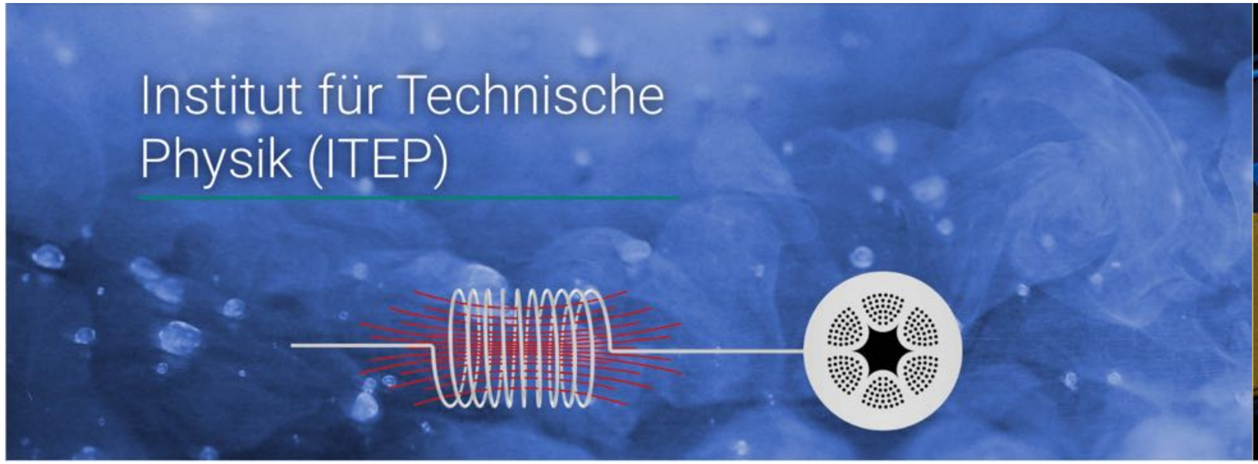
Karlsruhe Institute of Technology

Superconductivity for Engineers

Prof. Dr. Sebastian Kempf, Prof. Dr. Bernhard Holzapfel
Summer term 2021



Lecture overview

Literature

- Primary literature:
  - C. Enss, S. Hunklinger, Low Temperature Physics, Springer (2005)
  - M. Tinkham, Introduction to Superconductivity, McGraw-Hill (1996)
  - R. Gross, A. Marx, Applied Superconductivity, Lecture Notes, www.wmi.badw.de

- Secondary literature:
  - R. Gross, A. Marx, Festkörperphysik, De Gruyter (2018)
  - S. Hunklinger, Festkörperphysik, De Gruyter (2018)

Reminder: Josephson tunnel junctions

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Reminder: Magnetic flux quantization

Superconducting quantum interference devices

Basic principle of dc-SQUIDs

Basic principle of dc-SQUIDs

Supercurrent

Supercurrent

Supercurrent

Magnetic flux inside SQUID loop

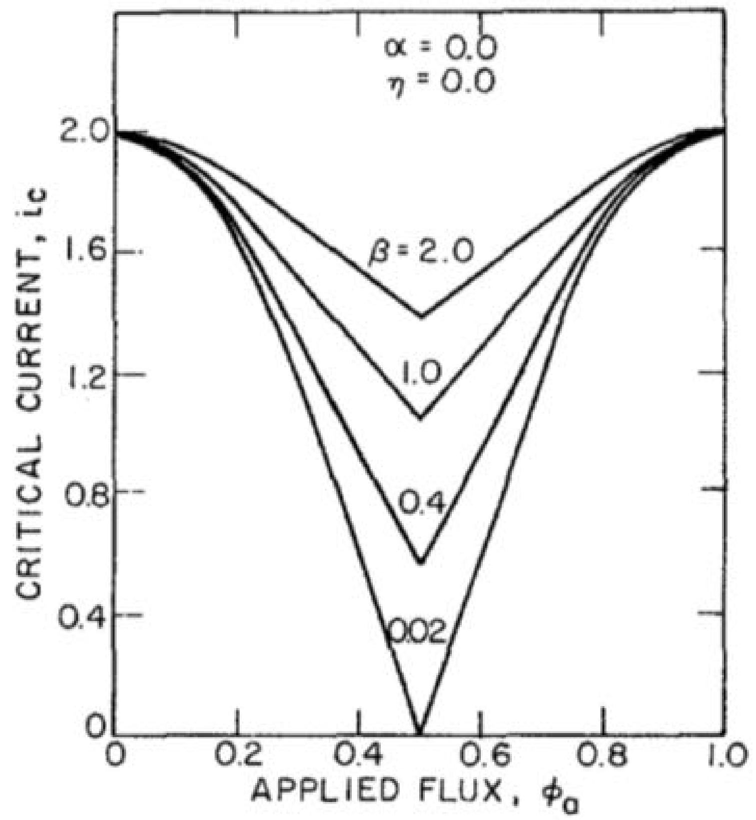
Magnetic flux inside SQUID loop

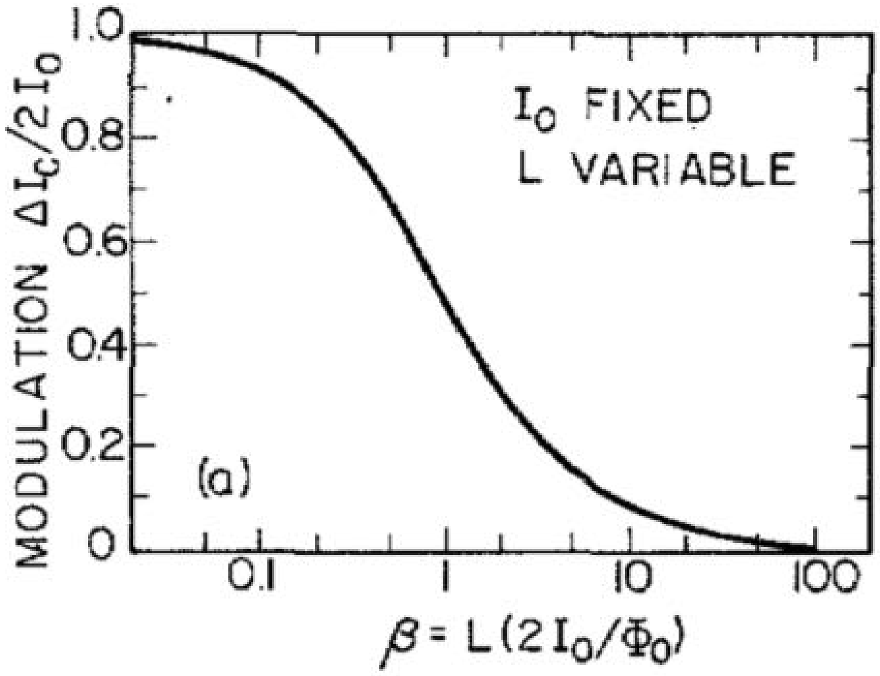
Hysteresis parameter β_L

Hysteresis parameter β_L

Hysteresis parameter β_{L}

Hysteresis parameter β_L





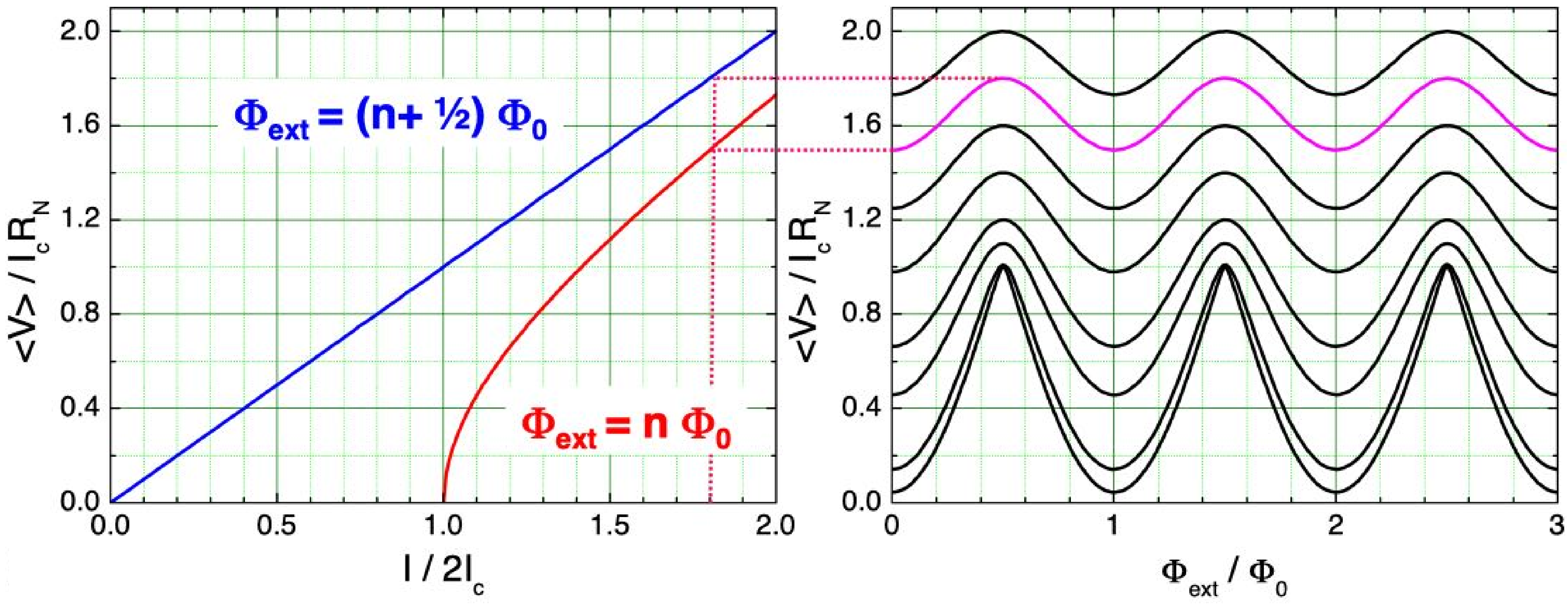
Voltage state of dc-SQUIDs

Voltage state of dc-SQUIDs

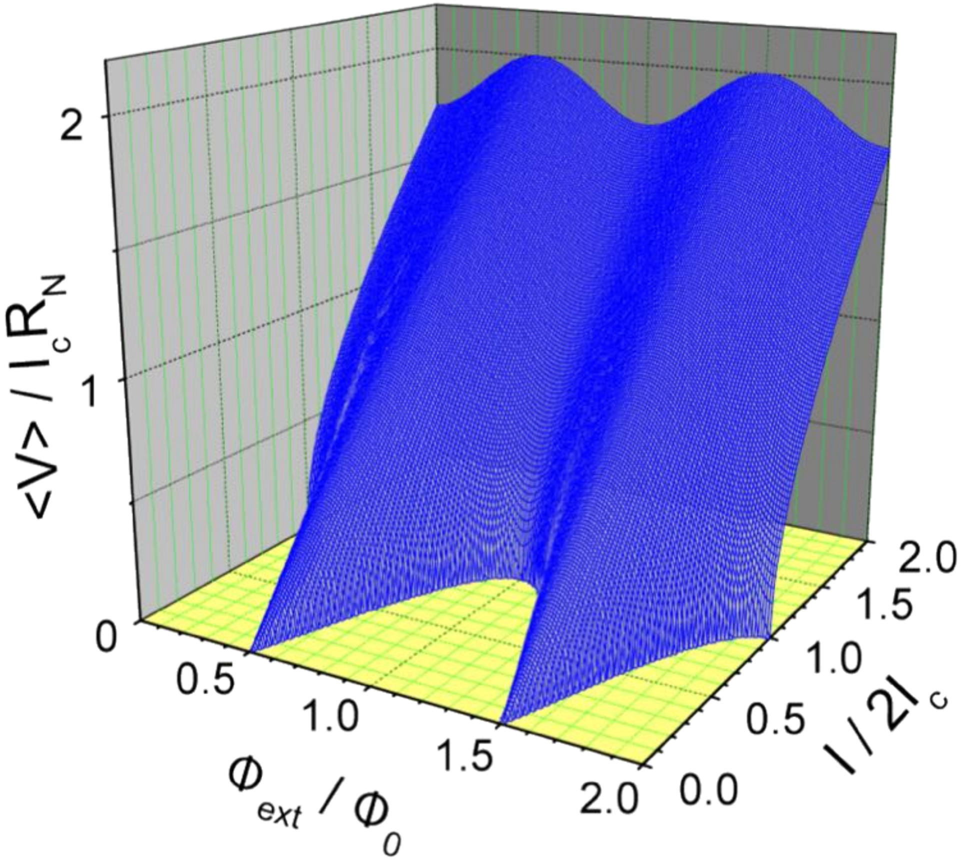
Strong damping, weak screening

Strong damping, weak screening

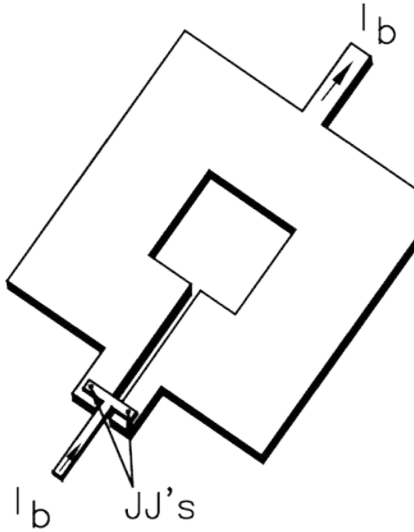
IVC for SQUIDs with negligible screening

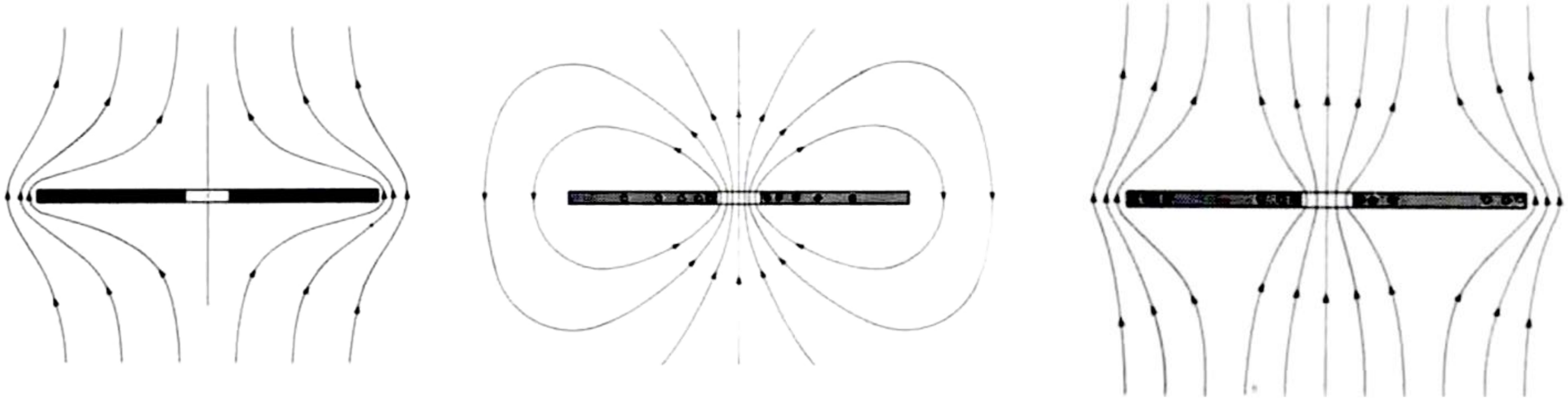


IVC for SQUIDs with negligible screening



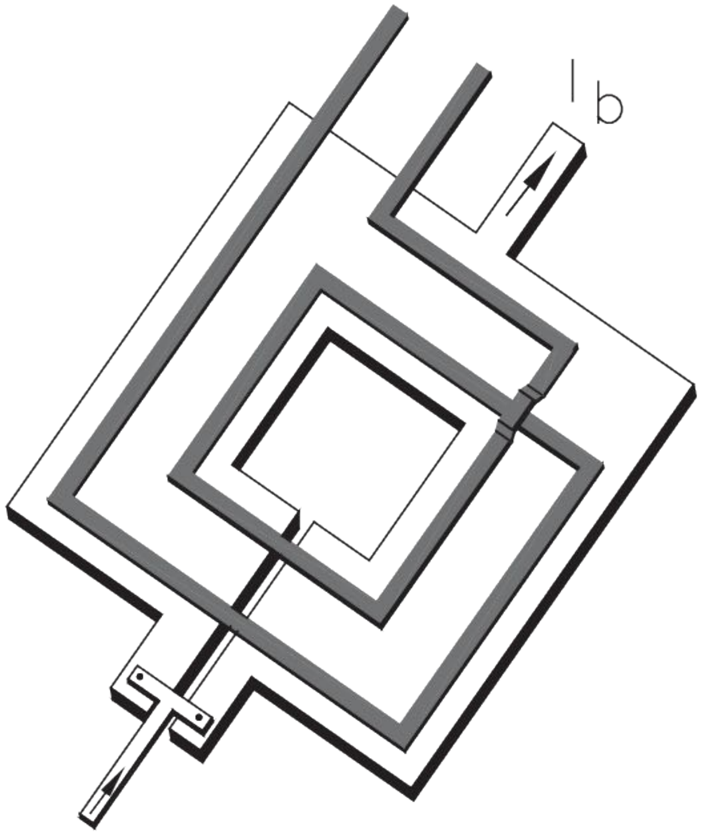
Washer SQUIDs





(a) (b)

Coupled washer SQUIDs



SQUIDs in practice

Basics of rf-SQUIDs

Basics of rf-SQUIDs

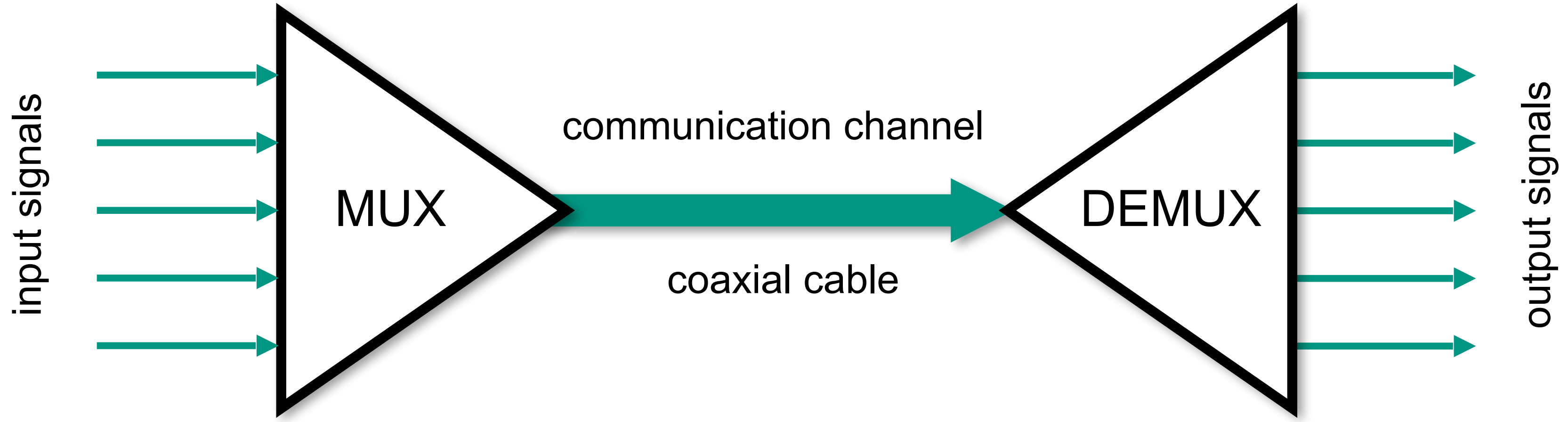
Basics of rf-SQUIDs

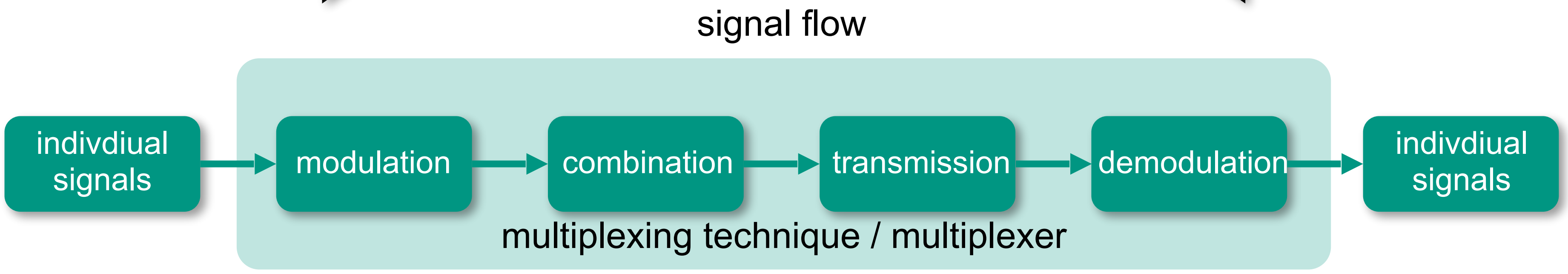
Flux locked loop

Flux locked loop

Multiplexing

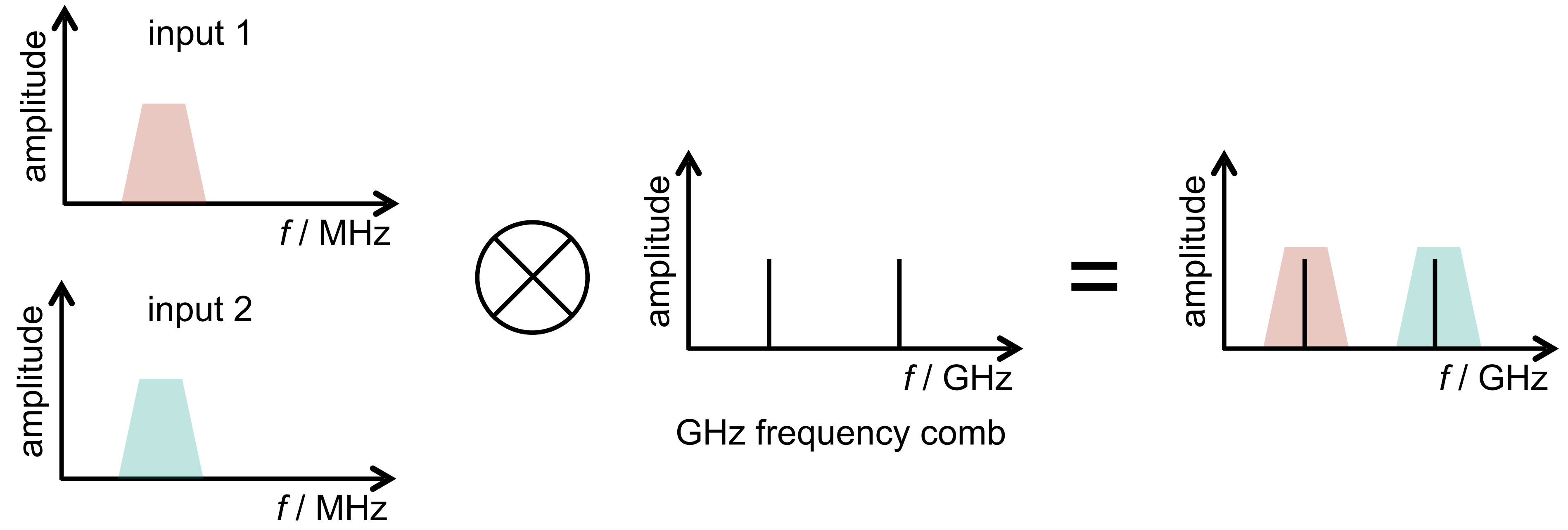
multiplexing (muxing)	method by which multiple signals are combined into one ‘physical’ channel to share a scarce resource.



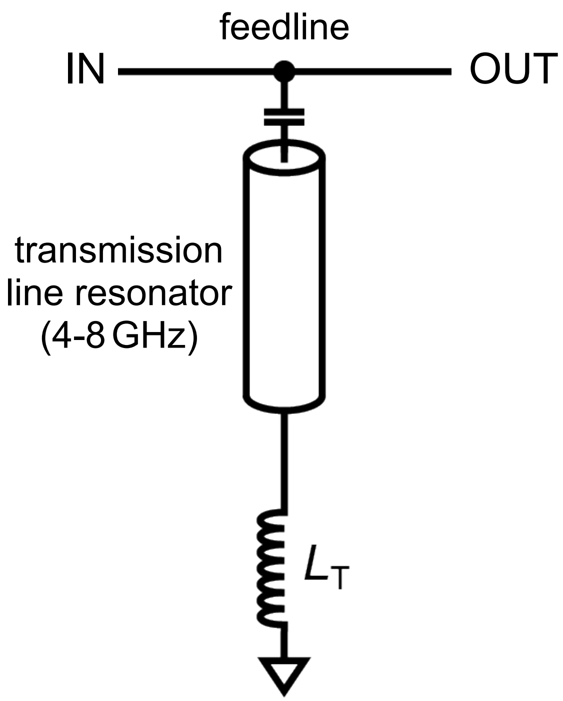


Frequency division multiplexing

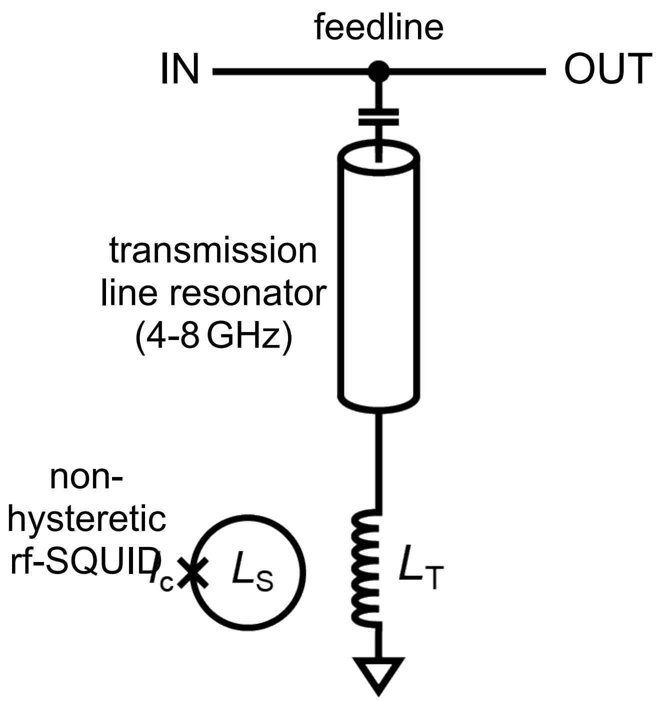
idea: input signals are modulated on independent GHz carrier signals

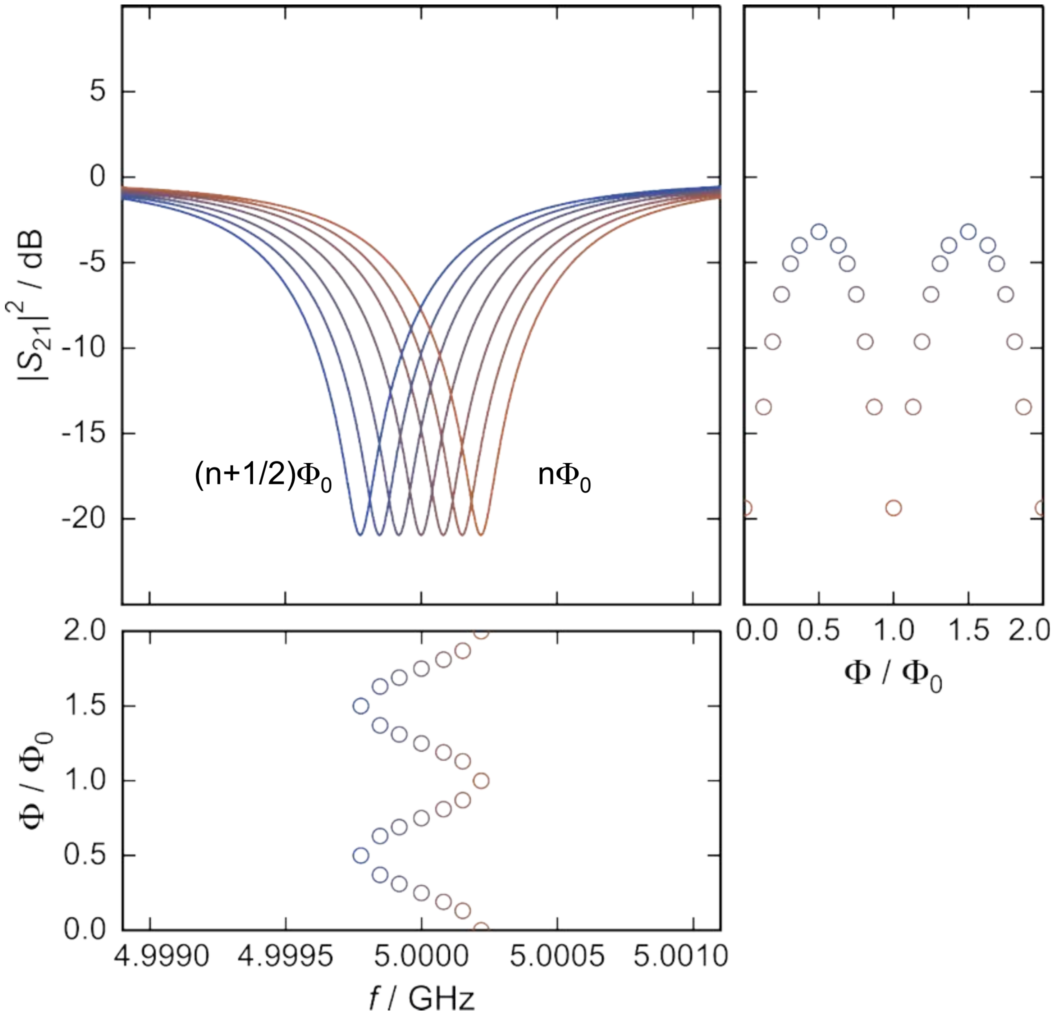


Non-hysteretic rf-SQUIDs

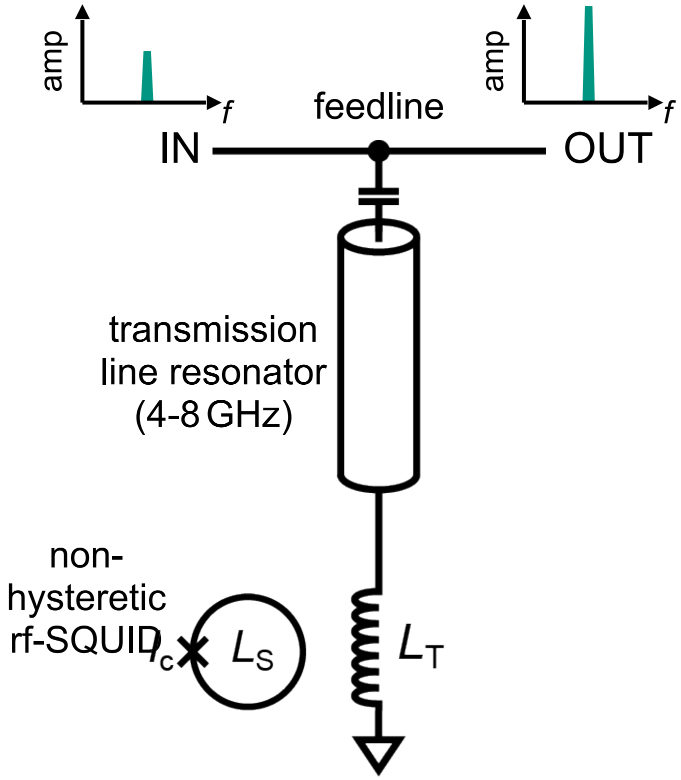


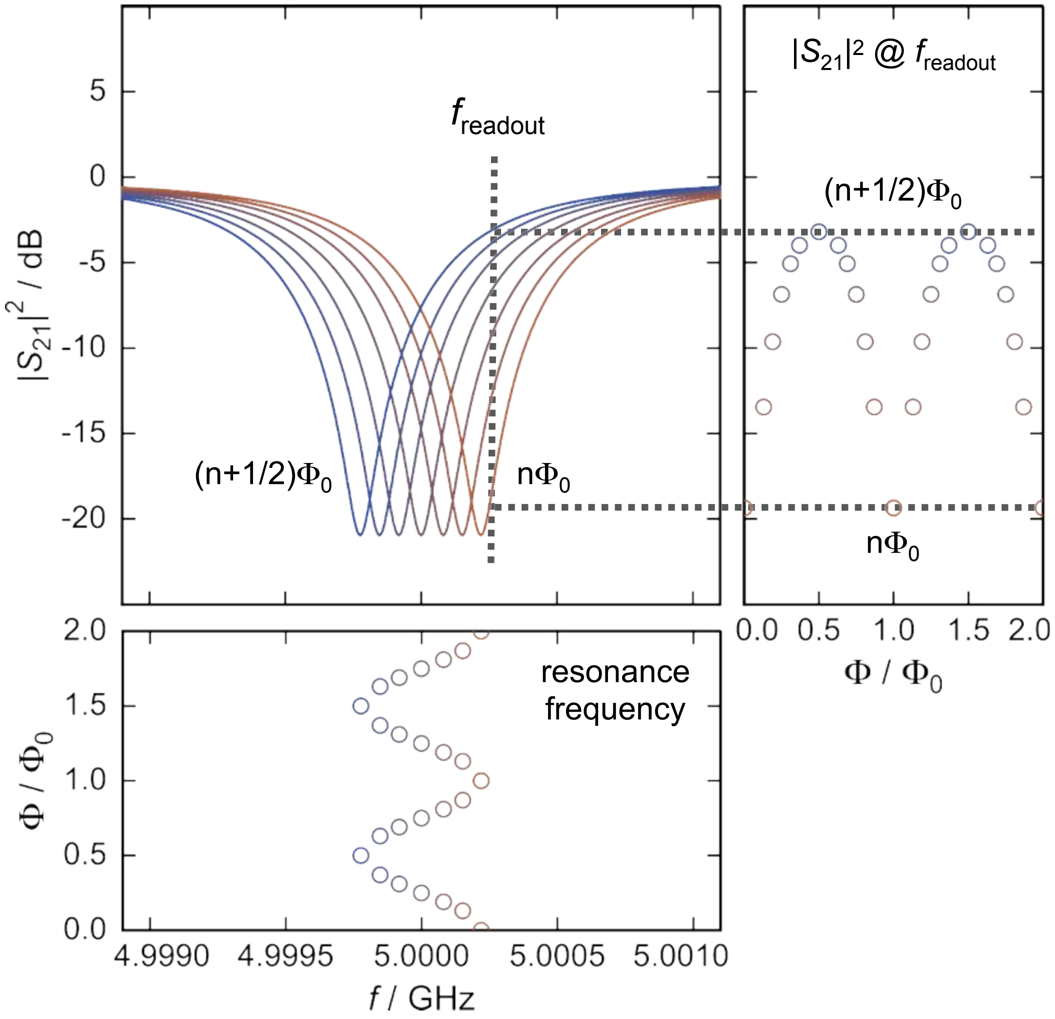
Non-hysteretic rf-SQUIDs



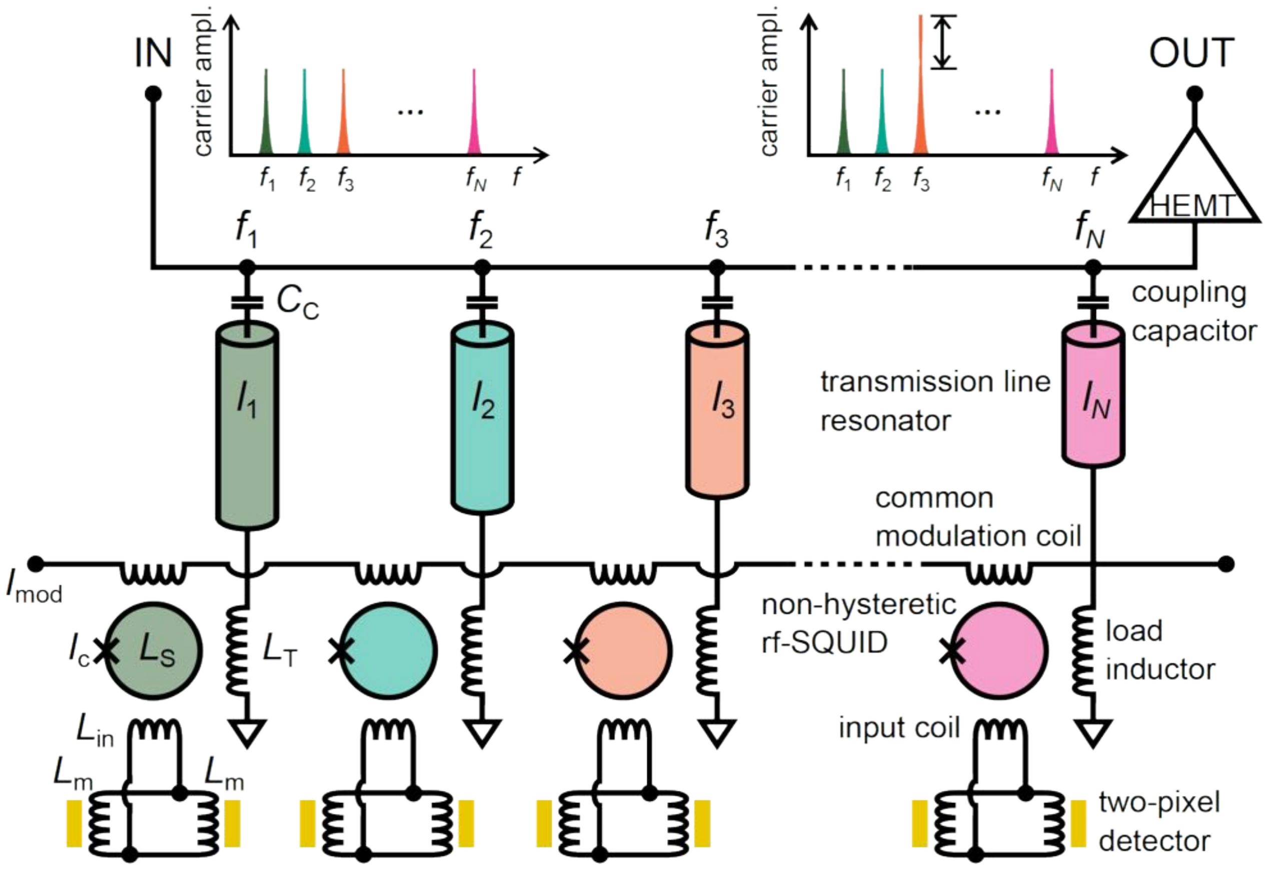


Non-hysteretic rf-SQUIDs



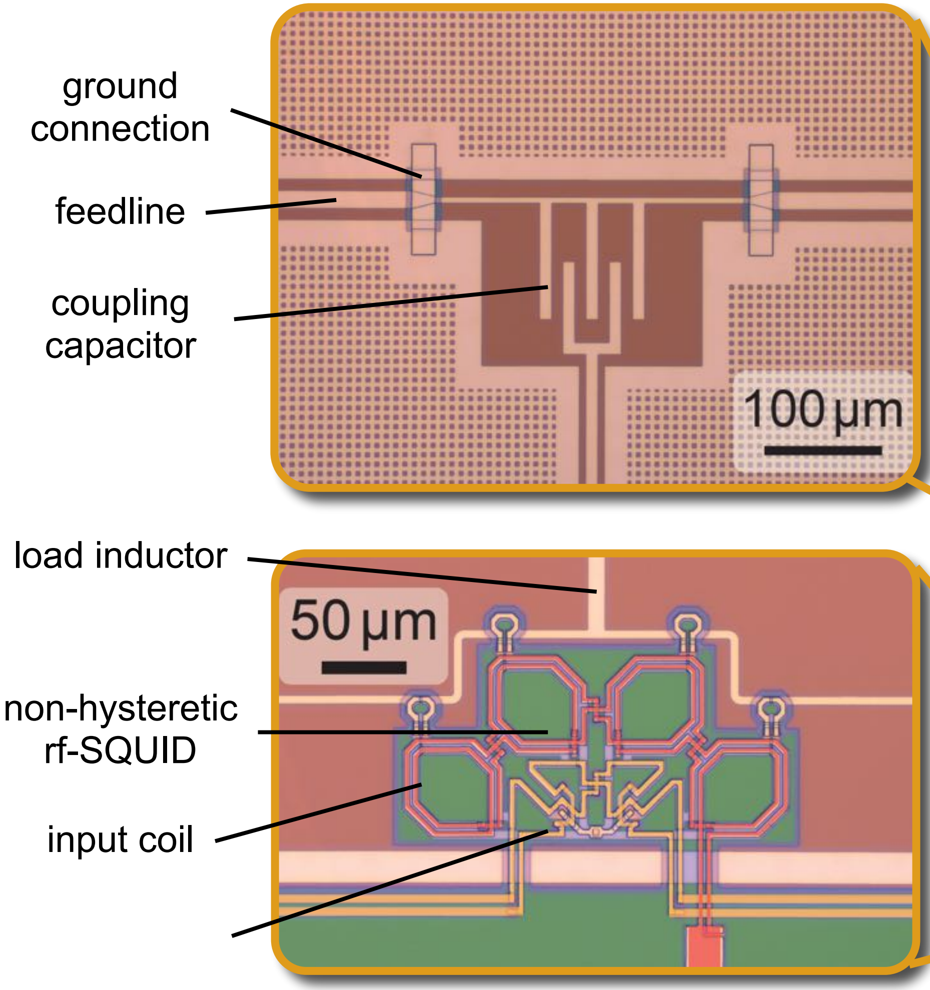


Microwave SQUID multiplexer



1 HEMT amplifier + 2 coaxial cables ⟶ ~1000 detectors

Microwave SQUID multiplexer



16 channel MUX based on CPW resonators

- Frequency range ~ 4.5 GHz … 4.8 GHz
- Resonator bandwidth ~ 1.0 MHz
- Frequency shift Δf_r ~ 1.2 MHz
- Frequency spacing ~ 20 MHz
- SQUID screening parameter β_L ~ 0.6
- Input coil inductance L_{in} ~ 1.5 nH (impedance matched to MMC)