“Metallic Magnetic Calorimeters: Micromachined Absorbers for Cosmic Microwave Background Radiation”.

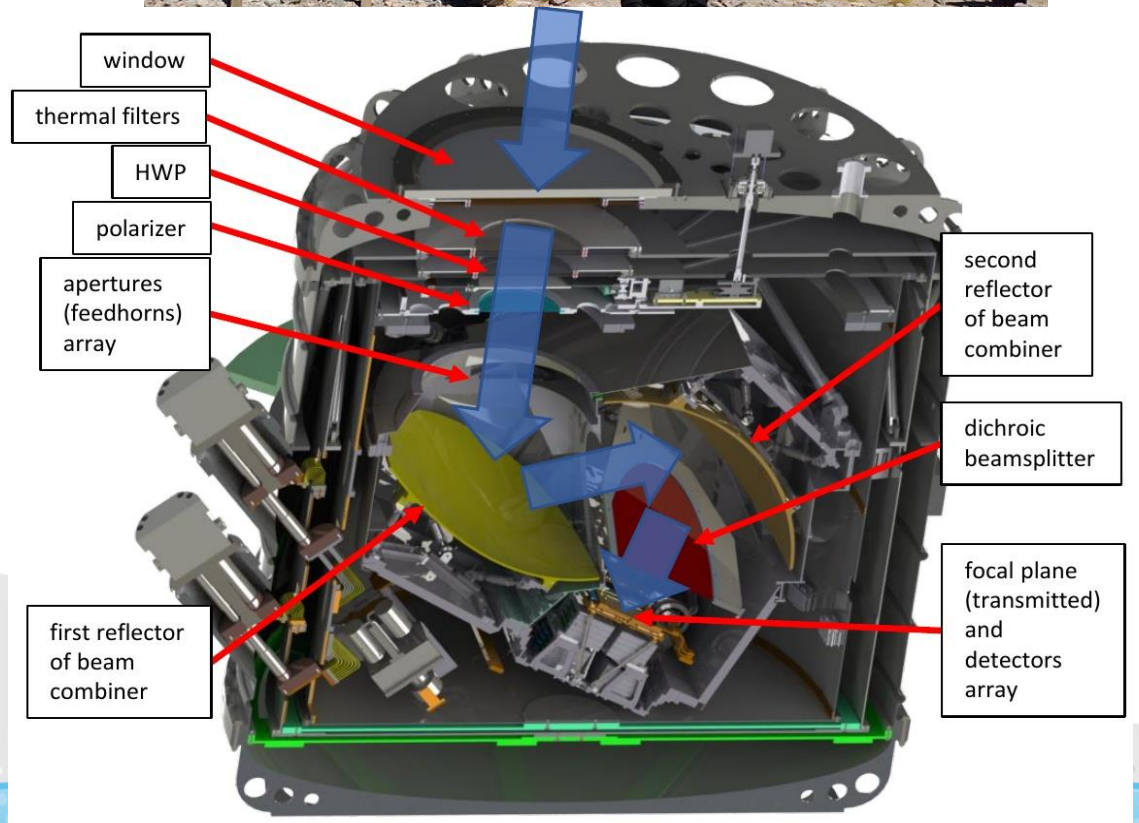
Ing. Juan J. Bonaparte
Departamento de Micro y Nanotecnología
Comisión Nacional de Energía Atómica, ARGENTINA

Directors:

Dr. Mariano Gómez Berisso
División Bajas Temperaturas / Instituto Balseiro
Comisión Nacional de Energía Atómica , ARGENTINA

Prof. Dr. Marc Weber
Institute for Data Processing and Electronics
Karlsruhe Institute of Technology, ALEMANIA

Motivation: QUBIC radiotelescope

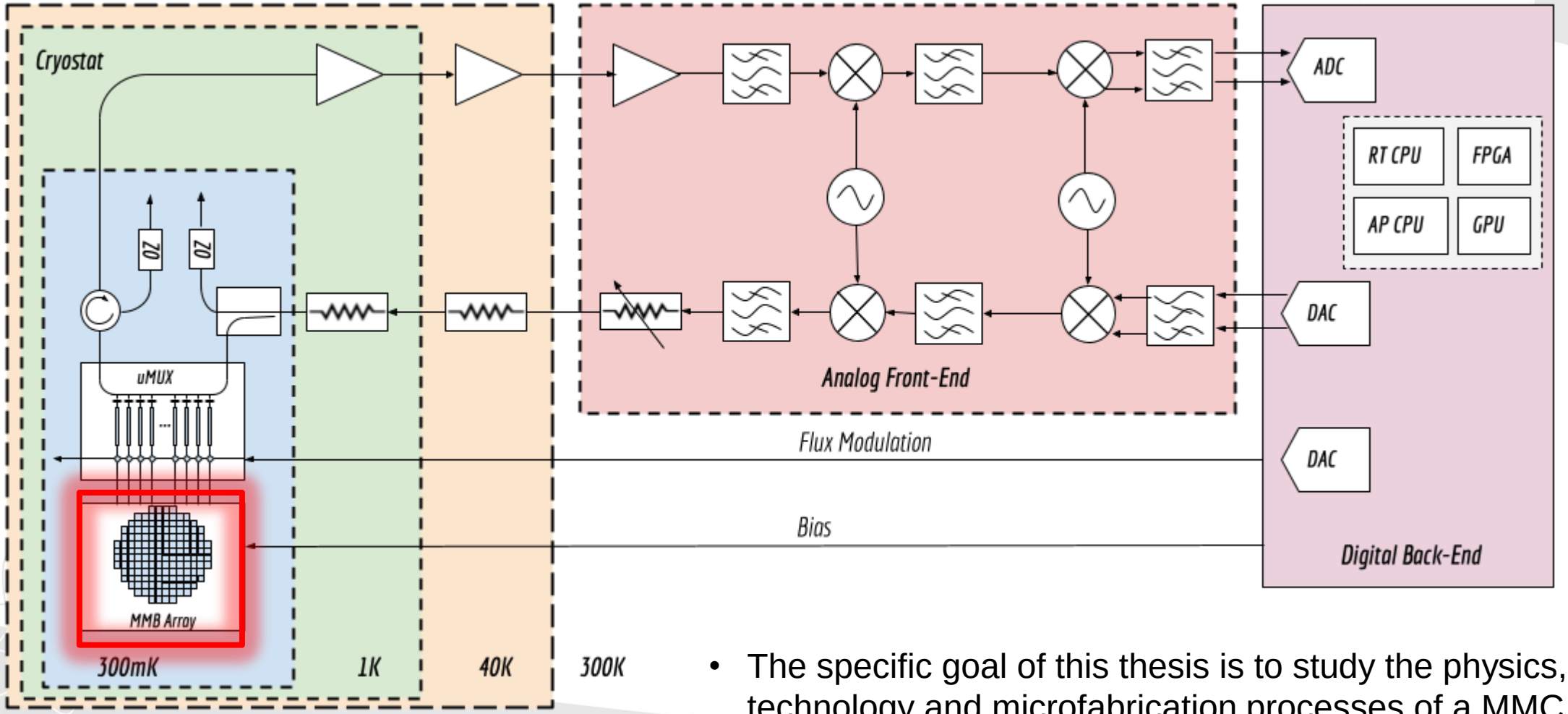


APC Paris, France
C2N Orsay, France
CSNSM Orsay, France
IAS Orsay, France
IRAP Toulouse, France
LAL Orsay, France
Universita di Milano-Bicocca, Italy
Universita degli studi di Milano, Italy
Universita La Sapienza, Roma, Italy
Maynooth University, Ireland
Cardiff University, UK
University of Manchester, UK
Brown University, USA
Richmond University, USA
University of Wisconsin, USA
Centro Atómico Constituyentes, Argentina
GEMA, Argentina
Comisión Nacional de Energía Atómica, Argentina
Facultad de Cs Astronómicas y Geofísicas, Argentina
Centro Atómico Bariloche and Instituto Balseiro, Argentina
Instituto de Tecnologías en Detección y Astropartículas, Argentina
Instituto Argentino de Radioastronomía, Argentina

130 Collaborators
22 laboratories
6 countries

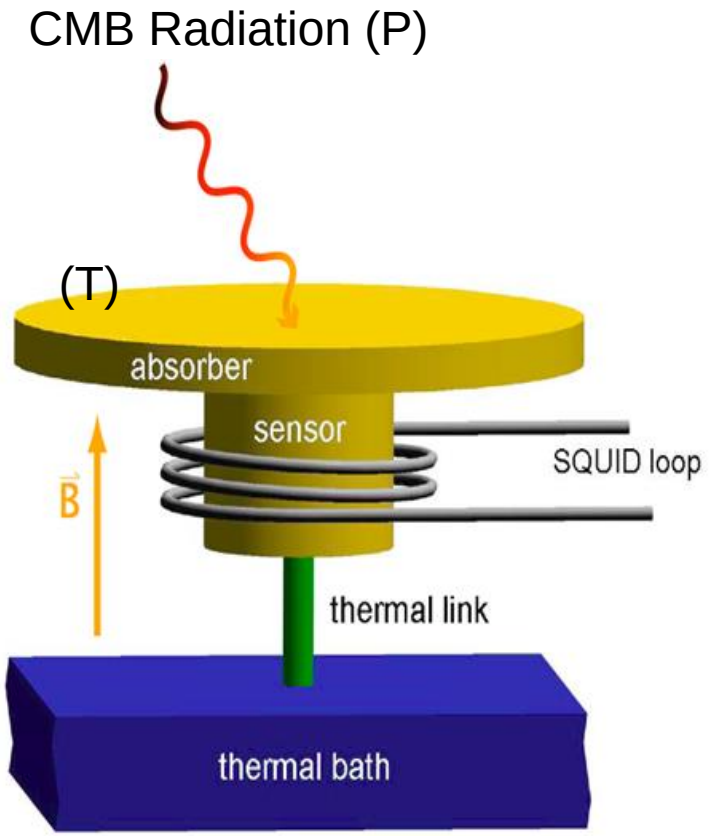
+SISSA Joined

Detection and front-end



- The specific goal of this thesis is to study the physics, technology and microfabrication processes of a MMC sensor, in particular its energy conversion layers.

MAGNETIC METALLIC BOLOMETERS (MMB)



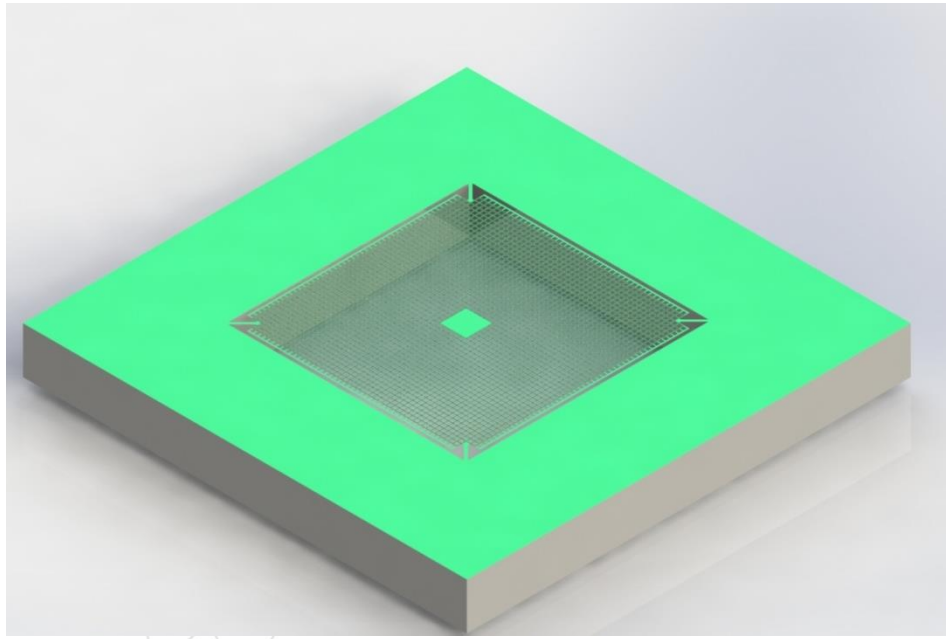
$$\Delta P \rightarrow \nabla T \rightarrow \nabla \Phi \rightarrow \nabla \Phi_s$$

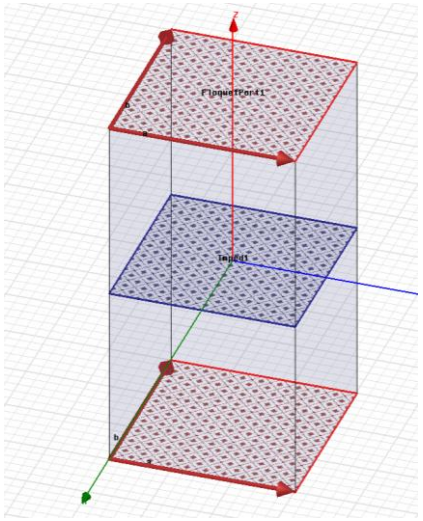
$$\Re_{MMB} = \frac{\partial \Phi_S}{\partial P} = \frac{\partial T}{\partial P}\frac{\partial \Phi}{\partial T}\frac{\partial \Phi_S}{\partial \Phi}$$

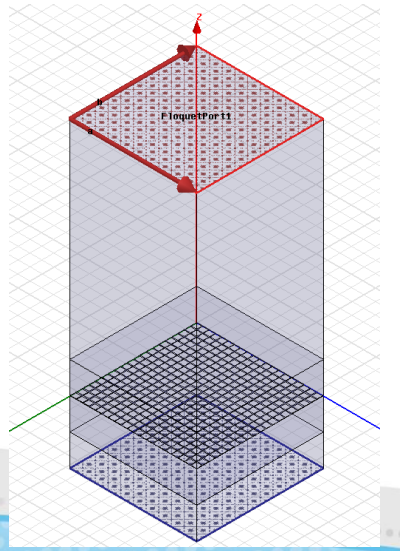
NEP = 5.10-17 W.Hz-0.5

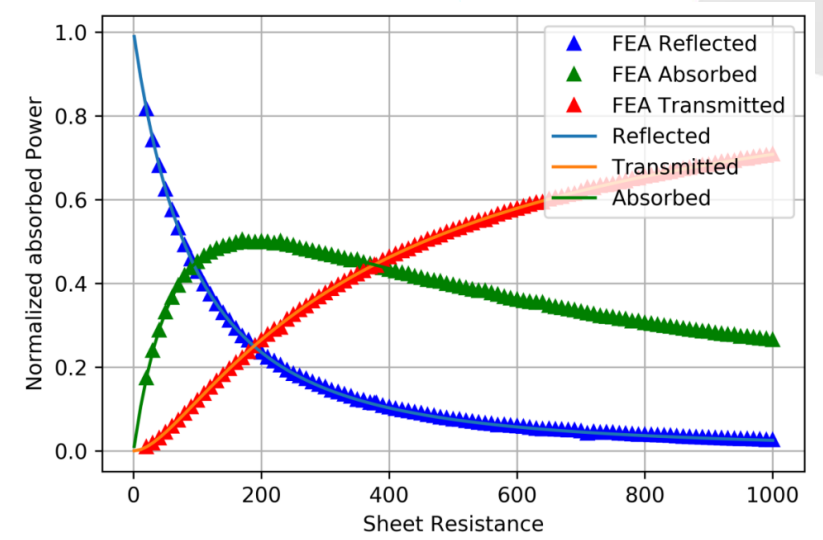
MAGNETIC METALLIC BOLOMETERS

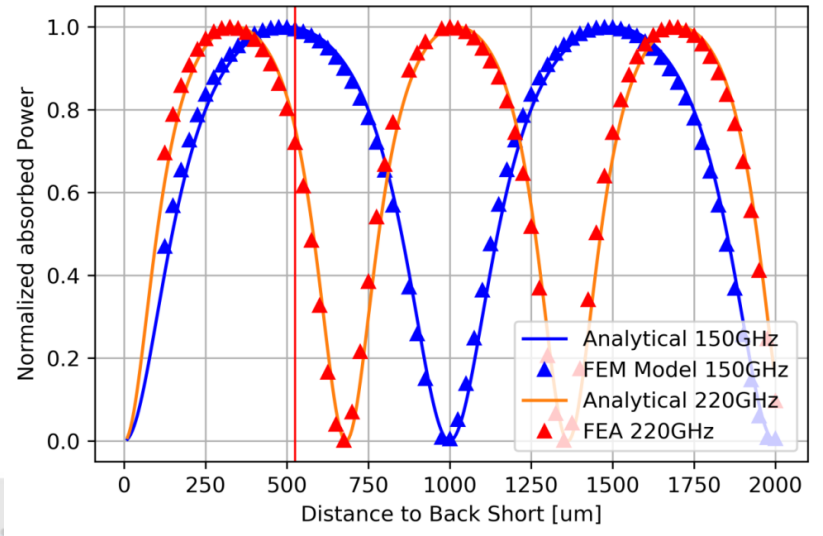
Absorbing models





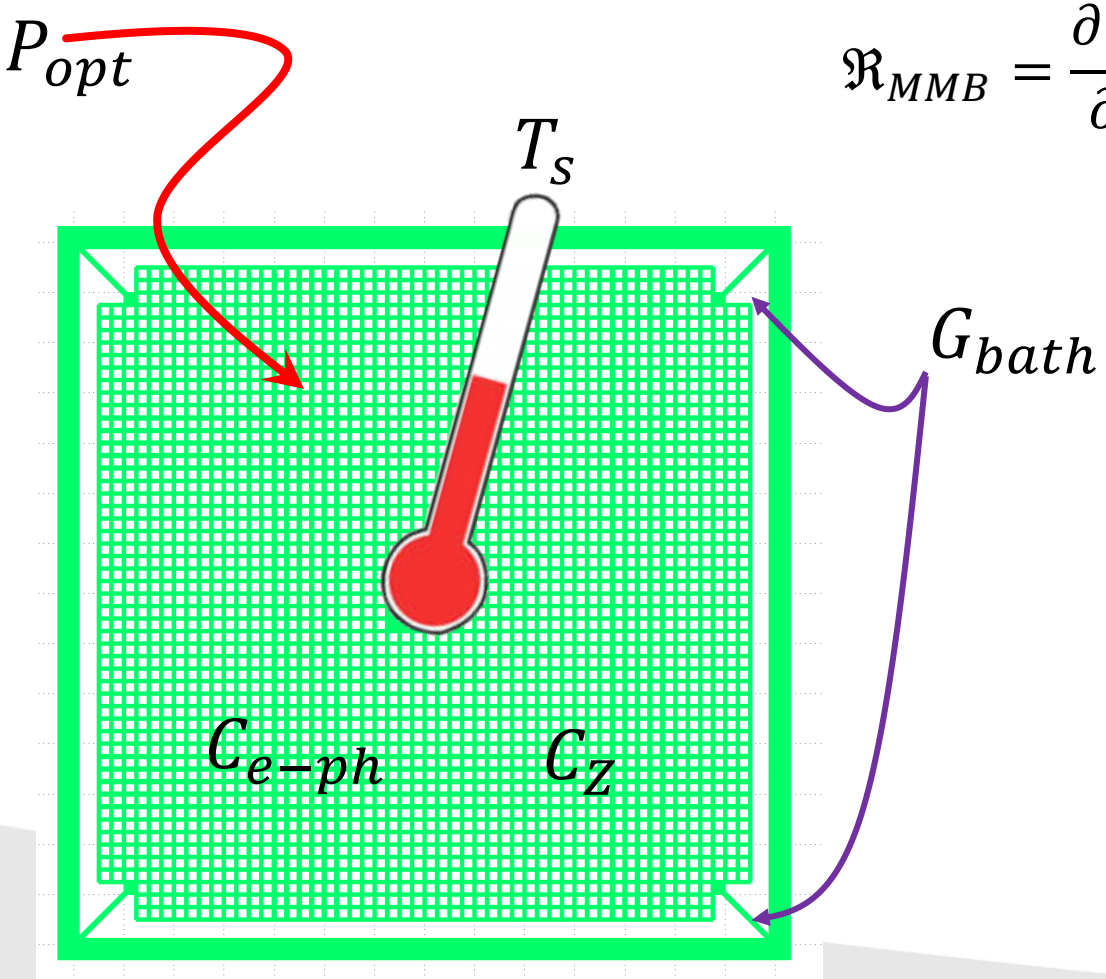




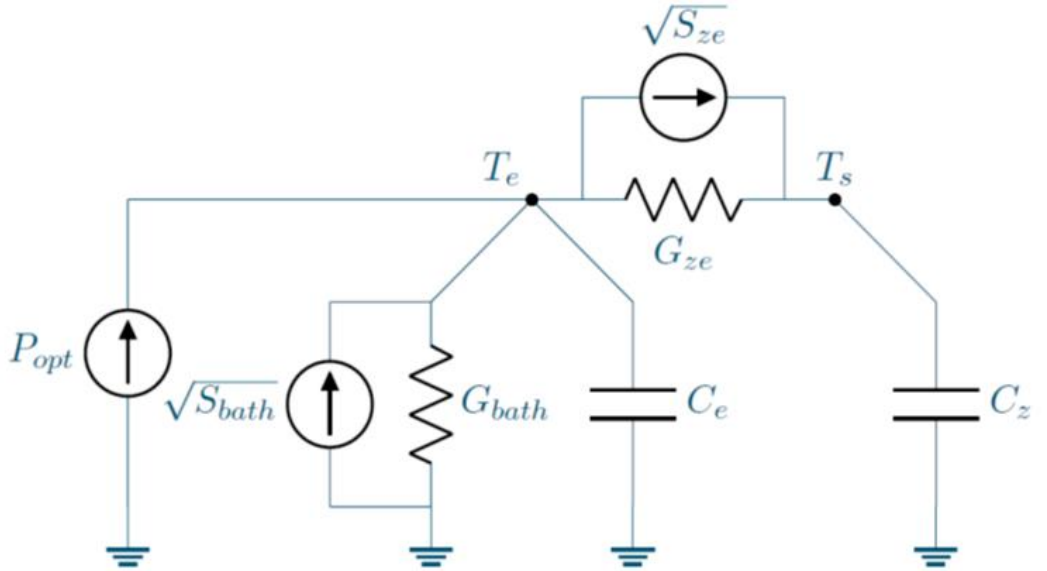


MAGNETIC METALLIC BOLOMETERS

Thermal models



$$\Re_{MMB} = \frac{\partial \Phi_S}{\partial P} = \frac{\partial T}{\partial P}\frac{\partial \Phi}{\partial T}\frac{\partial \Phi_S}{\partial \Phi}$$

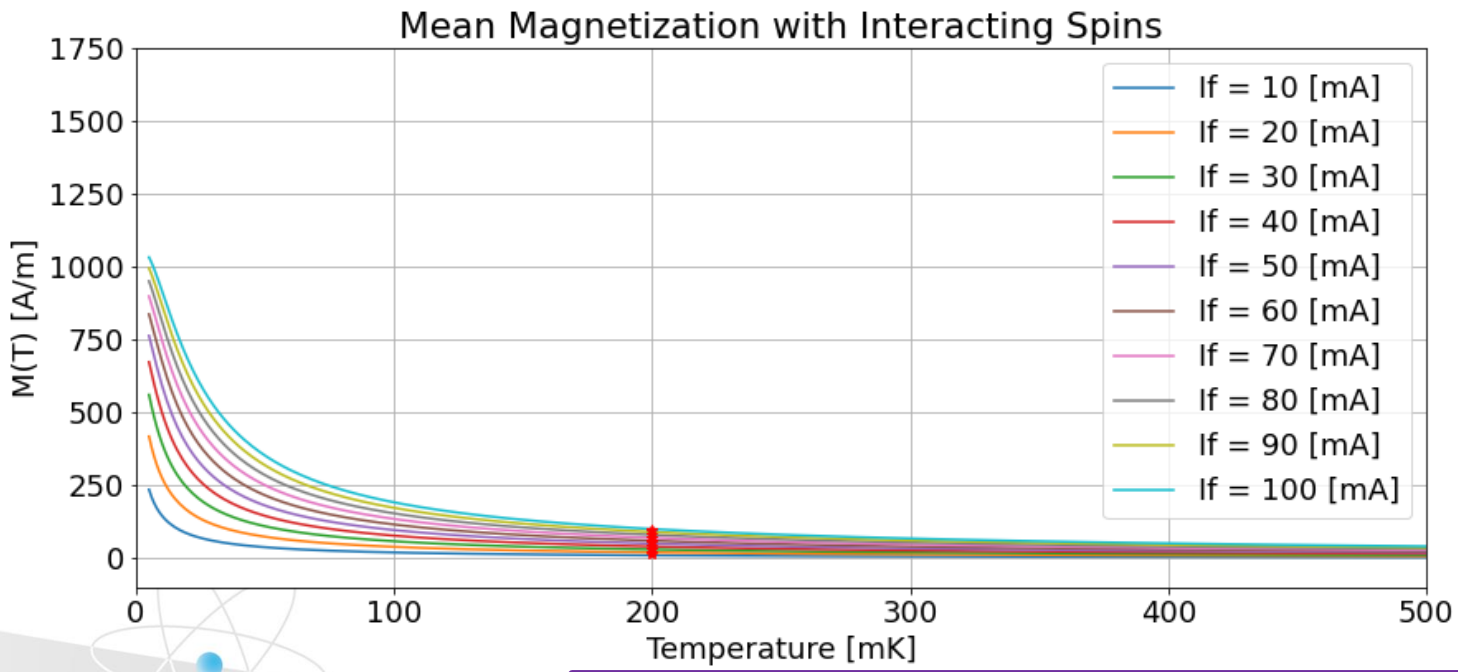


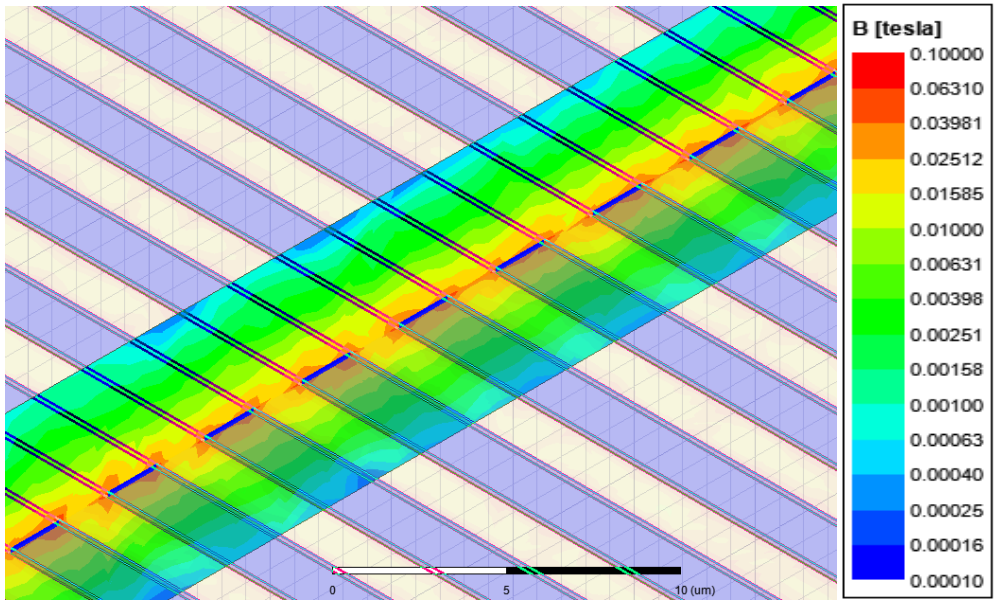
$$\frac{\partial T}{\partial P} = \frac{1}{G_{bath}} \cdot \frac{1}{\frac{C_e+C_z}{G_{bath}G_{ze}} \cdot S^2 + \frac{C_z(G_{bath}+G_{ze})+C_eG_{ze}}{G_{bath}G_{ze}} \cdot S + 1}$$

MAGNETIC METALLIC BOLOMETERS

Temperature dependant magnetization

$$\Re_{MMB} = \frac{\partial \Phi_S}{\partial P} = \frac{\partial T}{\partial P}\frac{\partial \Phi}{\partial T}\frac{\partial \Phi_S}{\partial \Phi}$$

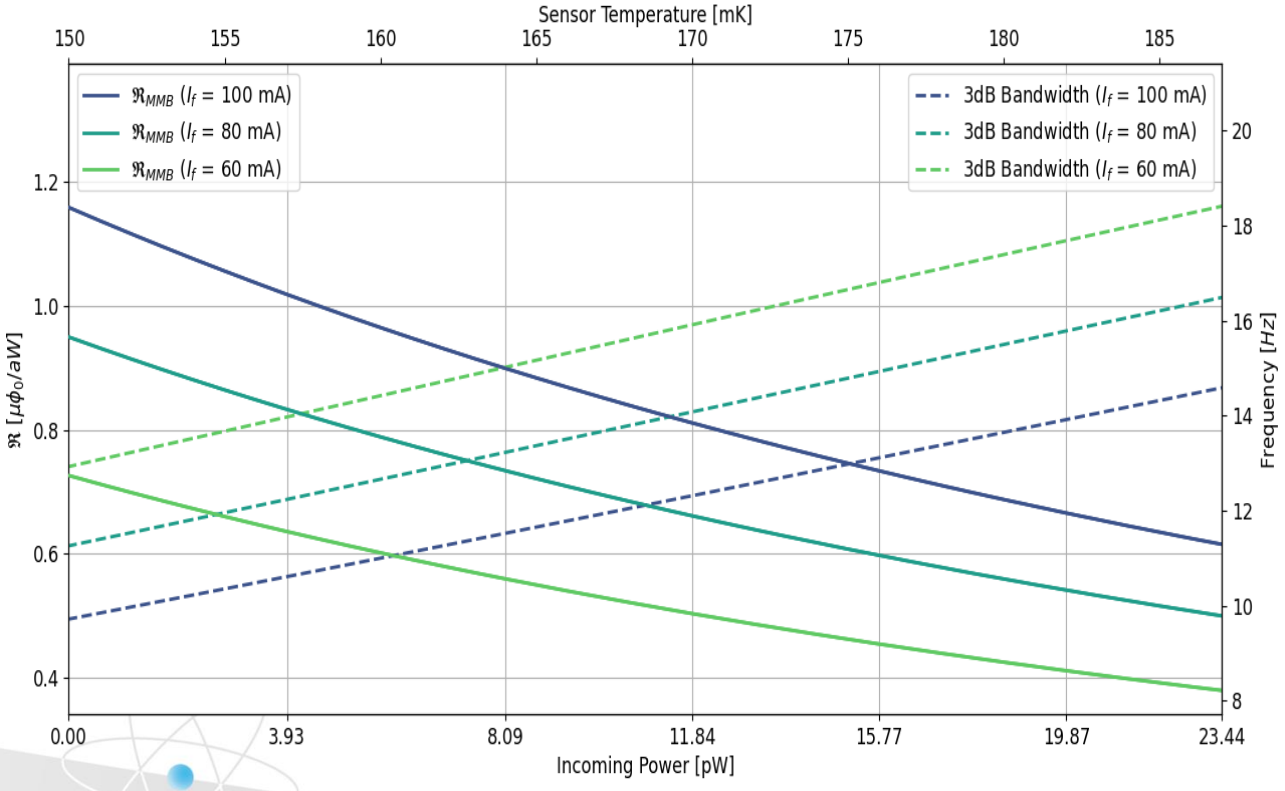


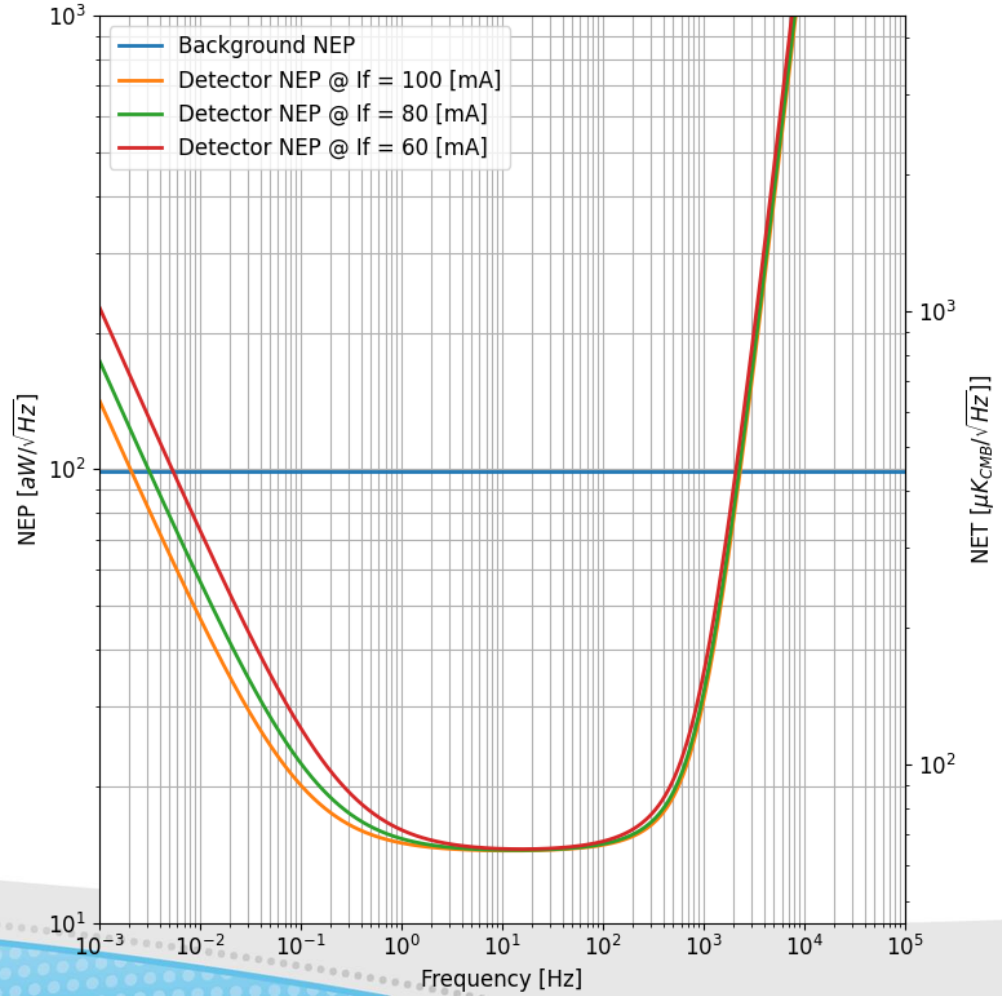


$$\Re_{MMB} = \frac{1}{G_{bath}} \cdot \sum \frac{\left|\overrightarrow{B_{(\vec{r})}}\right|}{I_{coil}} \cdot \left.\frac{\partial M}{\partial T}\right|_{\left|\overrightarrow{B_{(\vec{r})}}\right|} \cdot \Delta V \cdot \frac{k\sqrt{L_{in}L_s}}{L_s + 2\left(L_{stray} + L_{in}\right)}$$

MAGNETIC METALLIC BOLOMETERS

Responsivity and noise

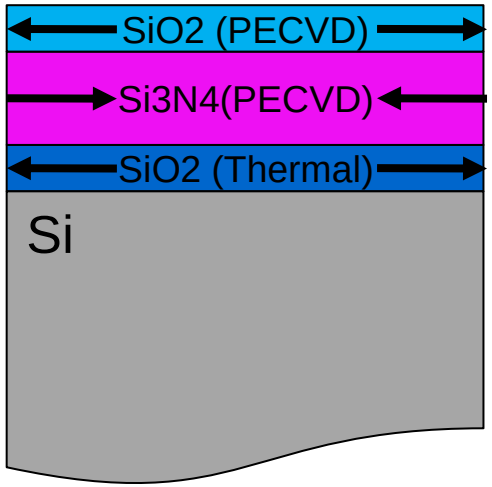




MAGNETIC METALLIC BOLOMETERS
Absorber fabrication

Constrains:

- Only with available equipment.
  - Fluorine(SF6, C4F8) chemistry for membrane release.
  - No Si_3N_4 exposed to etch.
  - High density
  - Yield >90%
- Keep cost as low as possible

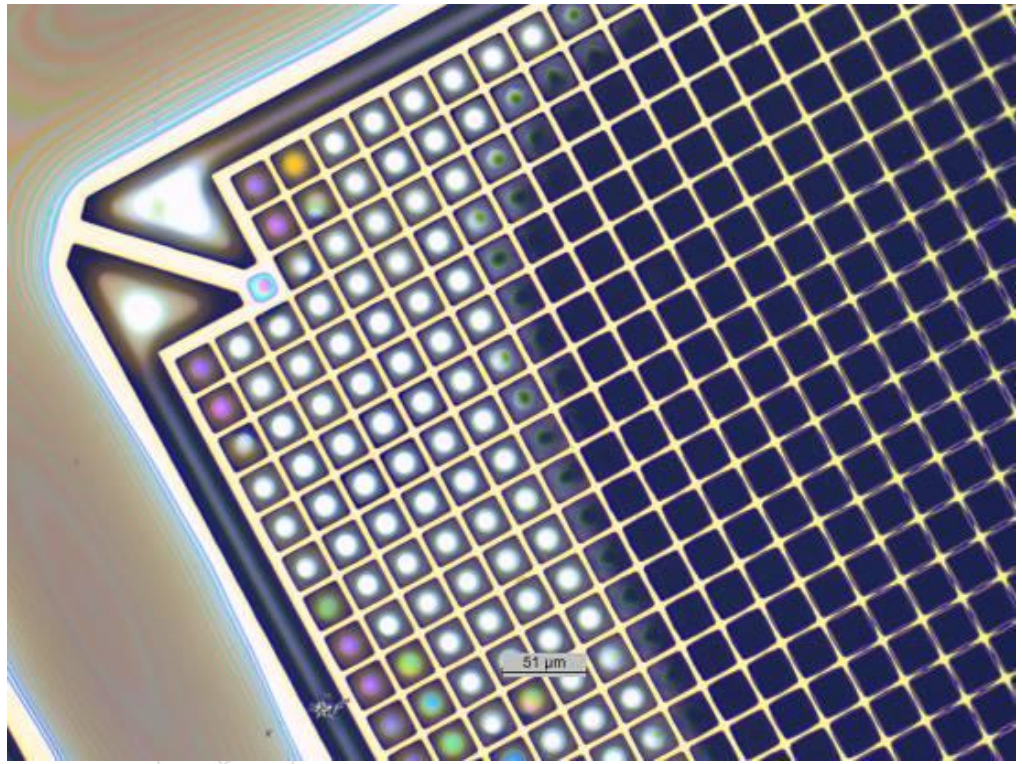


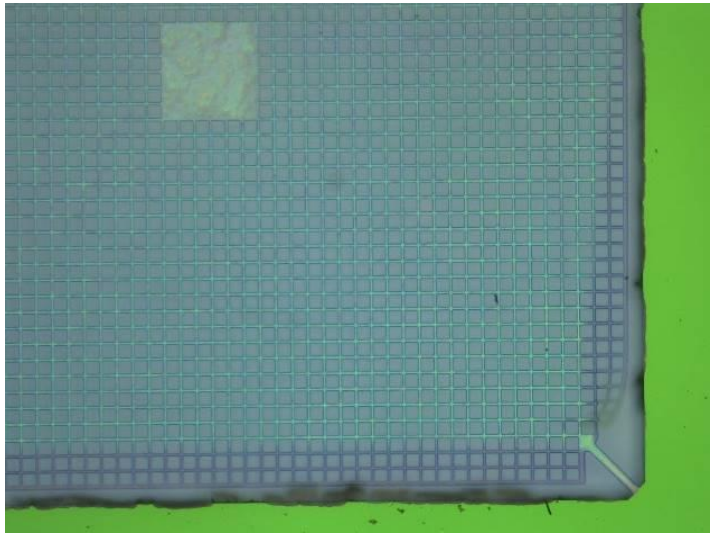
Results

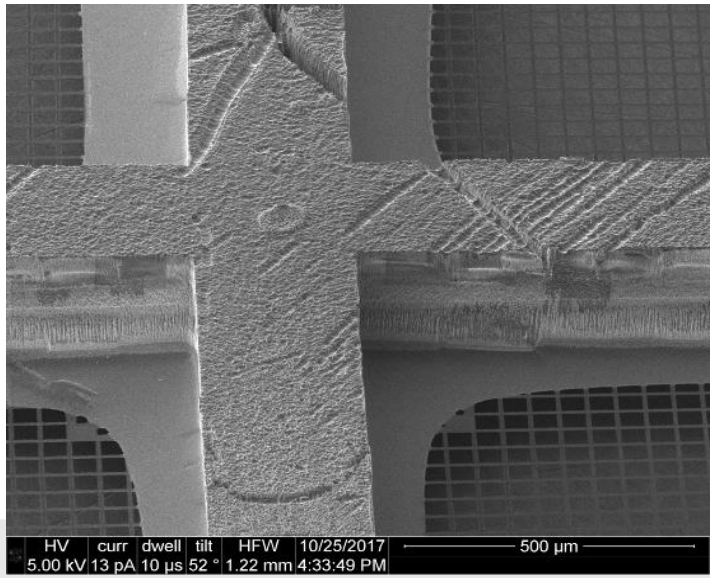
Stress Type:	Compression
Average Stress (MPa):	9.1
Center Stress (MPa):	7.6

MAGNETIC METALLIC BOLOMETERS

Absorber fabrication





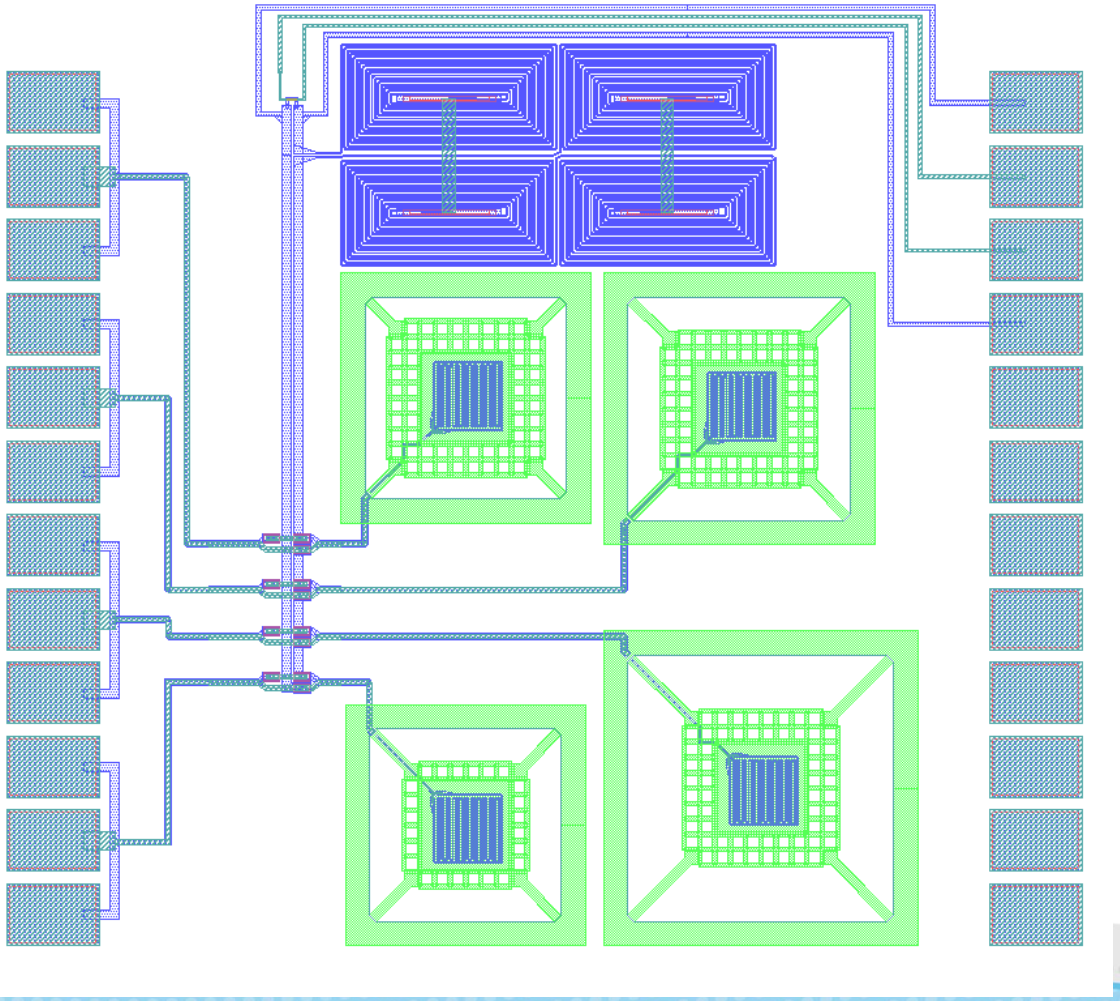


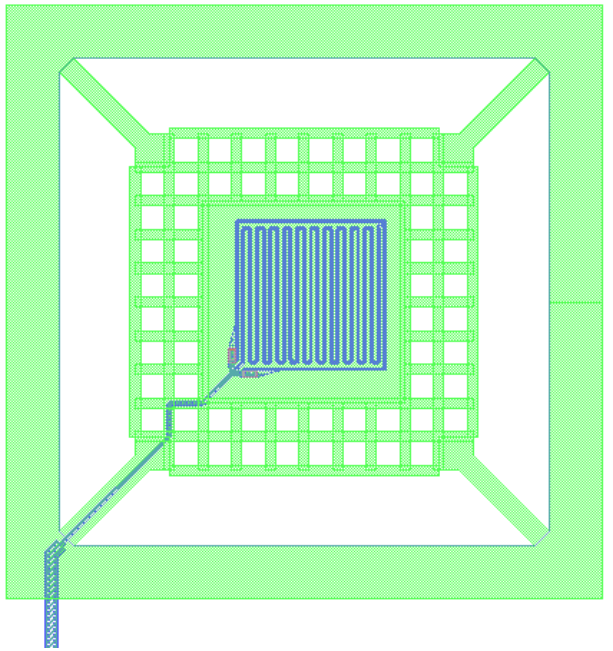
- High density
- Yield >90%

New process coming soon!

MAGNETIC METALLIC BOLOMETERS

First designs for the C and G determination





MAGNETIC METALLIC BOLOMETERS

Facilities up-grade

35m^2 added to cleanroom

New 6 guns AJA ACT2400 sputter tool for superconducting films deposition. PO Sept . 2021. expected to arrive in Jun. 2022

New Blufors LD450 DR PO June. 2021. expected to arrive in Ago. 2022

MAGNETIC METALLIC BOLOMETERS

Ongoing and future work

Ongoing

- New membrane release process
- Masks design for first prototypes and C - G determination experiment.

Future

- Fabricate and measure first sensor prototypes
- Set up superconducting film deposition processes and sensor characterization at mK in CNEA-CAC.
- Enhance KIT-CNEA cooperation in criogenic quantum detectors microfabrication.

Thanks!

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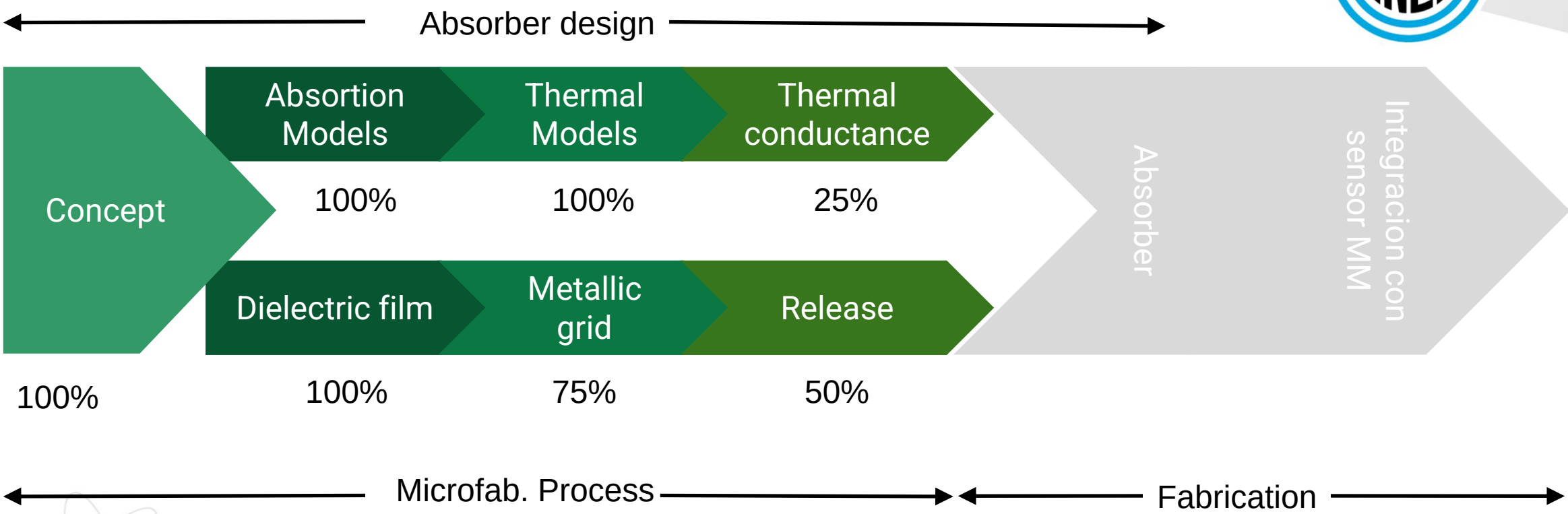
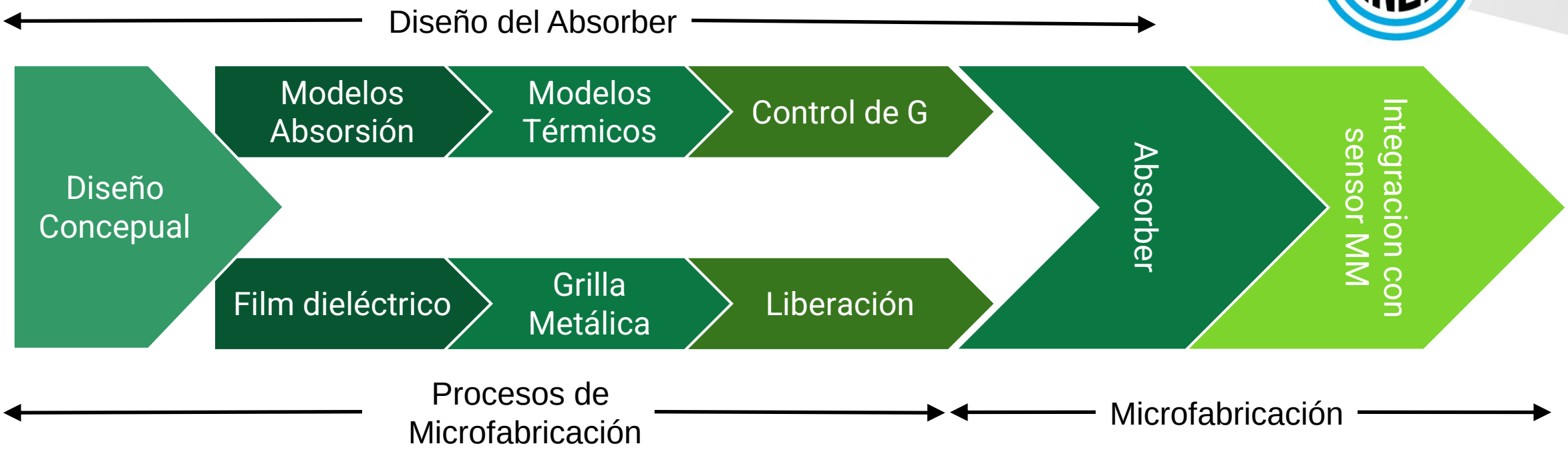
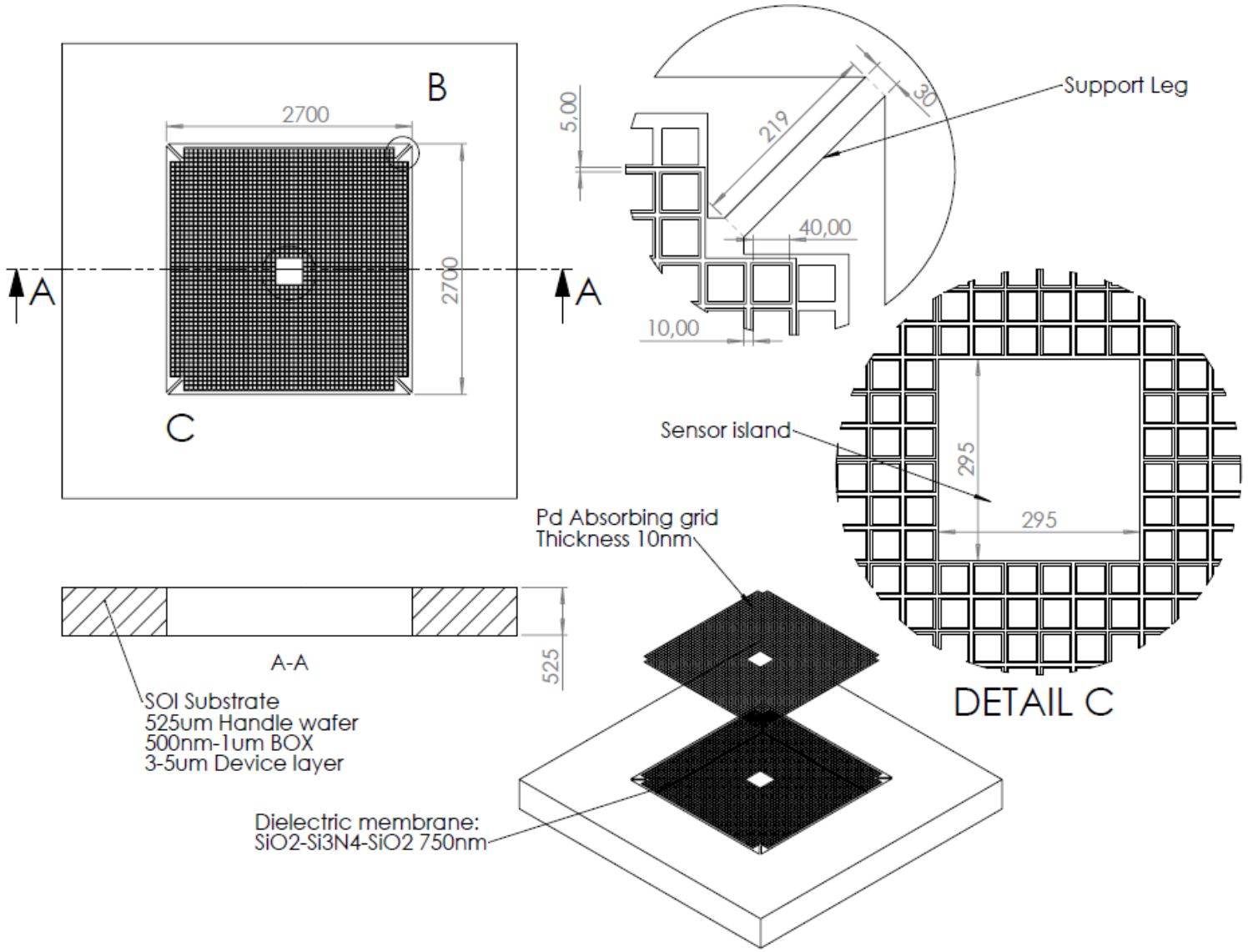
Ing. Manuel Garcia Redondo
Ing. Juan Salum
Ing. Juan Manuel Geria
Mg. Ing Alejandro Fasciswski
Dr. Matias Wegner
Ing. Andres Didonato
Ing. Claudio Ferrari
Ms. Diego Perez Gagni
Tec. Dante Mercado
Tec. Diego Silva

Advance


Absorber design
Concept
Absortion Models
Thermal Models
Thermal conductance
100%
100%
25%
Dielectric film
Metallic grid
Release
100%
100%
75%
50%
Absorber
Integracion con sensor MM
Microfab. Process
Fabrication

DESARROLLO


Diseño del Absorber
Diseño Concepual
Modelos Absorsión
Modelos Térmicos
Control de G
Film dieléctrico
Grilla Metálica
Liberación
Absorber
Integracion con sensor MM
Procesos de Microfabricación
Microfabricación



$$G_{bath} = \frac{\partial P}{\partial T} = N \cdot \frac{A\ l\ S}{3\ Leg\_L} \cdot \left(\frac{a}{4} \cdot T_s + \frac{b}{16} \cdot T_s^3\right)$$

Donde A es el área transversal de la barra de soporte.
Leg_L largo de la barra y
l es el camino libre medio de los fonones a la temperatura de trabajo.
a y b son parámetros experimentales

BACKUP

CNEA´s Micro and Nanotechnology Department: Located at Centro Atómico Constituyentes, Buenos Aires.

Composed by :

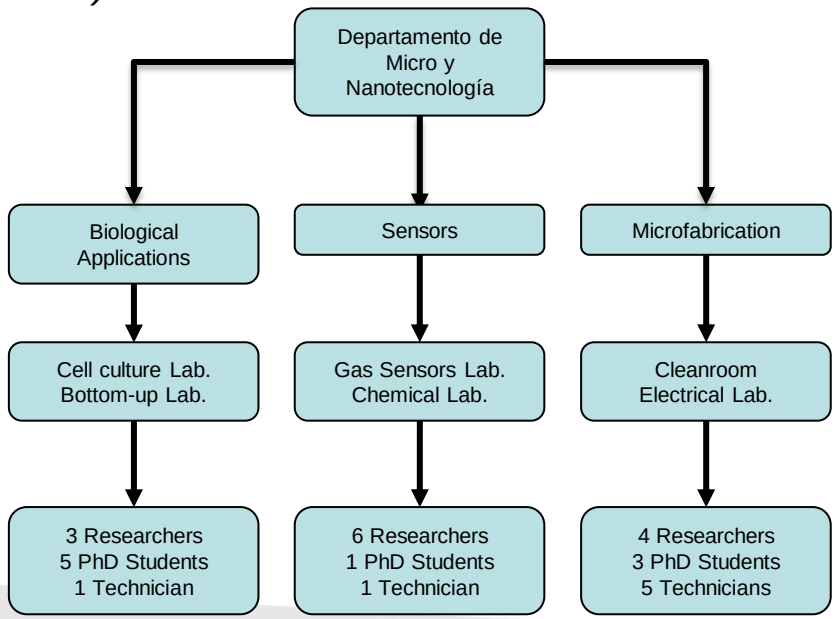
- *3 divisions: Sensors, Biology Applications, Microfabrication*
- *13 researchers (CNEA permanent staff + CONICET researchers)*
- *9 PhD. Students*
- *7 Specialized Technicians.*

Facilities:

- *5 application Labs for Cell culture, Gas Sensors, Electrical Characterization, Bottom-up and chemical.*
- *135 sqr. mts ISO 6 and 7 cleanroom (40 sqr.m to be added in 2020)*

Projects:

- *Pressure sensors for harsh environments*
- *Microfluidic devices for gas separation*
- *Environmental gas sensors*
- *Lab-on-a-chip detectors for endemic diseases*
- *TES detectors for CMB research*
- *AlGaN devices for radiation detection, and uwave devices*



BACKUP CLEANROOM I

Clean room

135m2 facility operated and maintained by a highly qualified technical staff open to CNEA´s and general scientific community.

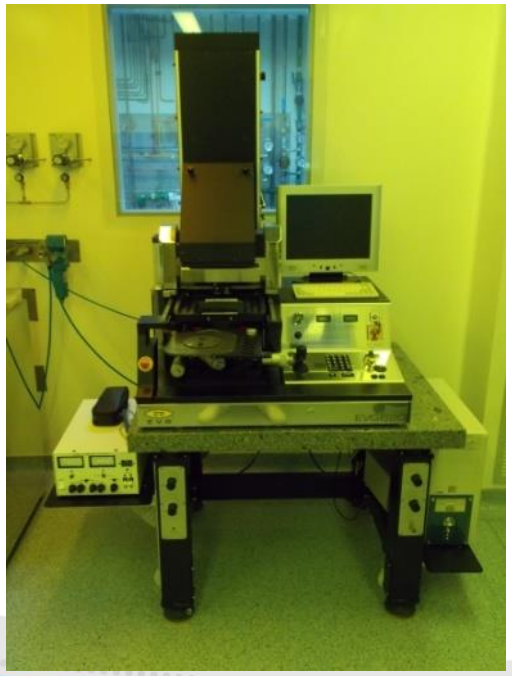
Statistics (Dic. 2018)

Projects:20
Users: 46
Total cleanroom usage: ~4600hs./yr.

BACKUP CLEANROOM II

Lithography		
ID	**Name**	**Ubicación**
L-01	EVG 620 Mask aligner / Wafer Aligner	Sala Litografía
L-02	EVG 501 wafer bonder	Sala Litografía
L-03	Litho Bench	Sala Litografía
L-04	HEIDELBERG Instruments DWL66fs Mask writer	Sala Masterizador

Generador de Máscaras HEIDELBERG DWL66fs



EVG 620 Mask Aligner

EVG 501 Wafer Bonder

BACKUP CLEANROOM II

Deposition		
ID	**Nombre**	**Ubicación**
D-01	Sputtering AJA Orion	Sala de Ataques por Plasma
D-02	PECVD ADVANCED VACUUM VISION 310	Sala de Ataques por Plasma
D-03	Electroplating Cell SEMCOM 1000	Sala Ataques Químicos
D-04	UNIVEX 350 E-beam + thermal evaporator	LAB C301

Sputtering AJA Orion

PECVD Vision 310

Electroplating Cell SEMCOM 1000

BACKUP CLEANROOM II

Etching		
ID	**Nombre**	**Ubicación**
A-01	RIE OXFORD INSTRUMENTS PLASMALAB80+	Sala de Ataques por Plasma
A-02	D-RIE OXFORD INSTRUMENTS PLASMAPRO COBRA	Sala de Ataques por Plasma
A-03	Oxigen plasma asher SPEC AURA1000	Sala de Ataques por Plasma
A-04	Wet etching BenchAMERIMADE	Sala Ataques Químicos
A-05	Wafer cleaning bench AMERIMADE	Sala Ataques Químicos

HEIDELBERG DWL66fs

SPEC AURA1000

PlasmaLab 80+

PlasmaLab 100

BACKUP CLEANROOM II

Inspection		
ID	**Nombre**	**Ubicación**
M-02	Perfilómetro Óptico 3D, Veeco Wyco NT1100	Sala Metro
M-03	Perfilómetro por contacto KLA-TENCOR ALPHA STEP D120	Sala Metro
M-04	Horiba AUTO-SE Elipsometer	Sala Metro
M-05	Dual Beam SEM-FIB FEI Quanta 3D 200i	Sala Metro

SEM-FIB

Perfilómetro óptico 3D

AUTO-SE Elipsometer

BACKUP CLEANROOM II

Auxiliary equipment		
ID	**Nombre**	**Ubicación**
DS-01	DISCO DAD3240 dicing Saw	Lab C220
DS-02	Wire Bonder Hybond 912	Sala de ataques por plasma
DS-03	Annealsys AS-ONE Rapid thermal annealer	Sala de ataques por plasma

Dicer Disco

Wire bonder