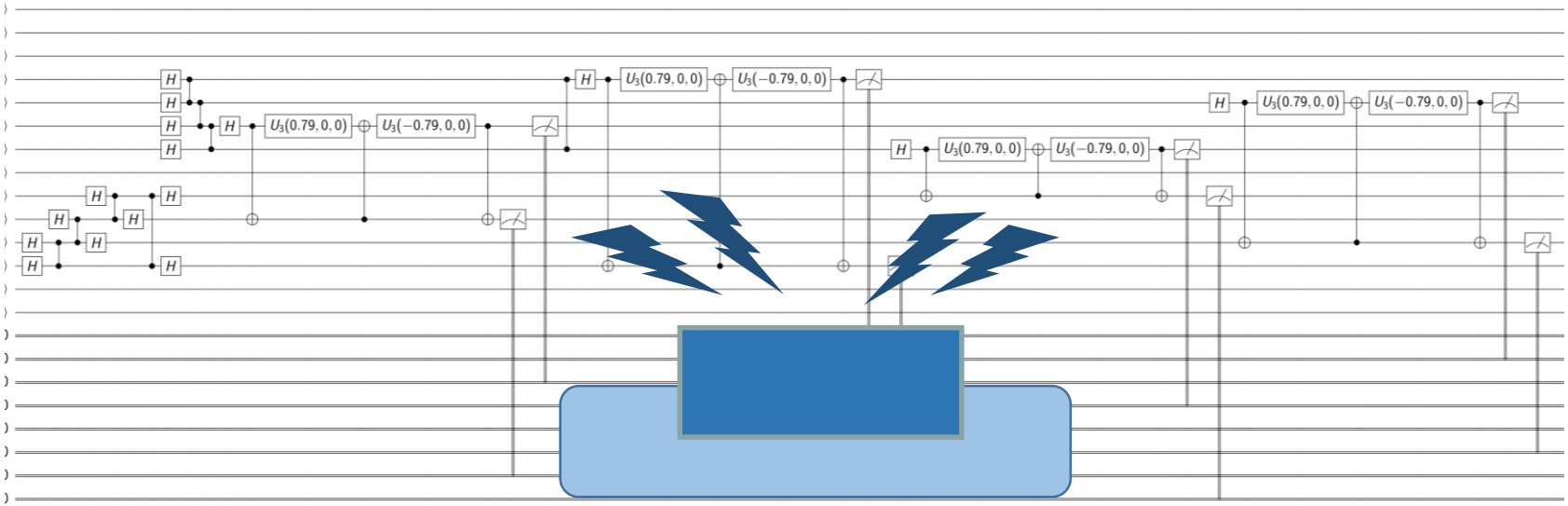
Many-body physics with superconducting circuits



Many-body quantum dynamics group

Mor Roses

Daniel Atzitz

Inbar Shani

Eran Sela
(TAU)

Yehuda Naveh
(IBM)

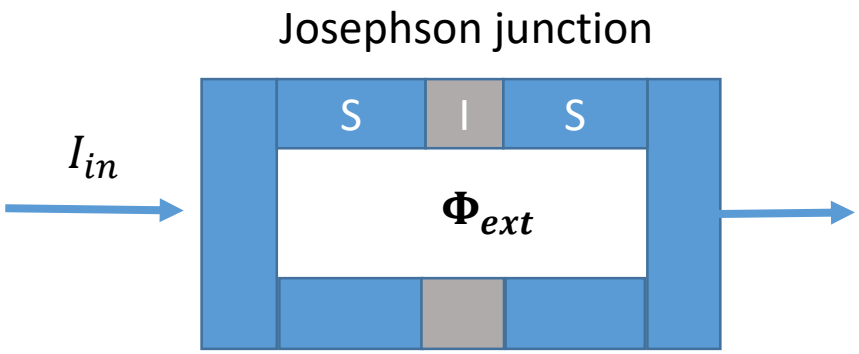
Yachin Ivry
(Technion)

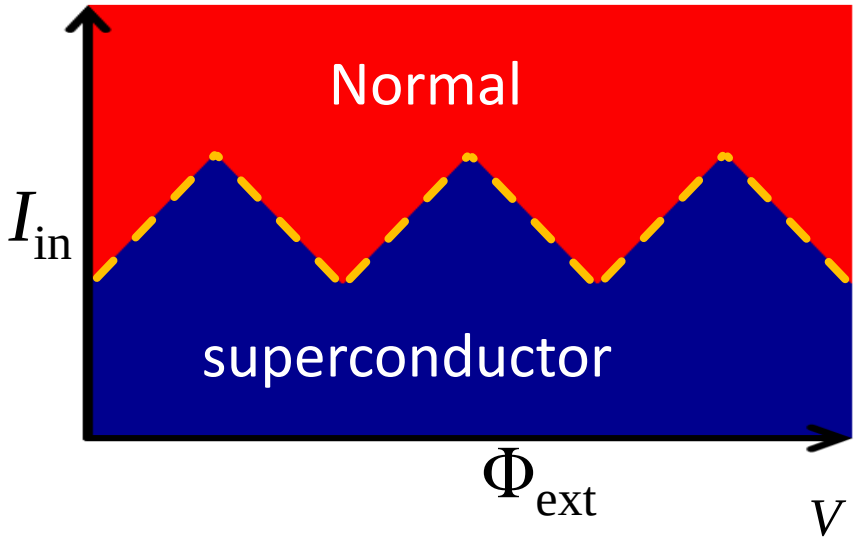
Eyal Buks
(Technion)

“Antipasti”

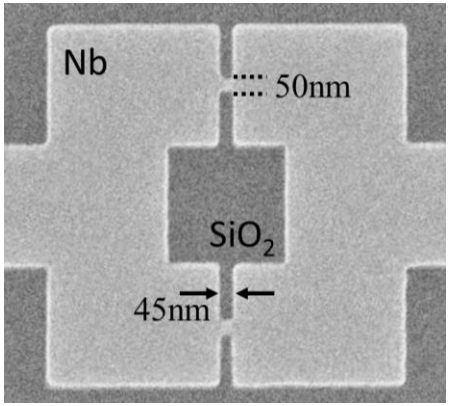
A three legged SQUID

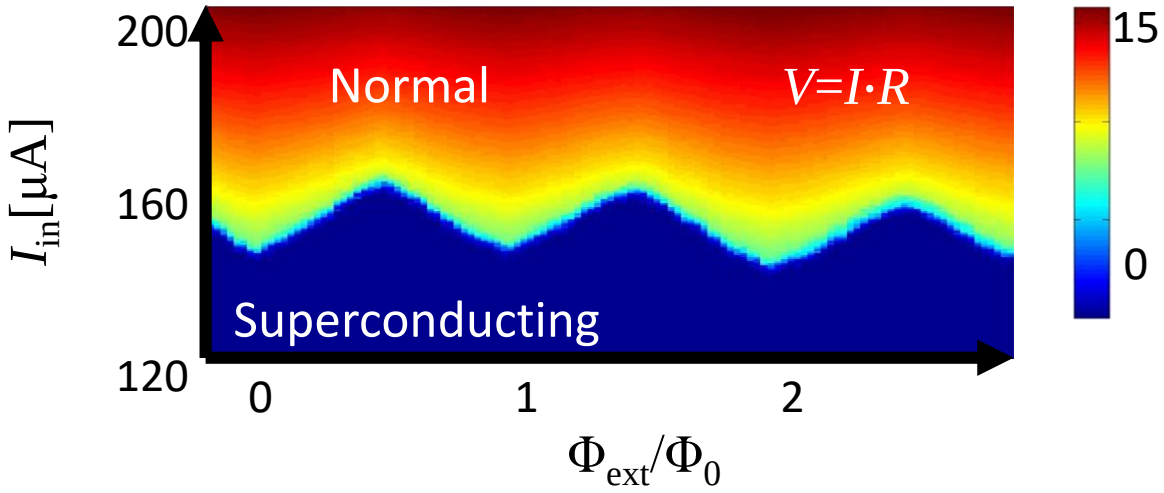
Superconducting Quantum Interference Device (SQUID)



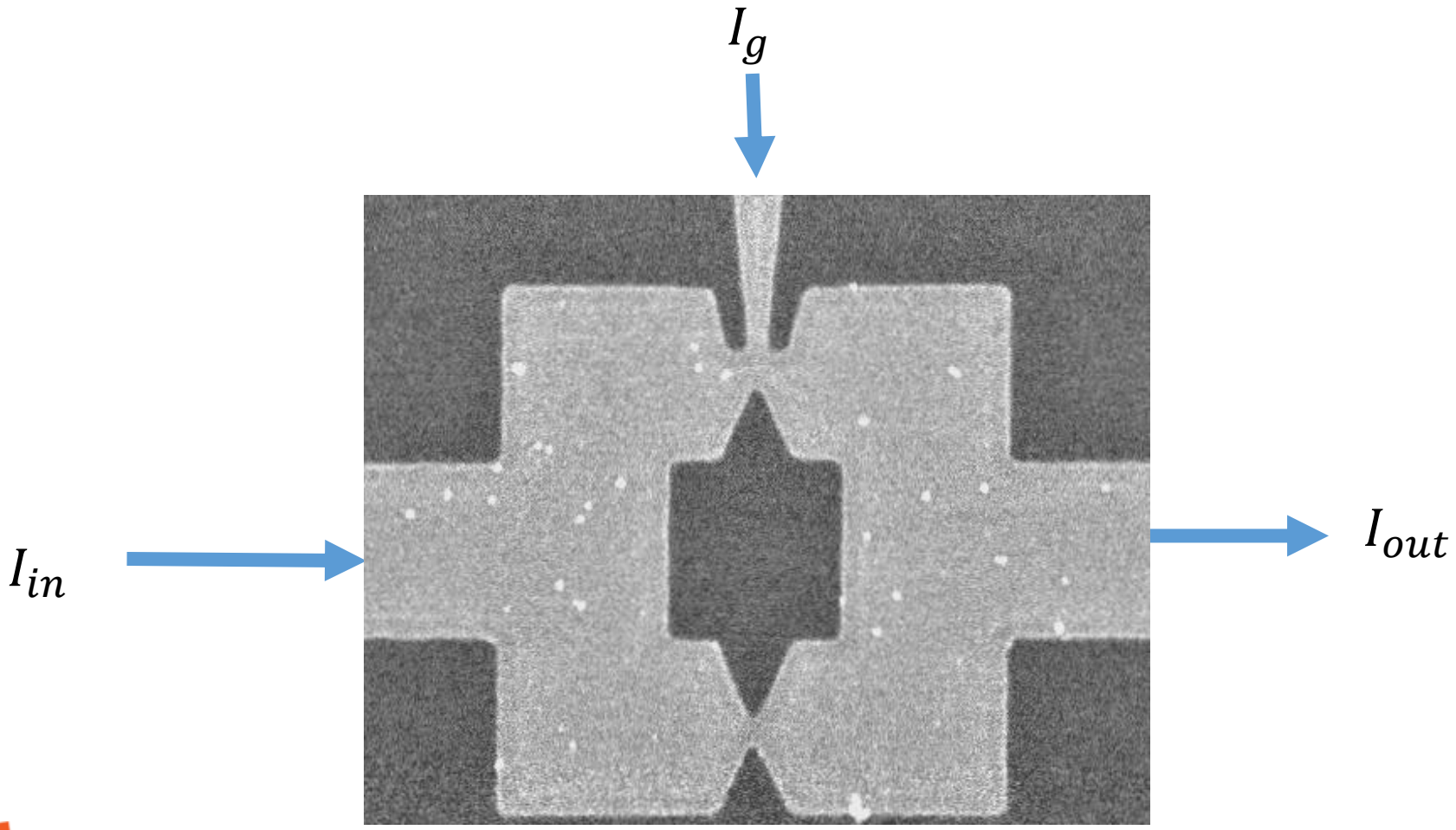


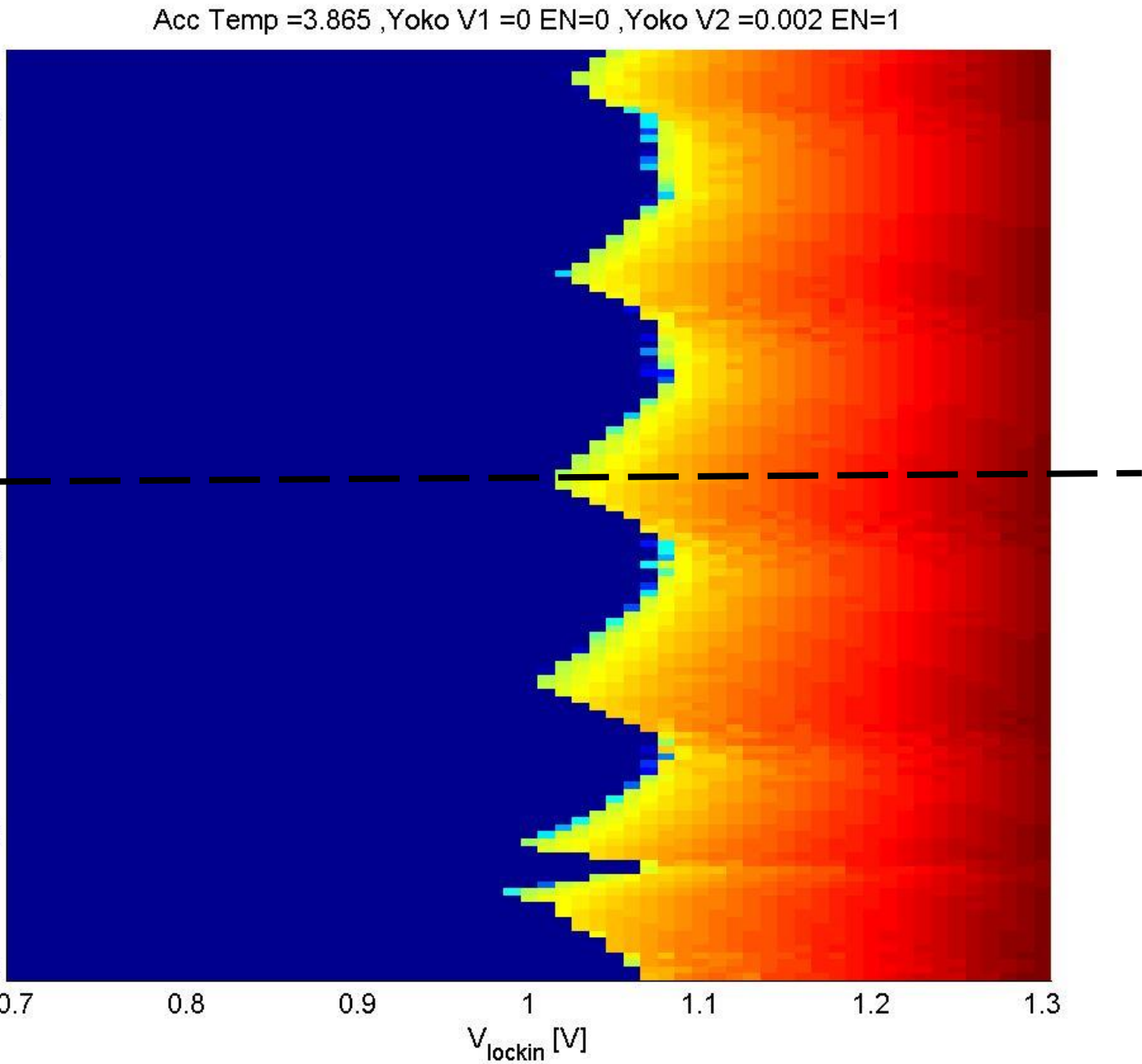
- New fabrication process (1 step)

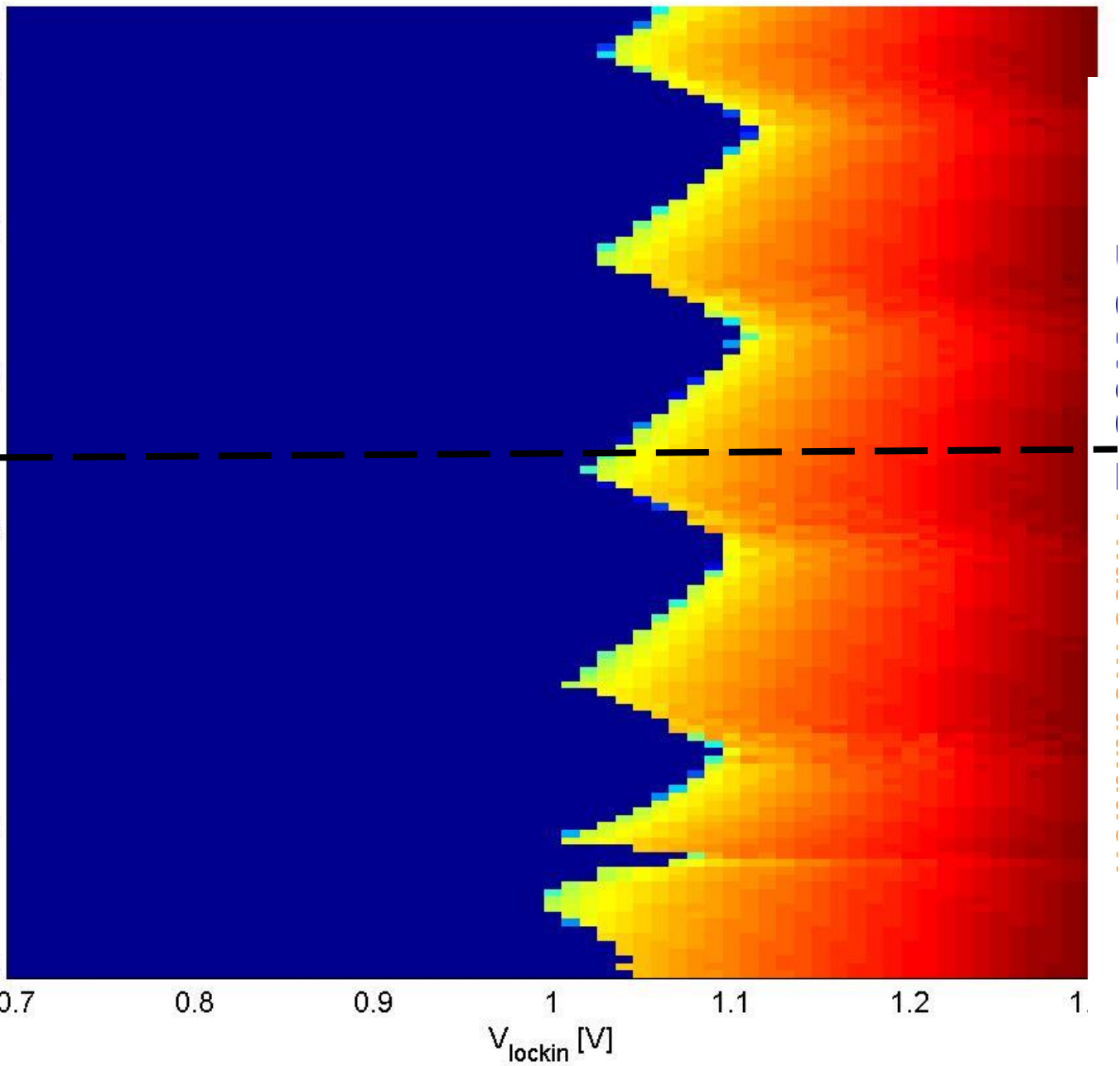


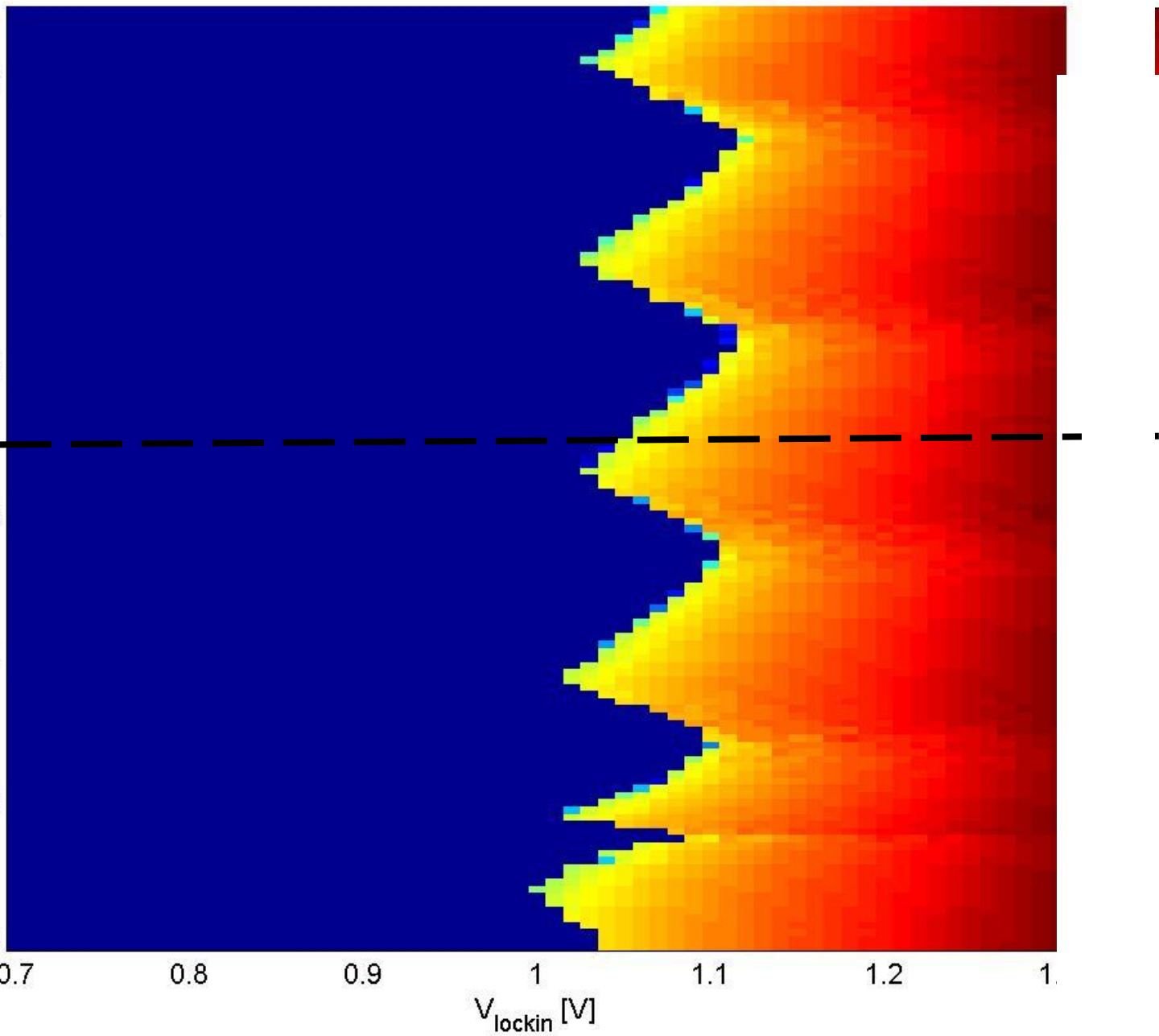


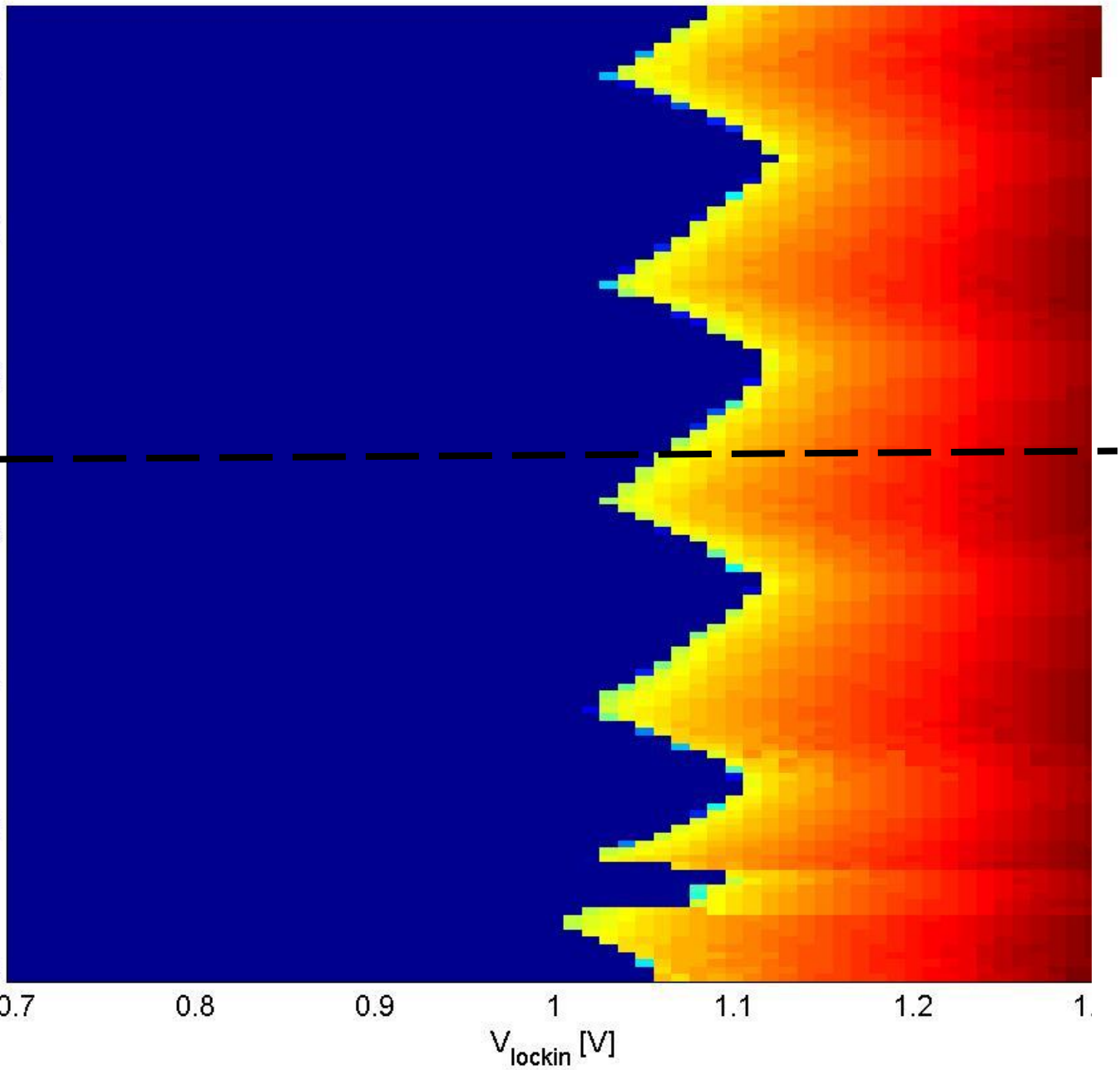
NEW : 3 legged SQUID




Acc Temp =3.865 ,Yoko V1 =0 EN=0 ,Yoko V2 =0.002 EN=1
0.7
0.8
0.9
1
1.1
1.2
1.3
V lockin [V]


Acc Temp =3.865 ,Yoko V1 =0 EN=0 ,Yoko V2 =0.004 EN=1
0.7
0.8
0.9
1
1.1
1.2
V lockin [V]


Acc Temp =3.865 ,Yoko V1 =0 EN=0 ,Yoko V2 =0.006 EN=1
0.7
0.8
0.9
1
1.1
1.2
V lockin [V]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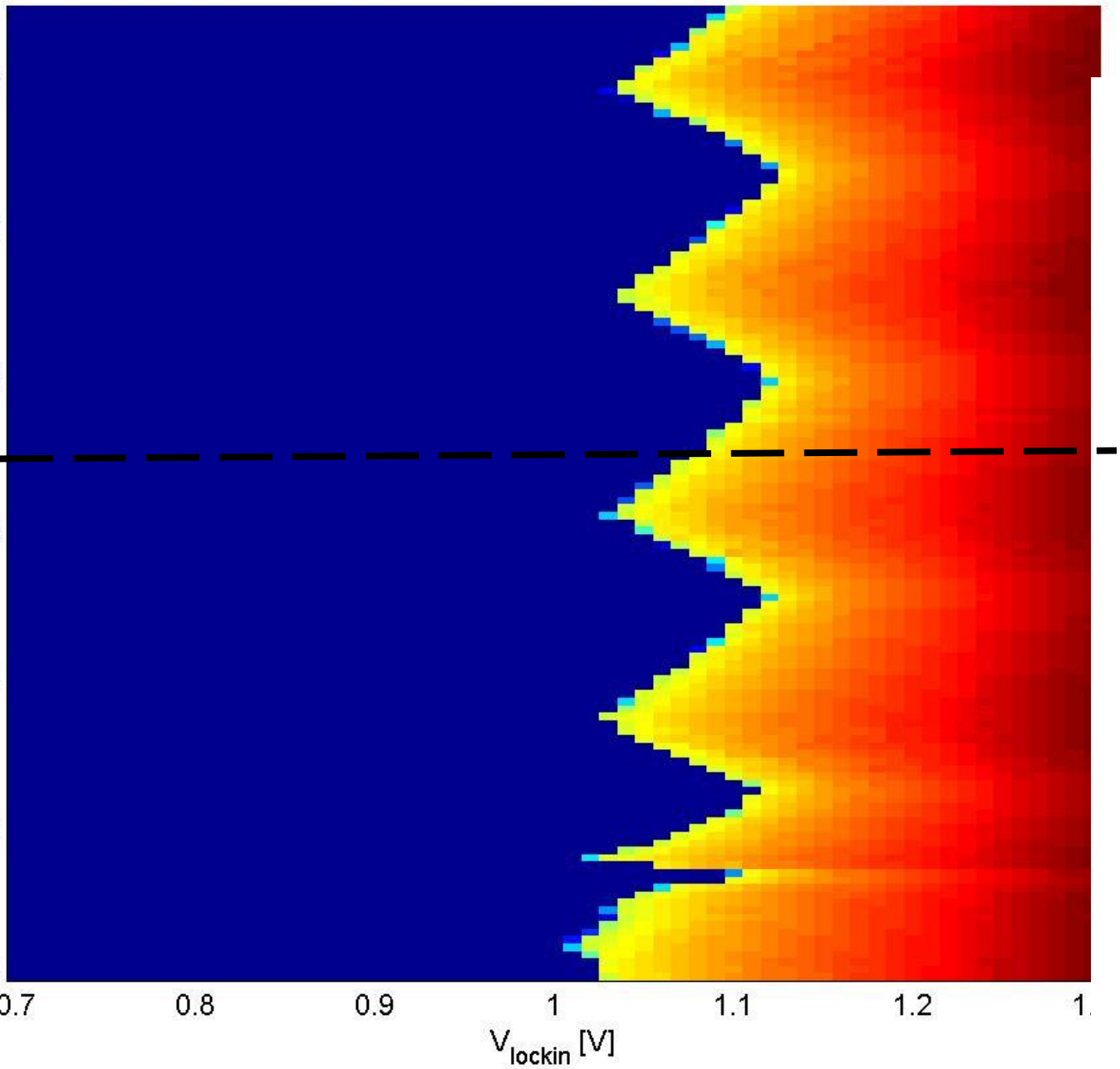
0.8
0.9
1
1.1
1.2
V lockin [V]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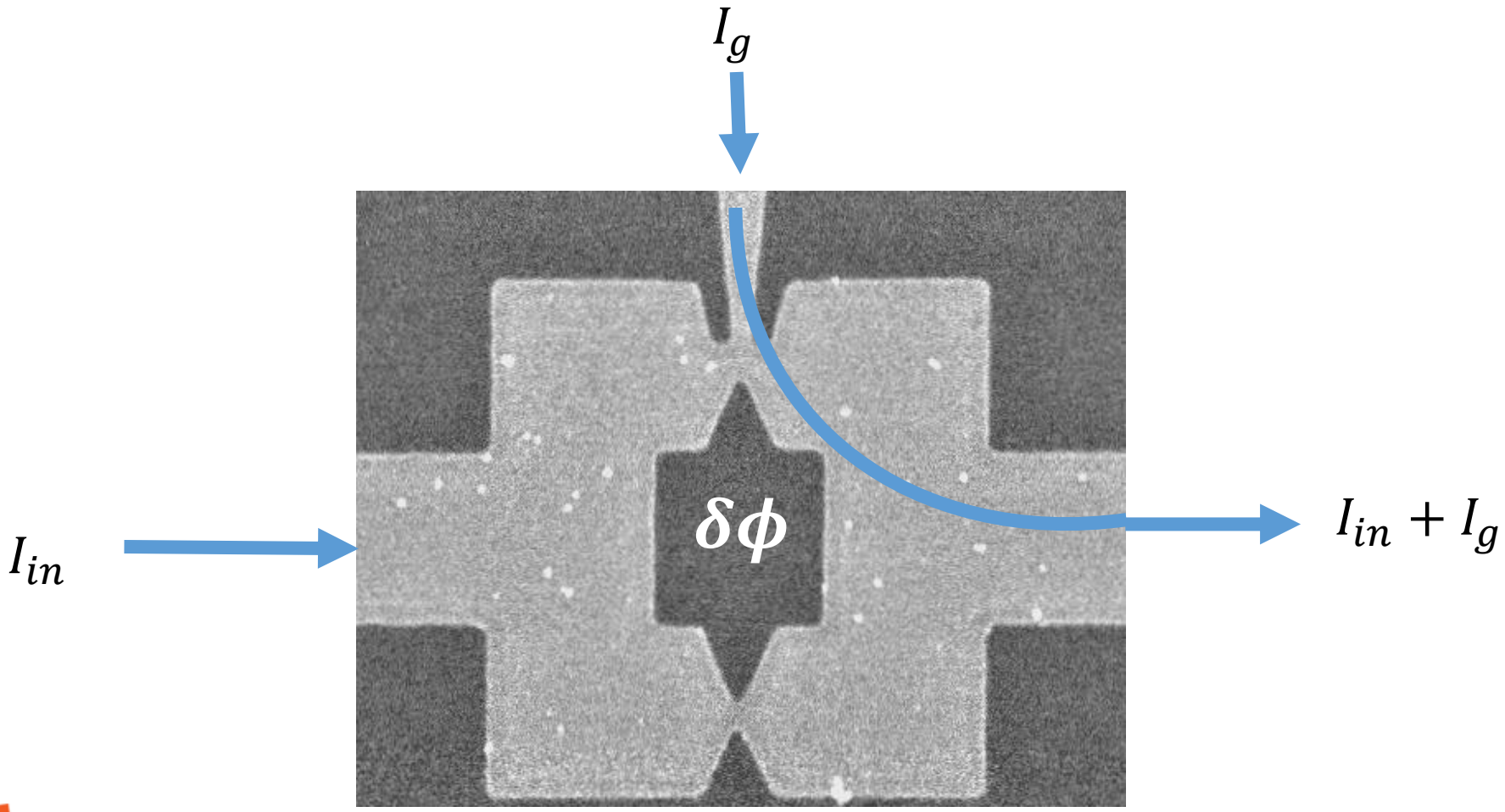
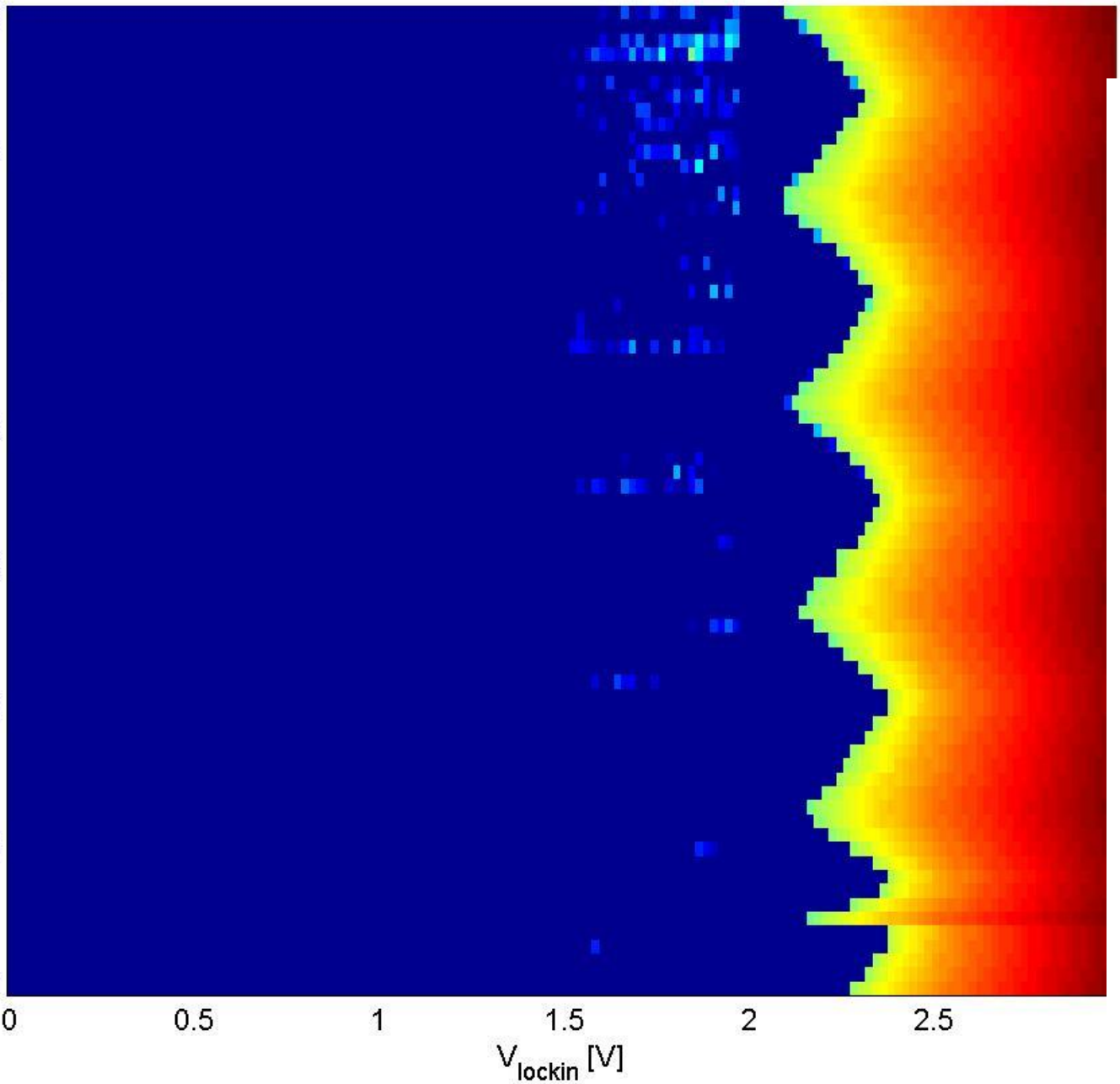
0.8
0.9
1
1.1
1.2
V lockin [V]

3-legged SQUID - phase mode

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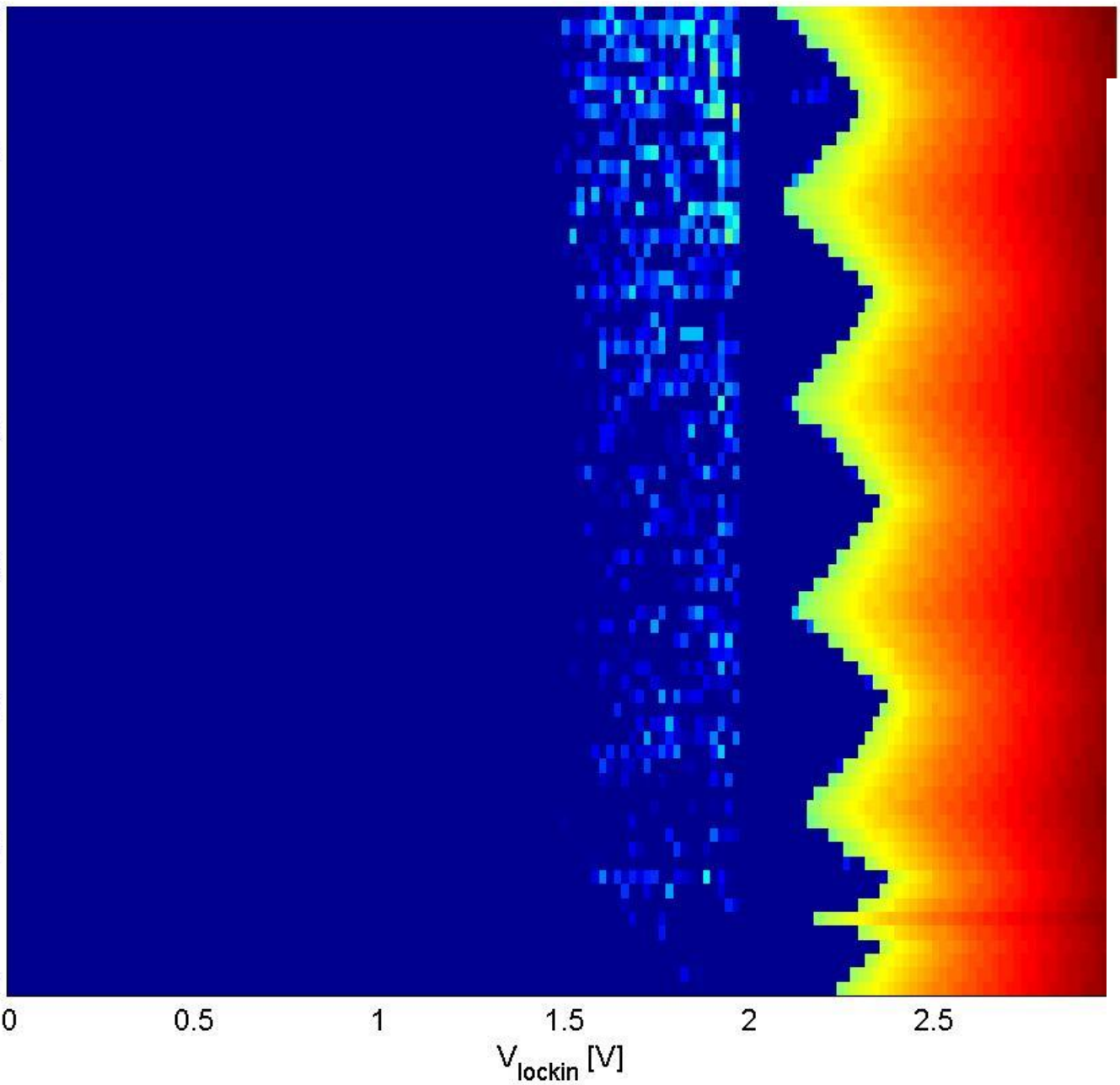
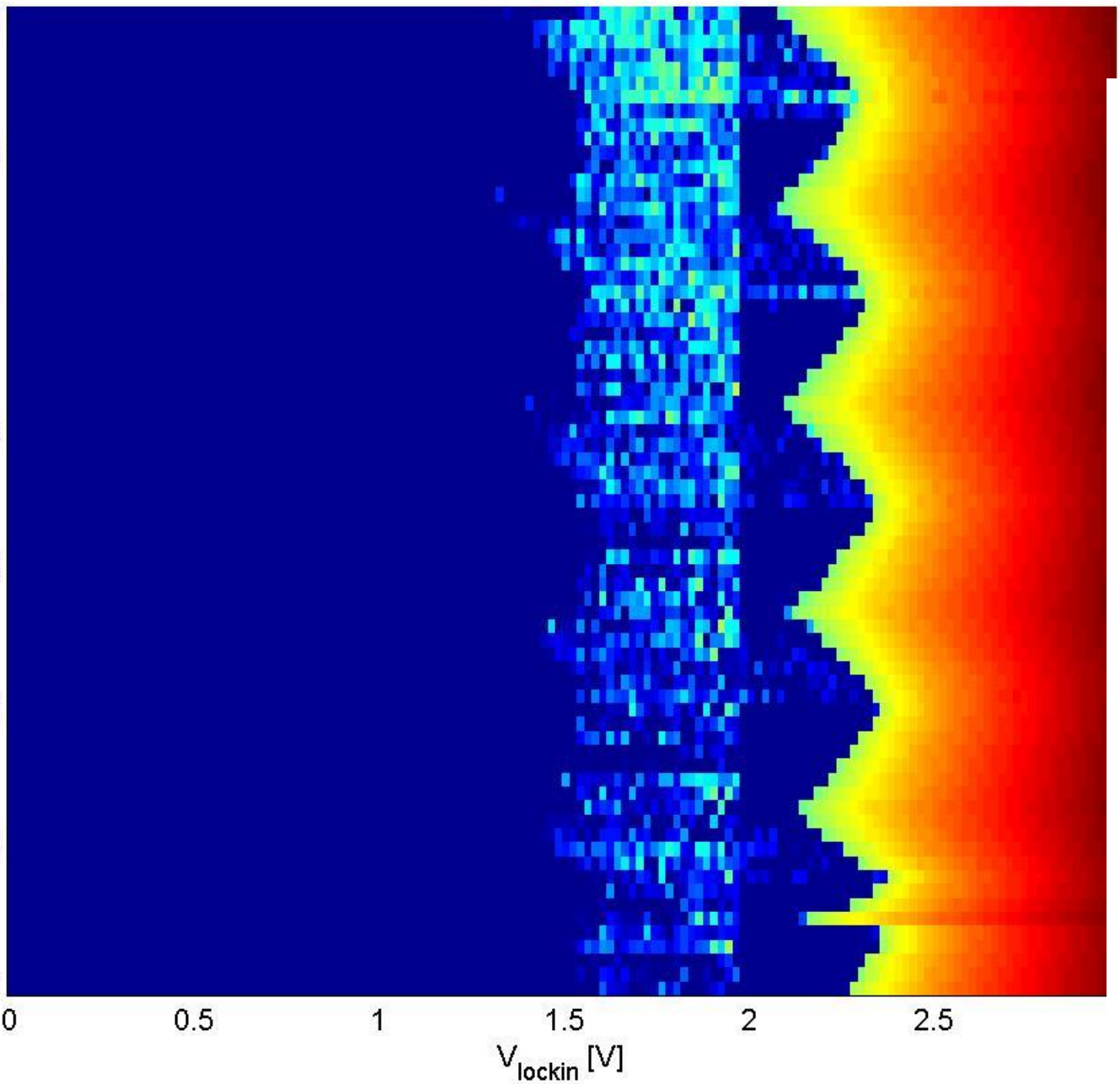
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.0102
0
0.5
1
1.5
2
2.5
V lockin [V]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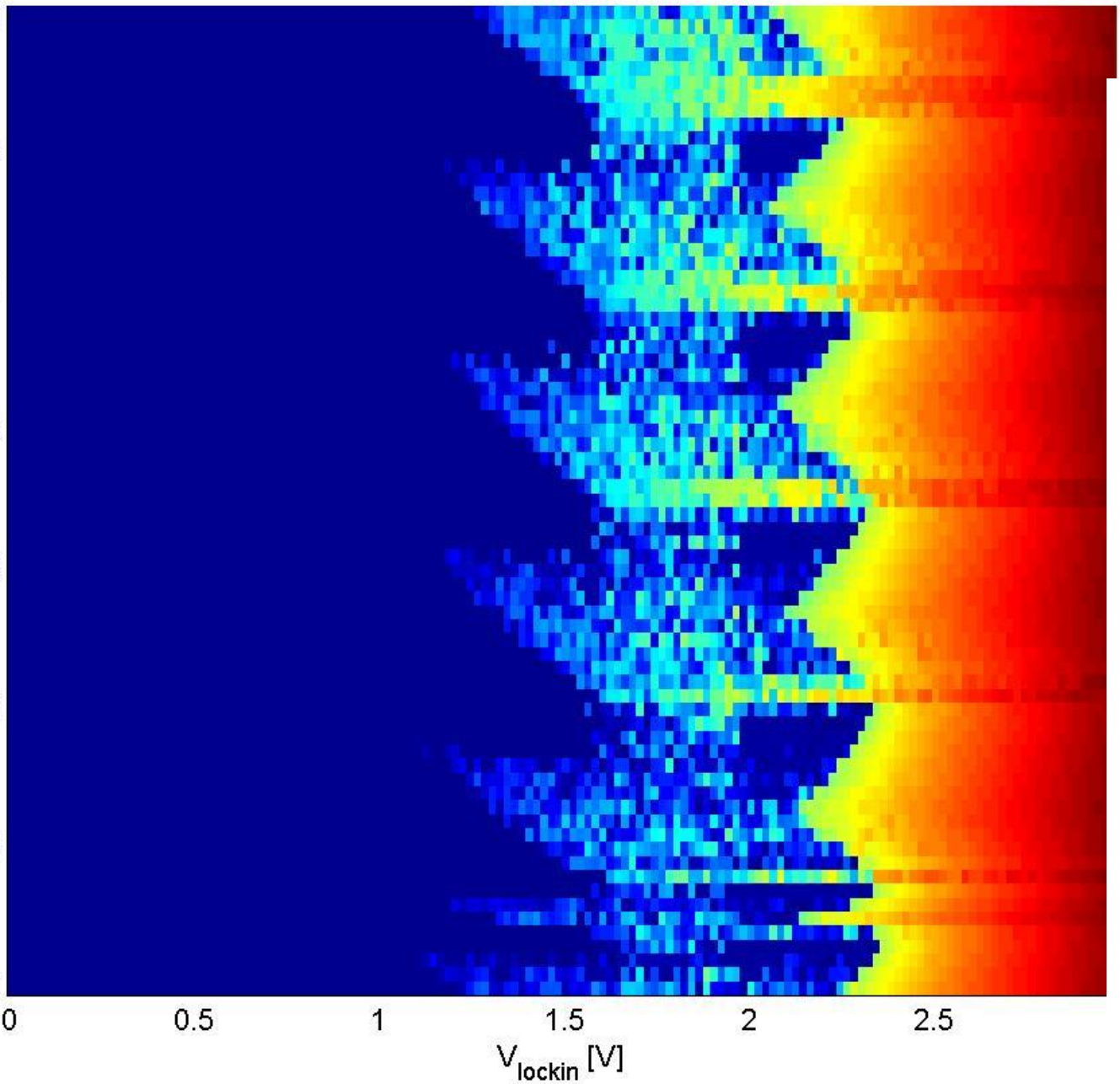
0.5
1
1.5
2
2.5
V lockin [V]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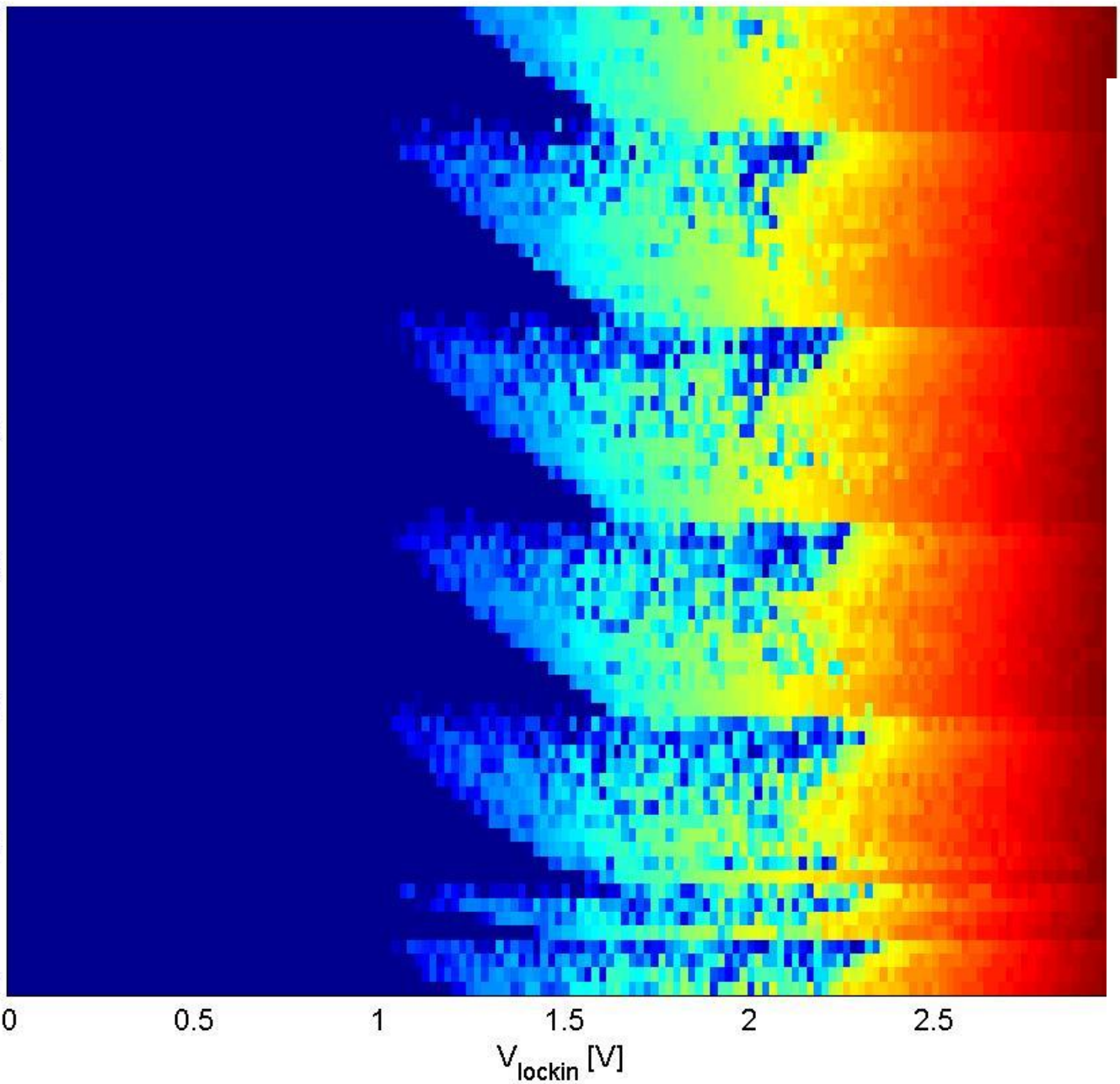
0.5
1
1.5
2
2.5
V lockin [V]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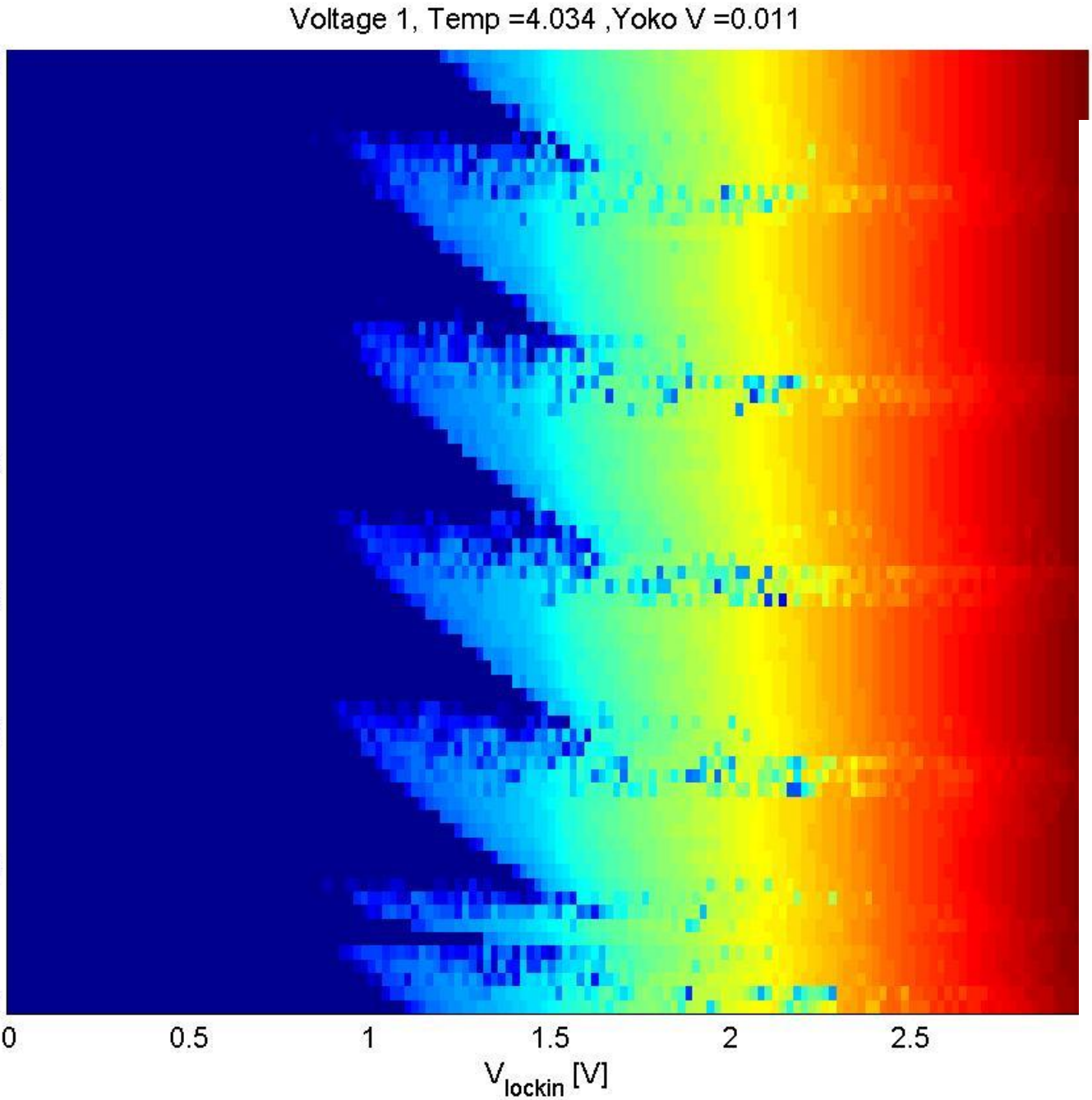
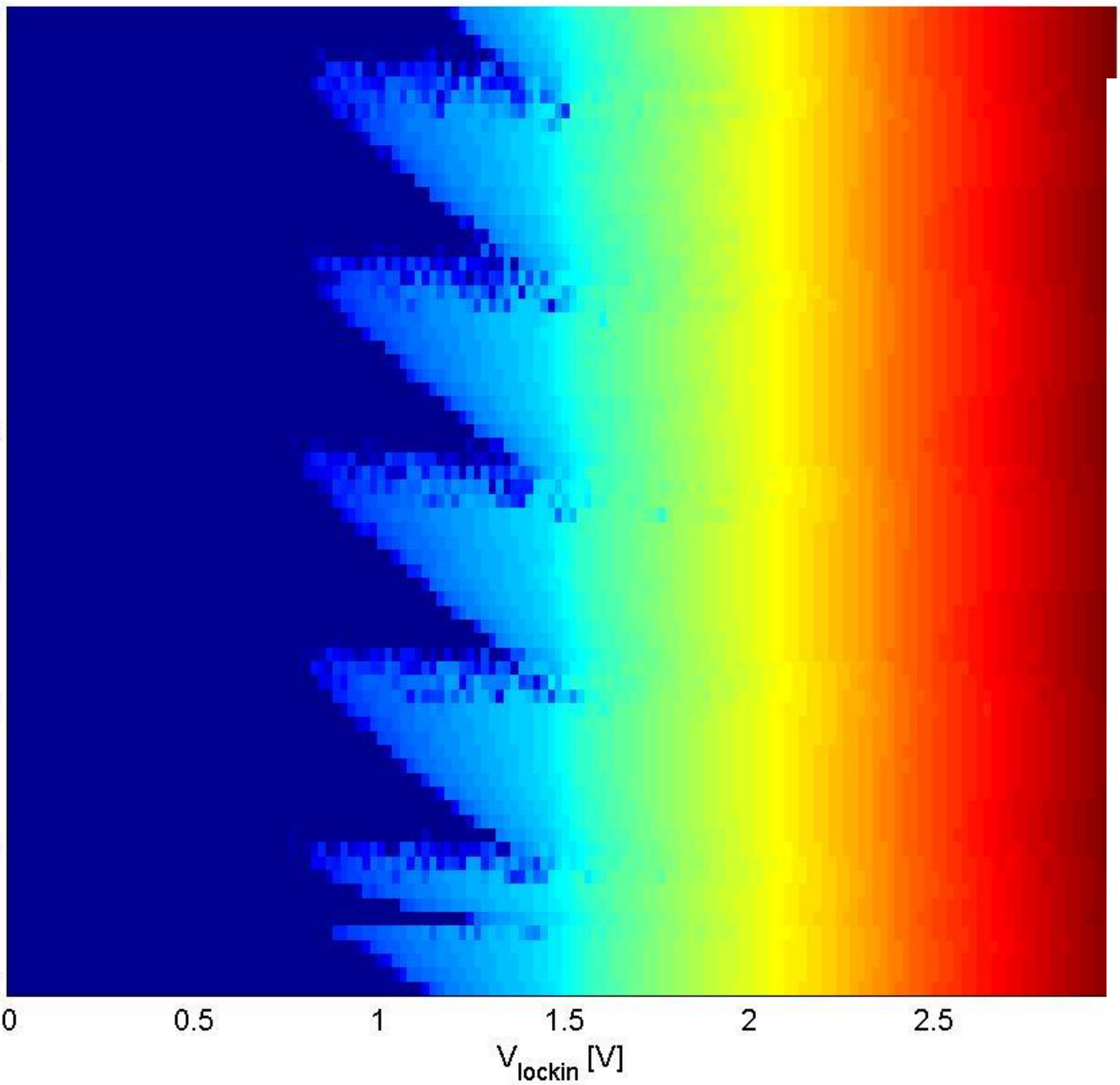
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.011
0
0.5
1
1.5
2
2.5
V lockin [V]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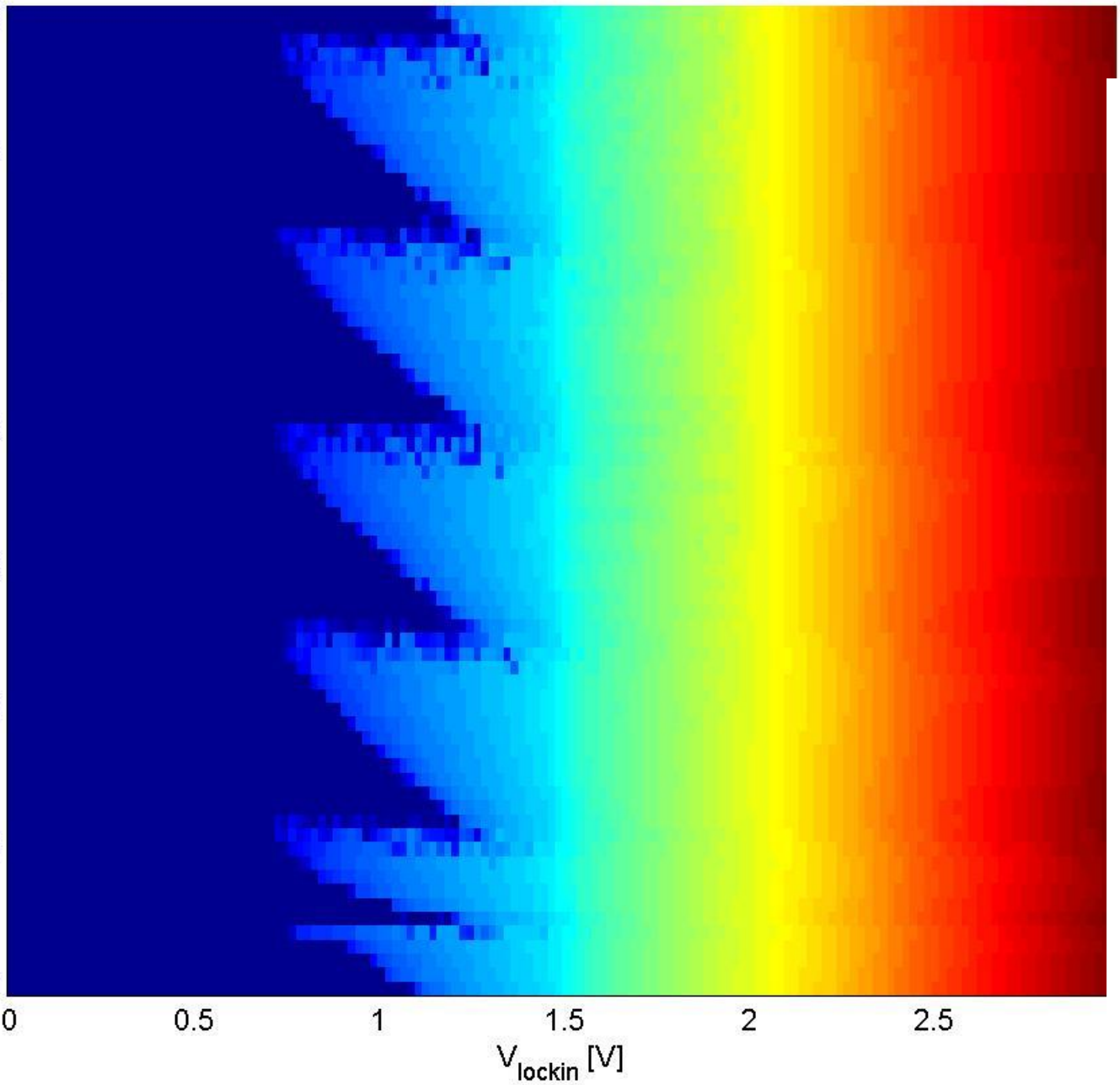
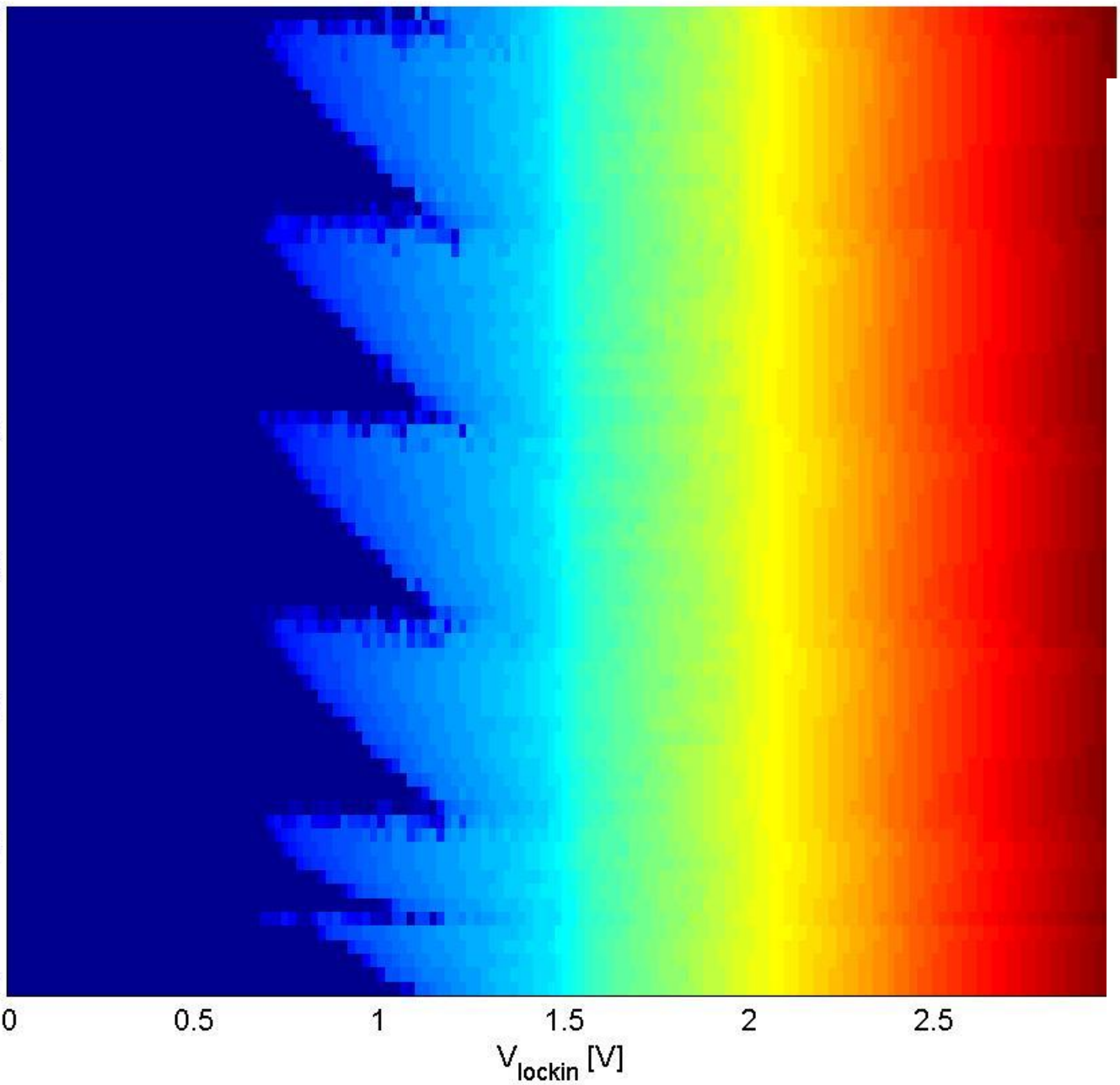
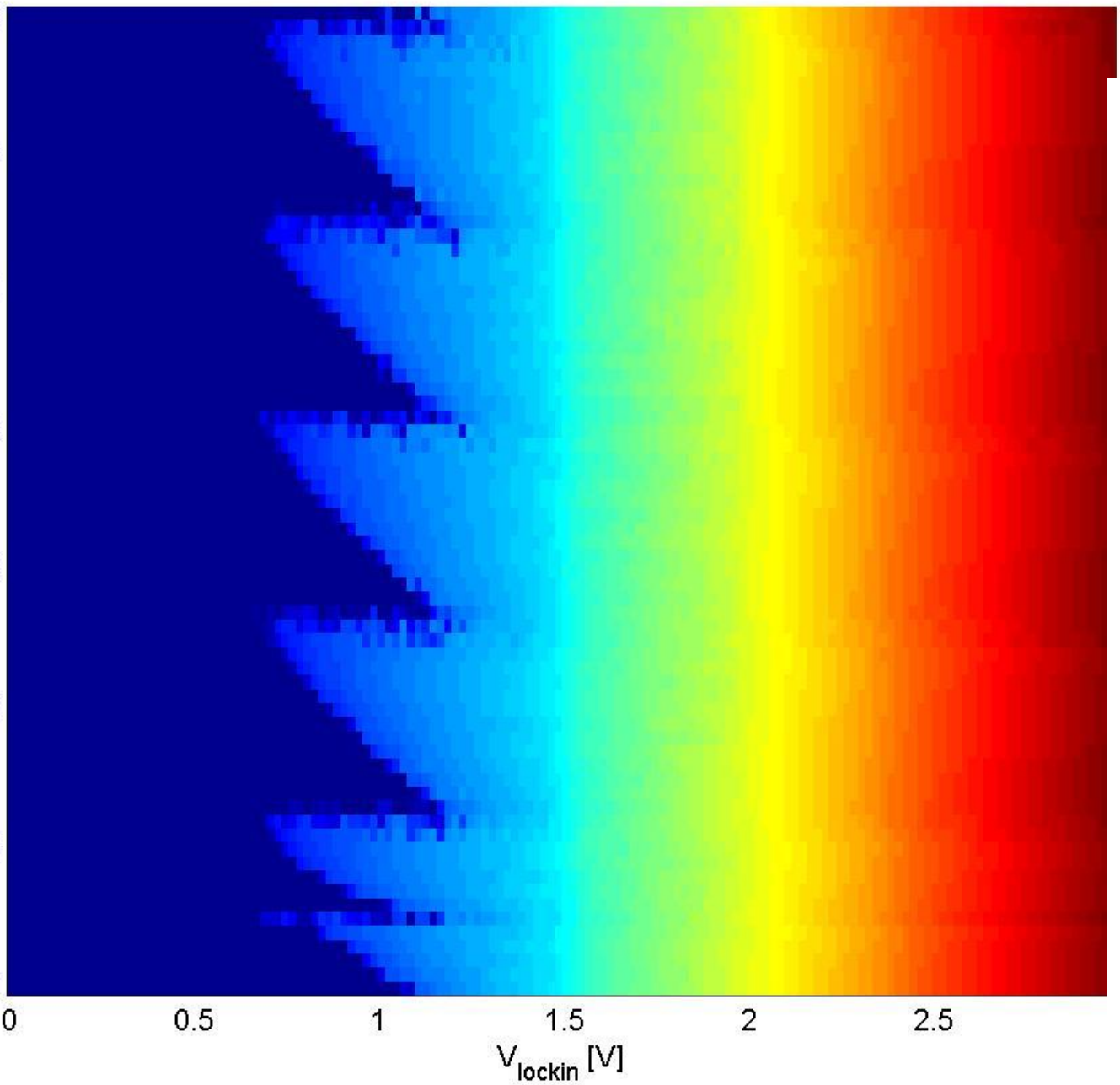
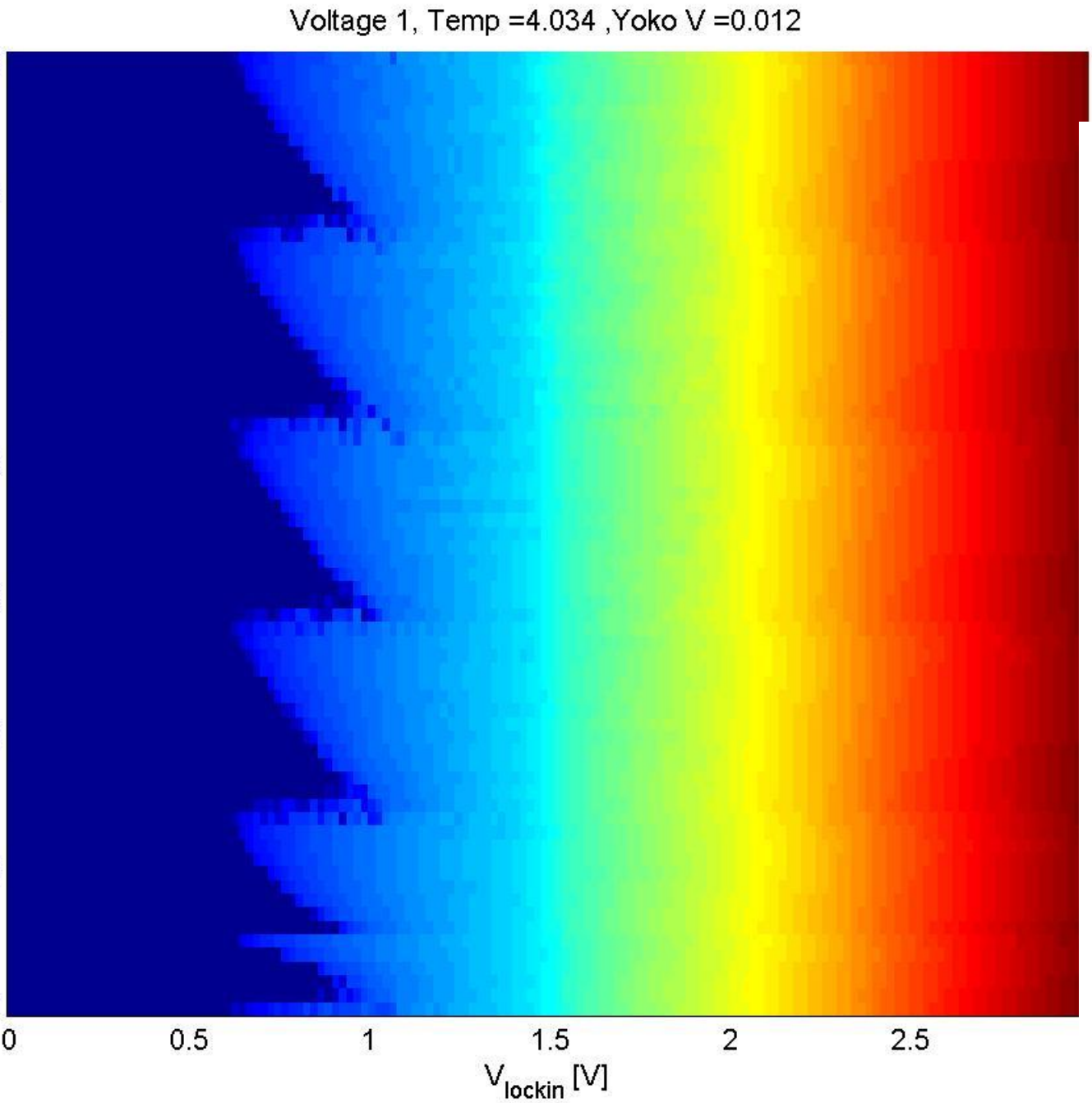
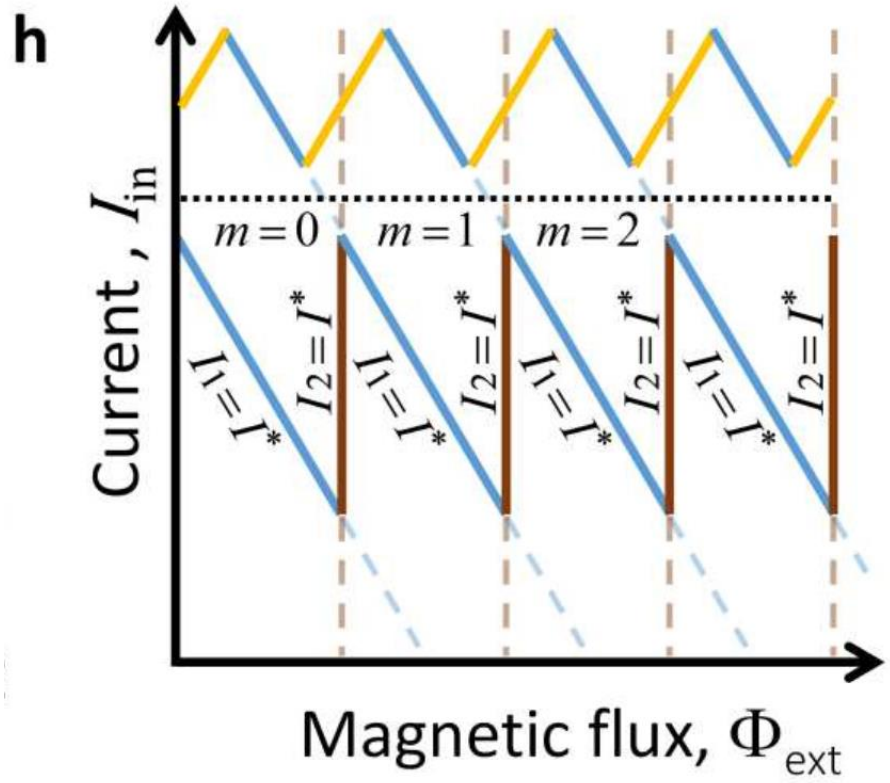
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.0114
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.0116
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.0116
0
0.5
1
1.5
2
2.5
V lockin [V]


Voltage 1, Temp =4.034 ,Yoko V =0.012
0
0.5
1
1.5
2
2.5
V lockin [V]

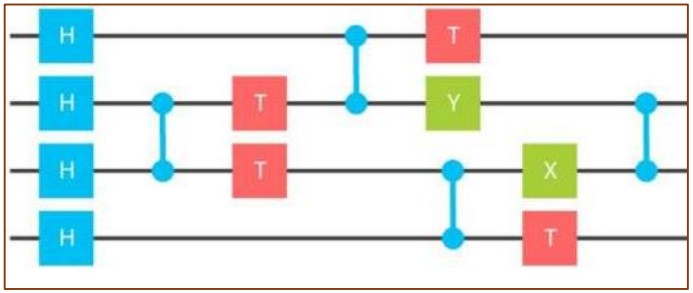


Winik, Holzman, Dalla Torre, Buks, Ivry, Applied Physics Letters (2018)

“Main dish”

Quantum circuits: the challenge

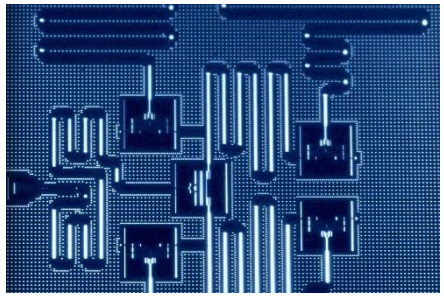
Model : Unitary quantum computer



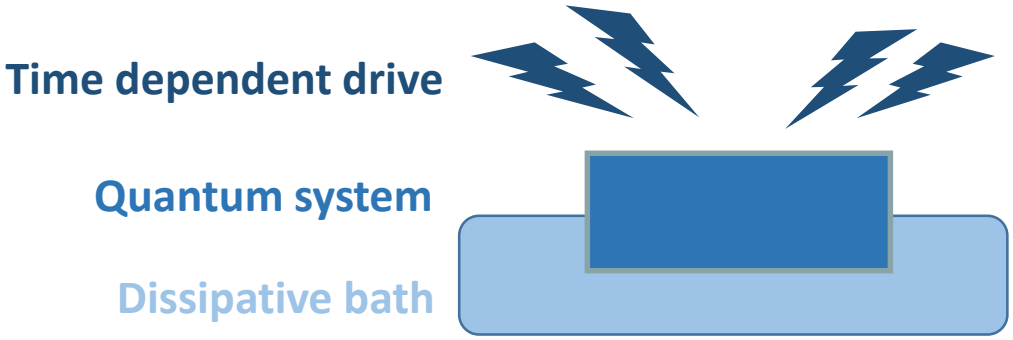
quantum error correction

open quantum systems

Reality : Noisy Josephson junctions



Many-body open quantum systems



Floquet engineering	Quantum bath engineering	Nonequilibrium universality	Symmetries and topology
* Nir Bar Gill	* Klaus Molmer	* Alex Retzger	* Eran Ginnosar
* Inbar Shany	* Bartolo Albanese	* Jason Ball	
		* Mor Roses	

Introduction : phases of matter

Ordered

0 1 0 1 0 1 0 1

Disordered

0 1 1 0 0 1 0 1

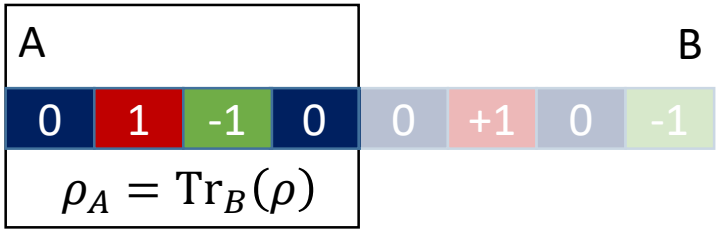
Topological

0 +1 -1 0 0 +1 0 -1

Haldane (1982), AKLT (1987), den Nijs&Rommelse (1989), Dalla Torre,Berg&Altman (2006), ….

Symmetry protected topological phases

Subsystem probabilities:



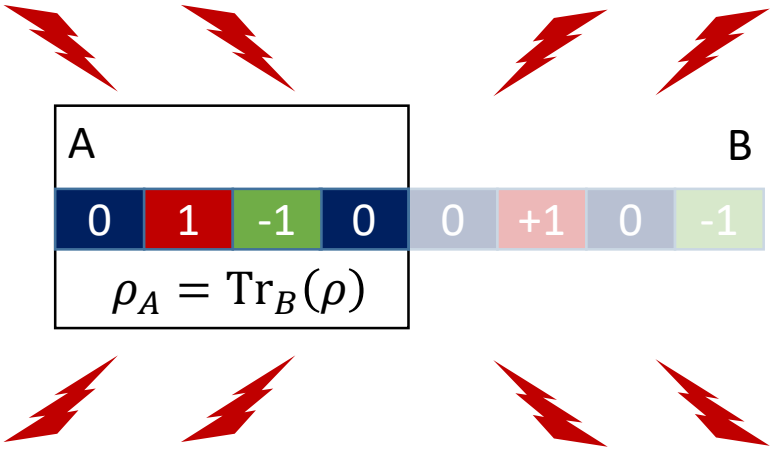
Eigs(ρ_A) = 0.3, 0.3, 0.15, 0.15, 0.05, 0.05, …

Degeneracy is “protected” by a symmetry

Pollmann, Turner, Berg, & Oshikawa (2010) Chen, Gu & Wen (2011)

Noisy symmetry protected topological phase

Extension to open quantum systems ?



Eigs(ρ_A) = 0.25, 0.25, 0.1, 0.1, 0.03, 0.03, … ?

Atzitz, Sela, Dalla Torre (in preparation)

Background : Quantum phases with qubits

Ising model (ordered)

$$H = \sum_i \sigma_i^z \sigma_{i+1}^z$$

Duality transform

Trivial model (disordered)

$$H = \sum_i \sigma_i^x$$

Duality transform

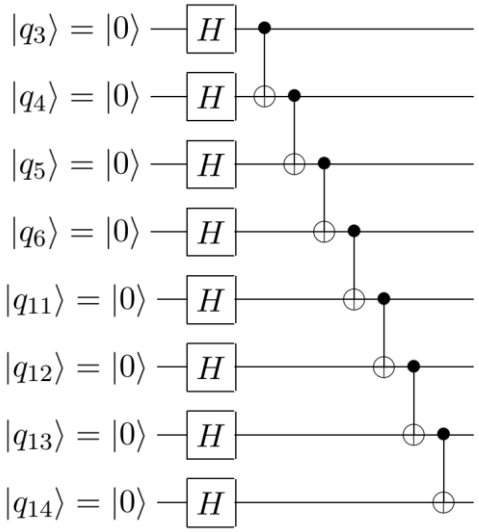
Cluster model (topological)

$$H = \sum_i \sigma_i^z \sigma_{i+1}^x \sigma_{i+2}^z$$

Friedman, Rajak, Dalla Torre (EPL, 2019) and ref. therein

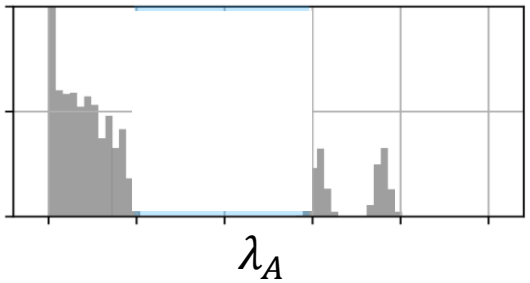
Cluster Ising model on a quantum computer

Trivial state



Topological state

Topology : Full tomography of ρ_A



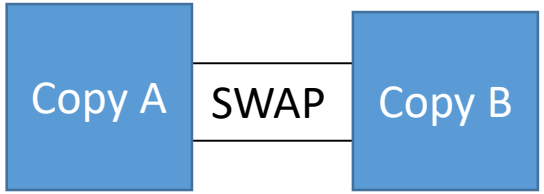
Choo, von Keyserlingk, Regnault & Neupert (PRL, 2018)

How to measure entanglement ?

Renyi entropy: $S_n = Tr[\rho_A^n]$

Replica trick

Daley, Pichler, Schachenmayer, Zoller, PRL (2012)



$n = 2$

PROOF: $\langle SWAP_{AB} \rangle = Tr[\rho^A \rho^B SWAP_{AB}] = \sum_{i,j} \langle i_A j_B | \rho^A \rho^B SWAP_{AB} | i_A j_B \rangle$

$$= \sum_{i,j} \langle i_A j_B | \rho^A \rho^B | j_A i_B \rangle = \sum_{i,j} \langle i_A | \rho^A | j_A \rangle \langle j_B | \rho^B | i_B \rangle = Tr[\rho^A \rho^B] = Tr[\rho^2]$$

How to measure **topological** entanglement?

Renyi Entropy $$S_n = Tr[\rho_A^n] = \sum_i \lambda_i^2$$

$$S_n = 0.3^n + 0.3^n + 0.15^n + 0.15^n + 0.05^n + 0.05^n$$

Symmetry resolved reduced density matrix

$$\rho_A^{\pm} = P^{\pm}\rho_A \quad \Rightarrow \quad S_n^{\pm} = Tr\left[\left(\rho_A^{\pm}\right)^n\right] = \sum_i \left(\lambda_i^{\pm}\right)^2$$

$$S_n^+ = 0.3^n + 0.15^n + 0.05^n$$

$$S_n^- = 0.3^n + 0.15^n + 0.05^n$$

$$S_n^+ = S_n^- \ ?$$

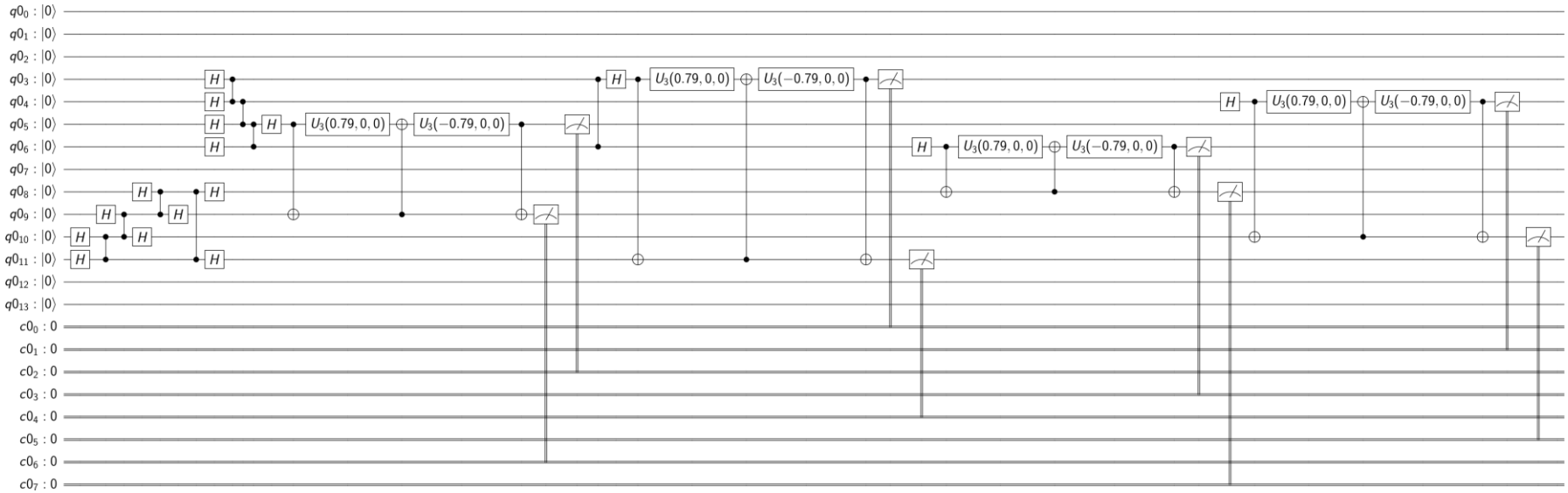
Goldstein & Sela (PRL, 2018) , Atzitz, Dalla Torre, Sela (work in progress)

Our circuit

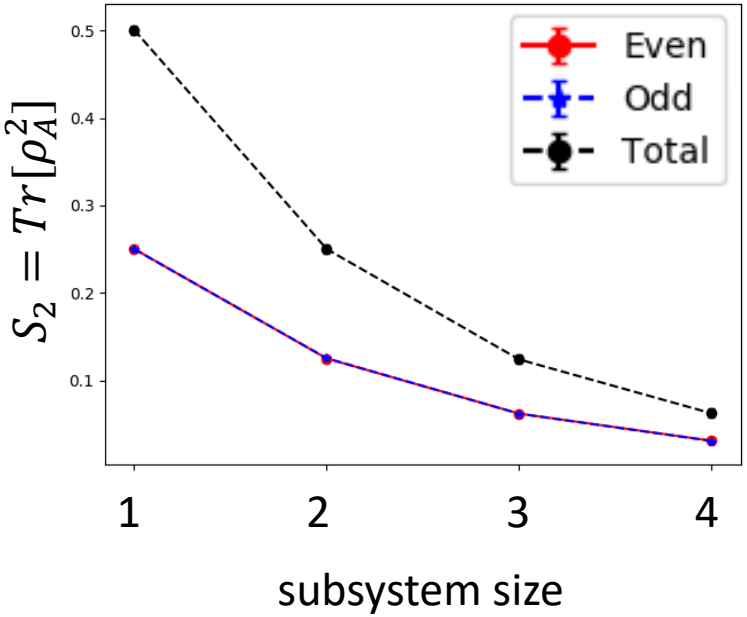
1) Initialize trivial state

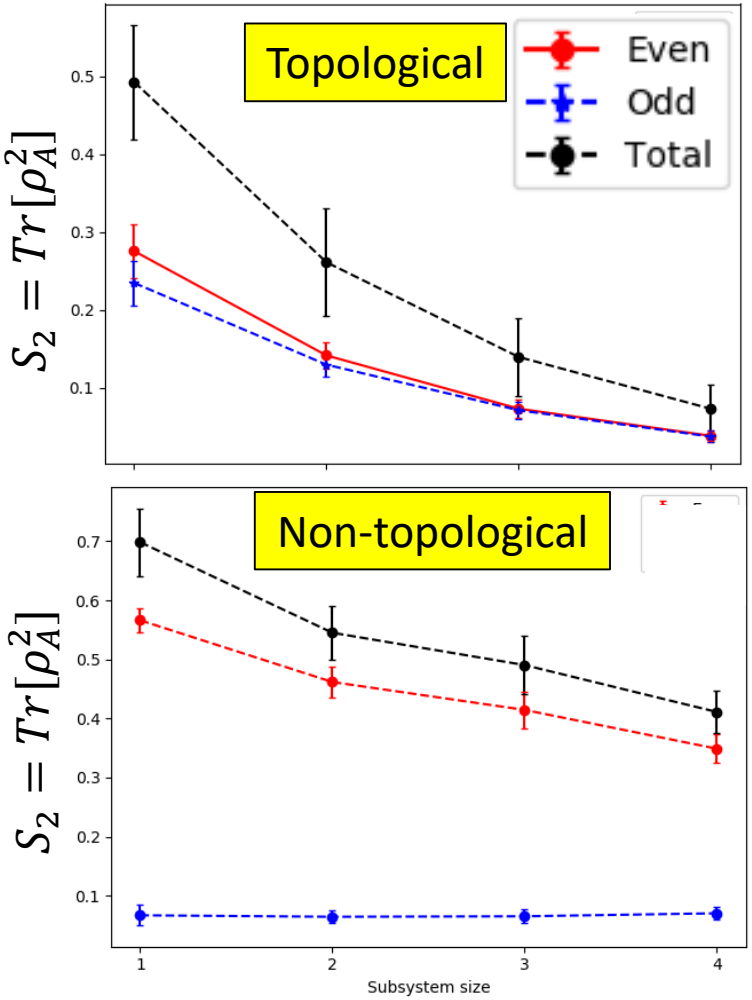
2) Unitary transformation to a topological state

3) Measure SWAP and Symmetry



Simulation vs. Experiment





Atzitz, Sela, Dalla Torre (in preparation)

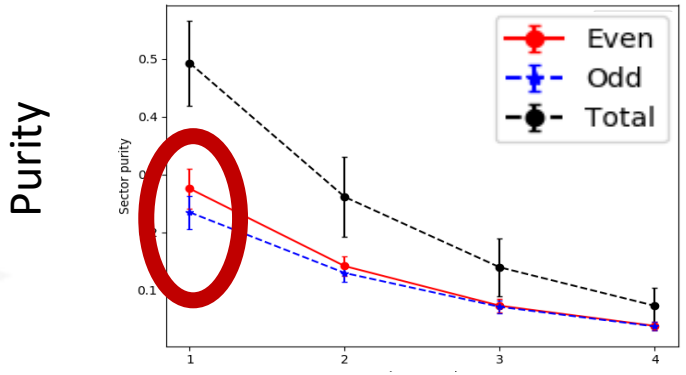
Summary

Many-body physics with superconducting circuits

New phase of matter (?) : Noisy symmetry protected topological states

All I need is … 8 qubits :

Noise characterization:



Purity

subsystem size

“Desert”

Quantum Entanglement Science and Technology *II*

The second meeting of the QUEST center will maintain its spirit of diversity and will bring together experts from various fields who share a common interest in deepening our understanding of quantum entanglement and searching for enlarging the circle of its practical applications. Systems that will be considered in the workshop include, but are not limited to, entangled photons, ultracold atoms and molecules, superconducting circuits, nano-mechanical resonators, spins in semiconductors and defects in diamonds.

16-18, 2019

Venue
Bar-Ilan University, Ramat Gan, Israel

Online Registration
See details on: http://quest.biu.ac.il

Deadline for poster submission
November 20, 2019

Bar-Ilan University

Bar-Ila

Bar-Ilan, December 16-18, 2019

UM ENTANGLEMENT & TECHNOLOGY N UNIVERSITY

Minerva-Gentner Symposium on Quantum Simulations using Atoms, Photons and Molecules

Tze'elim, Israel, February 23-27, 2020

http://quantumsimulations2020.ph.biu.ac.il

Organizers: Immanuel Bloch (Munich), Emanuele Dalla Torre (Bar Ilan), Tim Langen (Stuttgart), Moti Segev (Technion)

The symposium will be part of the distinguished series of Minerva-Gentner symposia, and will gather around 50 leading researchers and students in **all aspects of quantum simulation, including theory and experiment**.

The goal of this symposium will be to bring together the quantum science and, in particular, quantum simulation communities from Germany, Israel, and the rest of the world.

We particularly encourage the participation of young scientists that have only recently started to establish new research groups, as well as postdocs and students.

The symposium will encourage their interaction with established experts from both countries and around the world, to stimulate new and fruitful collaborations.

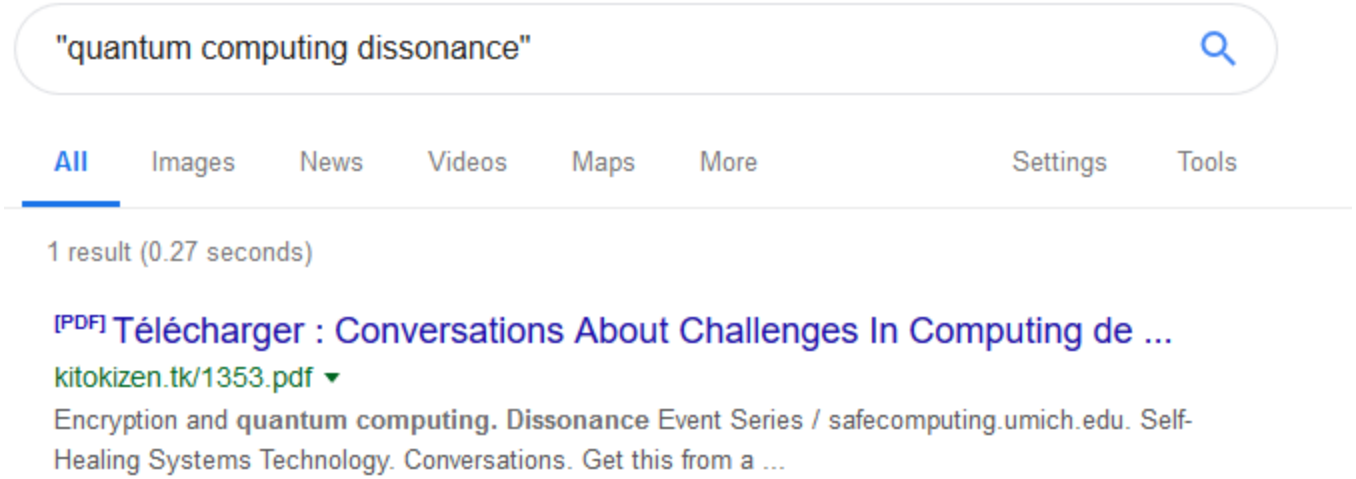
Thanks to generous contributions by our sponsors, several fellowships for young researchers are available. Accommodation will be onsite in Tze'elim, in the beautiful Negev desert.

Deadline for registration: November 30, 2019

Confirmed speakers:

- Monika Aidelsburger (Munich)
- Ehud Altman (Berkeley)
- Guy Bartal (Technion)
- Stefanie Barz (Stuttgart)
- Nir Davidson (Weizmann)
- Ofer Firstenberg (Weizmann)
- Sven Hoefling (Wuerzburg)
- Roni Ilan (Tel Aviv)
- Lev Khaykovich (Bar-Ilan)
- Michael Knap (Munich)
- Mikhail Lukin (Harvard)
- Ed Narevicius (Weizmann)
- Markus Oberthaler (Heidelberg)
- Ulf Peschel (Jena)
- Alex Retzker (Jerusalem)
- Yoav Sagi (Technion)
- Monika Schleyer-Smith (Stanford)
- Jonathan Simon (Chicago)
- Alex Szameit (Rostock)
- Susanne Yelin (UConn/Harvard)

EXTRA SLIDES


"quantum computing dissonance"
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Videos
Maps
More
Settings
Tools
1 result (0.27 seconds)
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