LAMPS laboratory

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INFN
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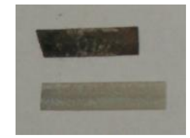
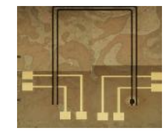
Laboratori Nazionali di Frascati

LAMPS host operative cryogenic systems for magnetic characterization and transport properties of technological INFN interest materials

a) Investigations of superconductors, magnetic materials as 'bulk, tape and nanoparticles'



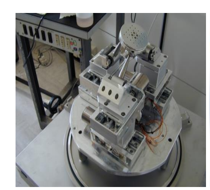
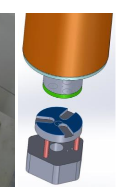
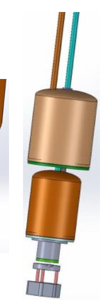
b) development of new materials for micro sensors, micro-devices,…. e.g., micro-thermometers, micro-heaters etc.



c) R&D of innovative instrumentations:

i) **PRESS-MAG-O**, study of materials under extreme conditions of pressure, temperature and magnetic fields with use of contemporary *magnetic techniques* and *IR spectroscopy*


ii) **SQUARE**, micrometer magnetic mappings with a SQUID microscope to characterize the magnetic microstructures to magnetic sensors and magnetic particle detectors sensitive to the position with a low threshold energy (meV)

LAMPS - 'LAboratory for Magnetism - high Pressure and Spettroscopy'

LAMPS collaborations

- ❑ Univ. Roma' Sapienza'
- ❑ Univ. Roma TRE
- ❑ Univ. di Firenze
- ❑ IFN (CNR)
- ❑ IPHT Jena (Ger)
- ❑ IPR (India)
- ❑ Diamond Materials GmbH (Ger)
- ❑ Univ. Roma II 'Tor Vergata'
- ❑ Univ. di Camerino
- ❑ *RICMASS* Rome International Center for Materials Science Superstripes
- ❑ NIMP (Romania)
- ❑ Brucker Energy (Ger)
- ❑ Univ. of Science and Tech. (China)
- ❑ HFML Radboud Univ. (Netherland)

➢ **Funds**: The LAMPS activities are related to Projects approved by the **Commission V (INFN)** and programs financed with **external funds** (MAE, PRIN, ecc.)

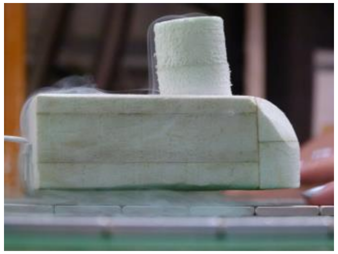
➢ **Call H2020**: Are in place collaborations with **INFN sections/labs, Italian and foreign Institutions** with interests to possible Call H2020

➢ **LNF Synergies**: Within the LNF-INFN, LAMPS is certainly synergistic with **DAFNE-Light**, **BTF**, **XLAB** and **SPARC Laboratories**

Educational

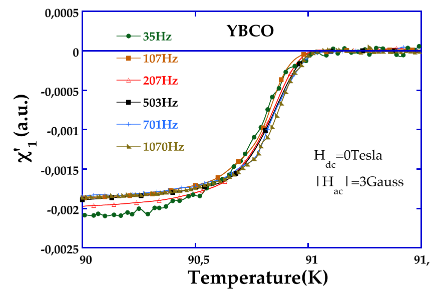
- Bachelor Degree thesis
- Master Degree thesis
- Ph.D. thesis
- Workshops
- Theoretical/practical superconductivity and magnetic courses for High School teachers
- Summer Stages for High School students

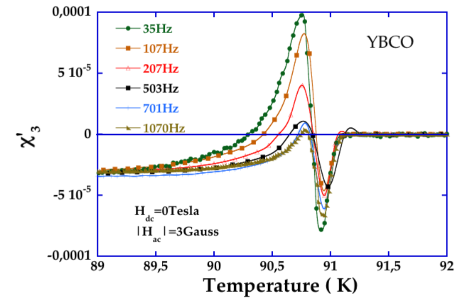




LAMPS instruments

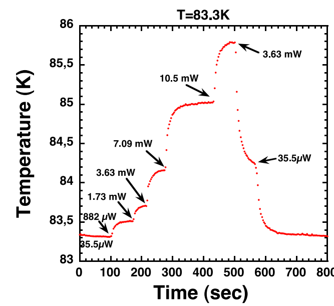
- AC magnetic multi-harmonic susceptibility vs. T(K) and DC magnetic field [B(T)]



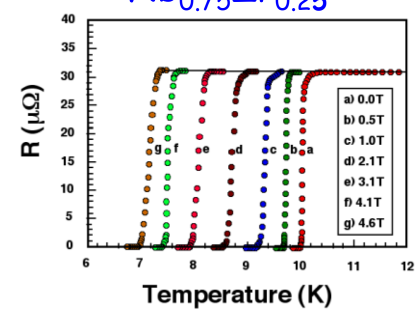


- R(Ω) vs. T(K) and DC magnetic field [B(T)]

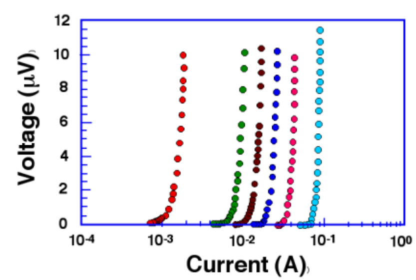
Carbon line on diamond



$Nb_{0.75}Zr_{0.25}$



- I-V characteristic for fixed T(K) and DC magnetic field [B(T)]



$Nb_{0.75}Zr_{0.25}$

Projects in progress

- PRESS-MAG-O
- SQUARE

AC susceptibility measurements

- A.C. Magnetic Susceptibility is a suitable **non destructive method** that provides a precise determination of the **magnetic and/or superconducting content** inside a material

- This technique uses the 'A.C. multi-harmonic magnetic susceptibility' signal to probe **the linear** and **non-linear response** of a sample to a sinusoidal variable magnetic field

AC susceptibility measurements

Characteristics

a) temperature range: 4.2-300 K
b) magnetic field range: 0-8 Tesla, D.C.
c) magnetic sinusoidal frequency range: 12-2070 Hz
d) magnetic sinusoidal amplitude: 3-30 Gauss

- **Susceptibility sensibility is 1E-6 emu**

Preparation of the samples:

the substrate has to be non magnetic,
maximum size
sample+substrate: width 3 mm, thickness 2 mm, length 10 mm.

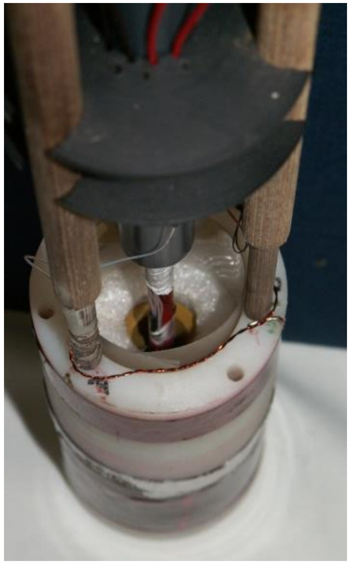
The maximum dimensions of the sensitive volume are:
width 5 mm, height 2 mm, length 5 mm

AC susceptibility measurements

The gradiometer insert

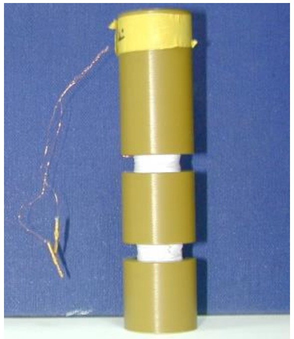
A) Slab sapphire sample-holder:
The sample and a thermometer
is fixed on the slab

B) Excitation coils



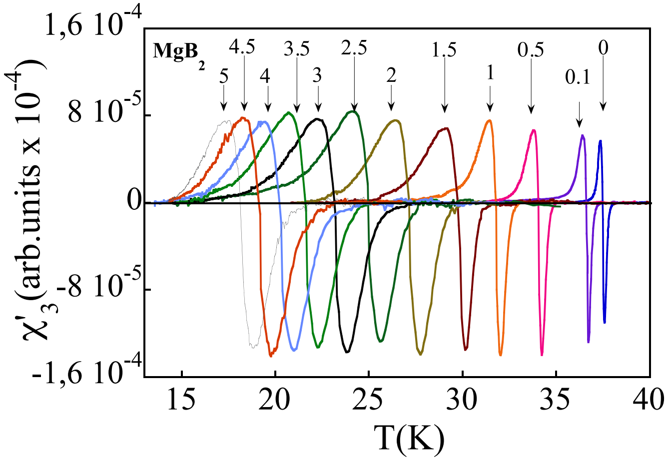
C) Pick-up bridge coils:

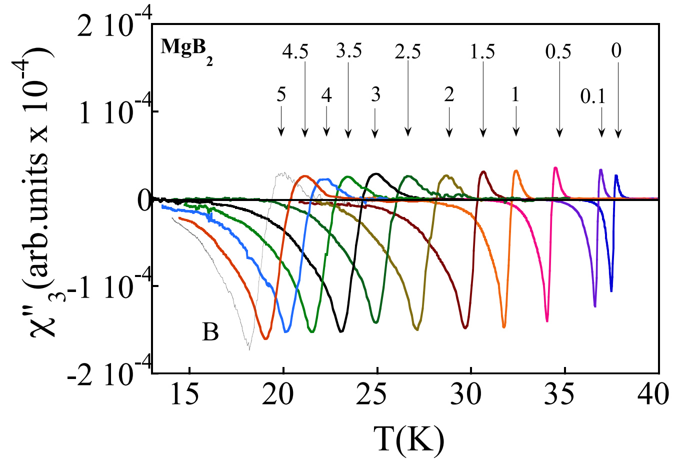
- ✓ sensing coil
- ✓ balance coil



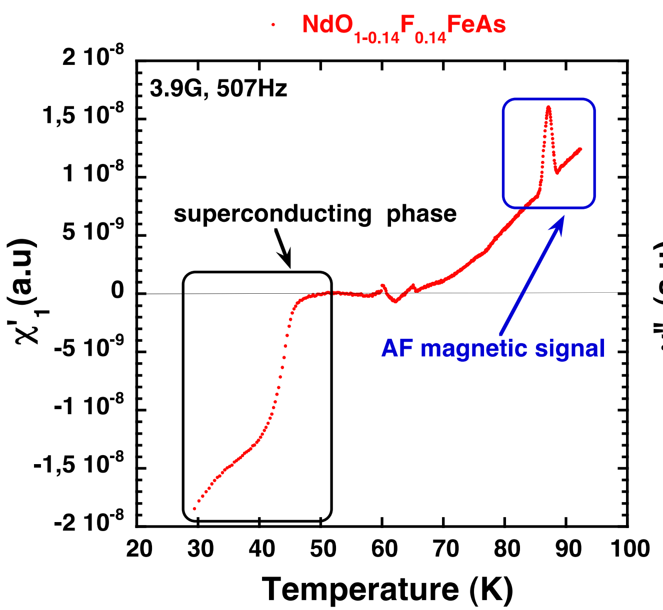
Some ac susceptibility measurements

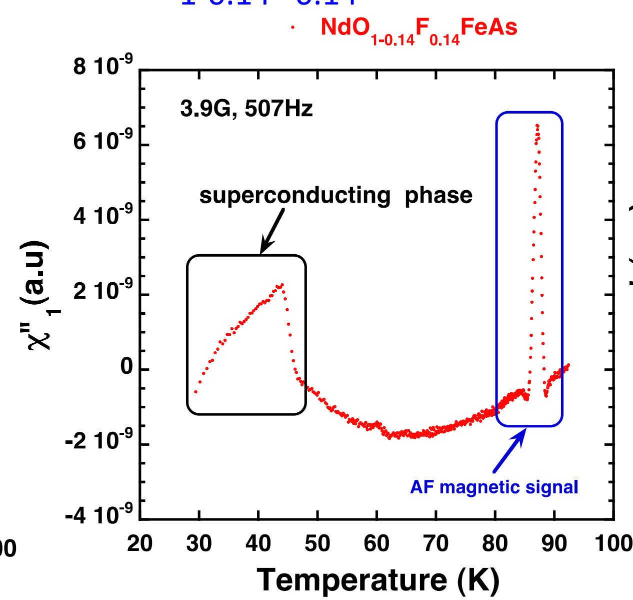
MgB_2

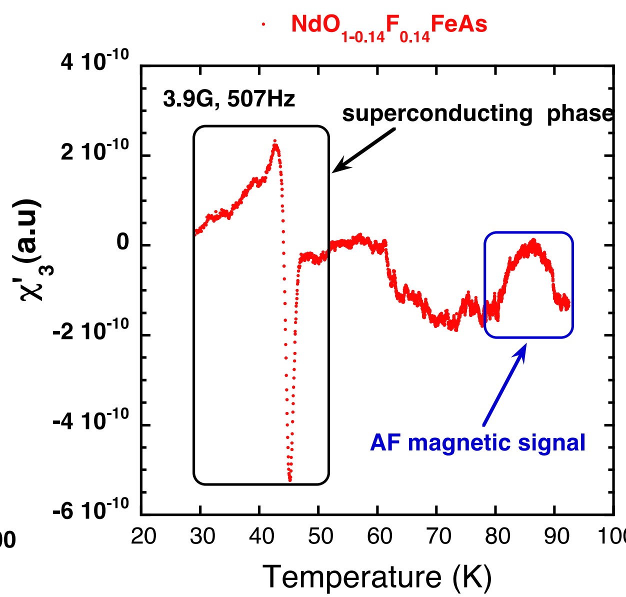




$NdO_{1-0.14}F_{0.14}FeAs$







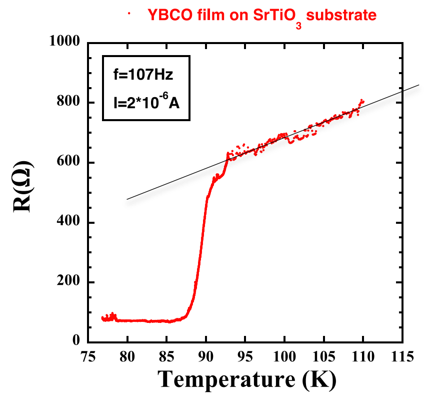
AC/DC transport measurements

AC/DC electric transport characterization vs. temperature is a suitable method to provide informations on:

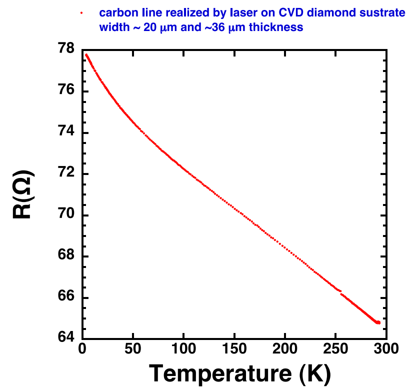
- electron-phonon interaction
- structural phase transitions
- Disorder
- transition phase in complex and correlated materials

AC/DC transport measurements

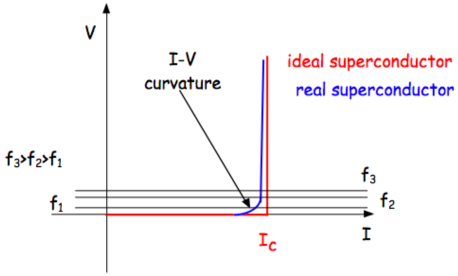
AC Resistance vs. temperature technique analyze the dynamic electric transport



DC Resistance vs. T(K) technique is the classical probe to study **phonon scattering** and at low temperature the **structural disorder** inside a material



I-V characteristic is a DC probe that may describe linear and non-linear transport dynamics

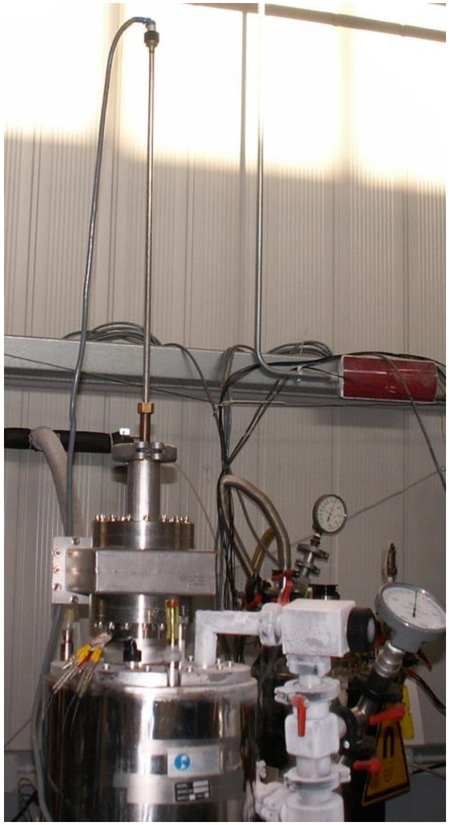


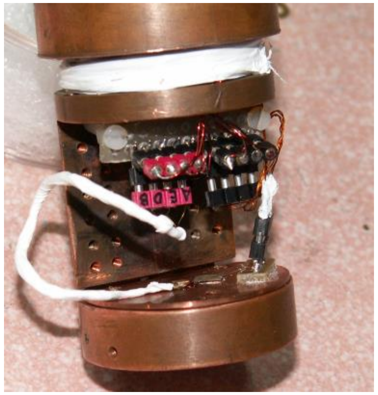
Resistivity inserts

- Sample-holder for cold flux-Helium cryostat



- Sample-holder for cold Helium-dip cryostat





AC/DC resistivity inserts

Technical characteristics:

a) temperature range: 4.2-300 K
b) magnetic field range: 0-8 T, D.C.
c) magnetic sinusoidal frequency range: 12-2070 Hz
d) AC sinusoidal current amplitude: 100 μA-10 mA
sensibility≈ 1E-6Ω
e) DC current amplitude: 10 μA-100 mA
sensibility≈ 1E-5Ω

Preparation of the samples:

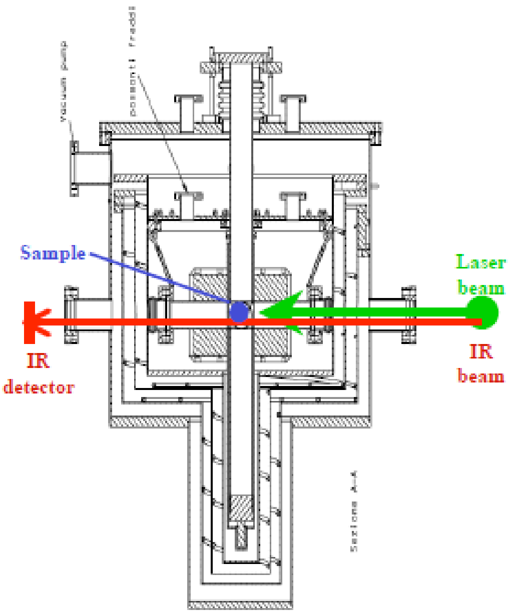
maximum size
sample+substrate: width 30 mm, length 50 mm.

PRESS-MAG-O device

✓Movable and compact cryostat

✓shield at LN2 temperature

✓8 T superconducting
split coil magnet

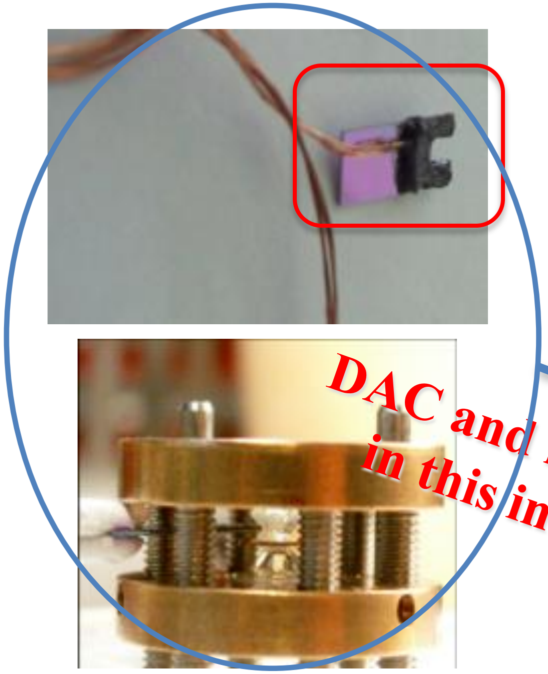


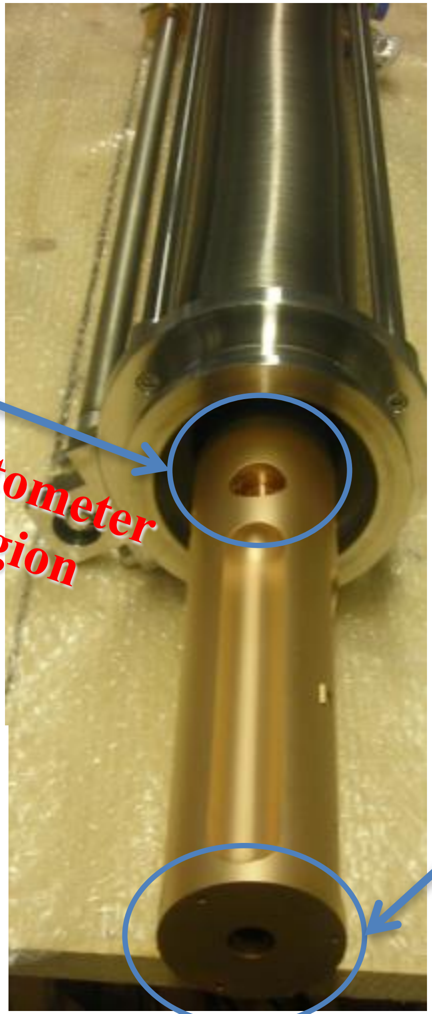
✓LHe reservoir around the magnet

✓Four optical access ports for optical experiments in transmission

PRESS-MAG-O sample insert

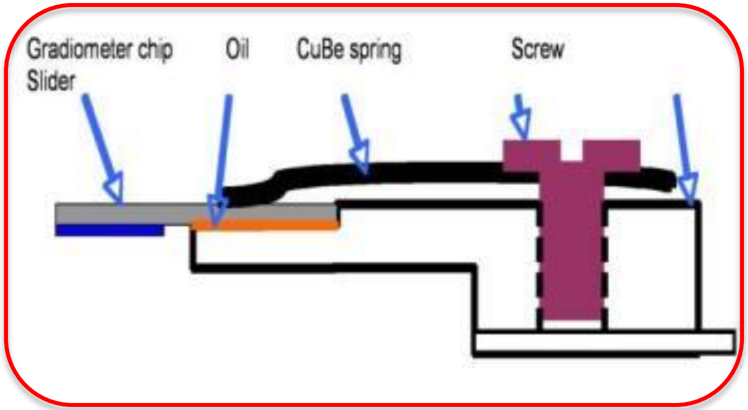
✓Know-how: SQUID microgradiometer





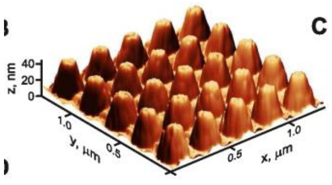
DAC and magnetometer in this insert region

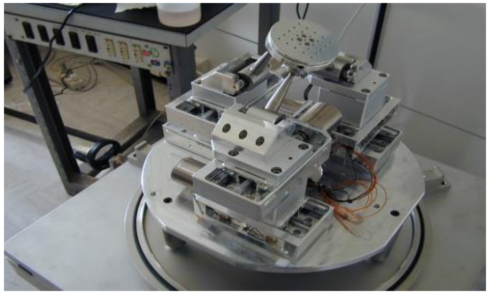
SQUID and shield fixed on the bottom of the insert inside the cold finger



SQUARE device

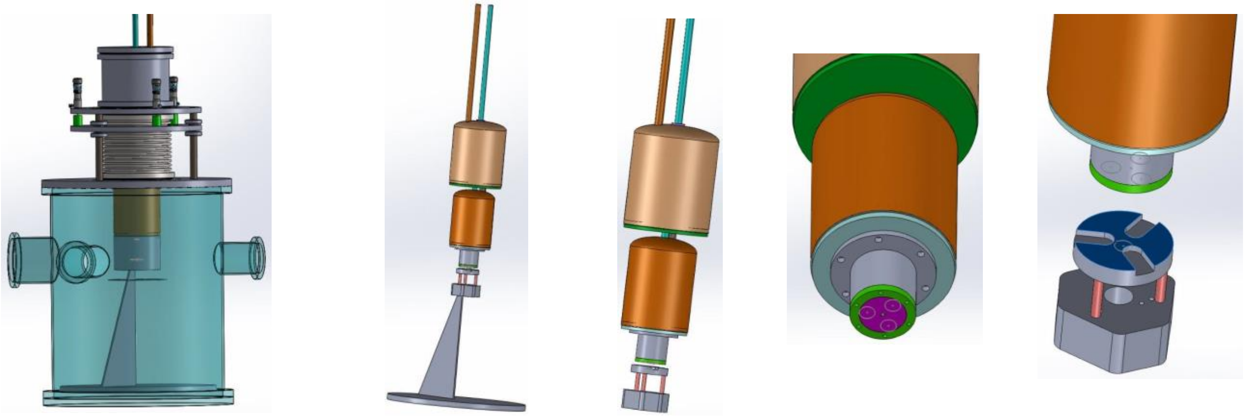
SQUARE_1 intends to **design and realize** the integration of a **SQUID microscope, with a micro X-Y-Z-Θ movement** to produce ***'NON contact image mapping of magnetic microstructures'*** in materials with **sub-micrometer resolution**





micrometric movement system (exapod)

Draft SQUARE project



- ➢ Possible new applications in INFN experiments, new research proposals and future development of this unique technology

- ✓ In progress **workshop** (2015) to discuss the present **SQUID technologies of INFN interest**
- ✓ The initiative intend involve **INFN researchers** and groups **already operating in these field** and recognized **experts**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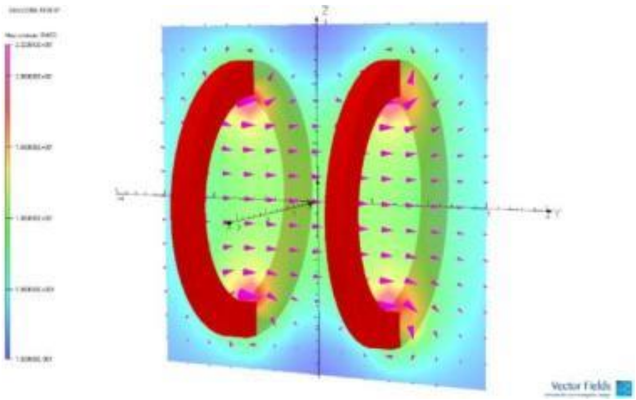
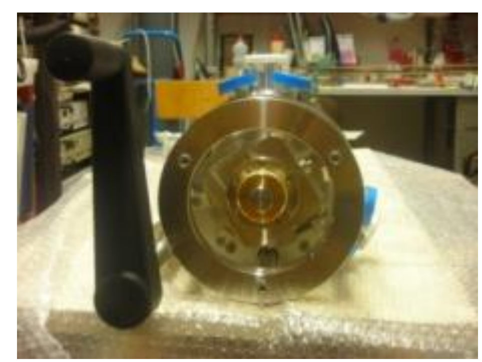
INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati
THANKS FOR YOUR ATTENTION

PRESS-MAG-O sample insert



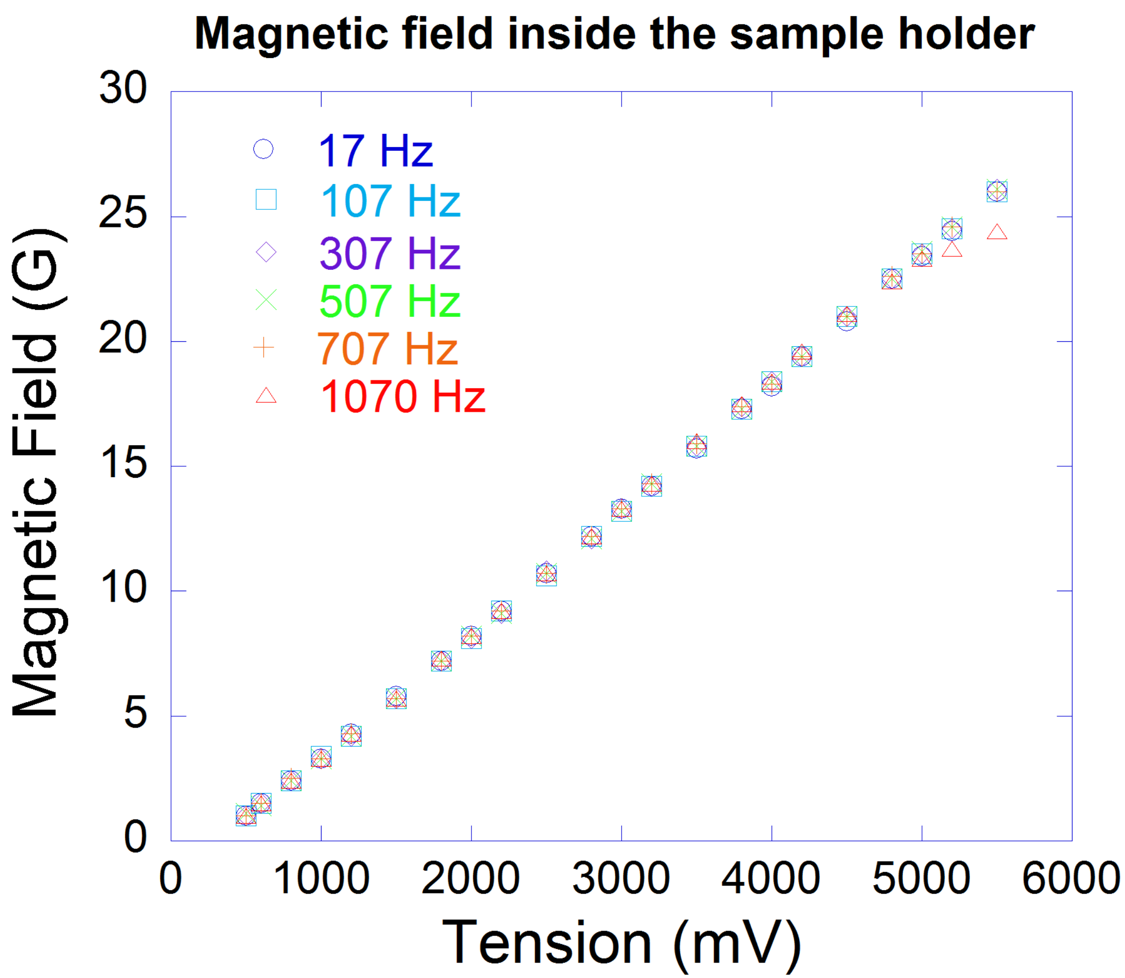
The upper part contains the X-Y-ϑ control with micrometer accuracy to align the sample inside the Diamond Anvil Cell

The lower section contains the Cu-Be/sapphire sample-holder, Cu-Be springs for thermal contact, DAC, a.c. exciting coil (10 G), magnetometer slider



R&D on diamagnetic sapphire sample holder

our design realized by Kiburtz (Swi)



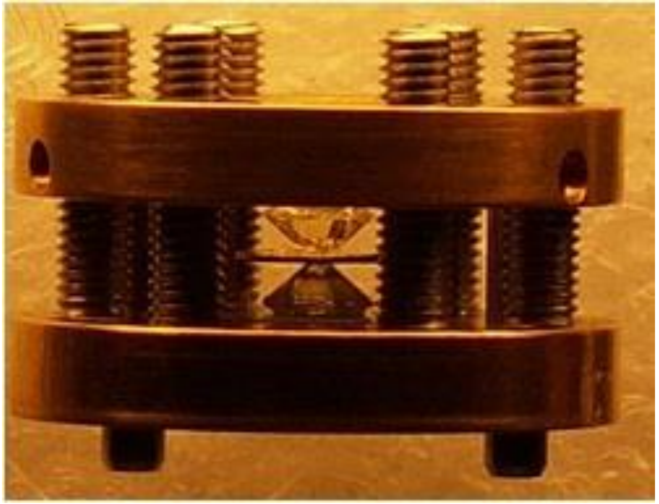
R&D on a diamagnetic DAC cell

realized by CECOM (ITA)

Non-magnetic 2% CuBe alloy miniature DAC to apply pressure

Two brilliant cut IIa type diamonds (IR transparent)

Two SiC-δ moissanite cylinders with a 400 μm conic hole to transfer pressure to anvils



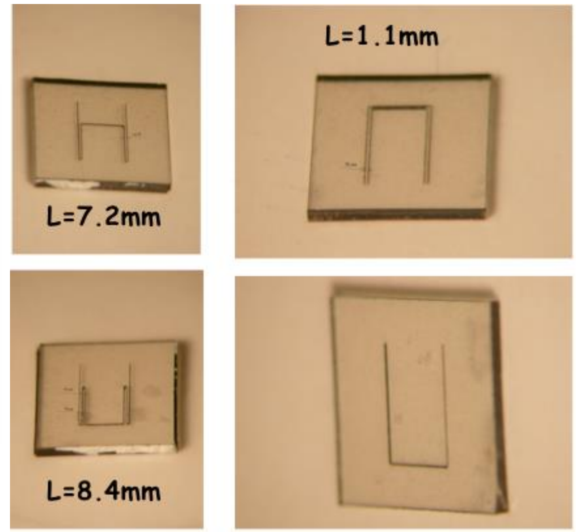
Our design manufactured by Sonic-Mill (NM USA)

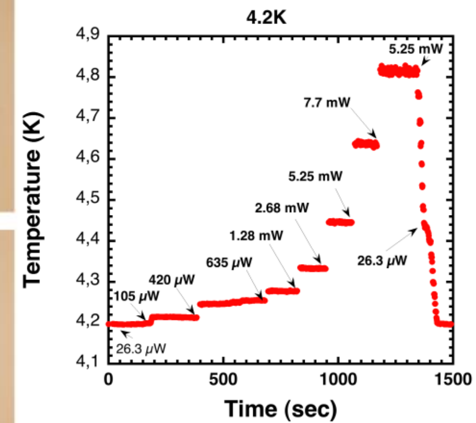
A new integrated heating system on diamond

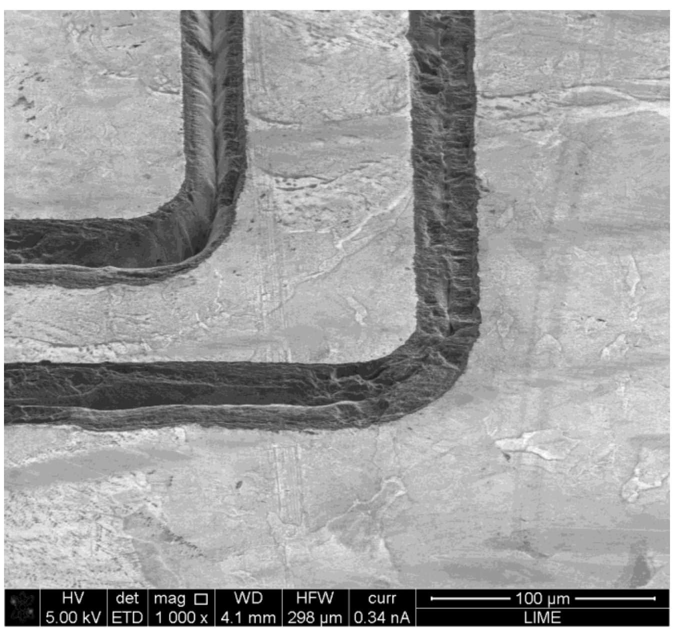
First layout of resistive line on diamond slabs

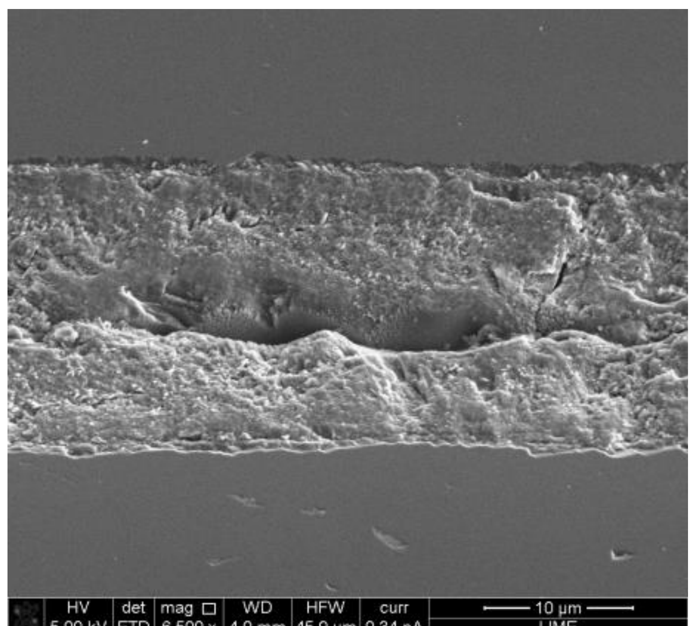
Line width= 17 µm to 42 µm, ρ=10 Ωmm

Collaboration with Diamond material GmbH





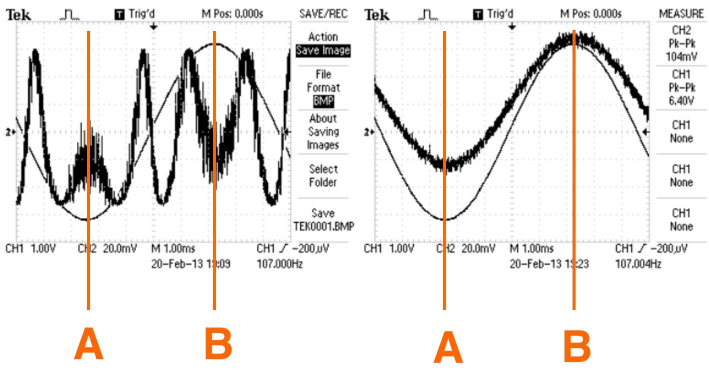


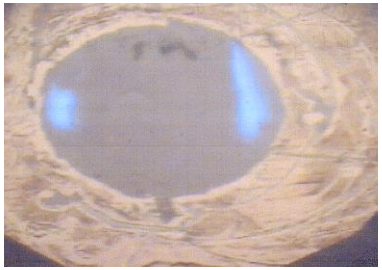


Characterization performed with the Focused Ion Beam (FIB) of the LIME laboratory of the University of Roma Tre

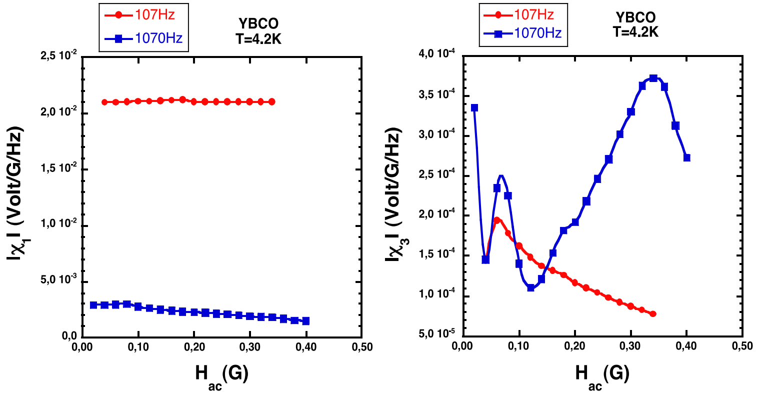
The new microSQUID gradiometer

test at 4.2 K with a YBCO loaded sample inside the DAC cell mounted on the PRESS-MAG-O insert





- ✓hole gasket in DAC
- ✓ diameter: 300μm
- ✓ YBCO sample: V= 0.16mm^3 (black zone)

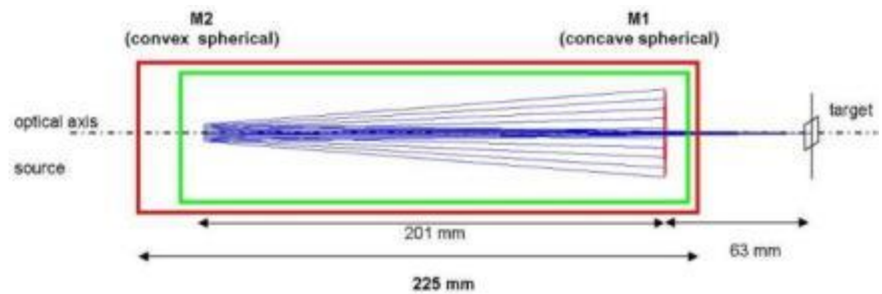


first and third magnetic susceptibility components at 4.2 K and both at 107 Hz and 1070 Hz as a function of the ac magnetic field and in the range 40 mG<H_{ac}<400 mG

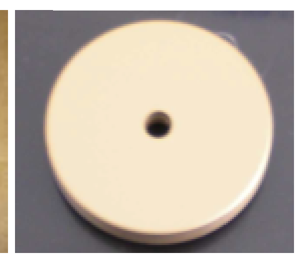
Press-Mag-O Optics

Two optical windows on the cryostat allow the transmission of both IR and visible light.

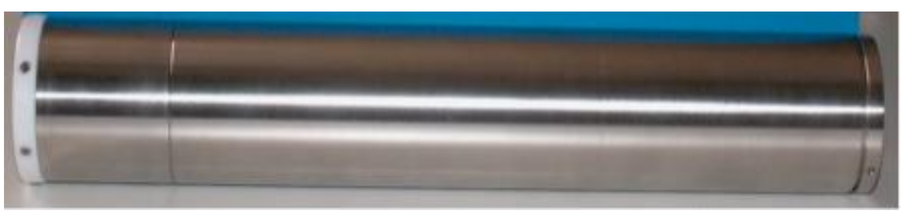
A Cassegrain concentrator designed to focus the light in a small spot inside the DAC (the diameter of the Airy disk is ~200 μm at the shortest wavelength).





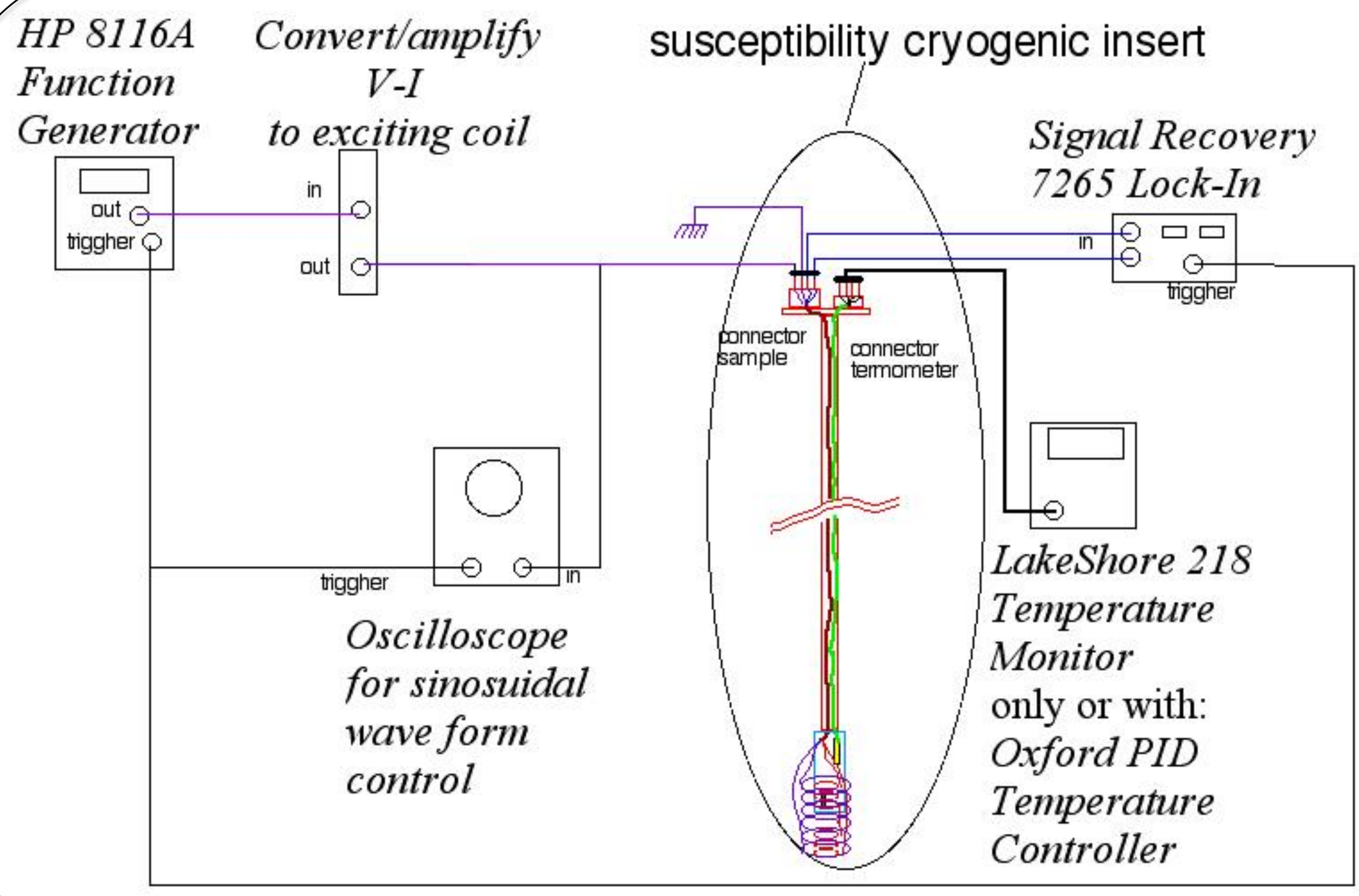



IR Wavelength range (micron)	2.5-50
Source beam diameter (mm)	30
Window thickness (micron)	500
Distance window-target (mm)	39
Optical Tube dimension (mm)	225/325



Optics designed and built in cooperation with CNR-INOA.

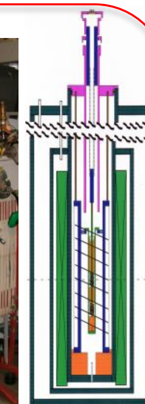
AC susceptibility inserts



Cryostats

1) one with a temperature control (300K-4.2K) using a manual dip in liquid He bath

2) second with a different temperature manage (300K-4.2K) via a cold flux from liquid helium bath by means of a needle valve, in this cryostat is present also a superconducting magnets up to **8Tesla**



3) third, an innovative apparatus called PRESS-MAG-O, to perform magneto dynamic susceptibility and IR optical experiments on materials under extreme conditions of pressure (20 GPascal), magnetic field (8T). It is in 'final commissioning'.