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Development of transducers and low noise two-stage SQUID amplifiers for miniGRAIL

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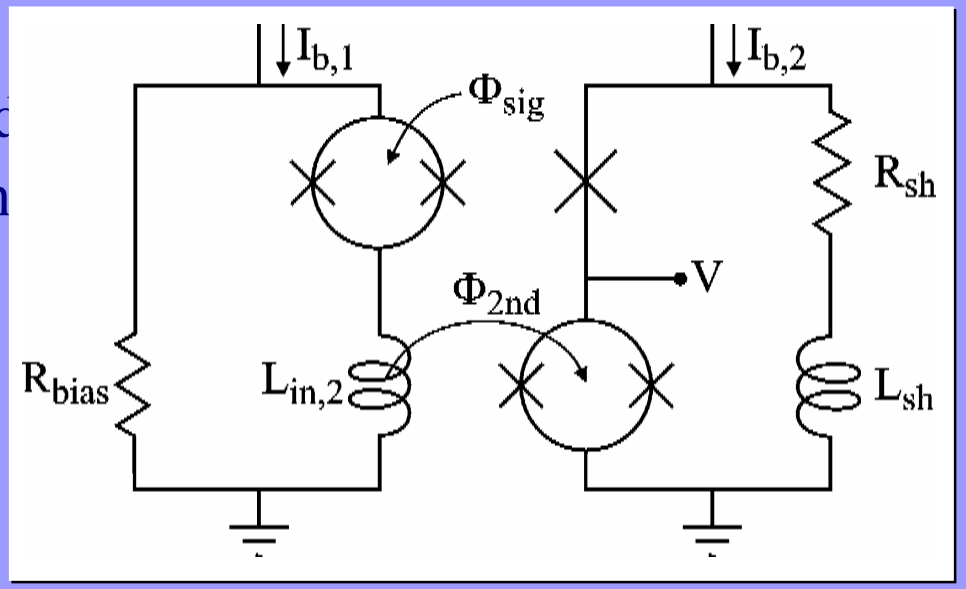
Outline

- low noise two-stage SQUID amplifiers based on a DROS
- mechanical “rosette” resonator for capacitive read-out
- miniGRAIL run with two capactive transducers
- high-mechanical Q resonator and Nb-film coil for a two-mode *inductive transducer*

Low noise two-stage SQUID based on DROS as amplifier SQUID

two-stage SQUID systems are developed
reduce the noise contribution of room
temperature pre-amplifier



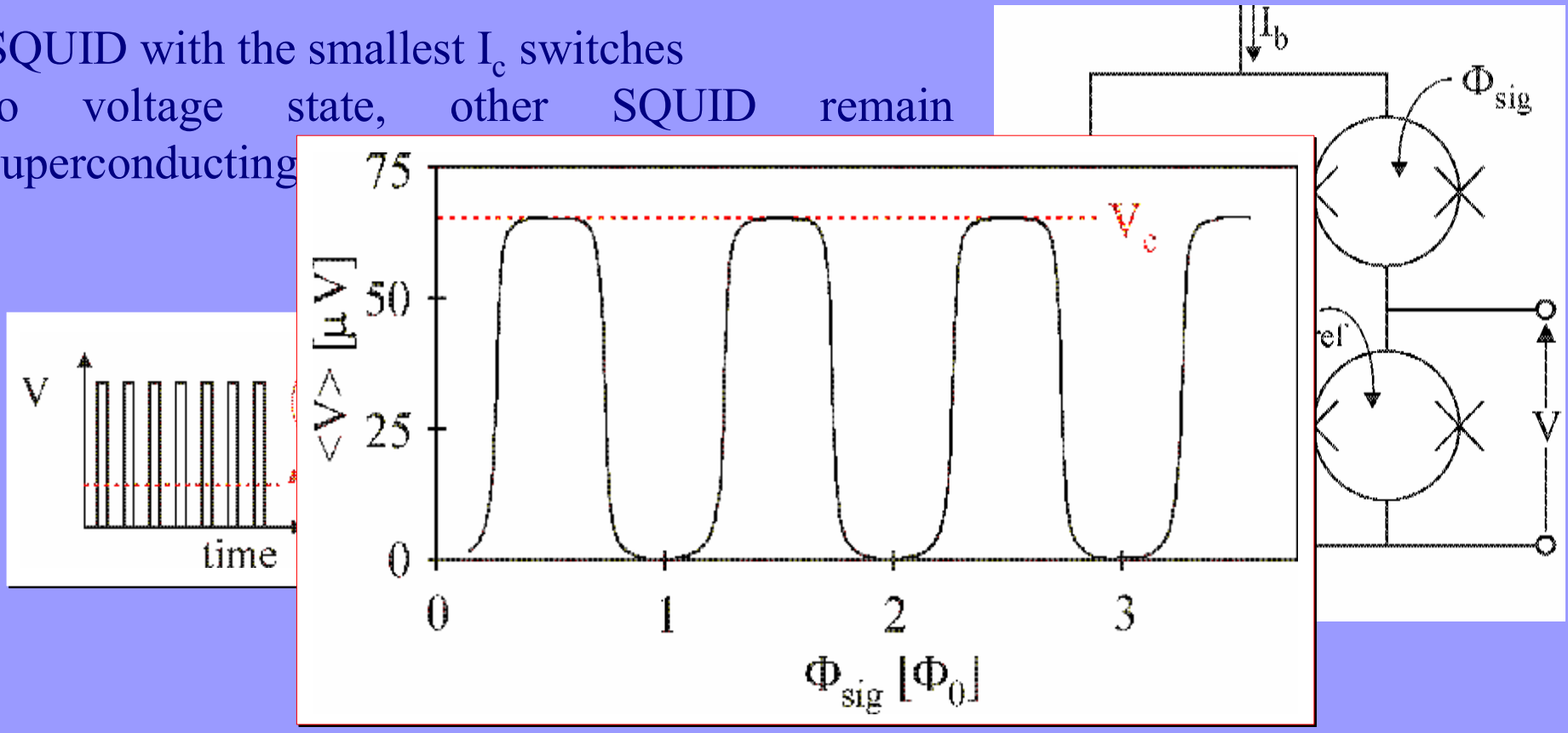
INCREASE OF ENERGY SENSITIVITY

dc-SQUID

DROS

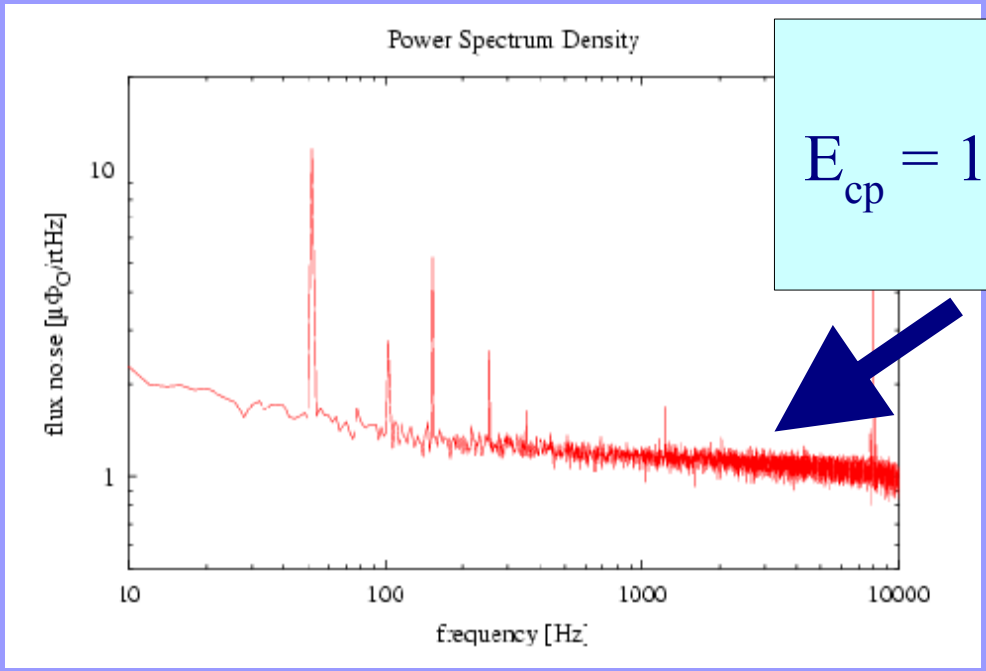
Double Relaxation Oscillation Squid

SQUID with the smallest I_c switches to voltage state, other SQUID remain superconducting



ADVANTAGES:
large flux to voltage trasfer (1mV/Phi_o)
direct voltage read out (no modulation)

Noise measurements of a Twente dc-SQUID with DROS



E_{cp} = 160 □ @ 1.5 K

DROS

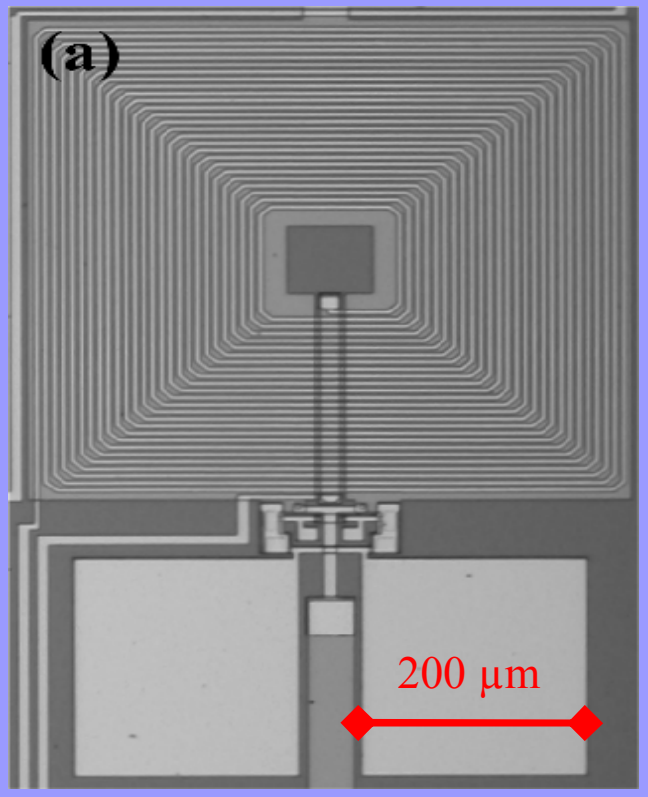
L_{SQ} =550pH
I_C = 4-5 μA
L_{IN} = 150nH
M_{IN} = 4.7 nH

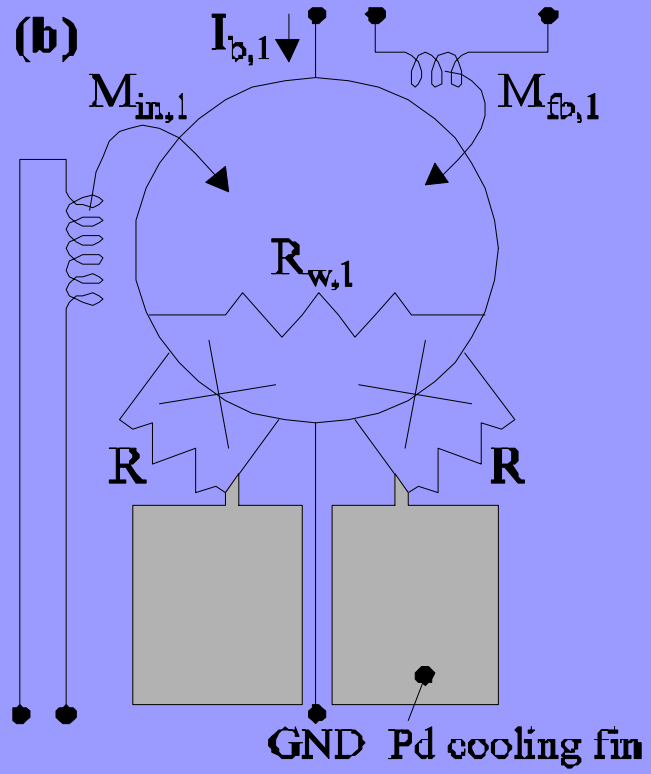
dc-SQUID

L_{SQ} =200pH
I_C = 11-12 μA
L_{IN} = 150nH
M_{IN} = 4.2 nH

New design dc-SQUID

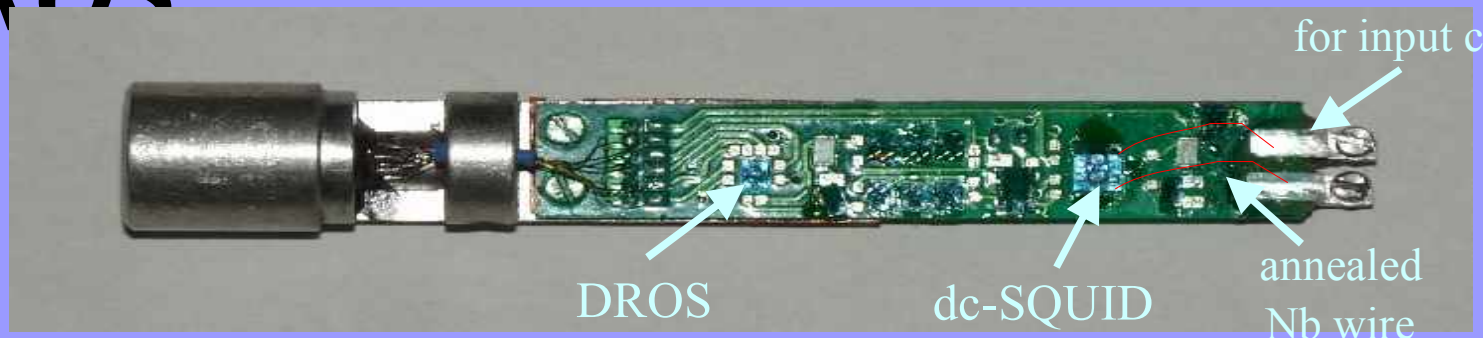
ready to be tested in a two-stage system





- larger input inductance: ~ 1.2 µH gradiometric design
- cooling fins to better thermalize the shunt resistors

Noise measurements of a Quantum Design dc-SQUID with DROS

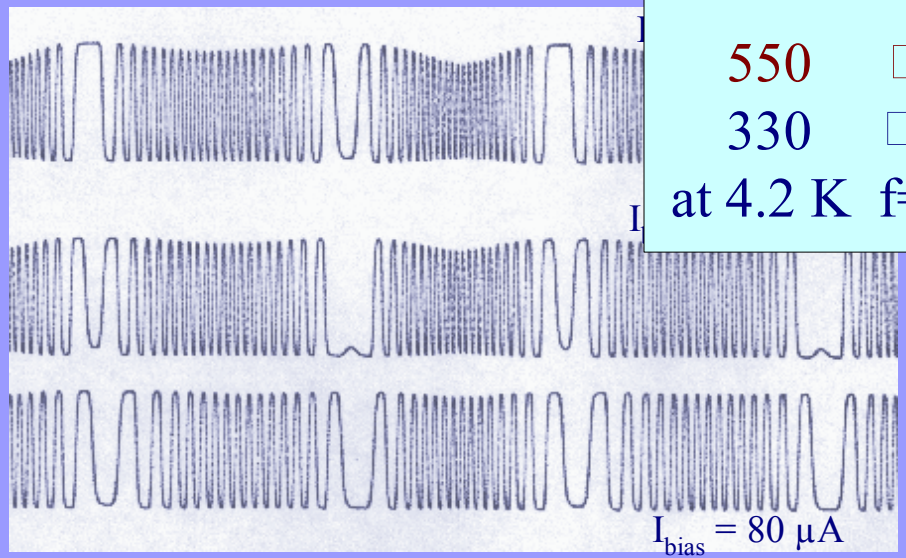


coupled energy resolution

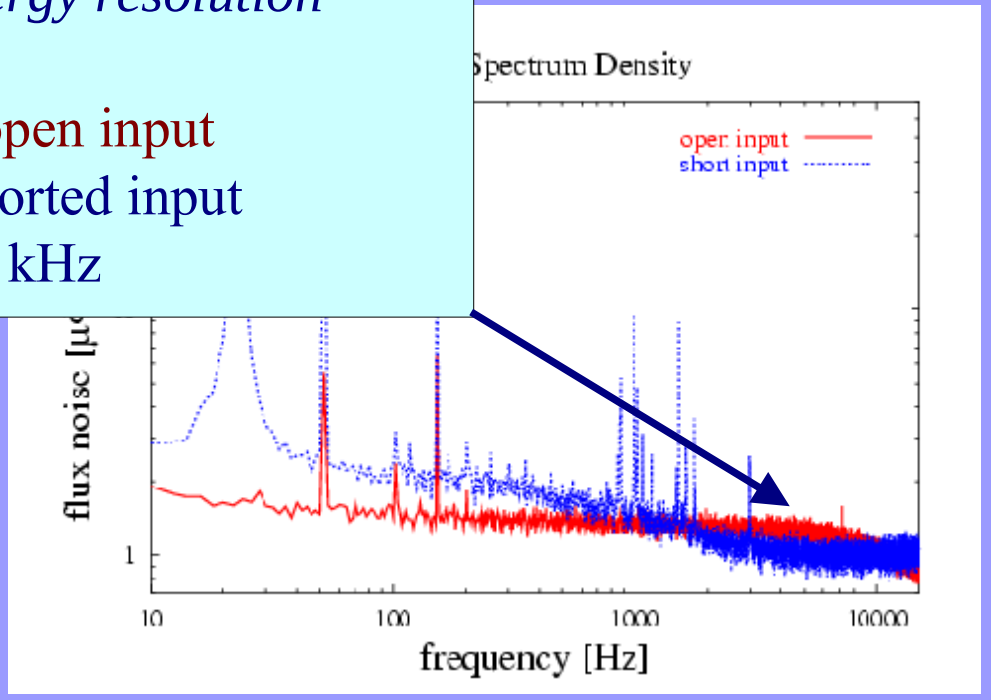
550 □ open input

330 □shorted input

at 4.2 K f=3 kHz



typical V-′ curves



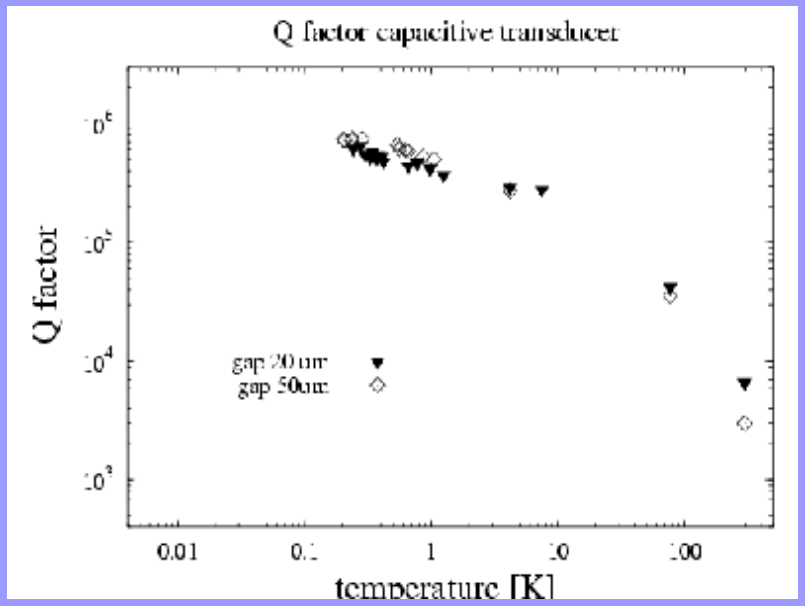
Capacitive transducers for miniGRAIL

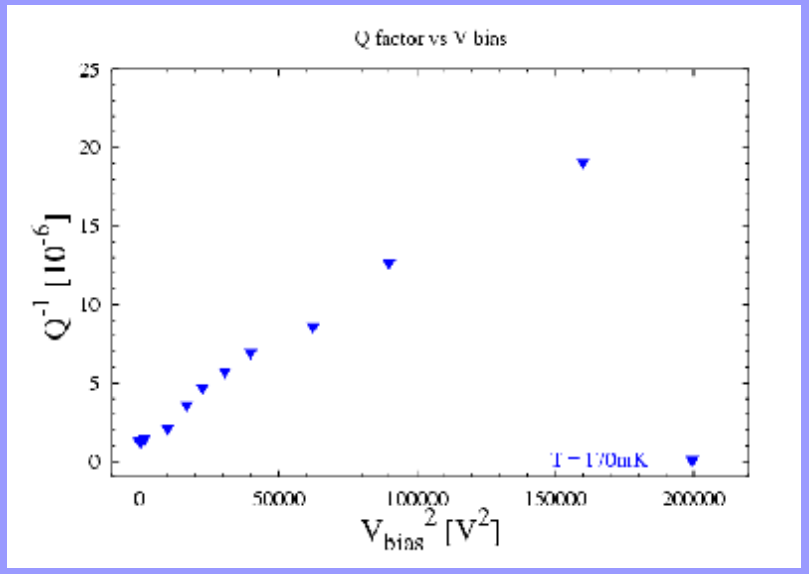
electrode

ring support

"rosette" resonator

material: CuAL 6%
effective mass: 450 g





Current miniGRAIL run

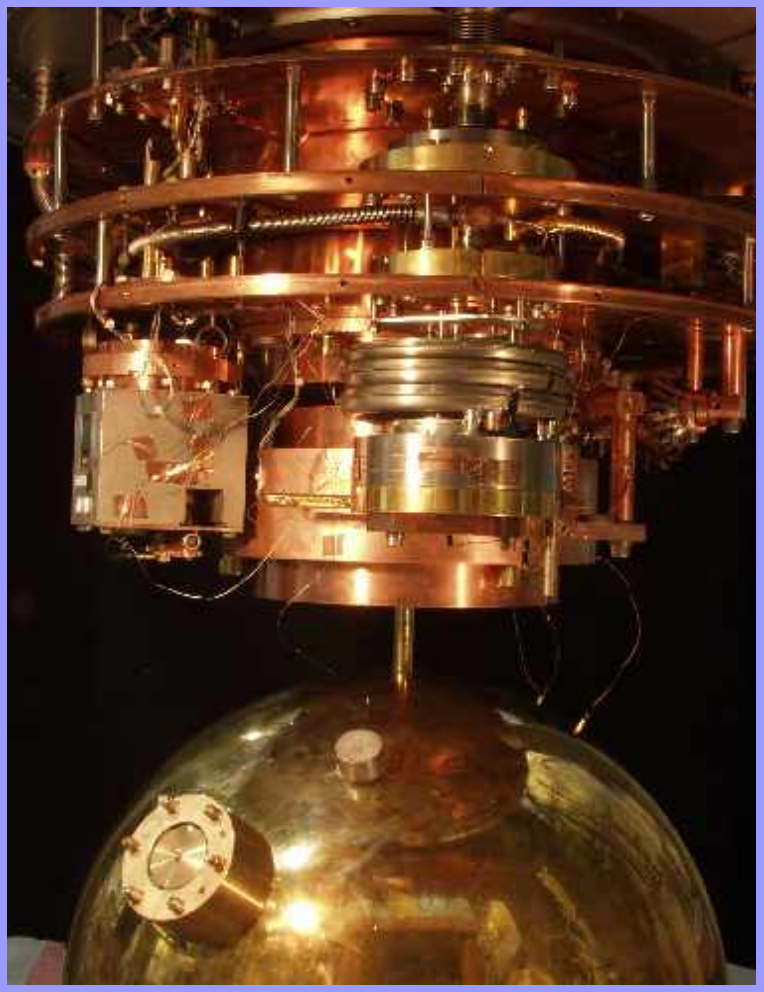
two capacitive transducer

transducer 1

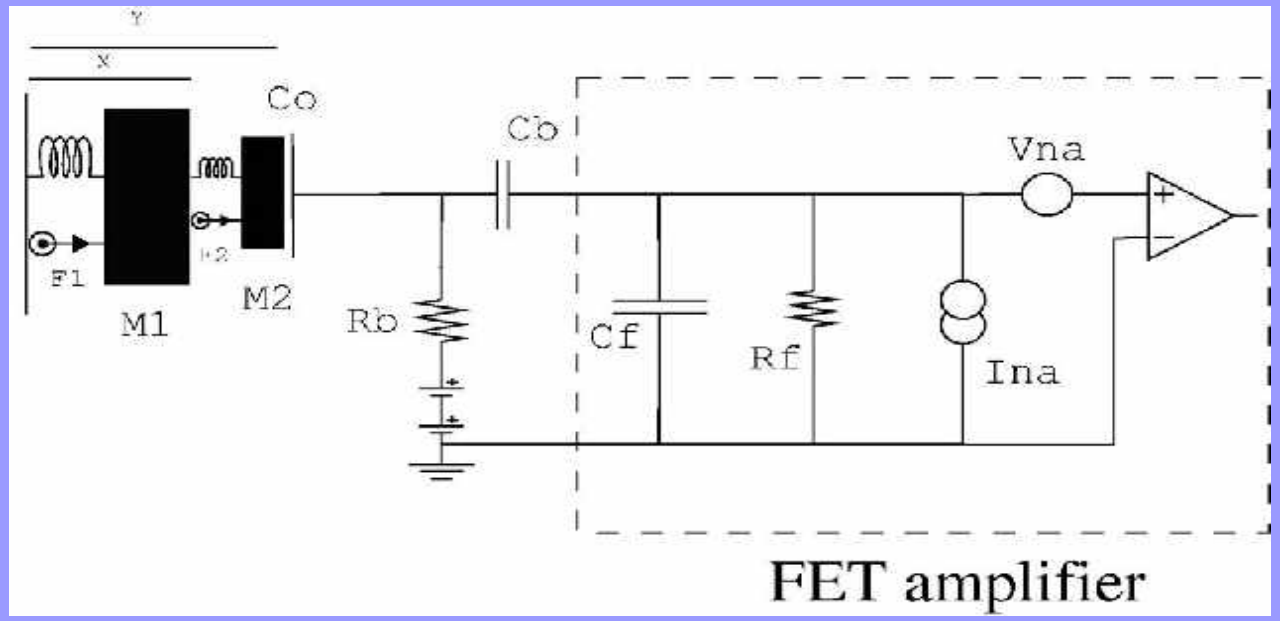
coupled

transducer 2

loosely coupled



transducer 1 - room temperature FET



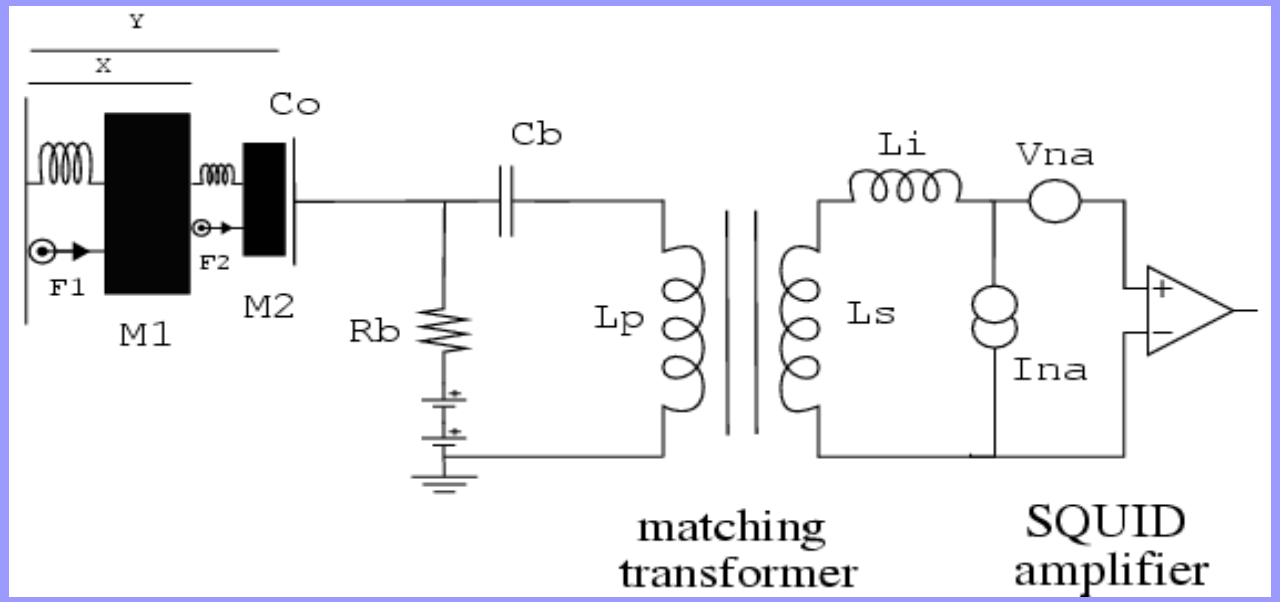
FET noise

V_{NA} = 1.4nV/√Hz

I_{NA}~1.5 fA/√Hz

T_N~0.15 K

transducer 2 - two-stage SQUID



matching trasformer

L_1 = 2.15H

L_2= 0.8μH

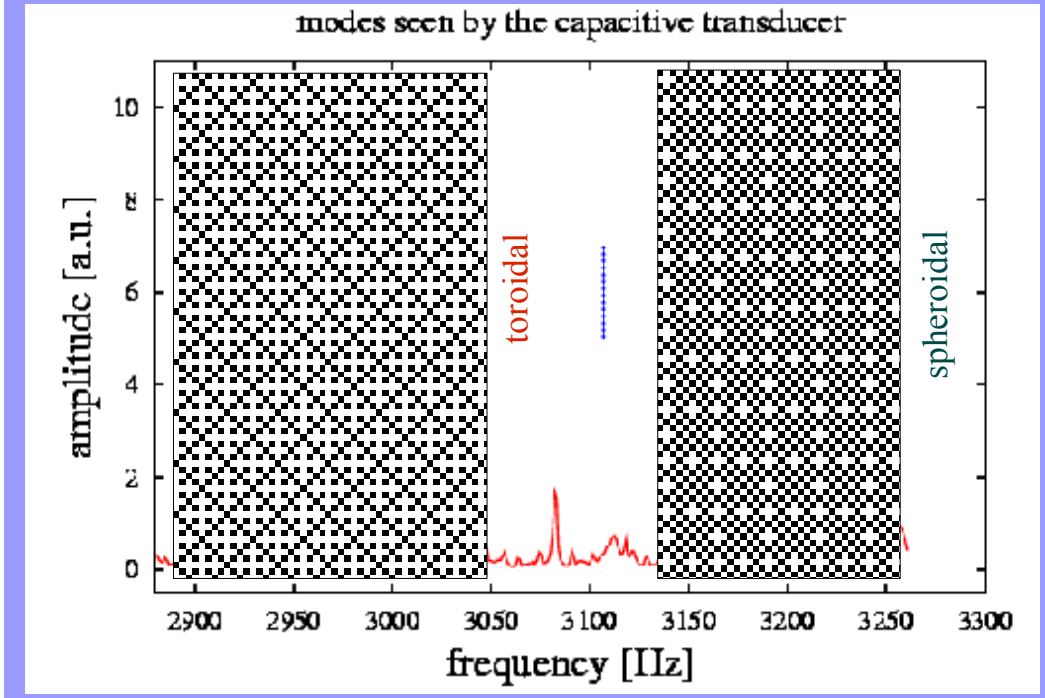
k^2=0.65

Q_E=30000

f_E~5500 Hz

Preliminary results

transducer 1



mode energy distribution

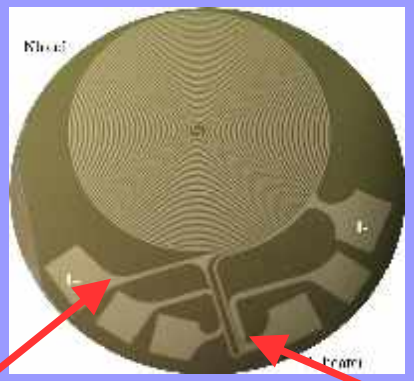
Energy (K)

transducer 2

the SQUID is ALIVE !

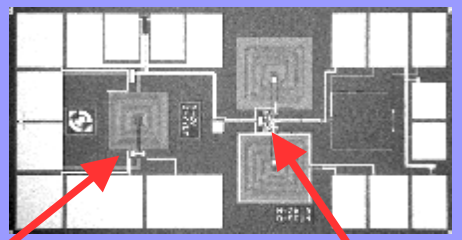
Two-mode inductive transducer

- first mechanical mode is a CuAl6% “rosette” resonator with effective mass of 450 g
- second mechanical mode is an Al5056 resonator with effective mass of about 1.5 g
- superconducting circuit made with Nb film coils deposited on silicon substrates
- integrated two-stage SQUID system based on a DROS with energy resolution of 200 at 4.2 K



current input

persistent switch

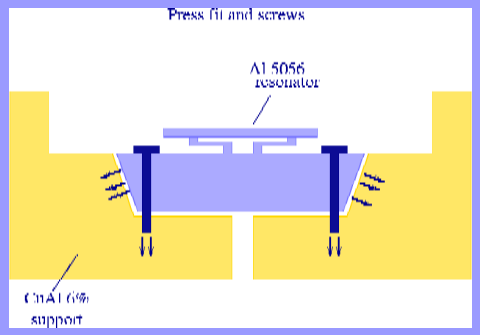


dc SQUID

DROS

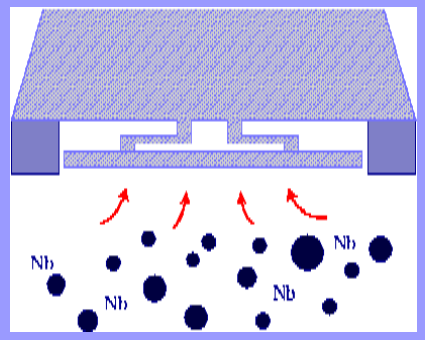
Current status of the inductive transducer

- mechanical Q tests at 4.2 K



resonator press fit in a CuAl support

Q= 1.20x10^6

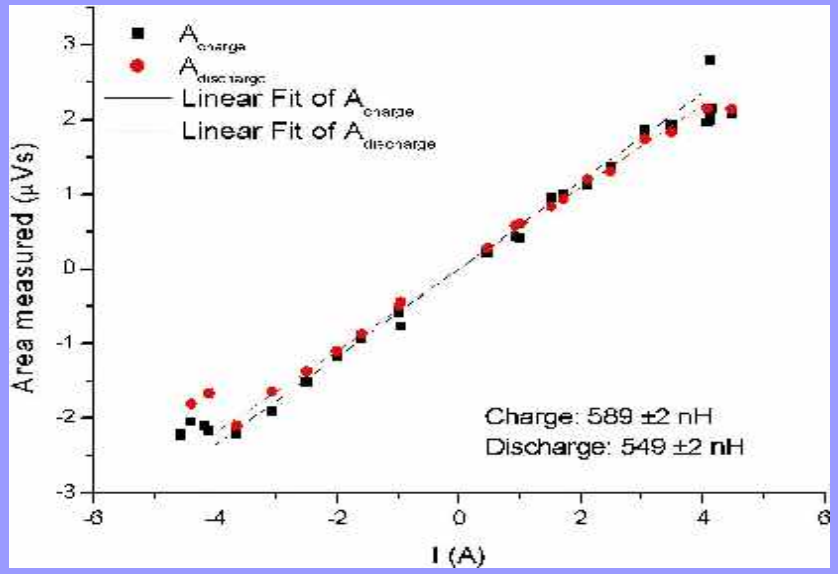


after 600nm Nb film deposition

Q= 1.06x10^6

- Nb film coil fabrication and persistent current tests

coil width	200 µm
coil pitch	200 µm
film thinkness	400 nm
inductance	550 nH

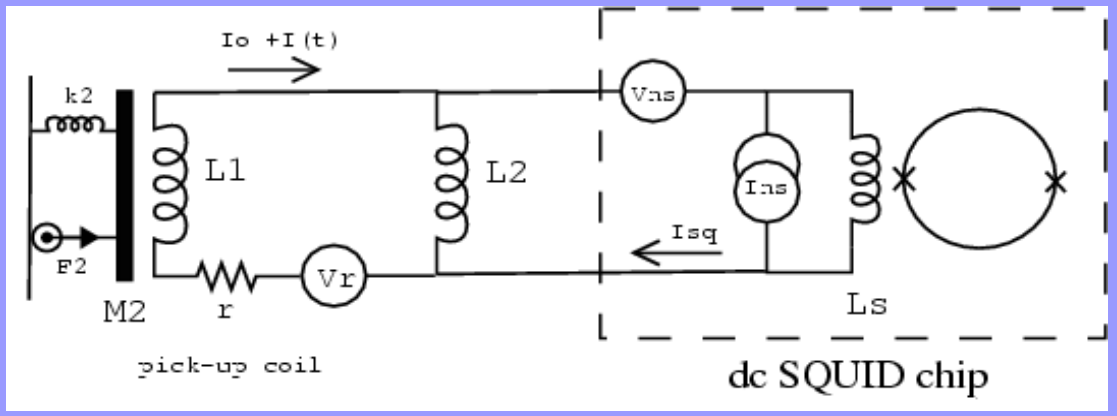


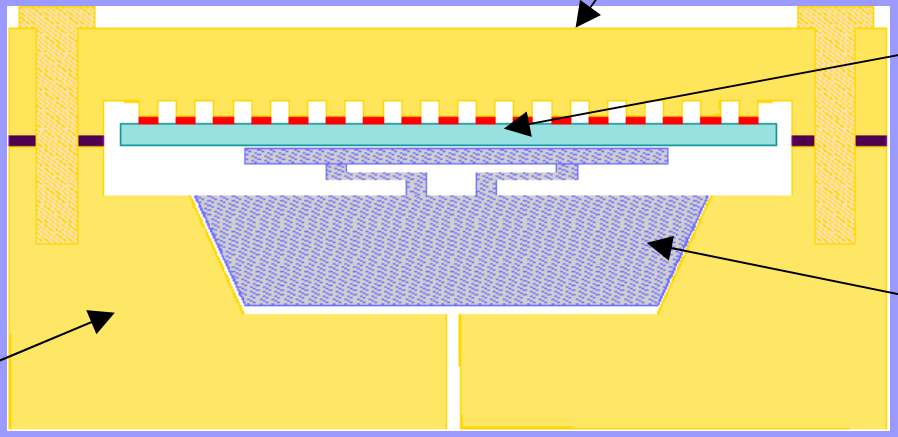
current in persistent mode: 4 A

Near future

test the complete system

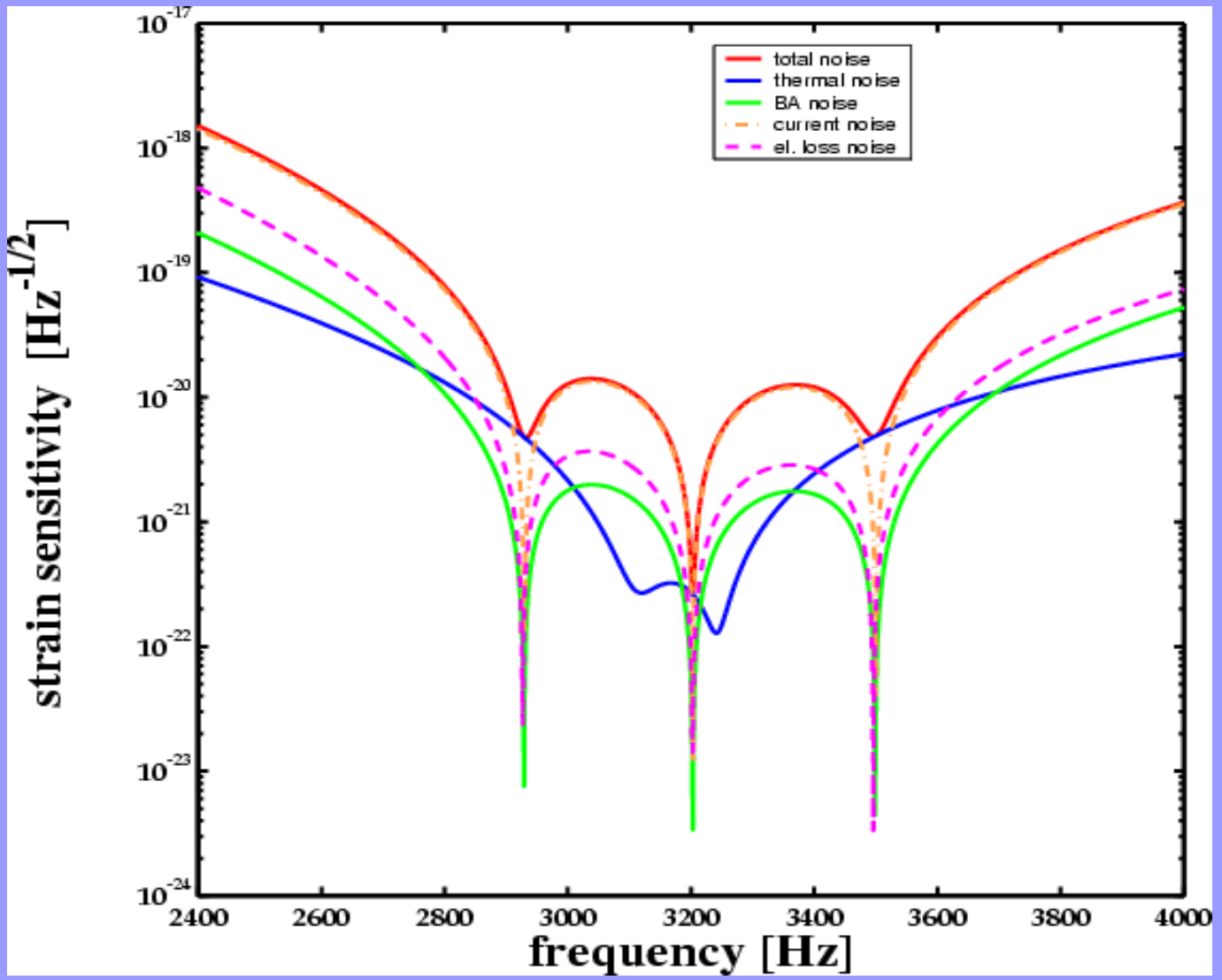
fabrication of the complete Nb film pick-up circuit





Summary

- we developed low noise two-stage SQUID amplifiers based on a DROS
- miniGRAIL is running with two capactive transducers read out by a FET amplifier and a two-stage SQUID. more results in the next weeks
- status in the development of a two-mode inductive transducer is shown


total noise
thermal noise
BA noise
current noise
el. loss noise
strain sensitivity [Hz^-1/2]
frequency [Hz]
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
2400
2600
2800
3000
3200
3400
3600
3800
4000