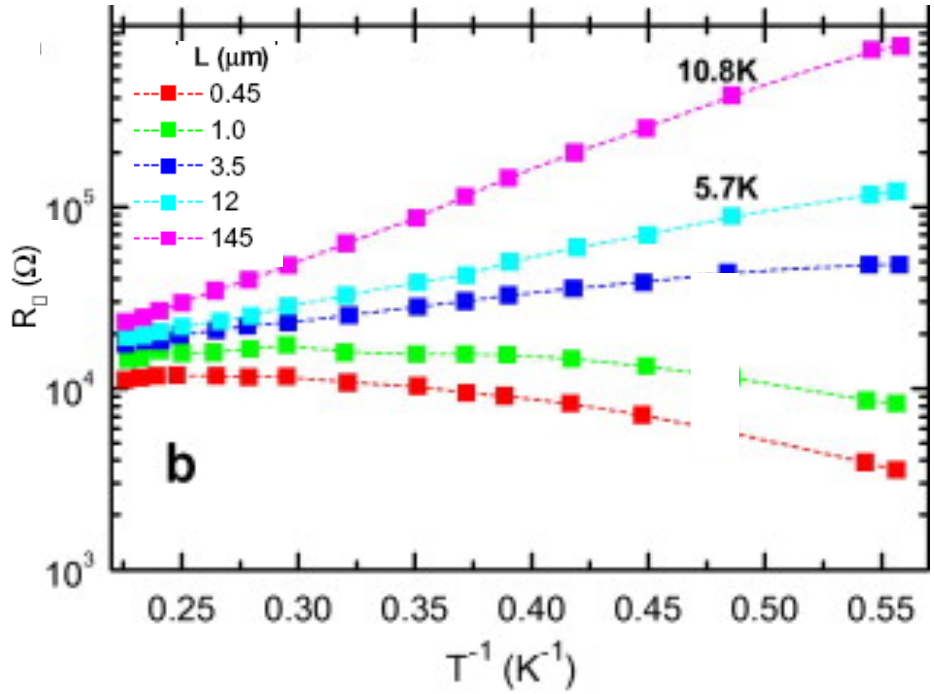


uniform Sn

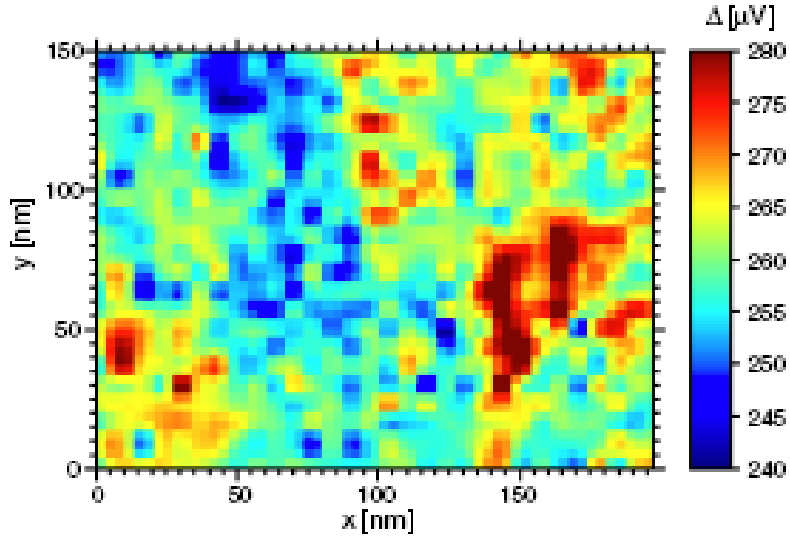


“Disorder induced granularity”

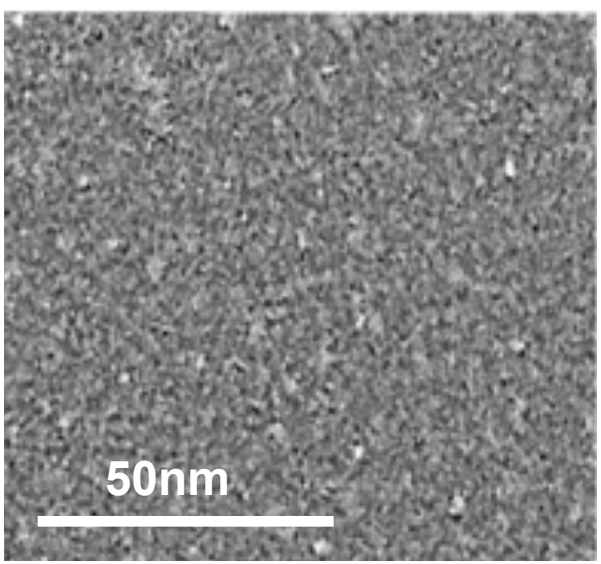
InO, TiN…

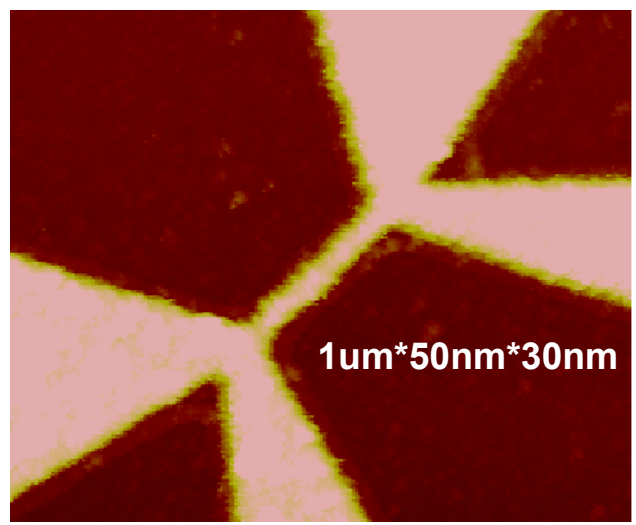


Kowal and Ovadyahu 94, 07



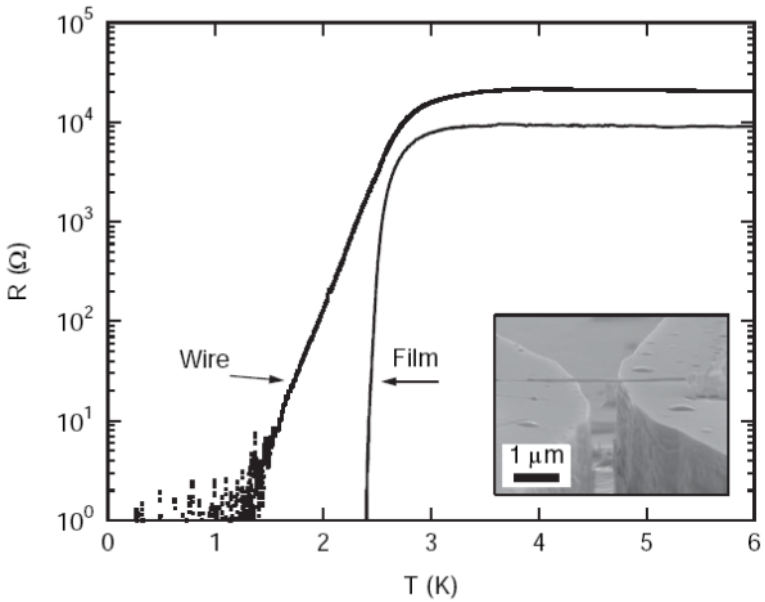
Sace´pe´, Chapelier, T.Baturina, Vinokur, Baklanov, M. Sanquer PRL (2008)

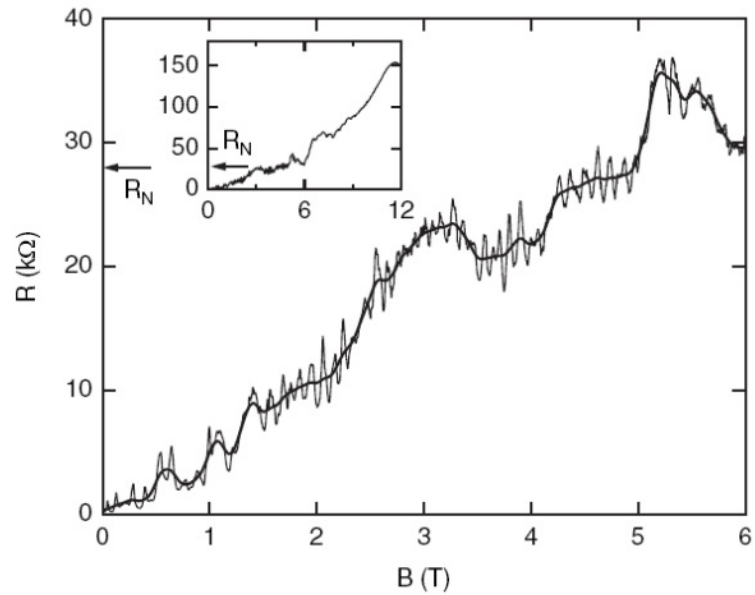




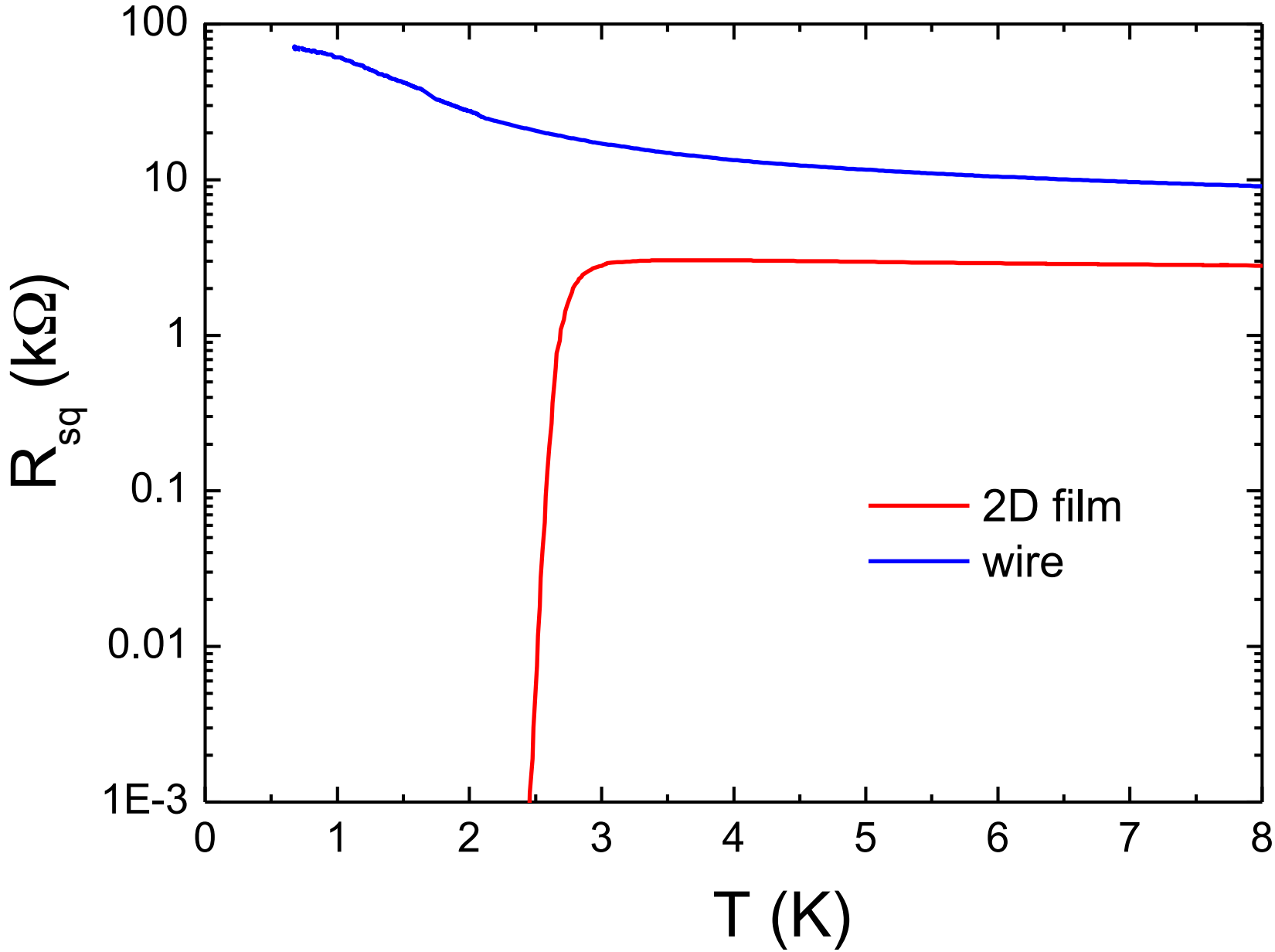
Nanowire Acting as a Superconducting Quantum Interference Device

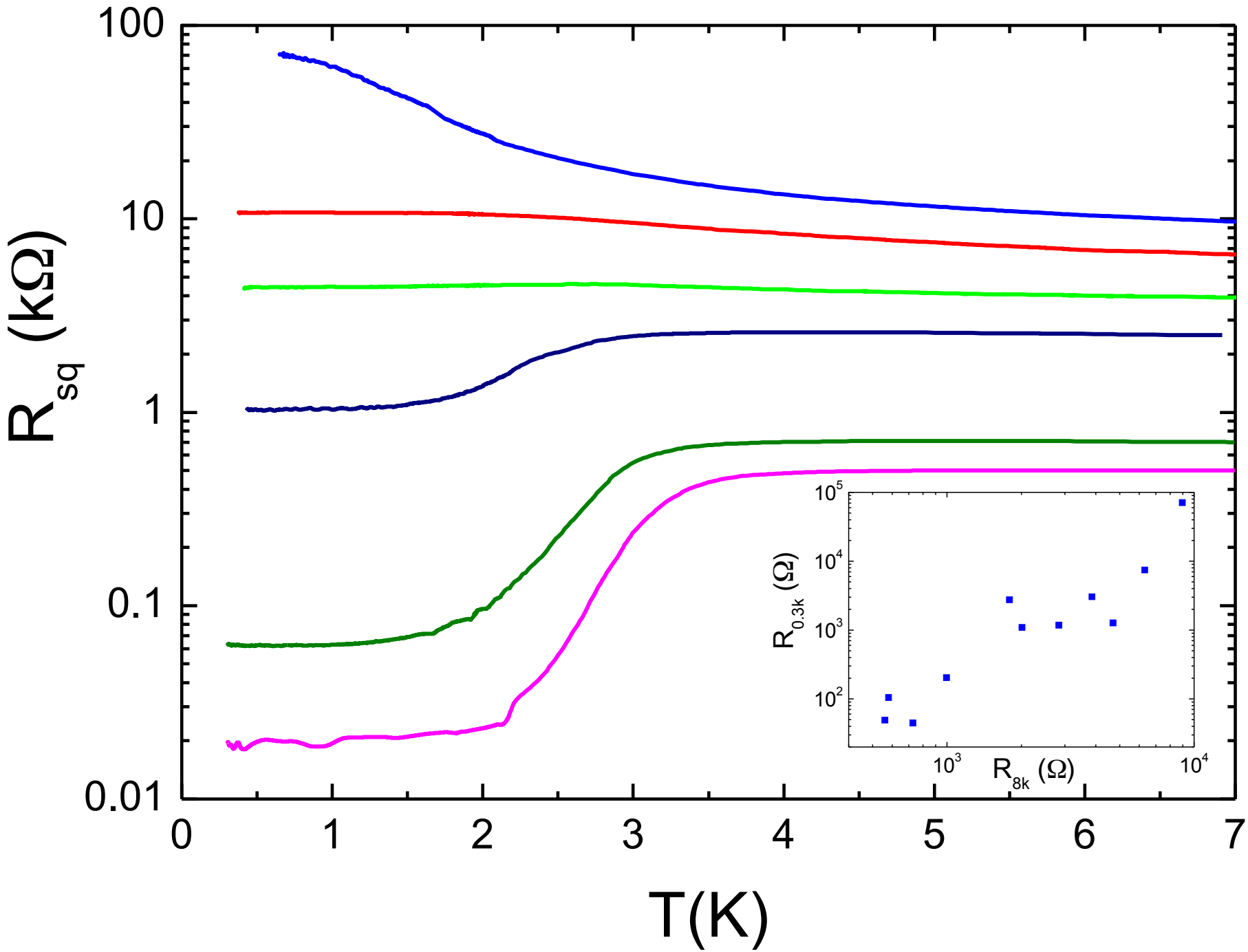
A. Johansson, G. Sambandamurthy,* and D. Shahar
Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot 76100, Israel

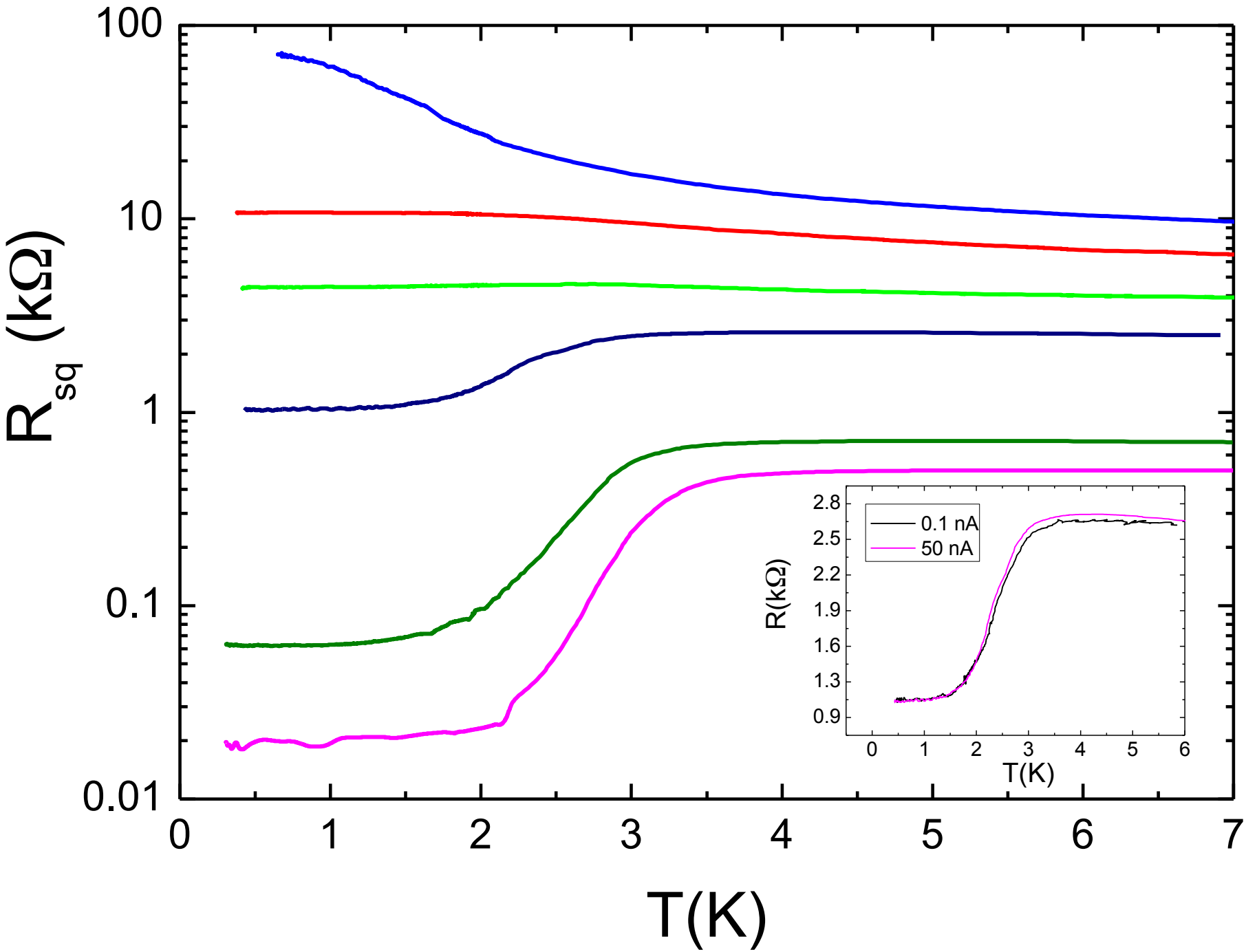


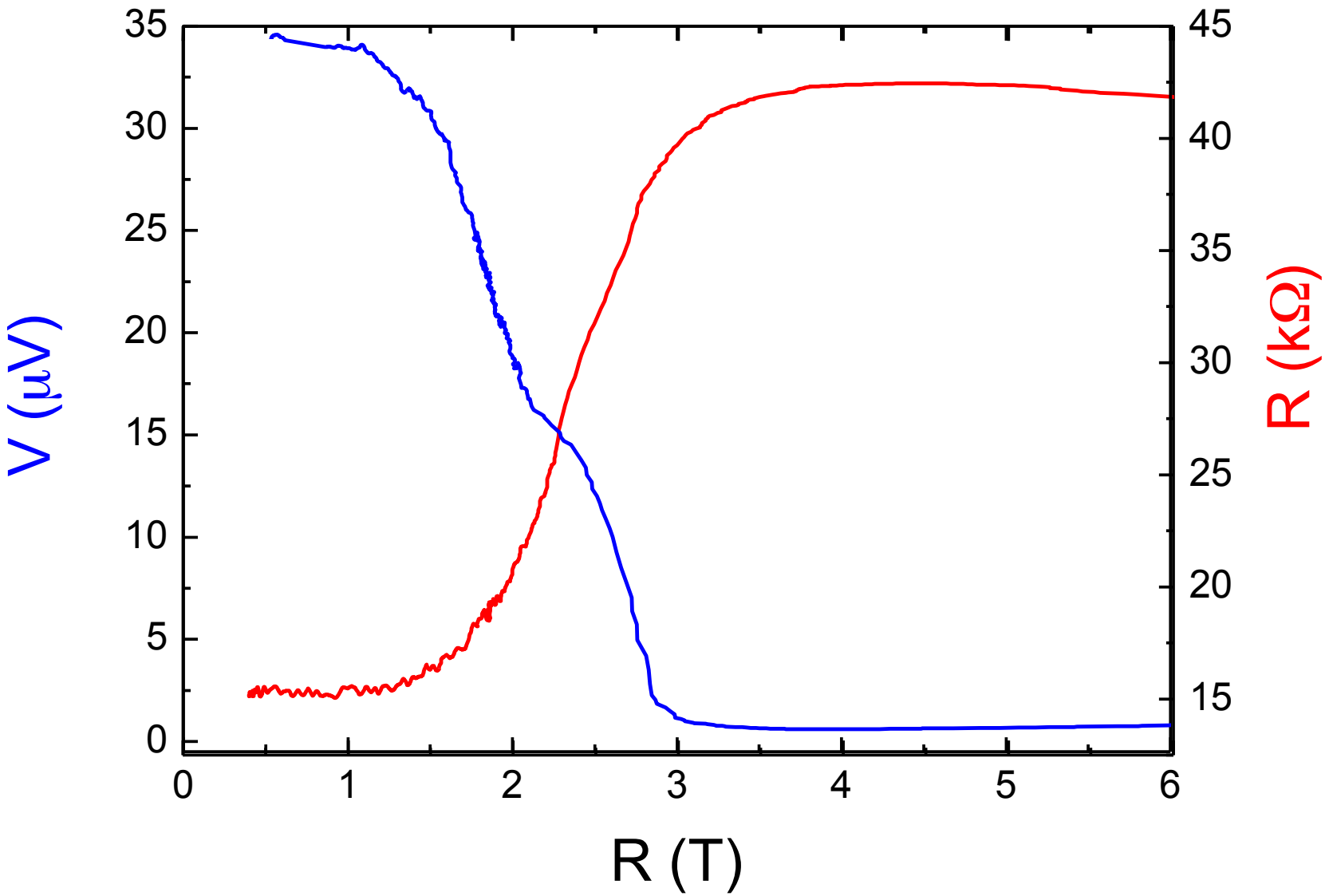


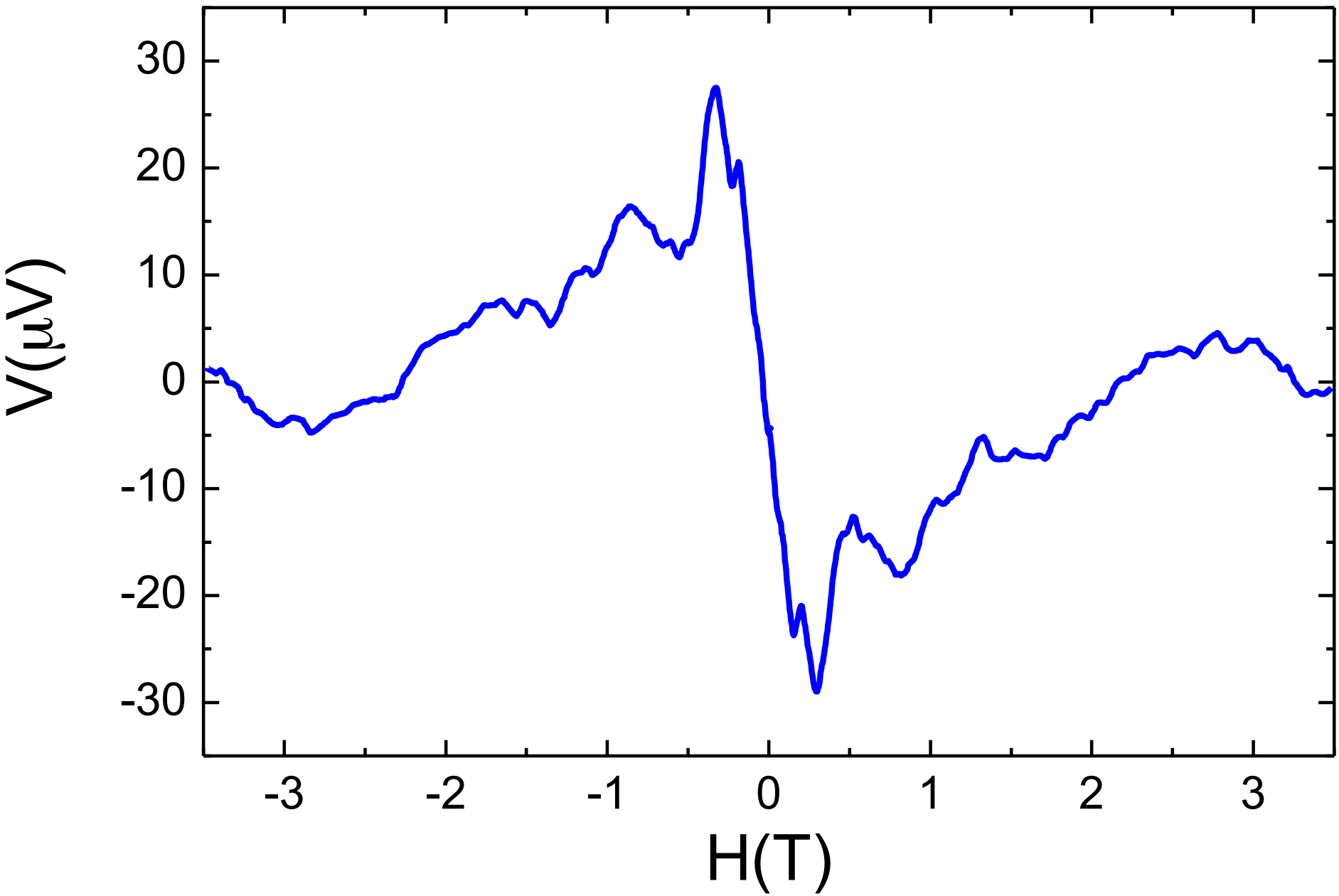
of 10^{20}–10^{21} cm^{-3} [21,22] when calculating l. In some of our wires, the resistance ceases to drop and saturates at a low-T value between 0.06–40 kΩ. Other wires, such as the wire in Fig. 1, show a vanishing resistance in the low-T

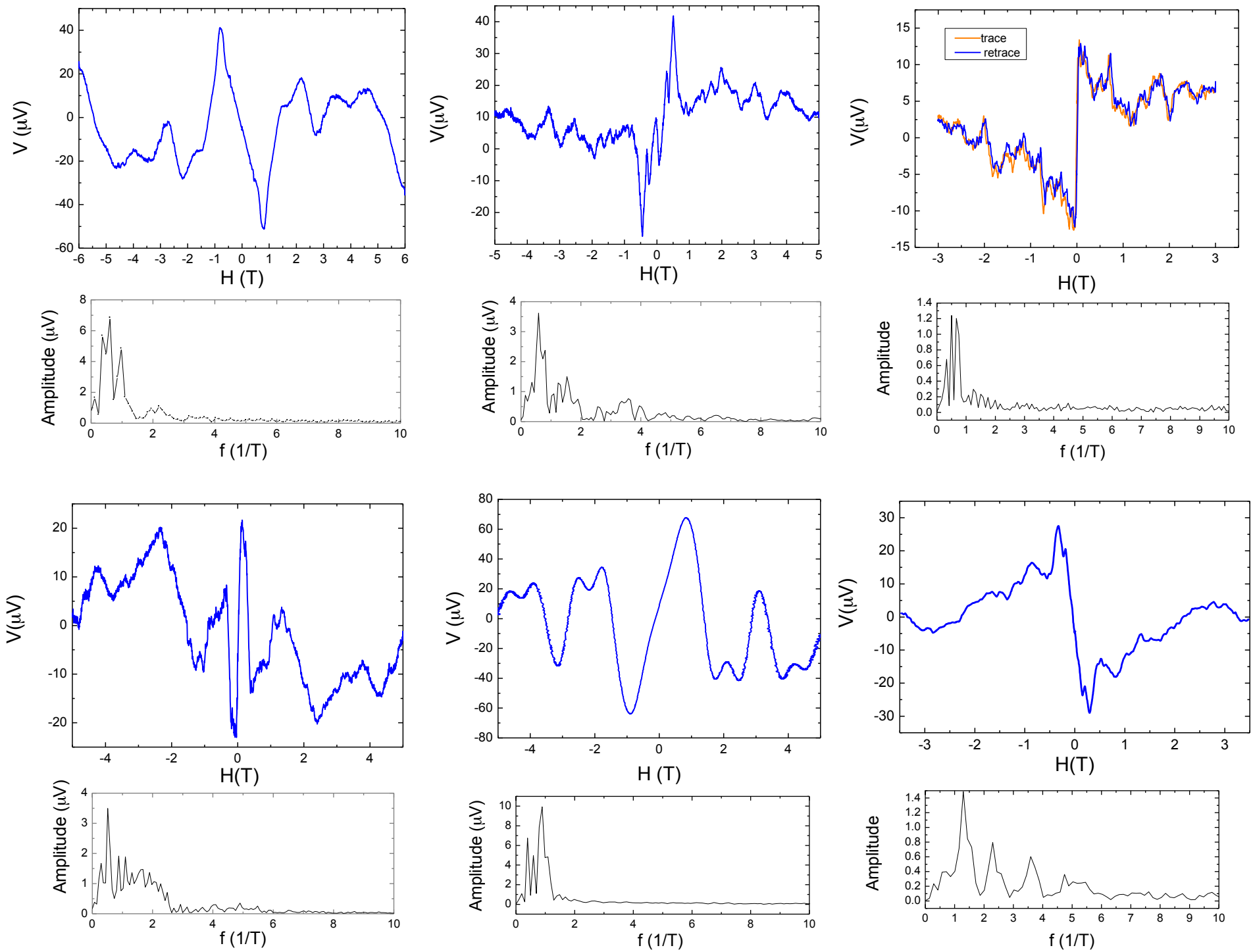

100
10
1
0.1
0.01
1E-3
0
1
2
3
4
5
6
7
8
R_{sq} (kΩ)
T (K)
2D film
wire


100
10
1
0.1
0.01
R_{sq} (kΩ)
0
1
2
3
4
5
6
7
T(K)
10^5
10^4
10^3
10^2
$R_{0.3k}$ (Ω)
10^3
R_{8k} (Ω)
10^4

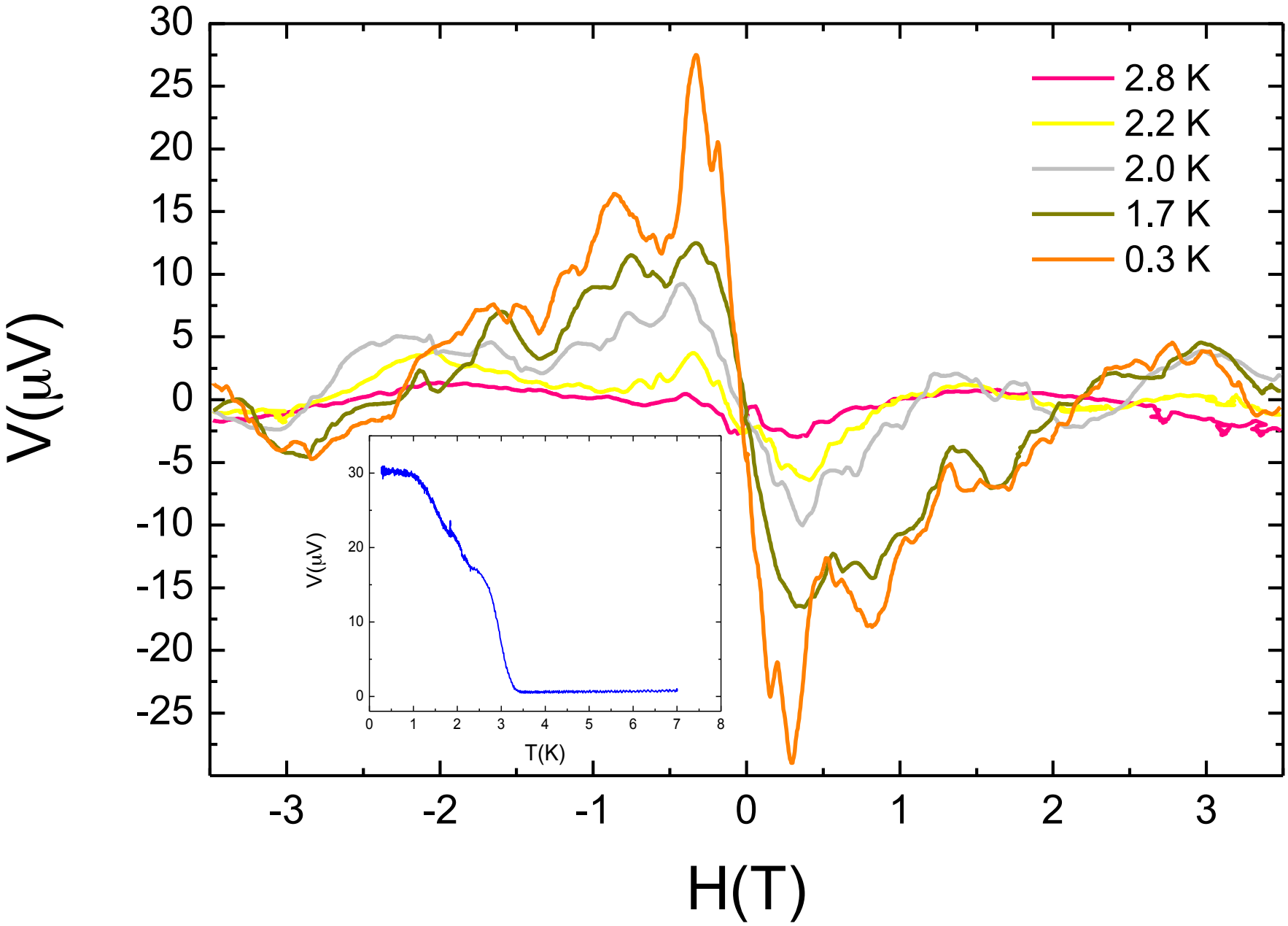

100
10
1
0.1
0.01
R_{sq} (kΩ)
0
1
2
3
4
5
6
7
T(K)
2.8
2.5
2.2
1.9
1.6
1.3
0.9
R(kΩ)
0.1 nA
50 nA
0
1
2
3
4
5
6
T(K)


35
30
25
20
15
10
5
0
45
40
35
30
25
20
15
0
1
2
3
4
5
6
V (μV)
R (kΩ)
R (T)

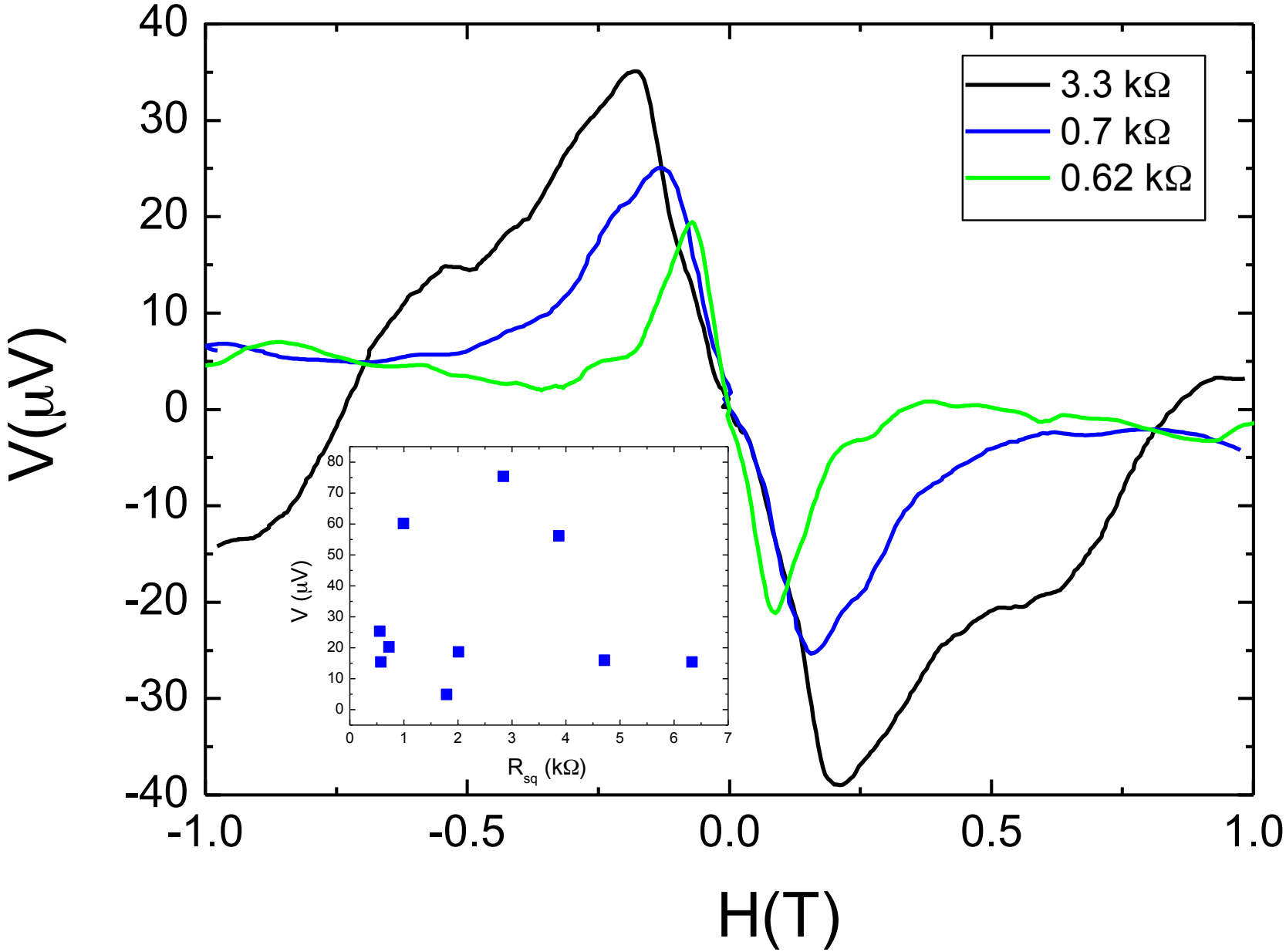

30
20
10
0
-10
-20
-30
V(μV)
-3
-2
-1
0
1
2
3
H(T)


V (μV)
H (T)
Amplitude (μV)
f (1/T)
V(μV)
H(T)
Amplitude (μV)
f (1/T)
trace
retrace
V(μV)
H(T)
Amplitude
f (1/T)
V(μV)
H(T)
Amplitude (μV)
f (1/T)
V (μV)
H (T)
Amplitude (μV)
f (1/T)
V(μV)
H(T)
Amplitude
f (1/T)

Temperature Dependence

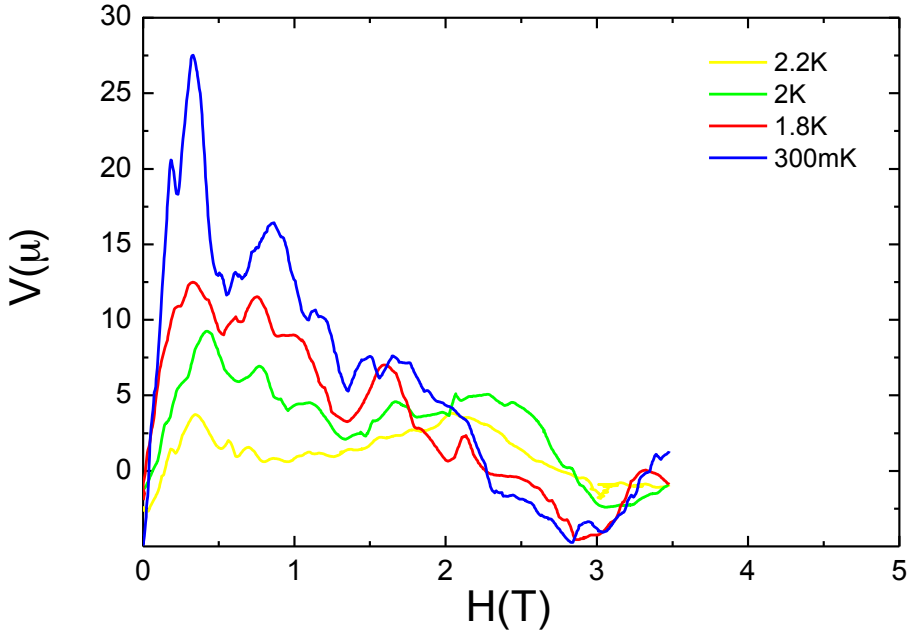


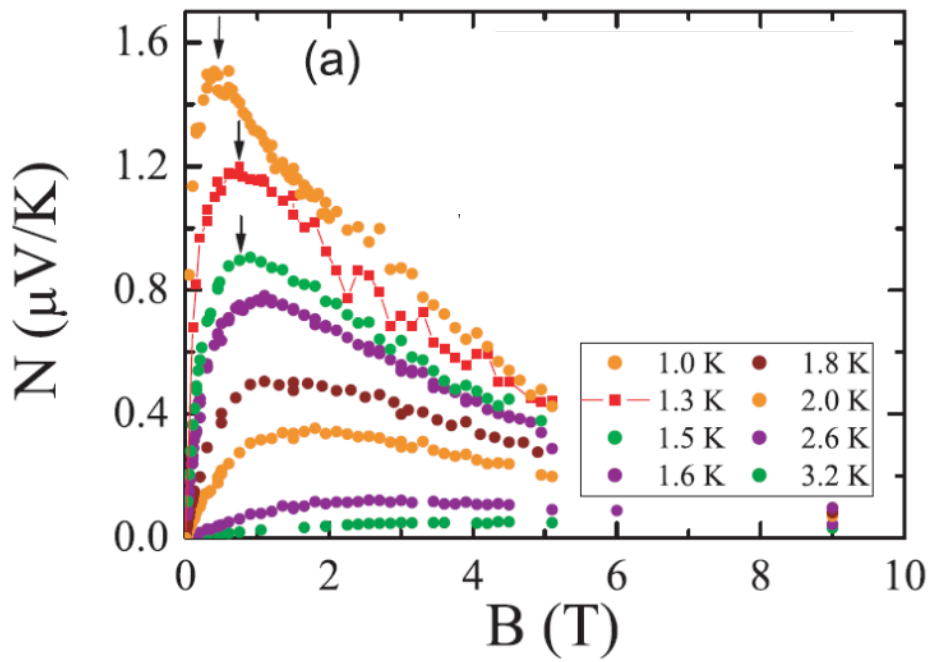
Disorder Dependence



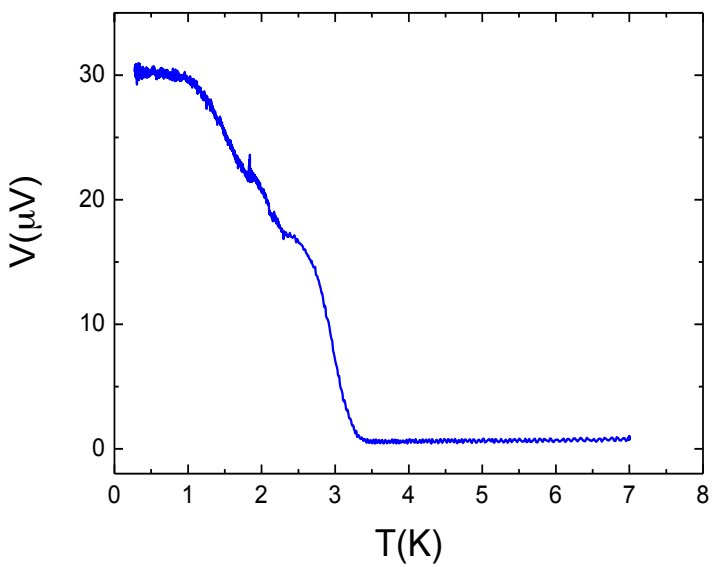
- Large voltage drop
- Antisymmetric with magnetic field
- Appears only in the disordered state (weak superconductivity)
- Quasi-periodic with H

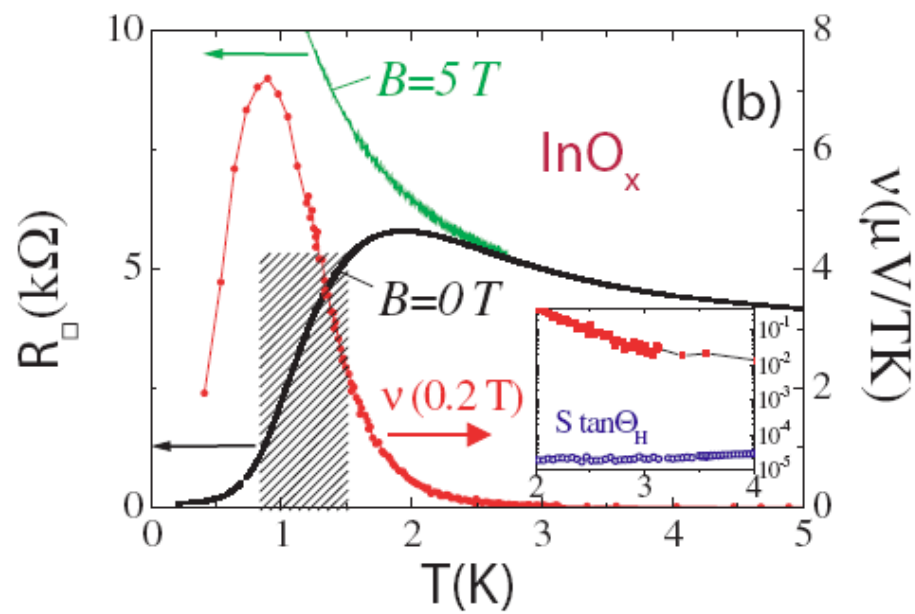
→ Vortex motion



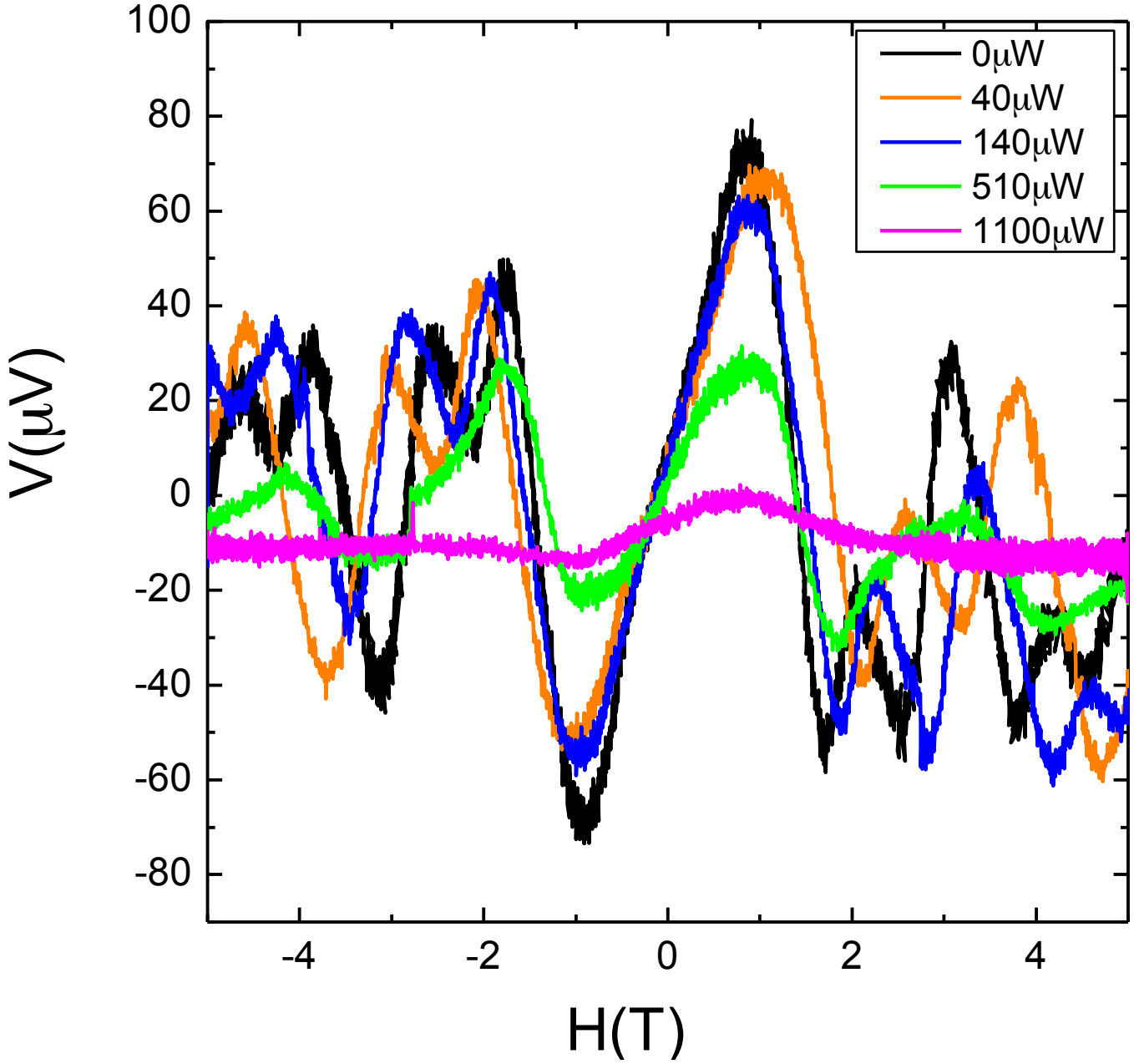


Spathis, Aubin, Pourret and Behnia, EPL (2008)

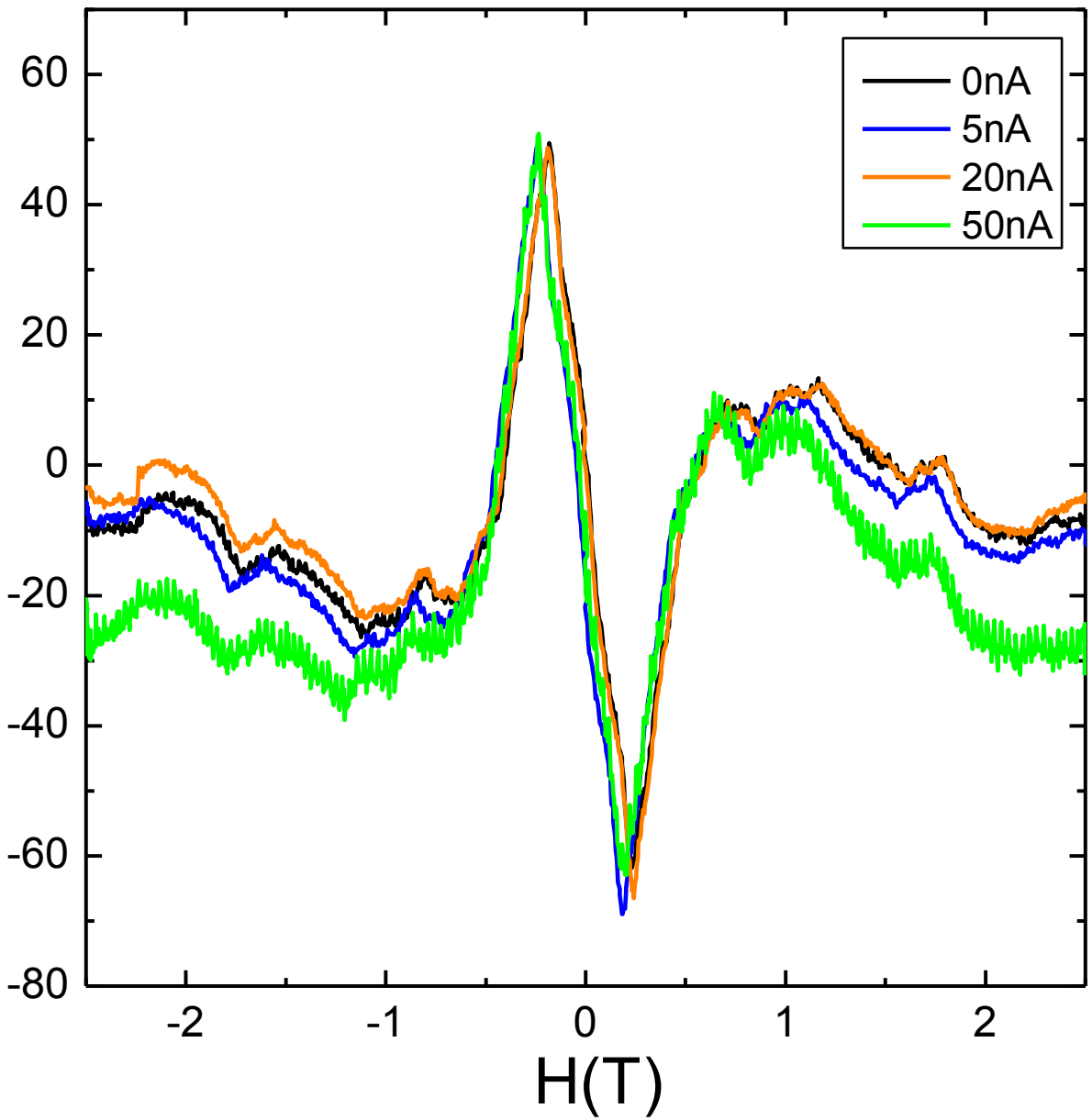




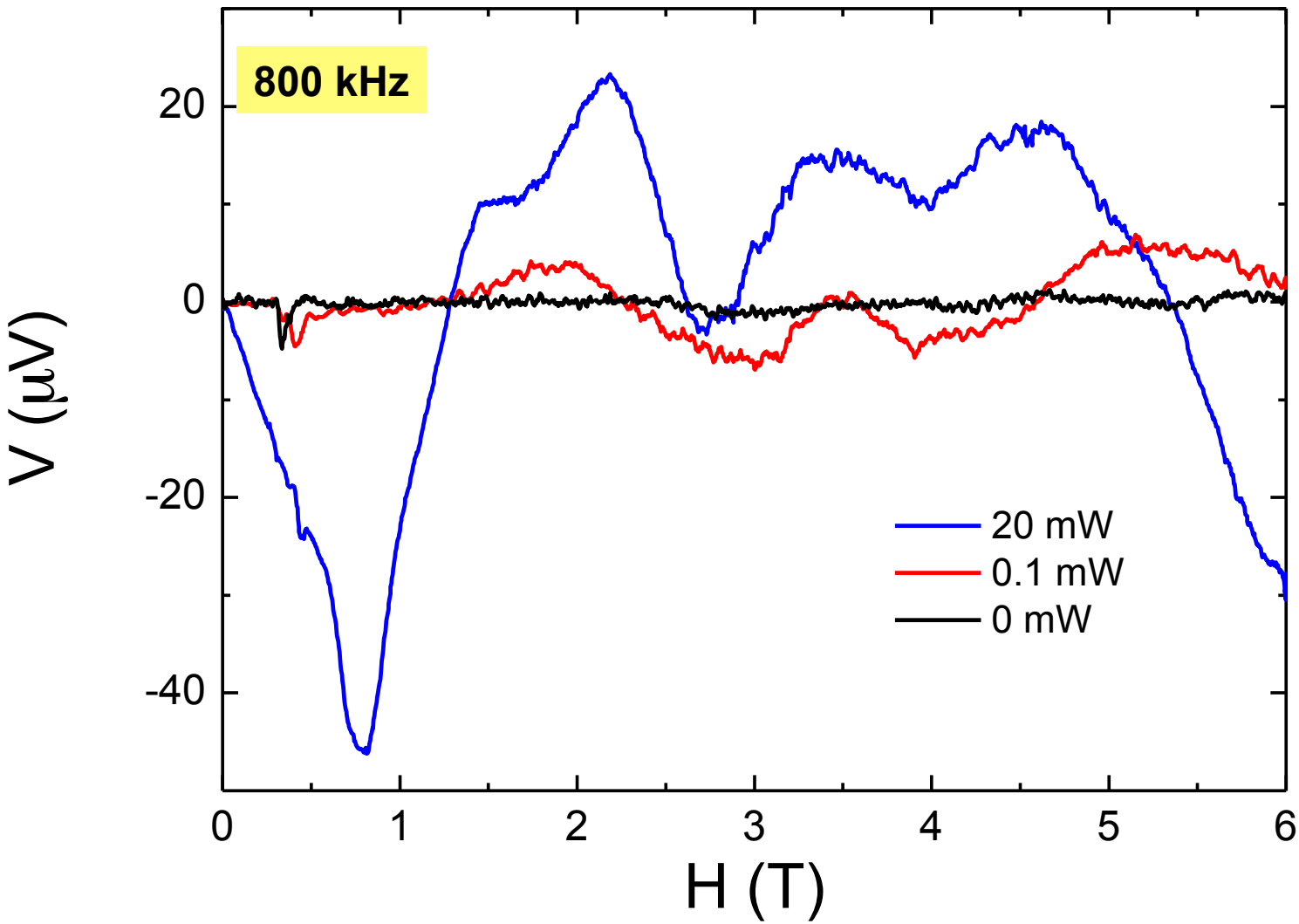
Induced temperature gradient



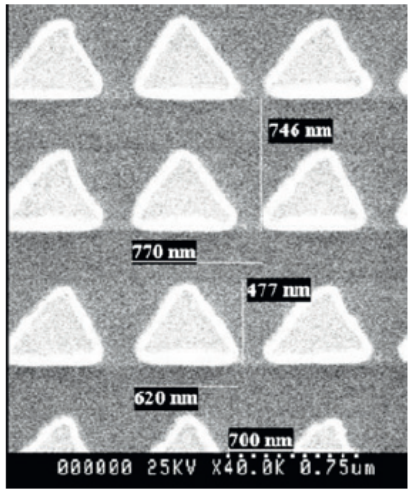
Applied dc current

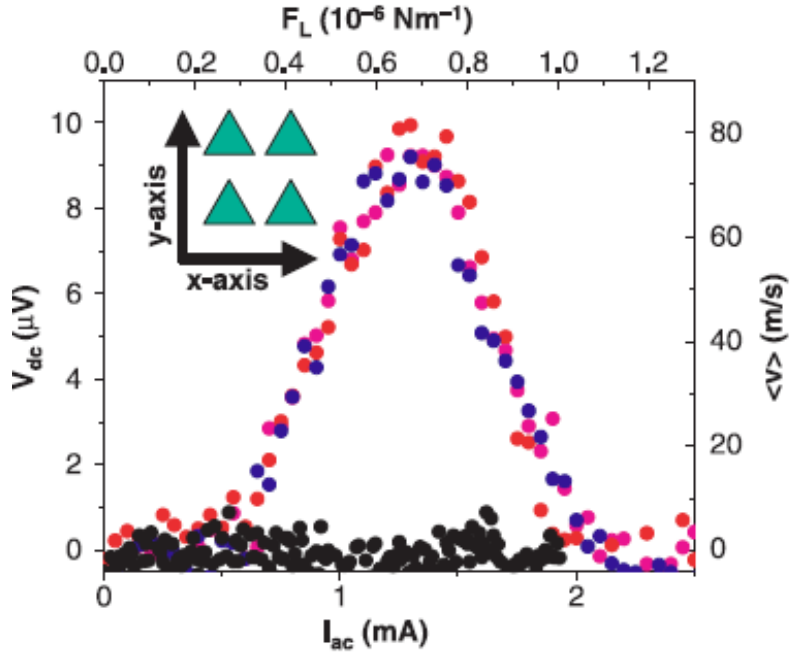


Effect of radiation



The Superconducting Ratchet Effect



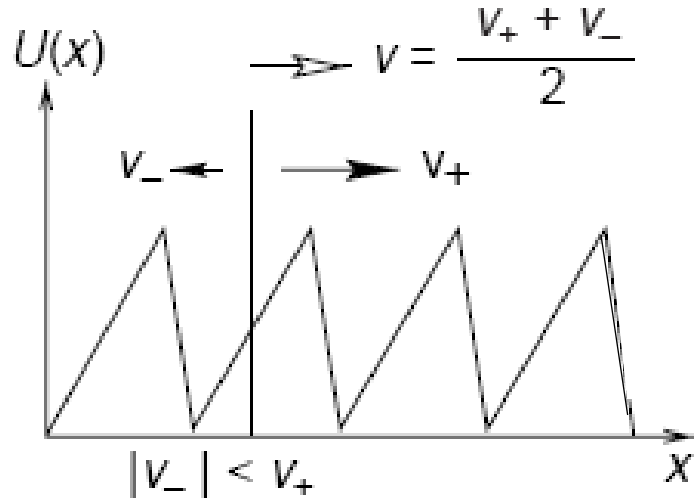


Villegas et-al. Science (2003)

$$F = (j \times \hat{h})\phi_0 d - \frac{dU}{dx}$$

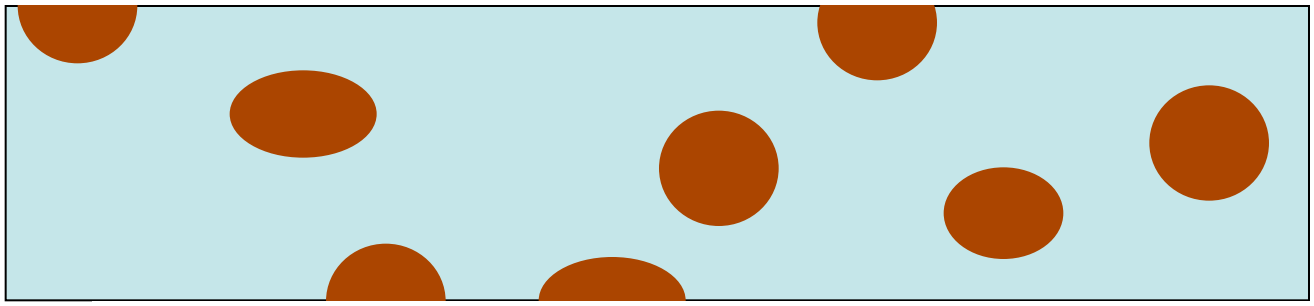
$$v = F / \eta$$

$$V \propto v \times H$$



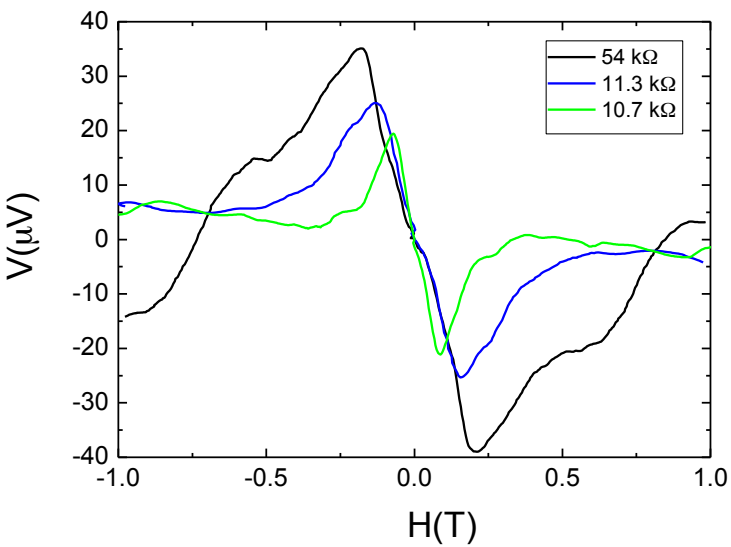
Lee et-al, Nature 1999

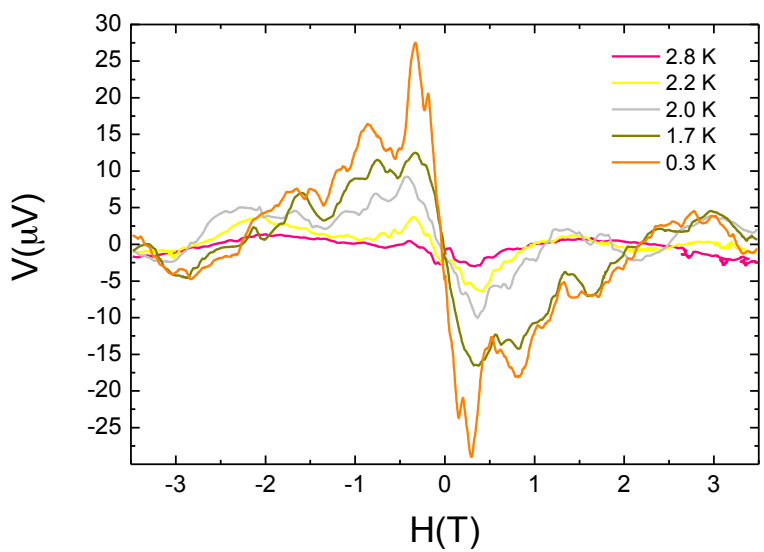
Geometry Induced Ratchet Effect



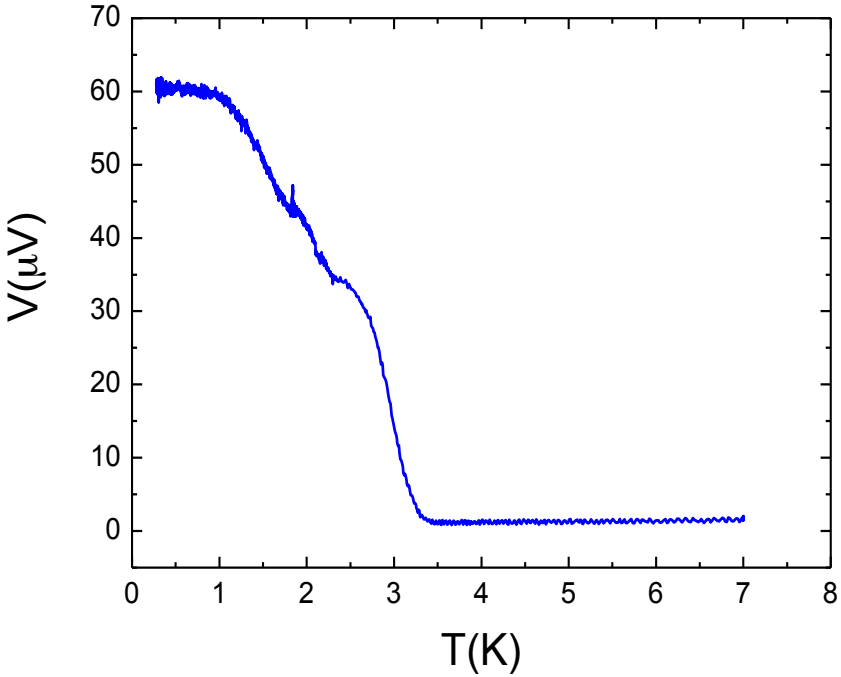
H

$$V \propto e^{\frac{U_1}{kT}} - e^{\frac{U_2}{kT}}$$

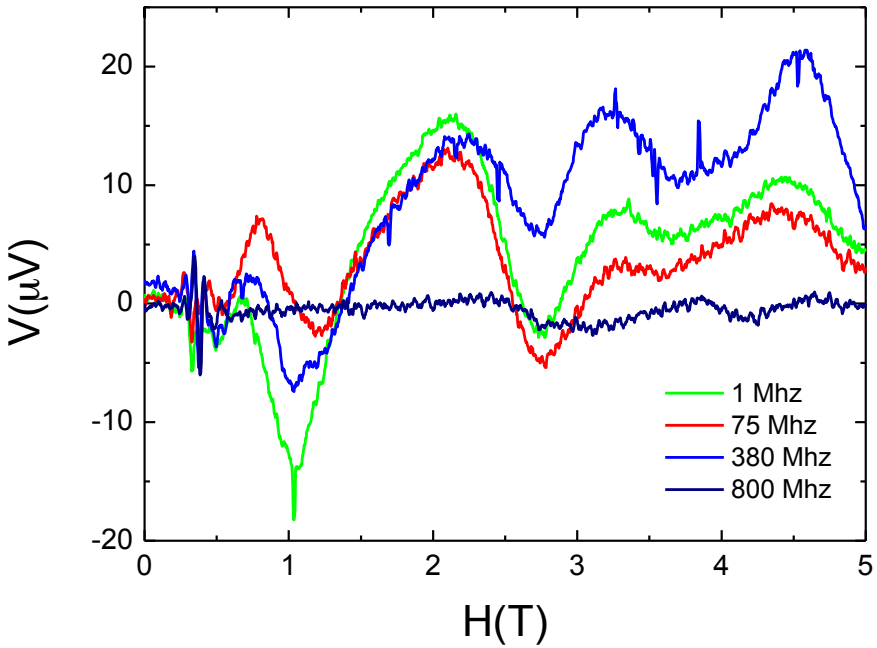




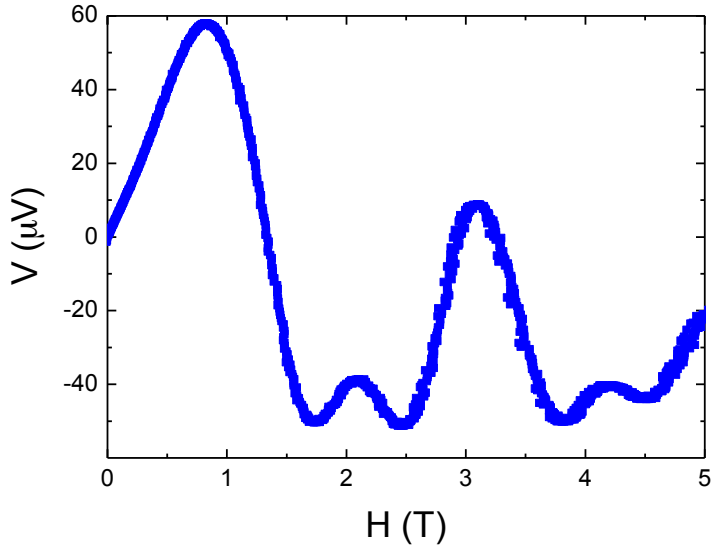
Crossover from thermal activation to quantum tunneling?

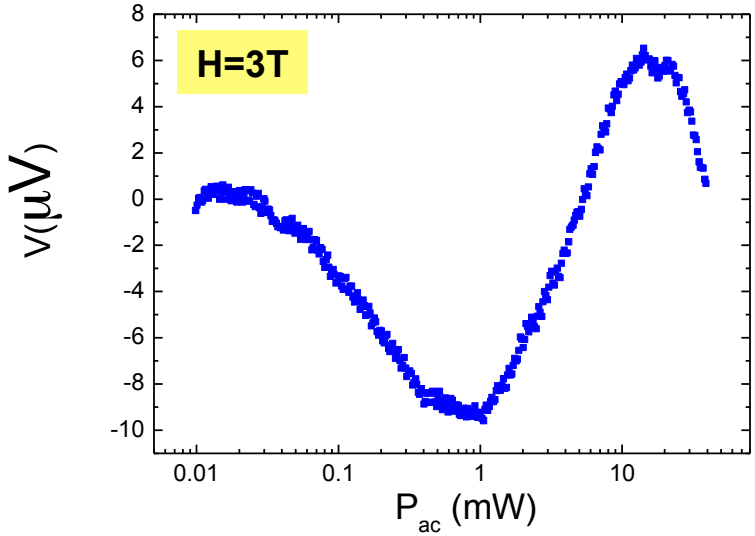


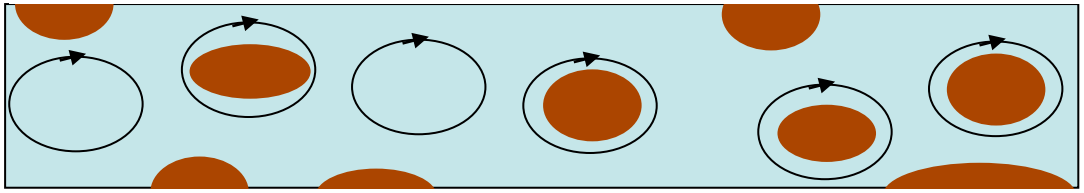
Frequency upper threshold?

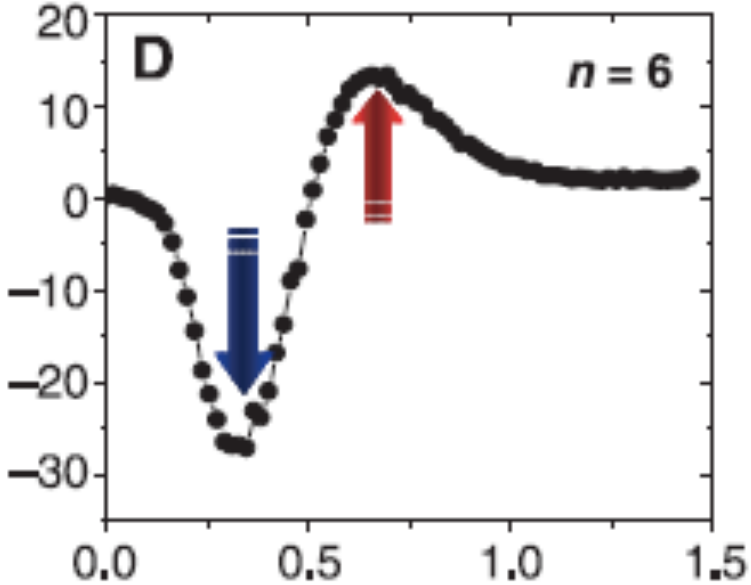


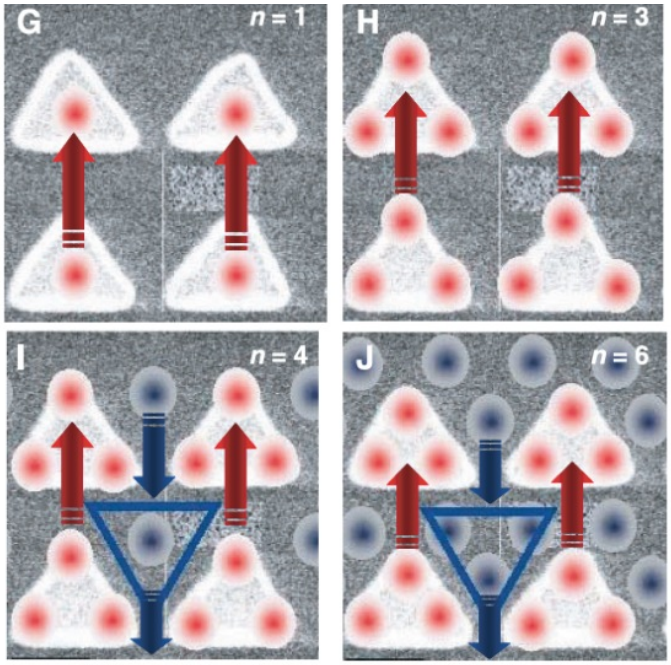
Reverse ratchet











Summary

InOx wires close to the SIT that are exposed to radiation exhibit the following:

- The low temperature resistance saturates at a finite value.

- A finite, antisymmetric with magnetic field, sample dependent voltage drops across the wire.

- The voltage increases with temperature below T_C but saturates at low T.

- The voltage decreases with decreasing the disorder thus approaching the clean superconducting limit.

- Non trivial frequency, amplitude and magnetic field dependence.

Suggested scenario: Geometry and disorder induced ratchet effect