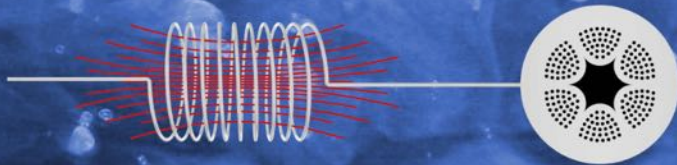


Superconductivity for Engineers

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Summer term 2021

Institut für Technische
Physik (ITEP)



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Nanoelektronische Systeme (IMS)



Lecture overview

Lecture 01:	(SK)	Introduction and overview
Lecture 02:	(BH)	Superconductor applications
Lecture 03:	(SK)	Normal metals and properties of the normal conducting state
Lecture 04:	(SK)	Perfect conductor, ideal diamagnetism, two-fluid model, London theory
Lecture 05:	(SK)	Disordered superconductors, Pippard theory, microwave properties
Lecture 06:	(SK)	BCS theory
Lecture 07:	(BH)	Ginzburg-Landau theory
Lecture 08:	(BH)	Type-I superconductors
Lecture 09:	(BH)	Type-II superconductors
Lecture 10:	(BH)	Type-II superconductors
Lecture 11:	(BH)	Current transport, ac-losses, thermal aspects
Lecture 12:	(BH)	Current transport, ac-losses, thermal aspects
Lecture 13:	(SK)	Josephson junctions
Lecture 14:	(SK)	SQUIDs

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

Reminder: Josephson tunnel junctions

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

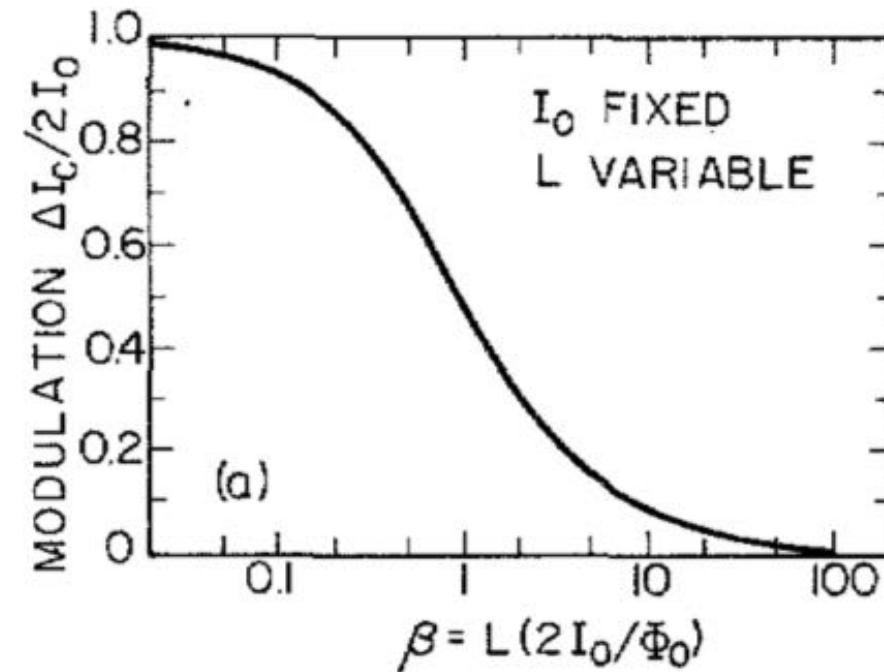
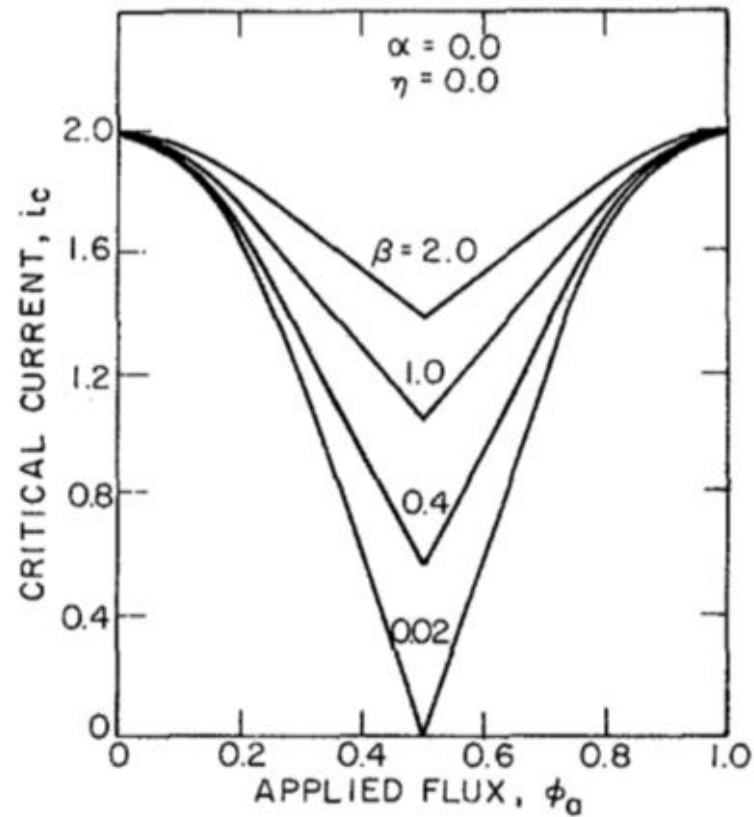
Magnetic flux inside SQUID loop

Hysteresis parameter β_L

Hysteresis parameter β_L

Hysteresis parameter β_L

Hysteresis parameter β_L



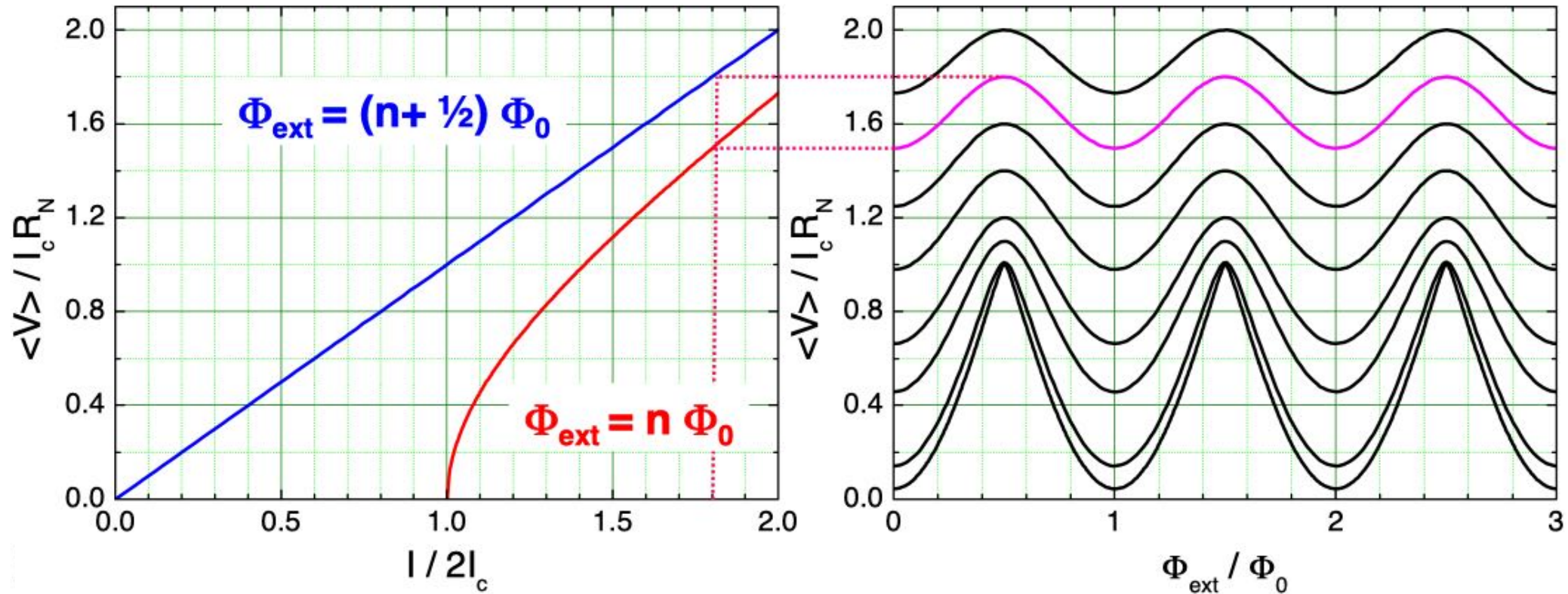
Voltage state of dc-SQUIDs

Voltage state of dc-SQUIDs

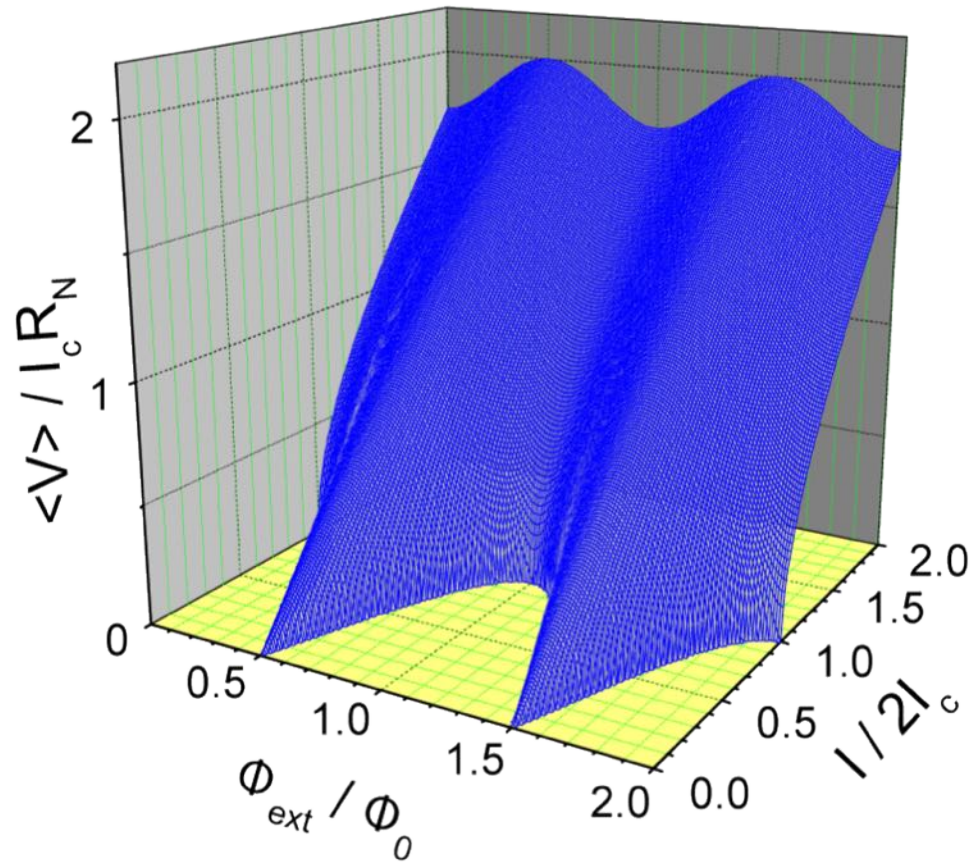
Strong damping, weak screening

Strong damping, weak screening

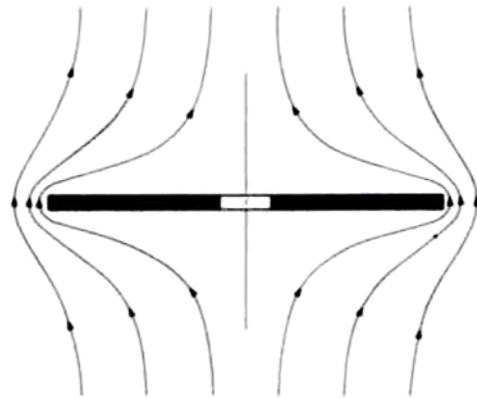
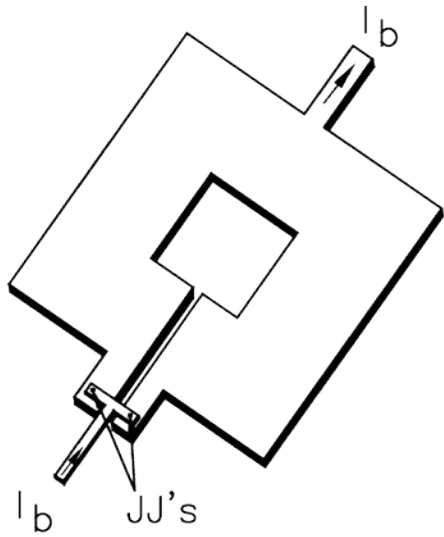
IVC for SQUIDs with negligible screening



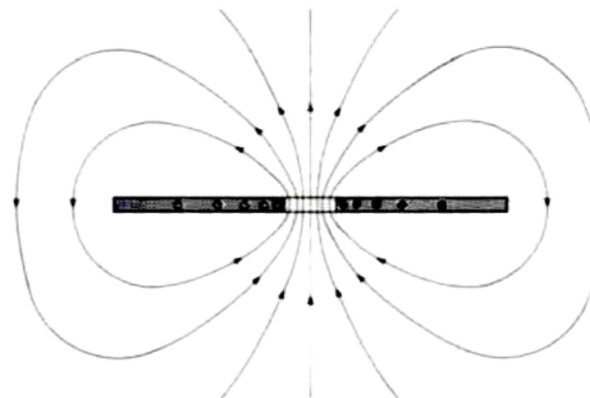
IVC for SQUIDs with negligible screening



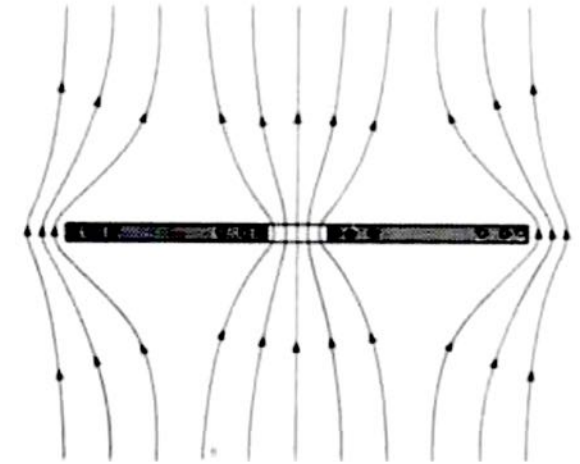
Washer SQUIDs



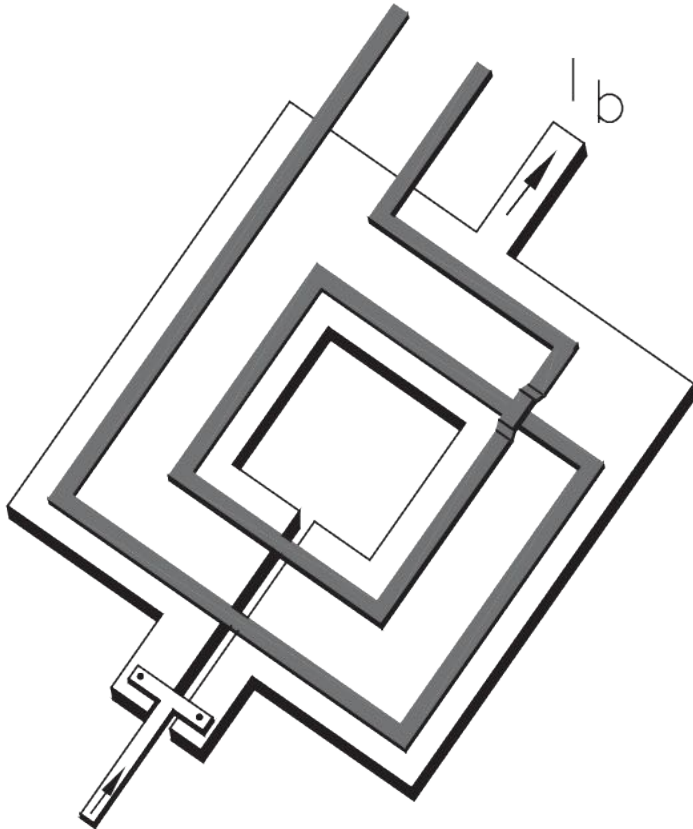
(a)



(b)



Coupled washer SQUIDs



SQUIDs in practice

Basics of rf-SQUIDs

Basics of rf-SQUIDs

Basics of rf-SQUIDs

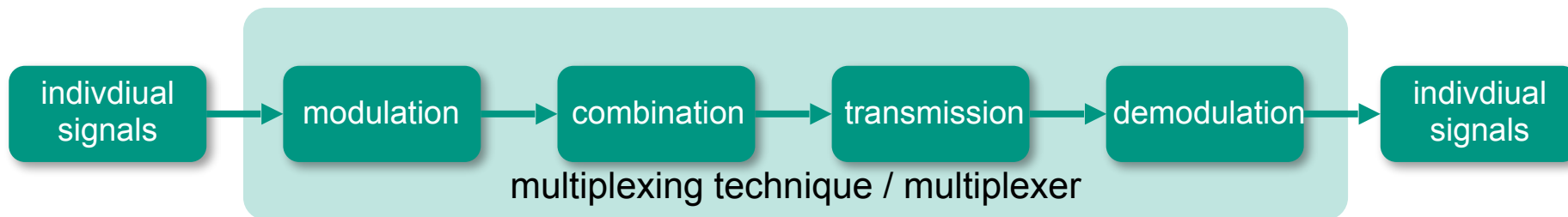
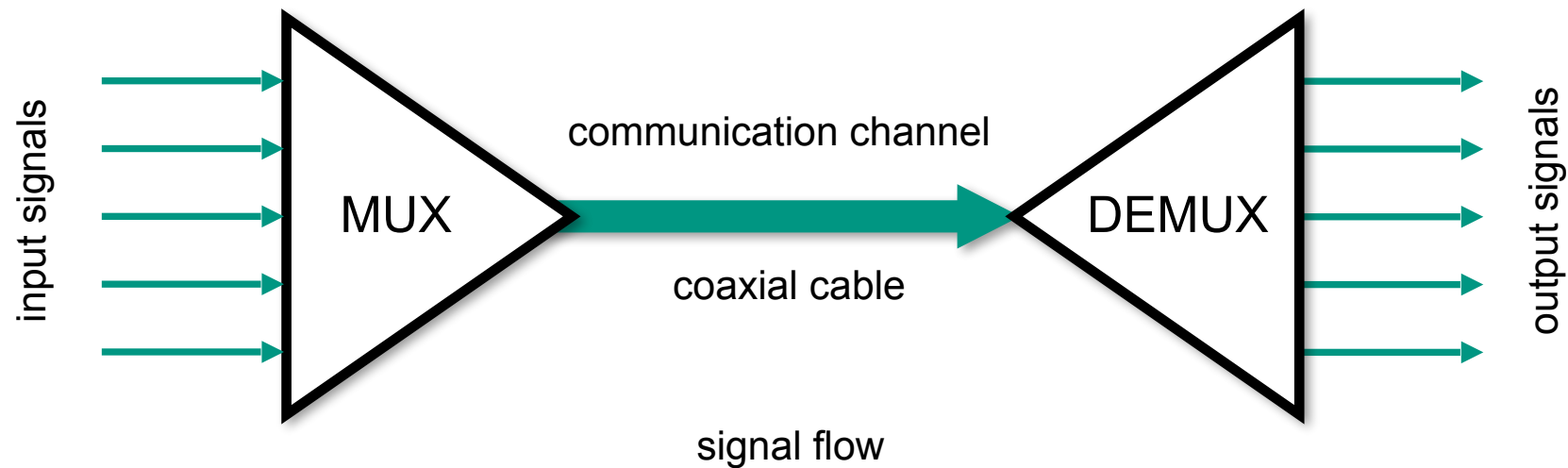
Flux locked loop

Flux locked loop

Multiplexing

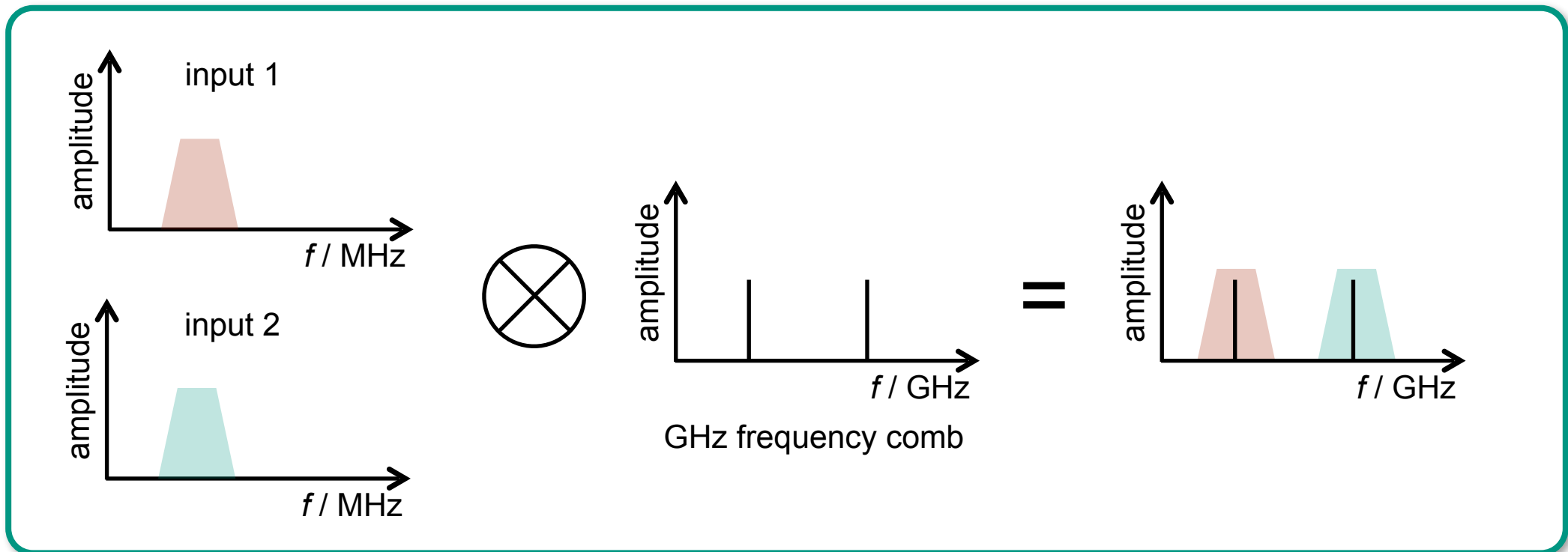
**multiplexing
(muxing)**

method by which **multiple signals** are combined into **one** 'physical' channel to share a scarce resource.

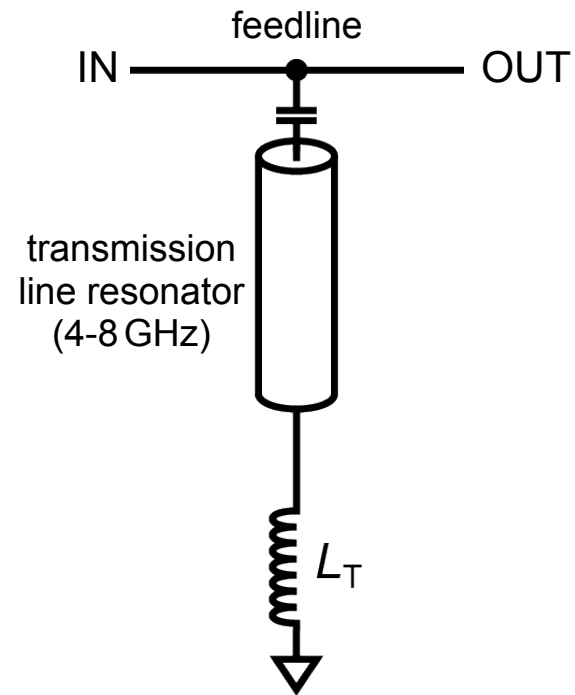


Frequency division multiplexing

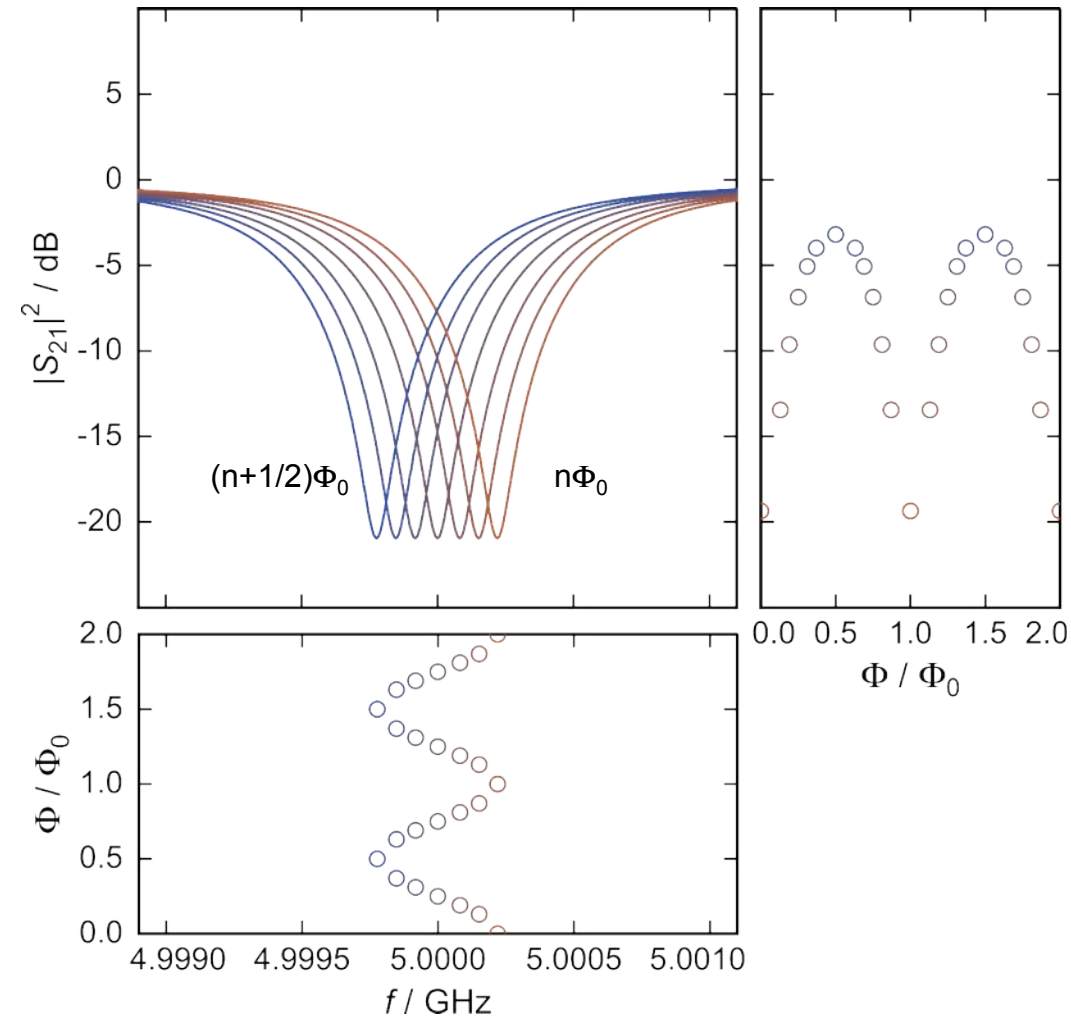
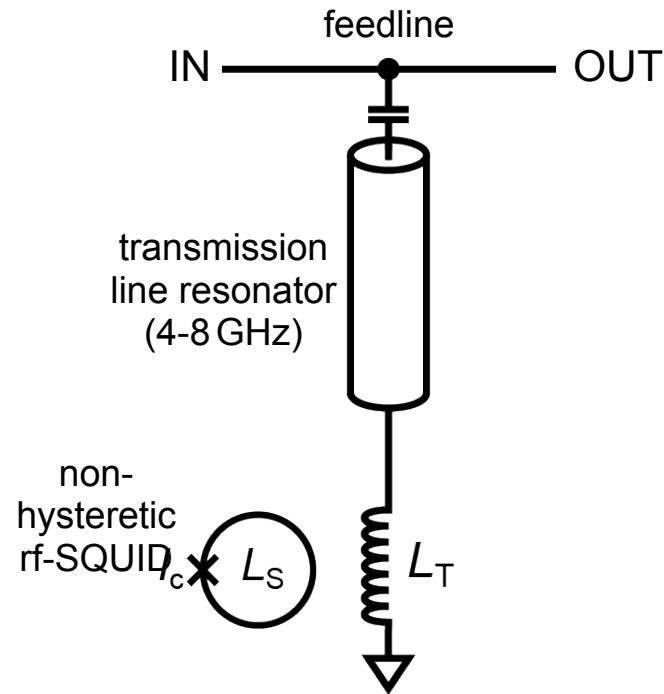
idea: input signals are modulated on independent GHz carrier signals



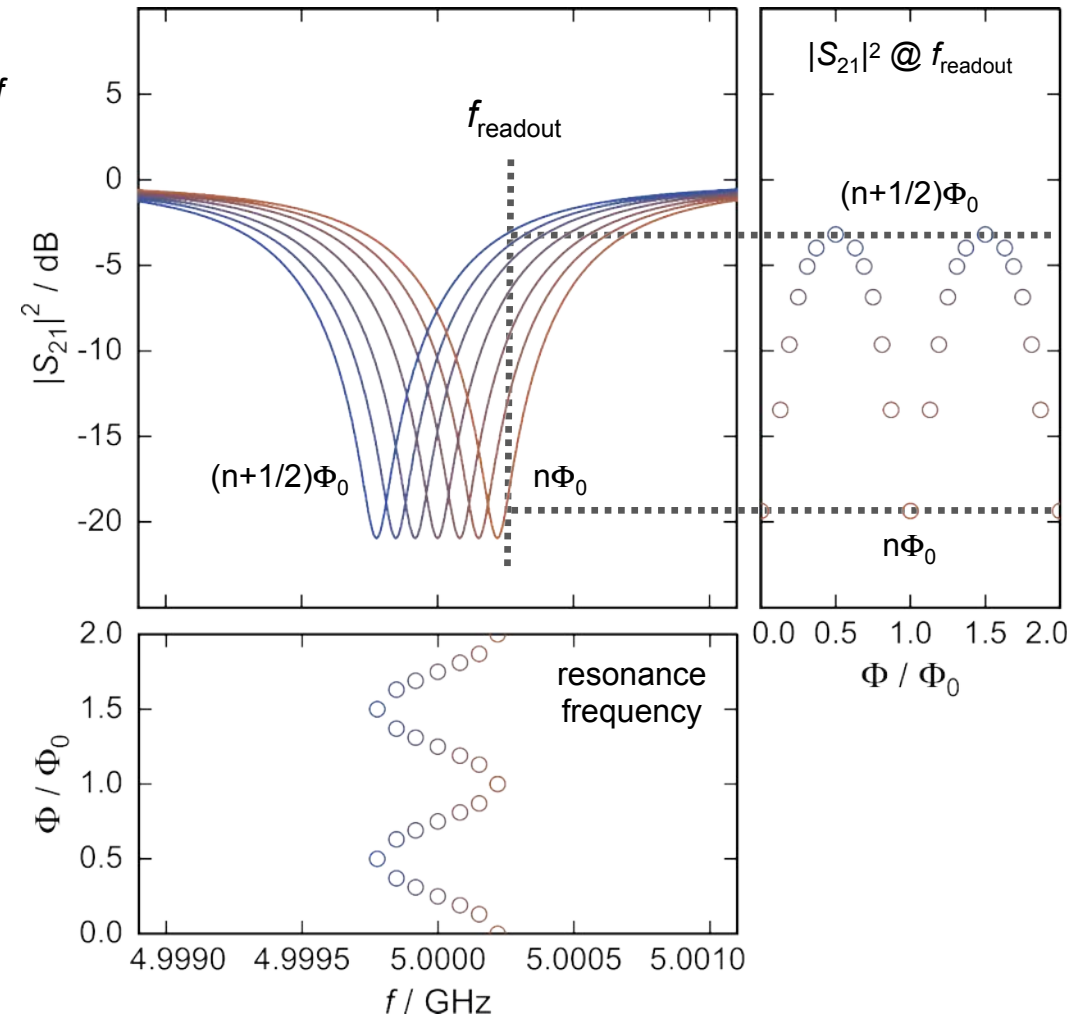
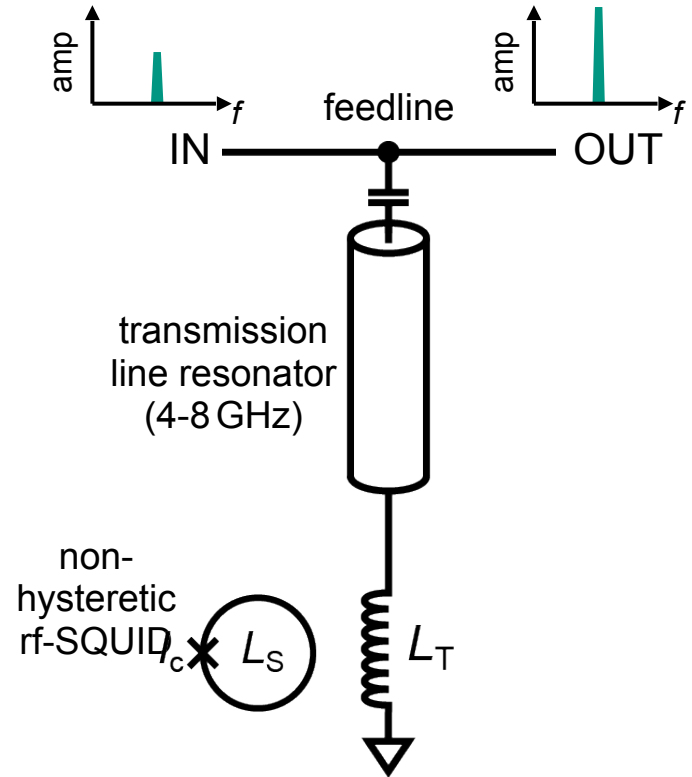
Non-hysteretic rf-SQUIDs



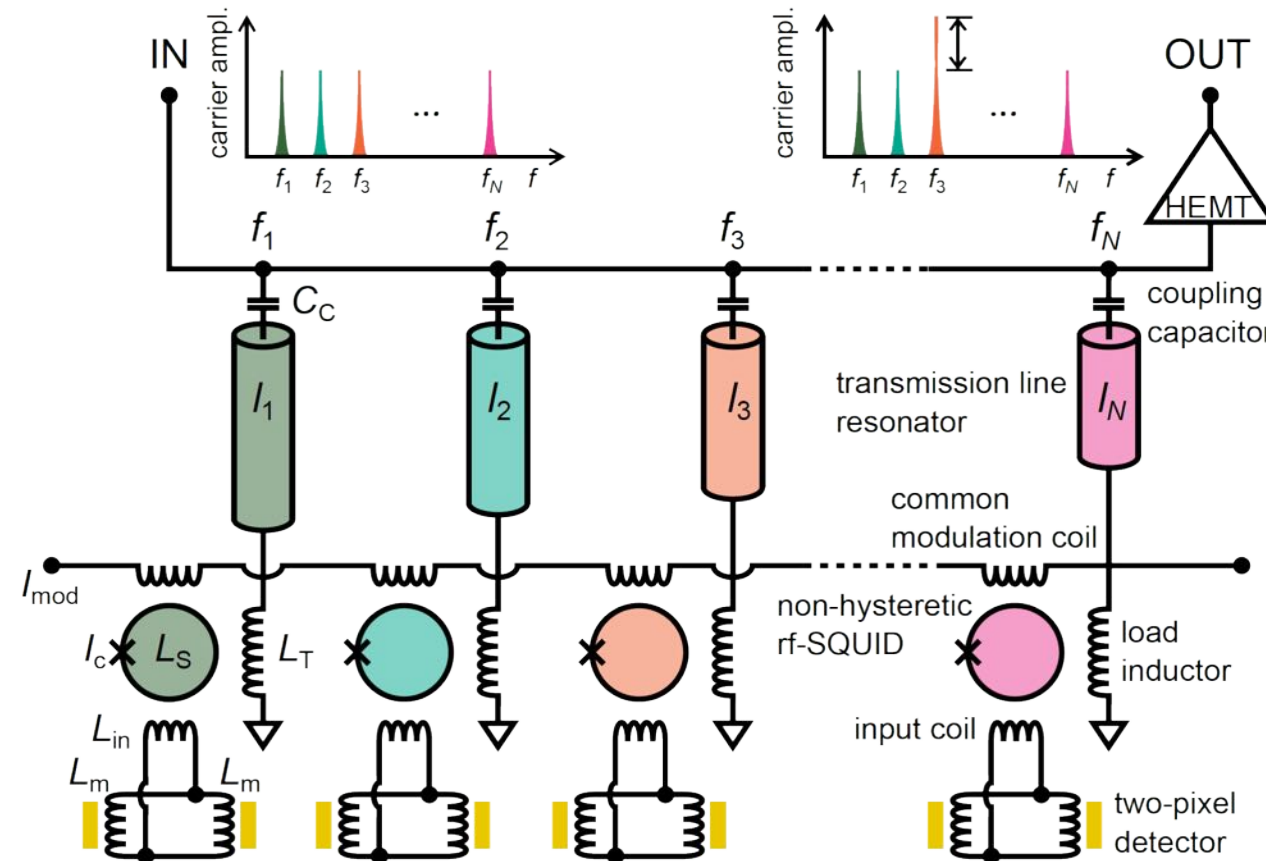
Non-hysteretic rf-SQUIDs



Non-hysteretic rf-SQUIDs



Microwave SQUID multiplexer



1 HEMT amplifier + 2 coaxial cables $\rightarrow$ ~1000 detectors

Microwave SQUID multiplexer

16 channel MUX based on CPW resonators

- Frequency range $\sim 4.5 \text{ GHz} \dots 4.8 \text{ GHz}$
- Resonator bandwidth $\sim 1.0 \text{ MHz}$
- Frequency shift $\Delta f_r \sim 1.2 \text{ MHz}$
- Frequency spacing $\sim 20 \text{ MHz}$
- SQUID screening parameter $\beta_L \sim 0.6$
- Input coil inductance $L_{in} \sim 1.5 \text{ nH}$ (impedance matched to MMC)

