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

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Departamento de Micro y Nanotecnología,
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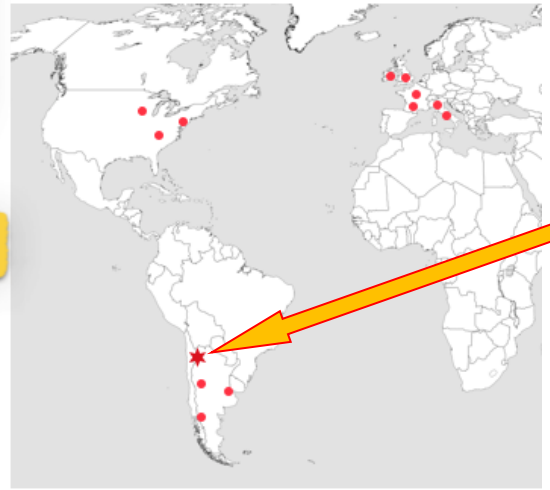
Prof. Dr. Marc Weber
Karlsruhe Institute of Technology, Germany

Motivation: QUBIC

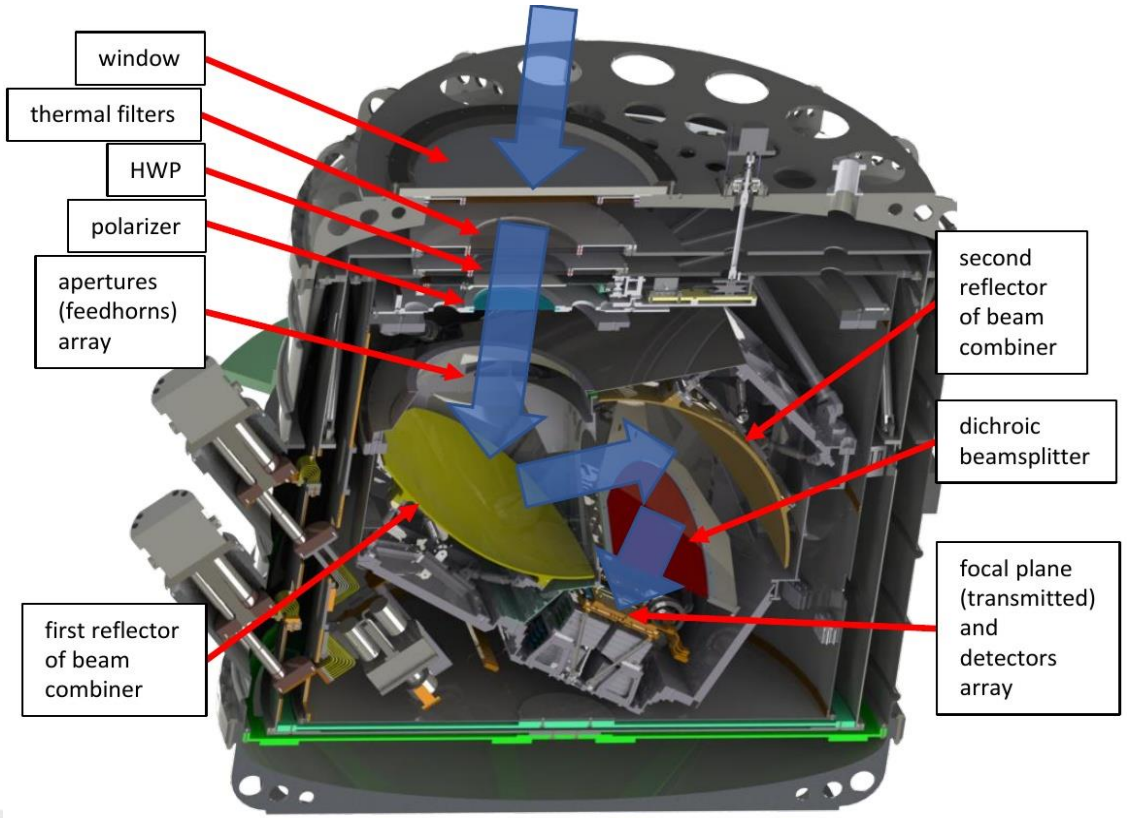
APC Paris, France
C2N Orsay, France
CSNSM Orsay, France
IAS Orsay, France
IRAP Toulouse, France
LAL Orsay, France
Universita di Milano-Bicocca, Italy
Universita degli studi di Milano, Italy
Universita La Sapienza, Roma, Italy
Maynooth University, Ireland
Cardiff University, UK
University of Manchester, 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

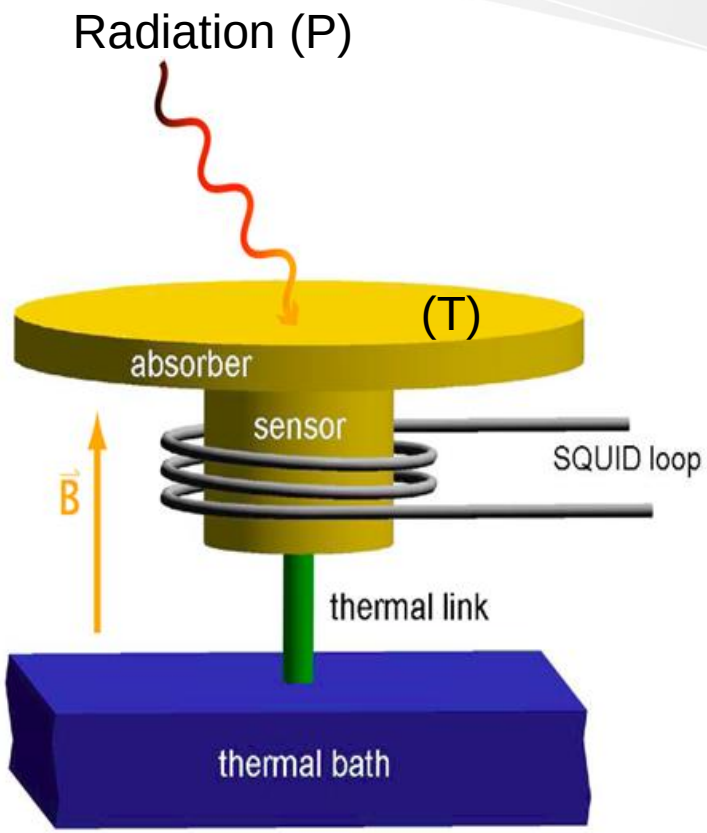
130 Collaborators
22 laboratories
6 countries

+SISSA Joined



Motivation: QUBIC





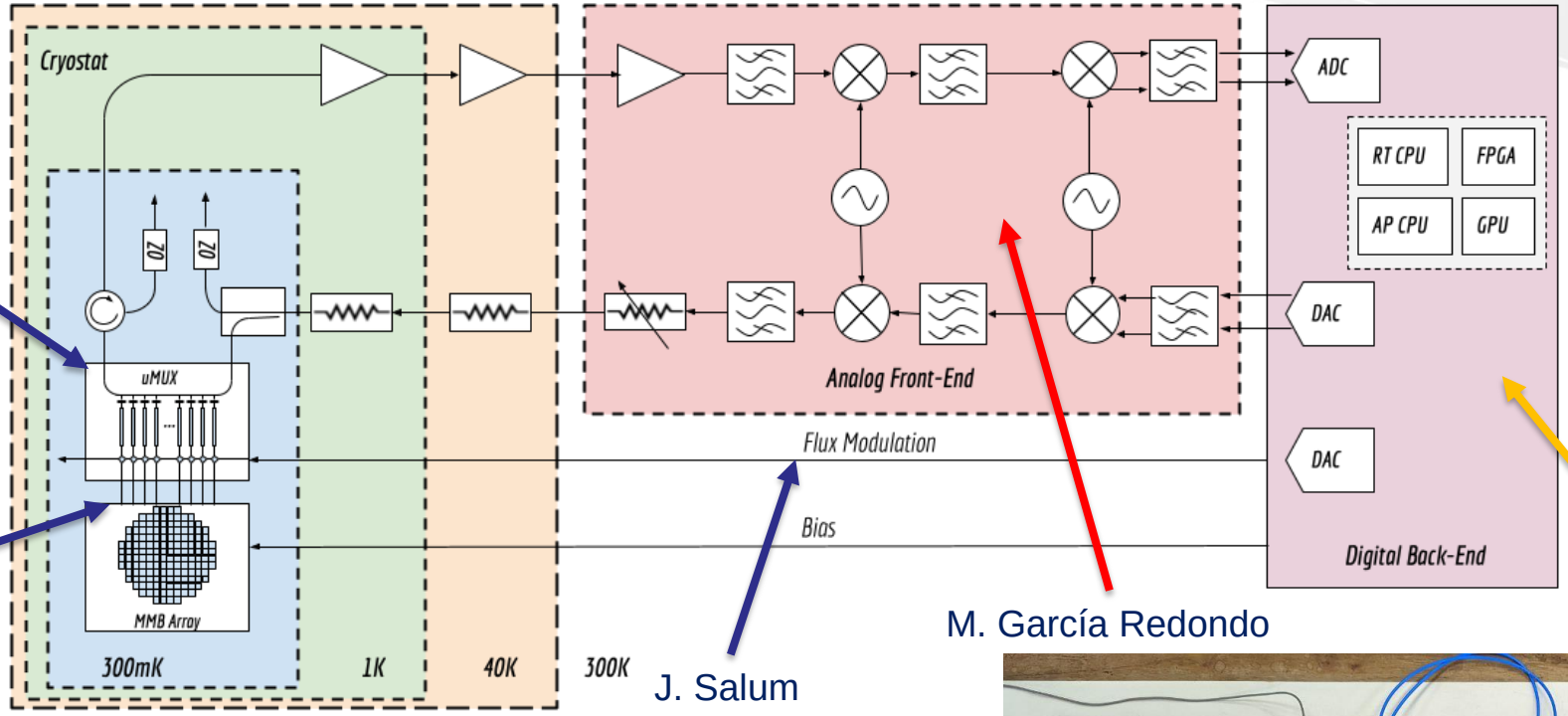
- Interferometro Bolométrico
  - *Extreme sensitivity with TESs→* future with MMBs
  - *Sistematics corrections due to interferometric nature*
  - *Self calibration and spectroscopic capability*

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

QUBIC: Bolometric Camera Upgrade

N. Muller
J. Bonilla
A. Almela

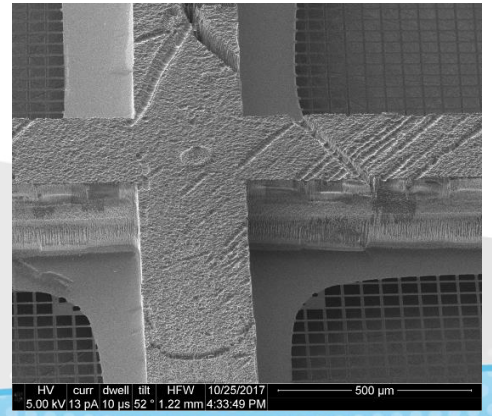
J. M. Geria
J. Bonaparte
E. Petriella
M. Hampel
S. Kempf

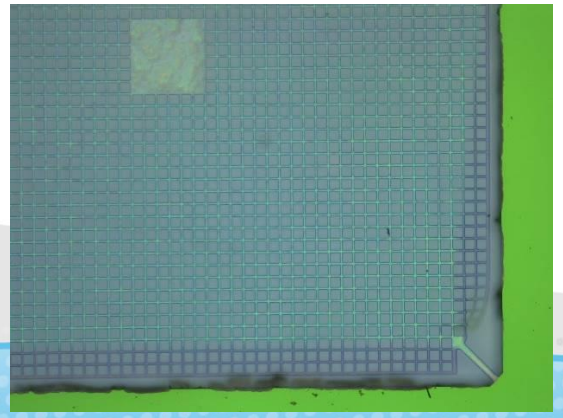


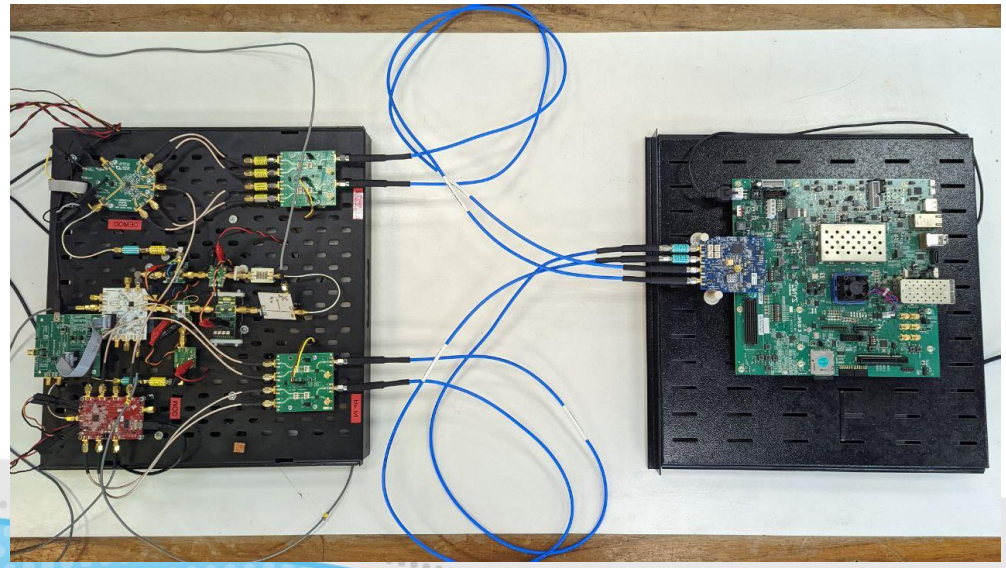
J. Salum
A. Fuster

M. García Redondo

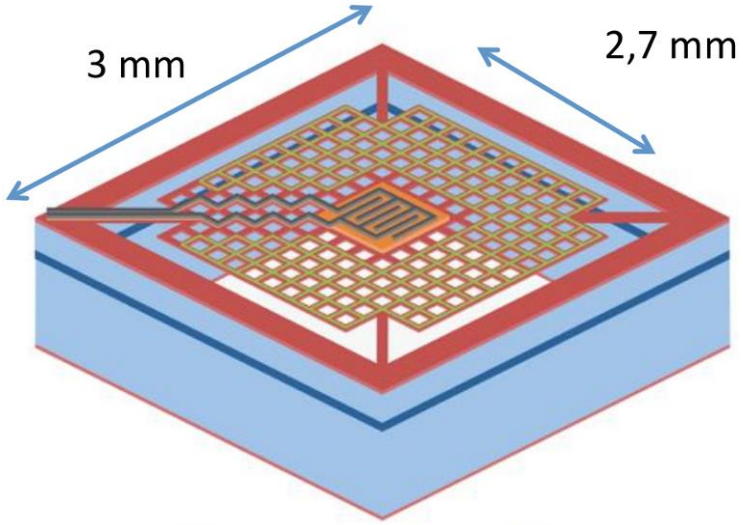
L. Ferreyro



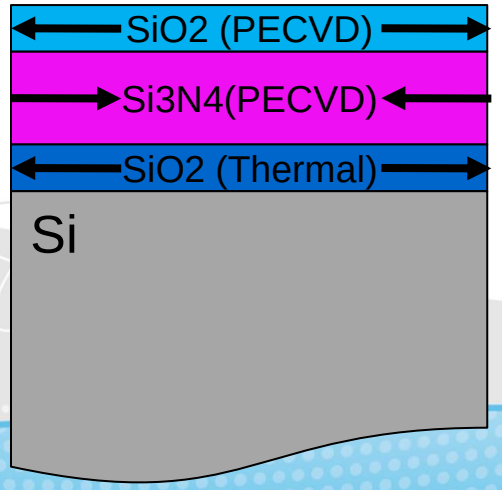


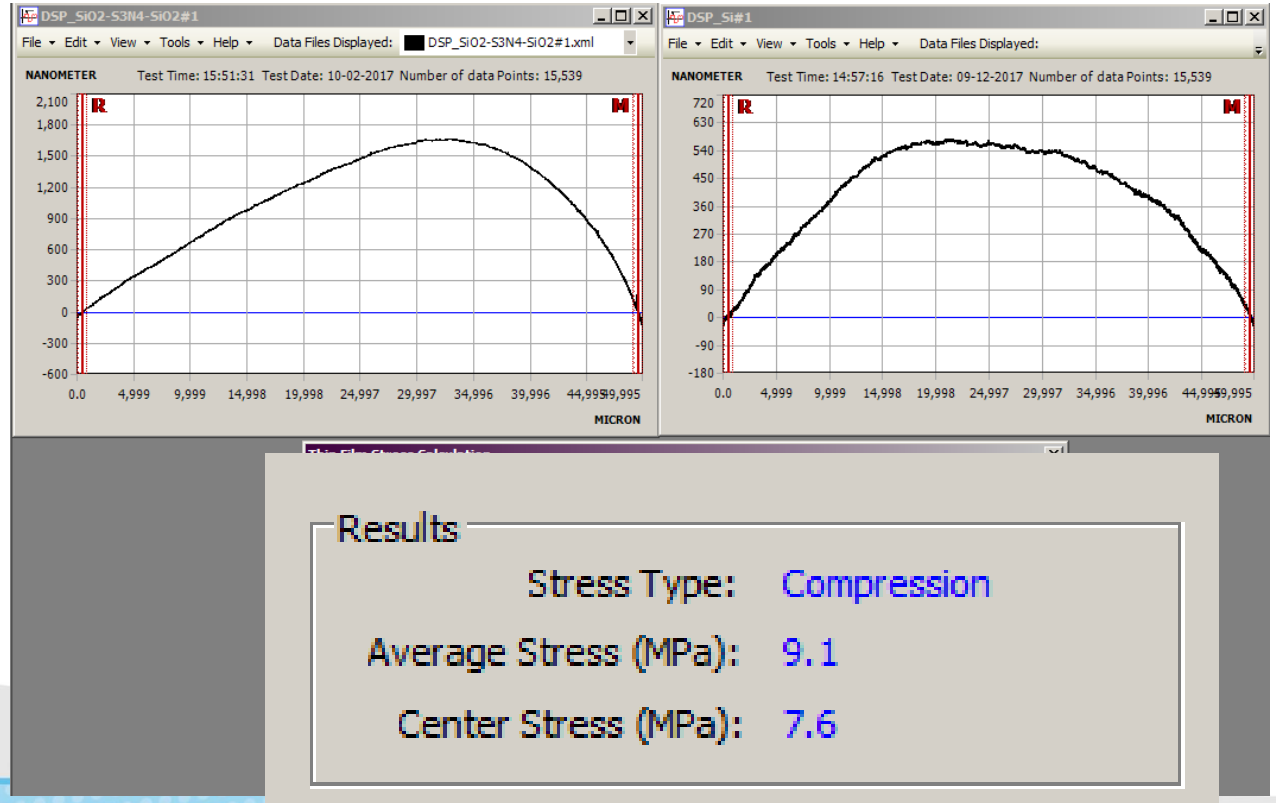


Microfabrication I: ULS Membrane

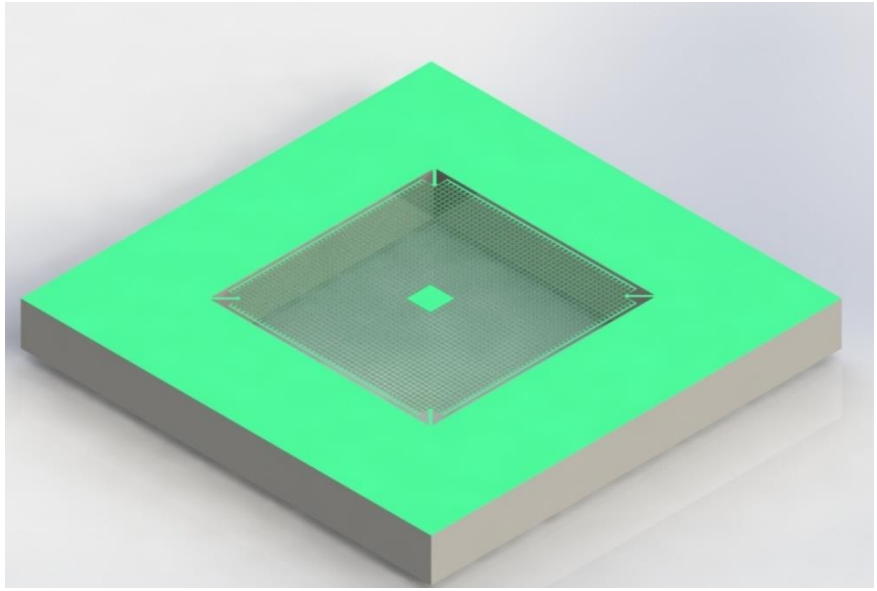


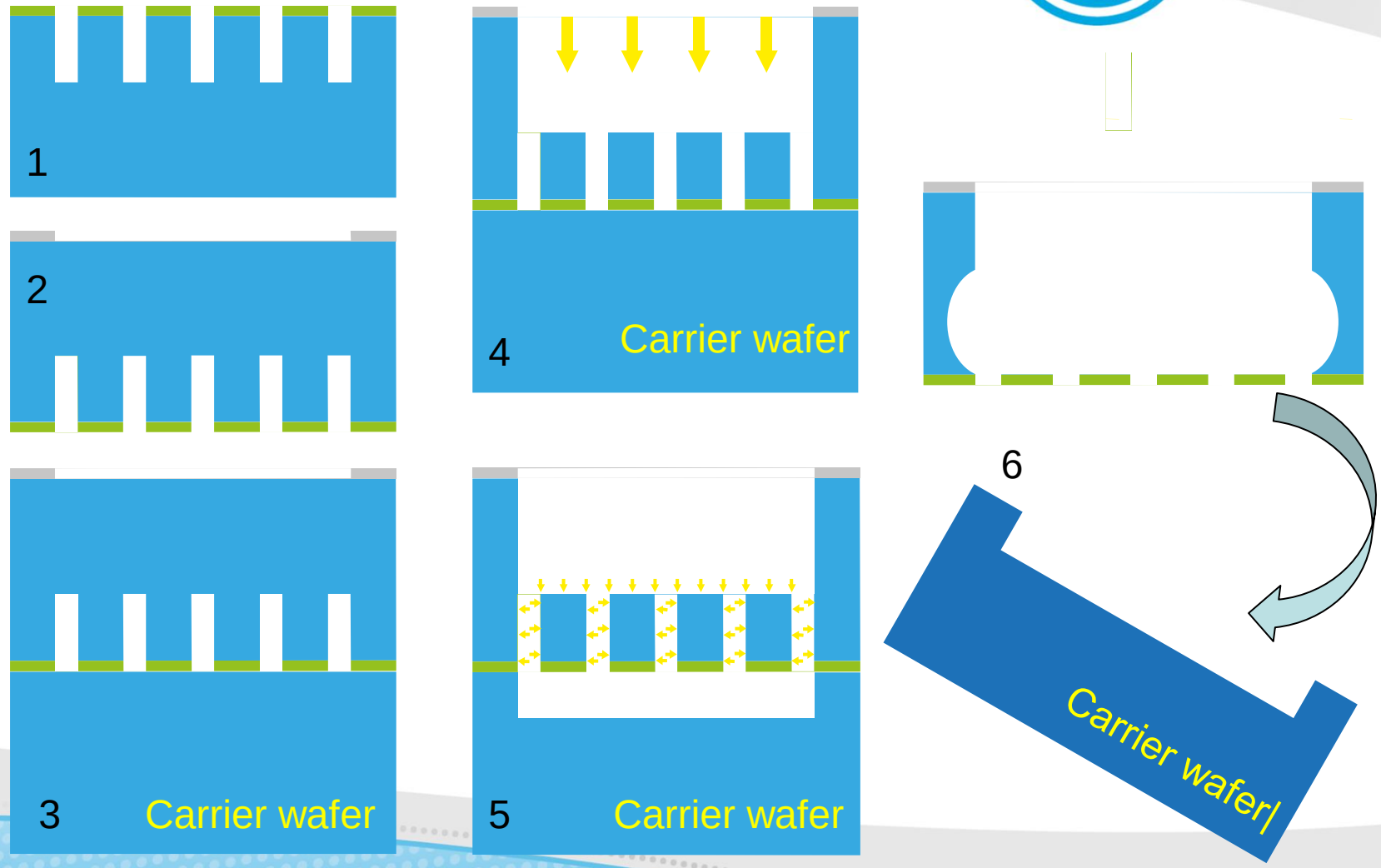
Material	Grow method	Stress [MPa]	Thickness [nm]
SiO2	Dry Oxidation	230 +/- 30	170
Si3N4	PECVD	-577 +/- 20	200
SiO2	PECVD	266 +/- 15	174



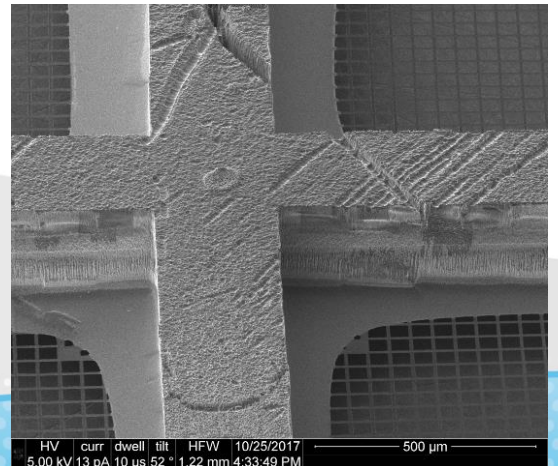


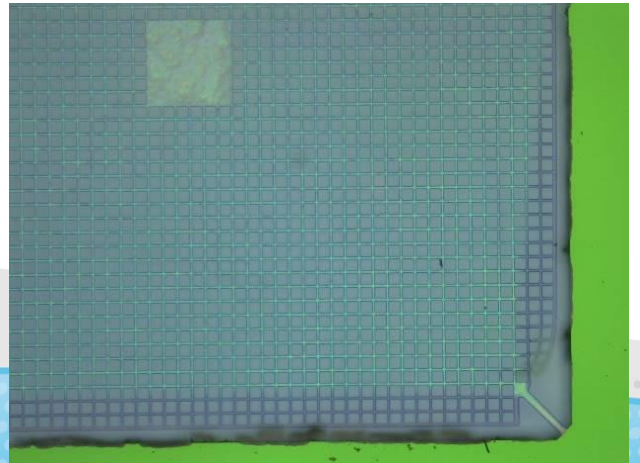
Microfabrication II: Release process

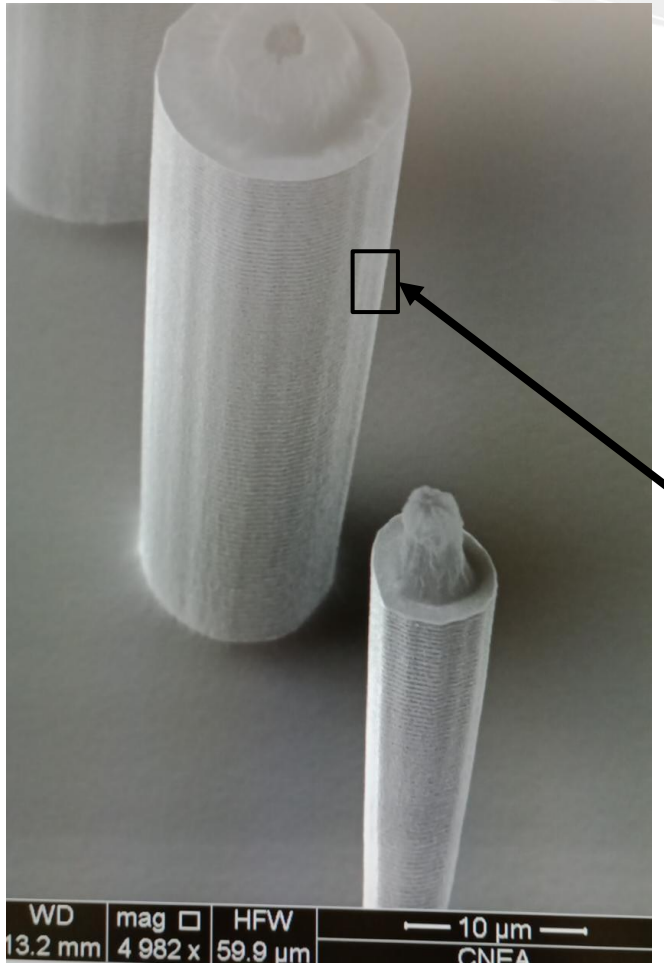


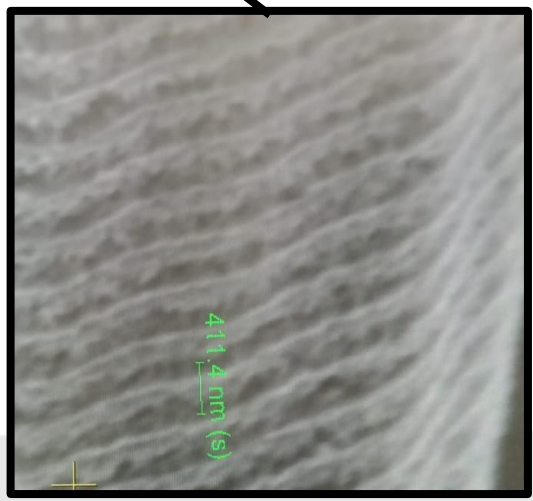


Microfabrication II: Release process

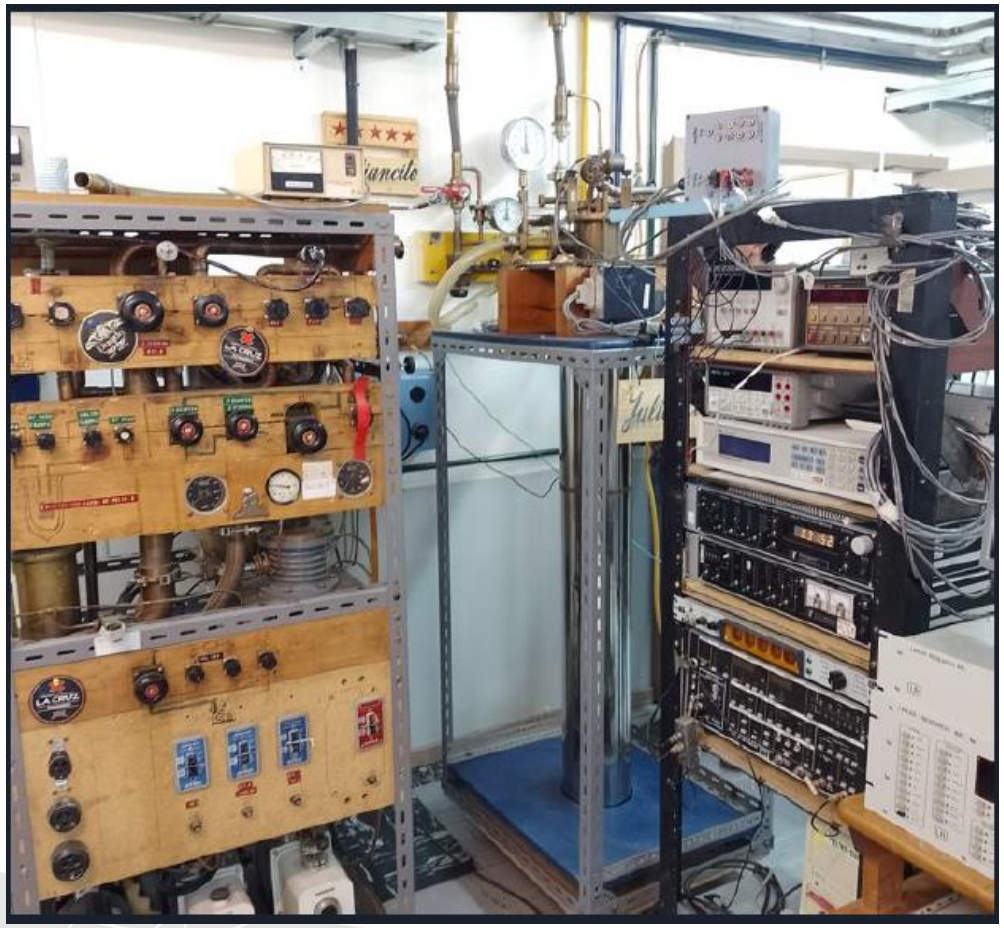


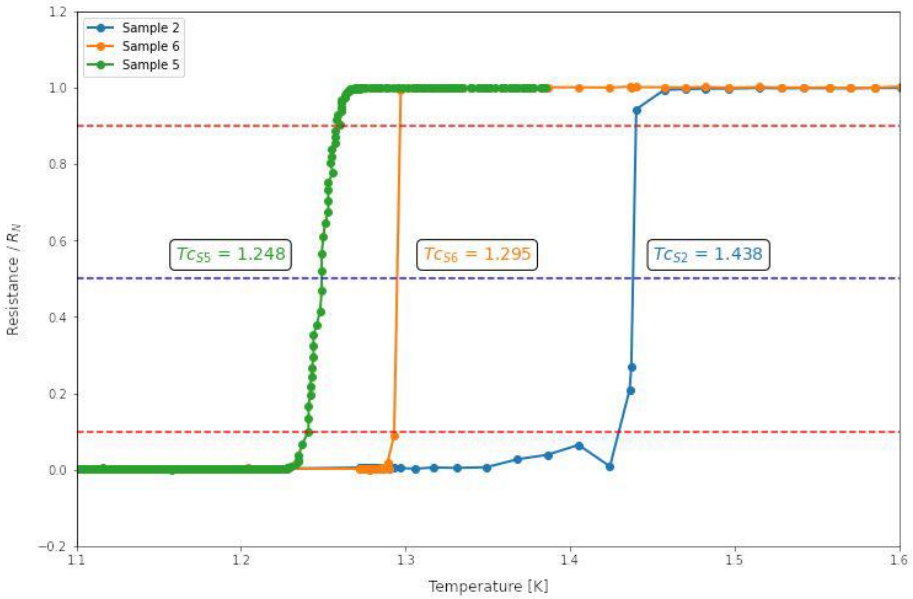


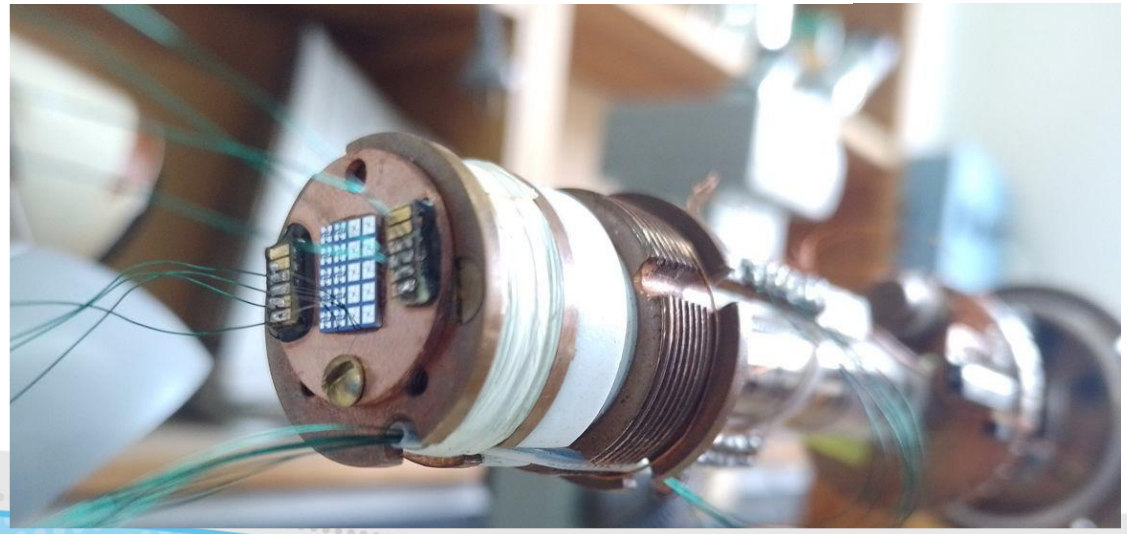




Microfabrication IV: Al Superconductor







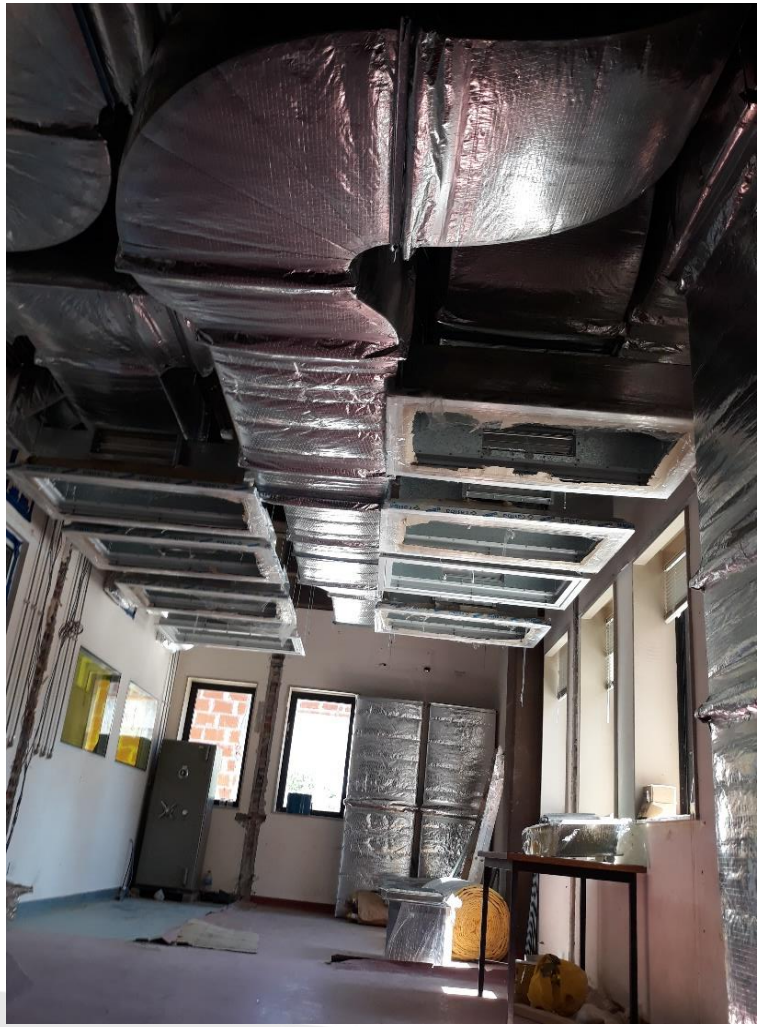
EQUIPMENT I

He3/He4 Dilution Fridge
Bluefors LD250
Arrival: 8 December 2022

AJA ATC2400 Sputter
Estimated Date Arrival: May 2023

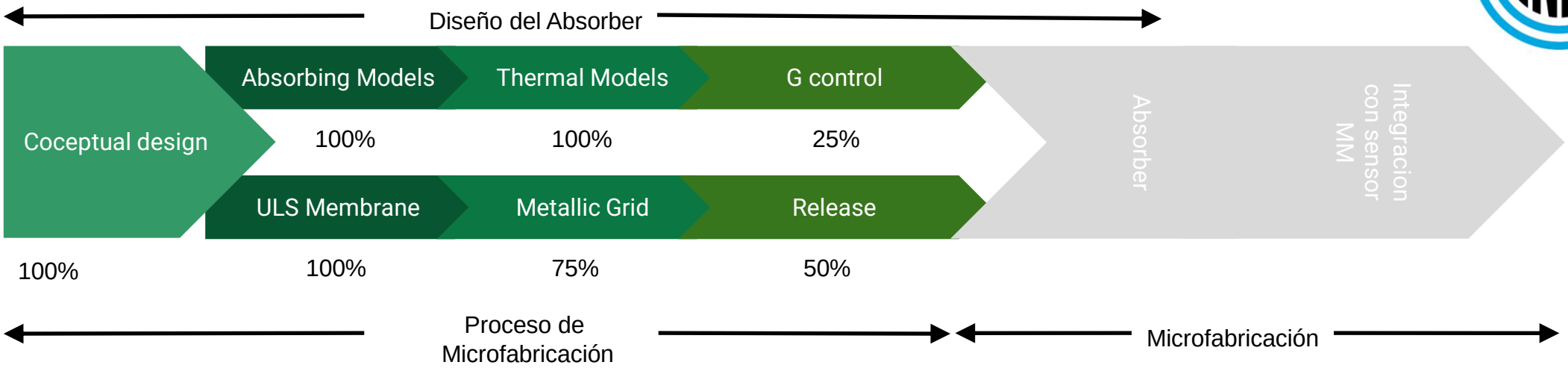
Keysight X-PNA
Arrivado: Mayo 2022

LABS I



LABS II

Estado de avance



Courses:

Introducción a Microscopías de Barrido por Sonda, Inst. Sabato, 2022
Cosmología, ITeDA, Agosto 2022
Escuela de Nanociencia y Nanotecnología 2021, “Sensores y Dispositivos”

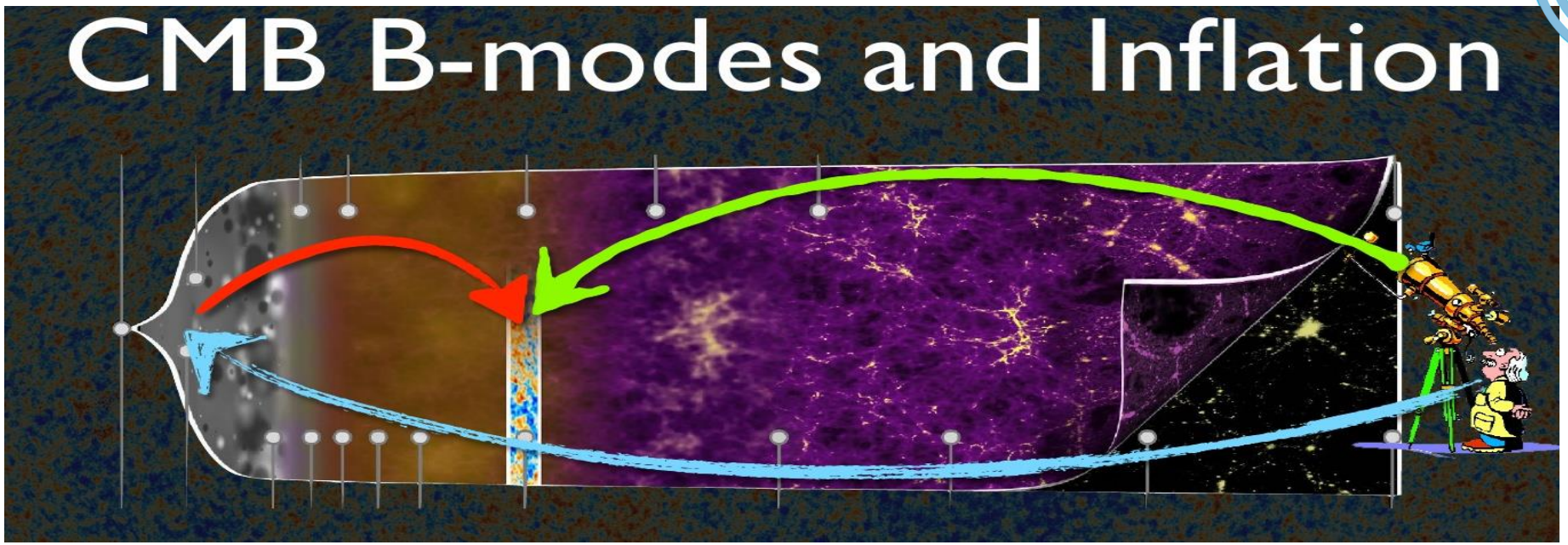
Thanks for your atention

Dr. Alberto Lamagna
Dr. Alberto Etchegoyen
Prof. Dr. Christian Enss
Prof. Dr. Sebastian Kempf
Ing. César Belinco
Ing. Cristian Arrieta
Dr. Christian Kristukat
Dr. Alejandro Almela
Dr. Matias Hampel
Ing. Luciano Ferreyro
Ing. Manuel Garcia Redondo
Ing. Juan Salum
Dr. Manuel Platino

Ing. Juan Manuel Geria
Ing. Nahuel Müller
Ing. Andres Didonato
Ing. Claudio Ferrari
Ing. Enrico Petriela
Mg. Ing Alejandro Fasciswski
Dr. Matias Wegner
Ms. Diego Perez Gagni
Tec. Dante Mercado
Tec. Diego Silva
Lic. Belén Manente
Lic. Micaela Álvarez
Prof. Dr. José F. Bonaparte

Backup Slides

Motivación: Detección de modos B de polarización del CMB



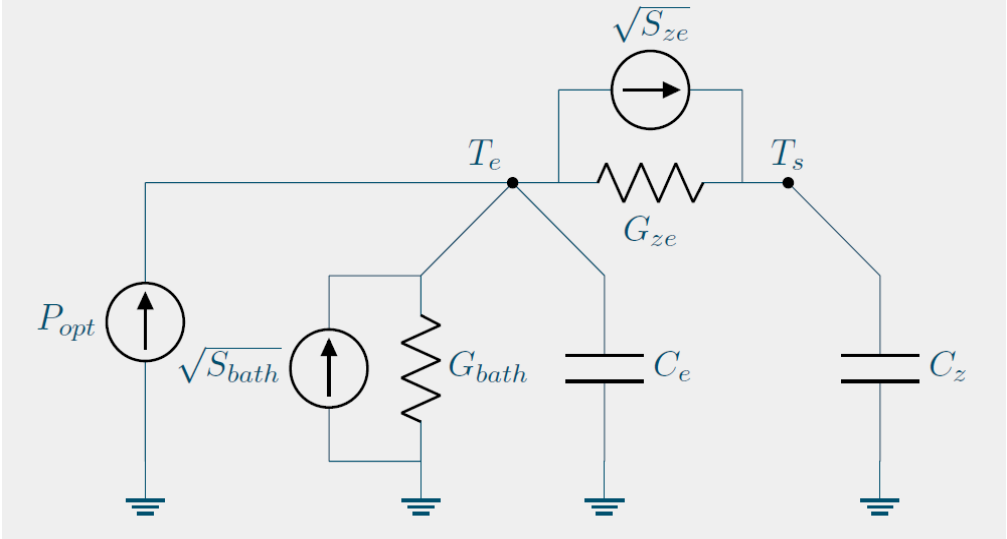
La observación de la polarización (modos B) del CMB, nos daría acceso al periodo inflacionario y abriría las puertas a la física del universo primordial

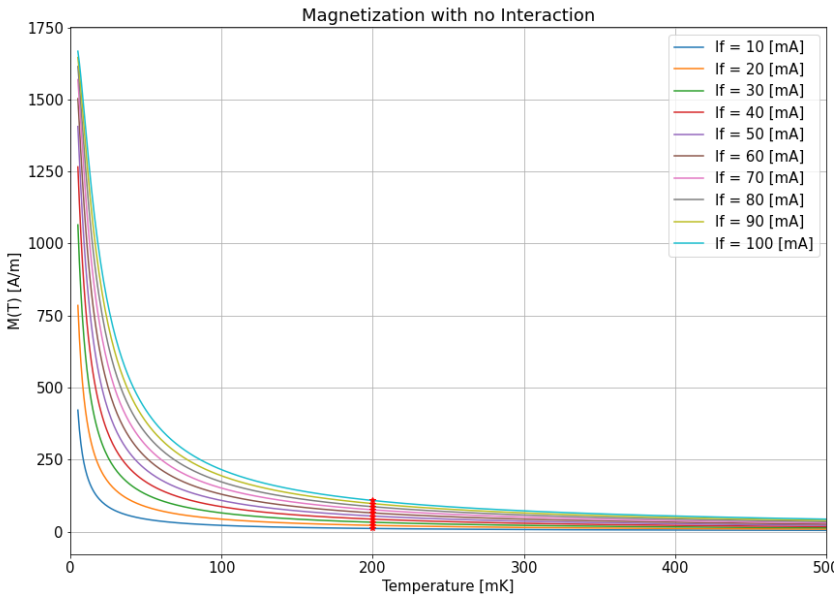
Dificultades: Instrumentos extremadamente sensibles: algunos nK sobre un fondo de 7K
Errores sistemáticos instrumentales: Polarización cruzada entre modos
Primeros planos (Foregrounds): Polvo galáctico polarizado, lensing gravitacional…

DESARROLLO

Maximize

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



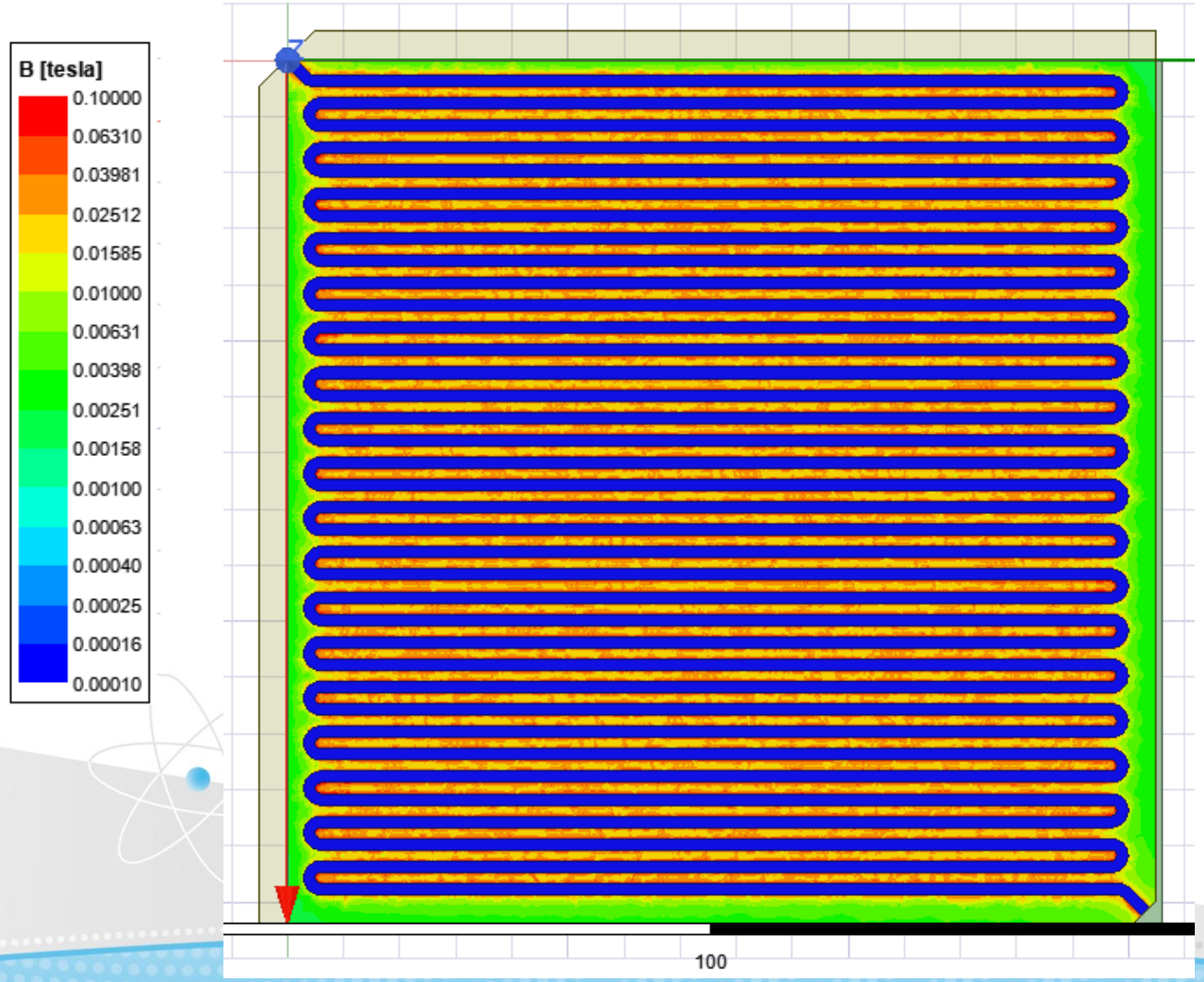


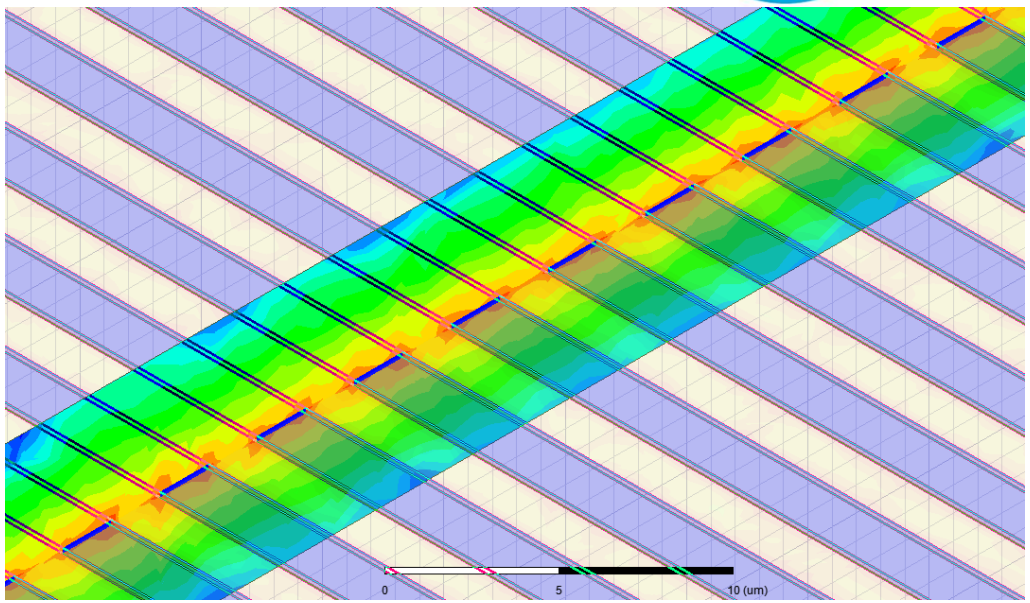
$$\frac{\partial T}{\partial P} = \frac{1}{G_{bath}} \cdot \frac{1}{\frac{C_e+C_z}{G_{bath}G_{ze}} \cdot S^2 + \frac{C_z(G_{bath}+G_{ze})+C_eG_{ze}}{G_{bath}G_{ze}} \cdot S+1}$$

$$\frac{\partial \Phi}{\partial T} = \sum \frac{\left|\overrightarrow{B_{(\vec{r})}}\right|}{I_{coil}} \cdot \frac{\partial M}{\partial T}\bigg|_{\left|\overrightarrow{B_{(\vec{r})}}\right|} \cdot \Delta V$$

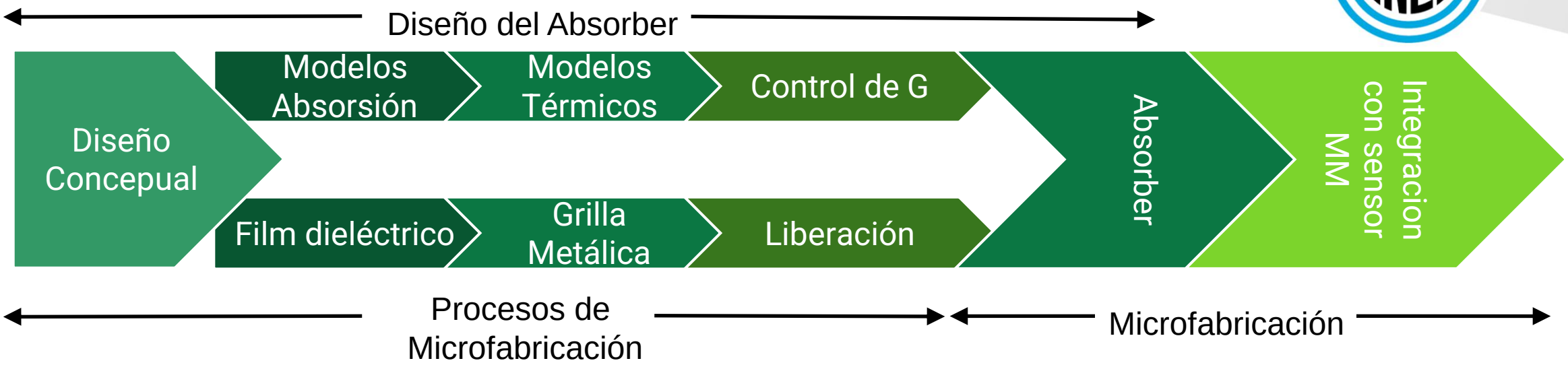
$$\frac{\partial M}{\partial T} = \frac{N_s g^2 J^2 \mu_B^2}{m_v k_B} \cdot \mathcal{B}_s' \cdot \frac{B_{ext}}{T^2}$$

DESARROLLO

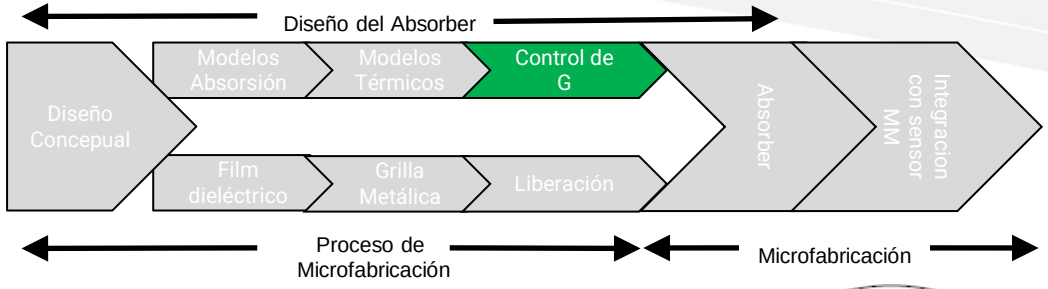

B [tesla]
0.10000
0.06310
0.03981
0.02512
0.01585
0.01000
0.00631
0.00398
0.00251
0.00158
0.00100
0.00063
0.00040
0.00025
0.00016
0.00010
100

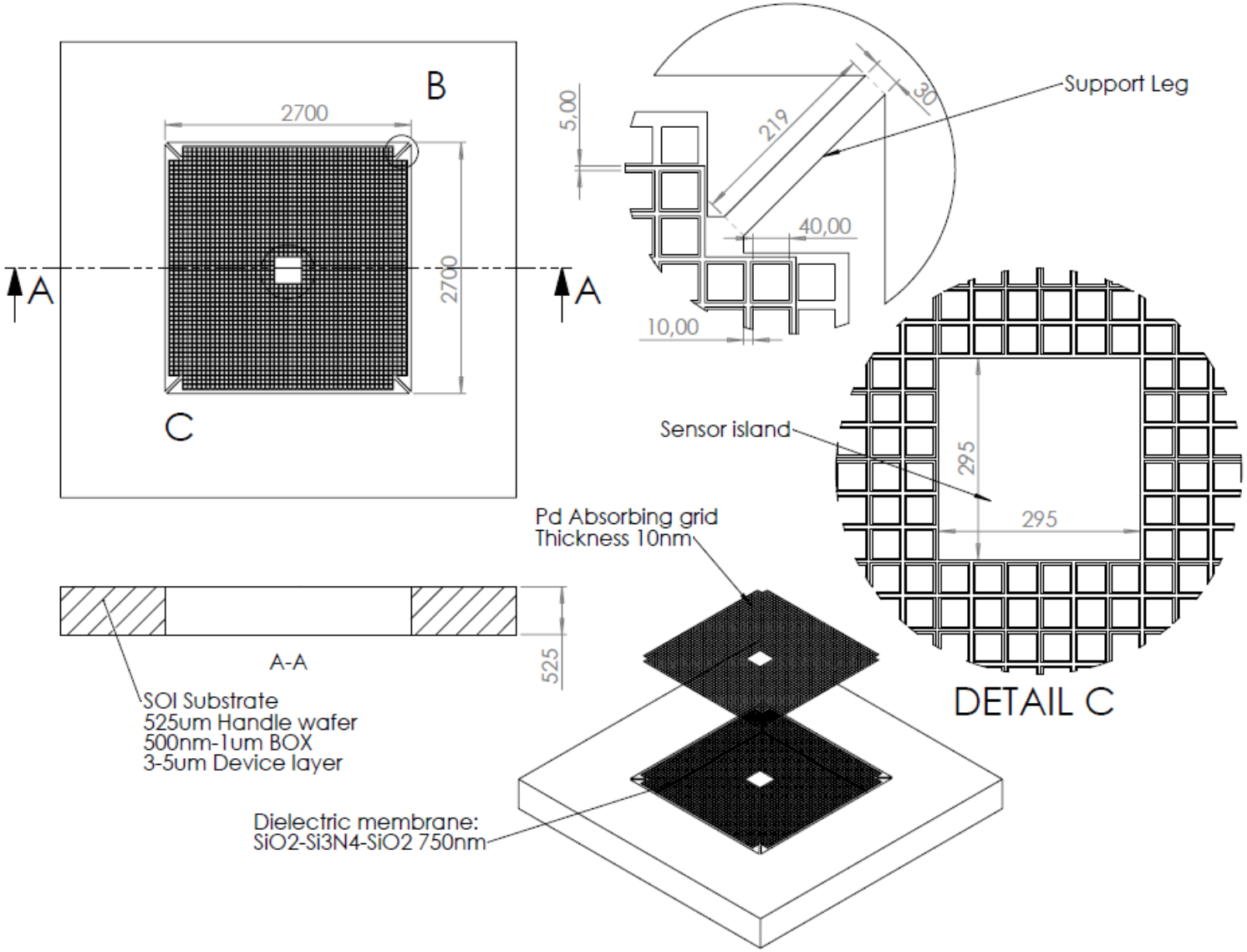

0
5
10 (um)

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

DESARROLLO

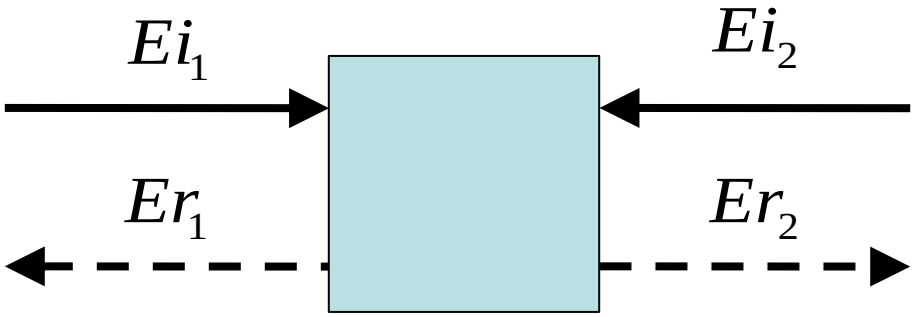


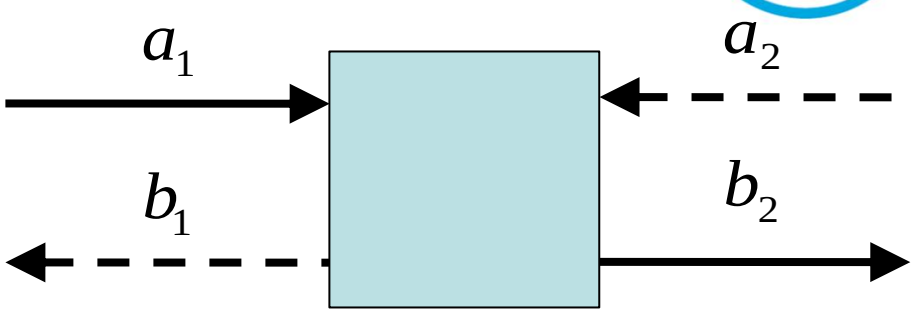


$$G_{bath} = \frac{\partial P}{\partial T} = N \cdot \frac{A\, l\, S}{3\, Leg_L} \cdot \left(\frac{a}{4} \cdot T_s + \frac{b}{16} \cdot T_s^3\right)$$

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

Scattering Matrix





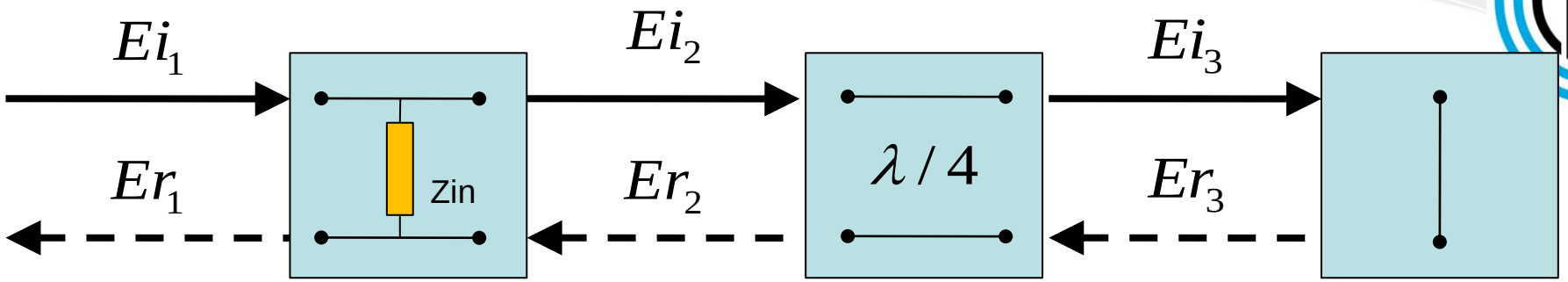
$$Er_1 = \Gamma E_{0_1} e^{+jk_0 z} + \mathrm{T} E_{0_2} e^{-jk_0 z}$$

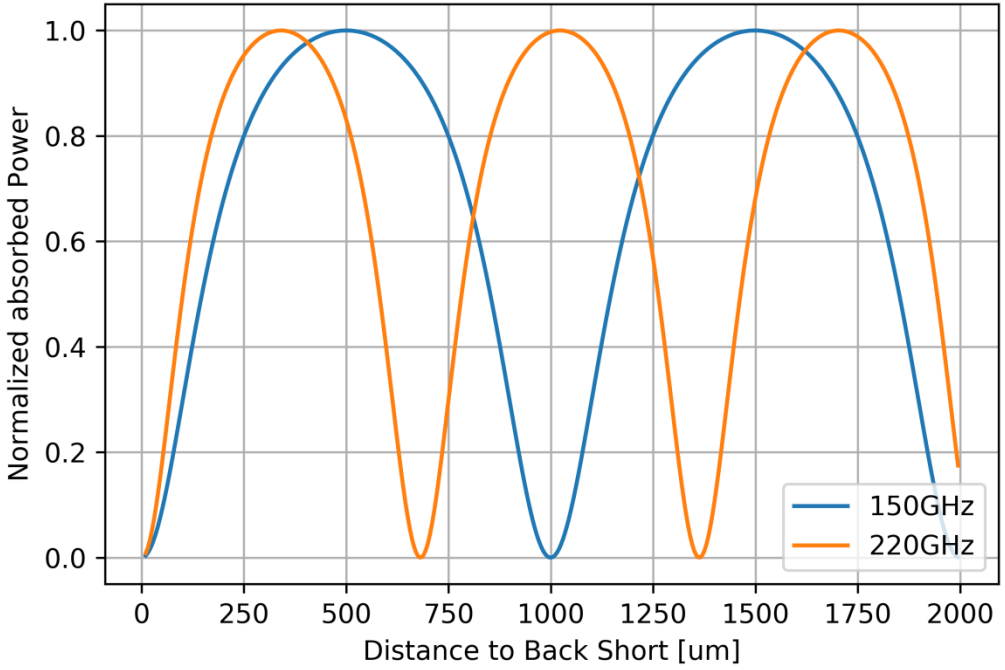
$$Er_2 = \mathrm{T} E_{0_1} e^{+jk_0 z} + \Gamma E_{0_2} e^{-jk_0 z}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

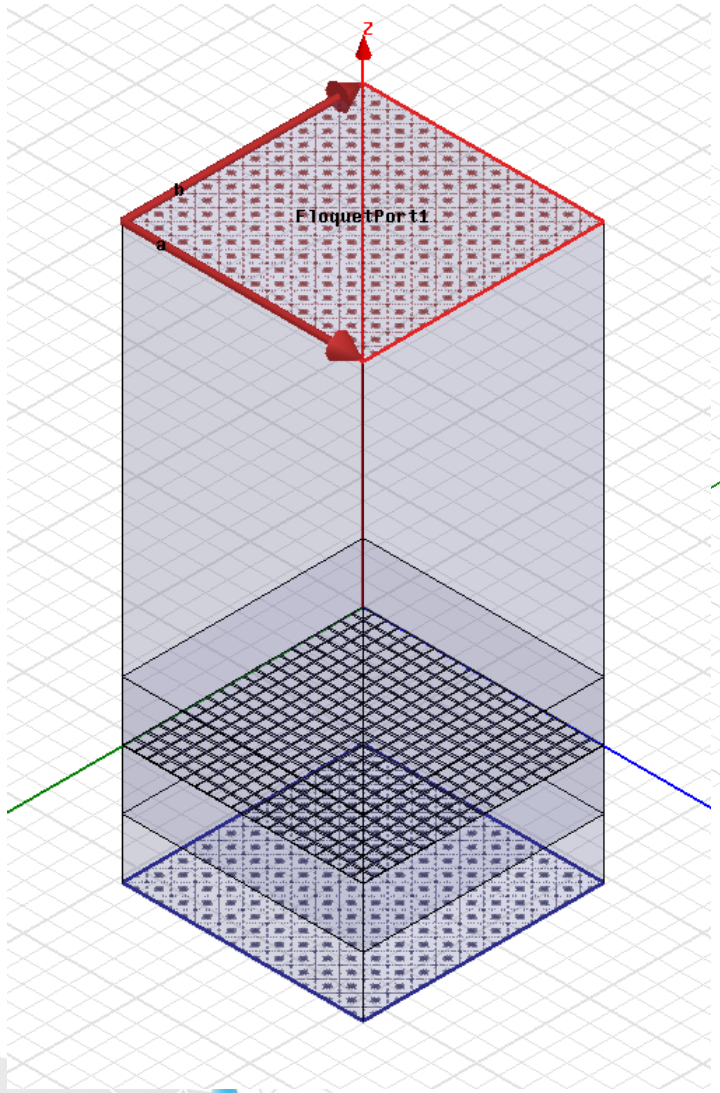
$$\begin{bmatrix} Er_1 \\ Er_2 \end{bmatrix} = \begin{bmatrix} \Gamma & \mathrm{T} \\ \mathrm{T} & \Gamma \end{bmatrix} \cdot \begin{bmatrix} E_{0_1} e^{+jk_0 z} \\ E_{0_2} e^{-jk_0 z} \end{bmatrix}$$

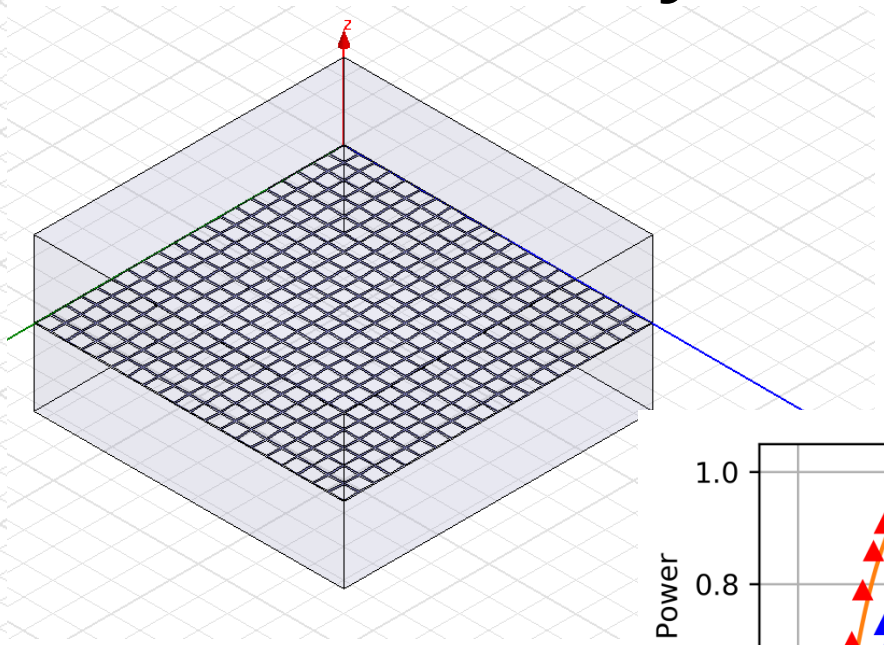
Media cascading

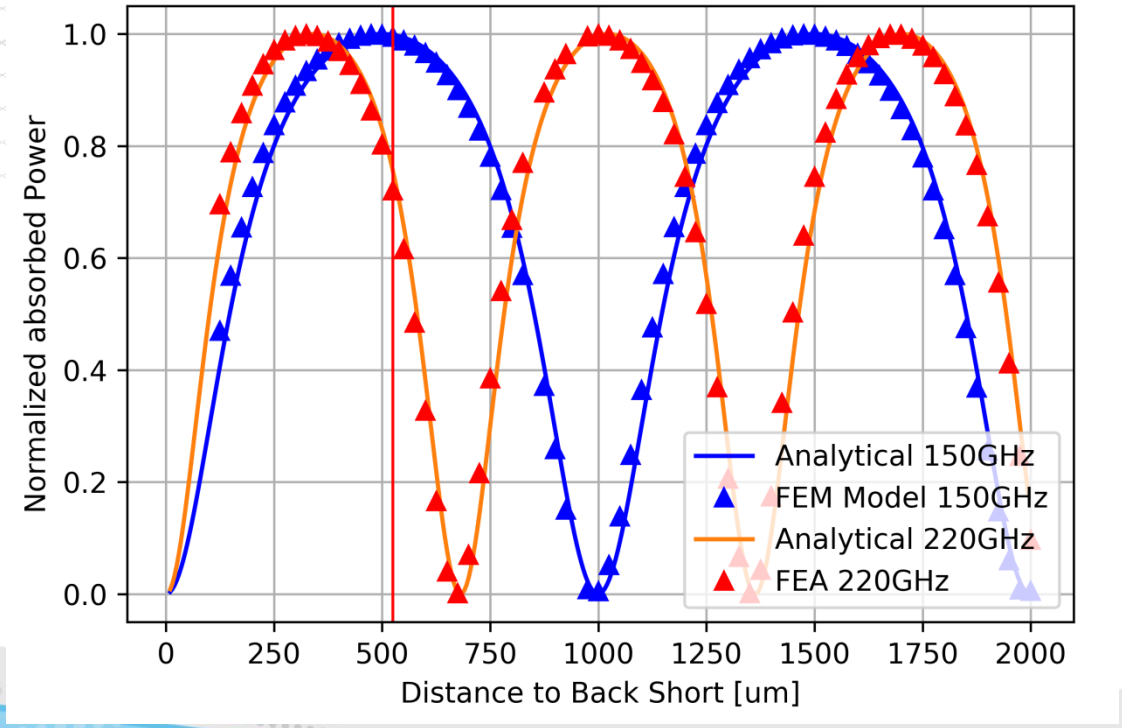


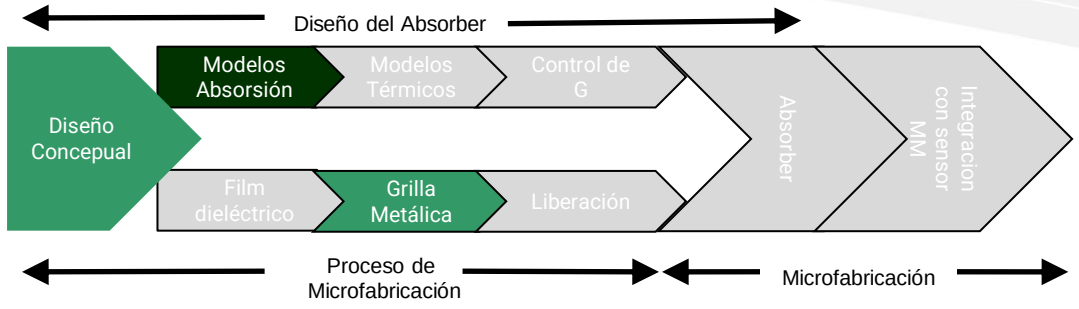


FEA analysis





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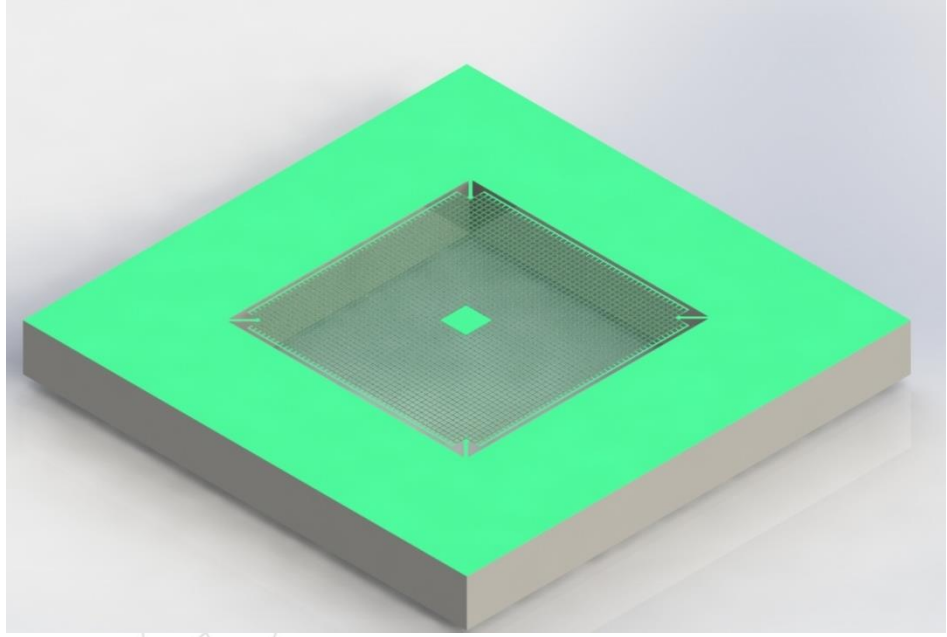
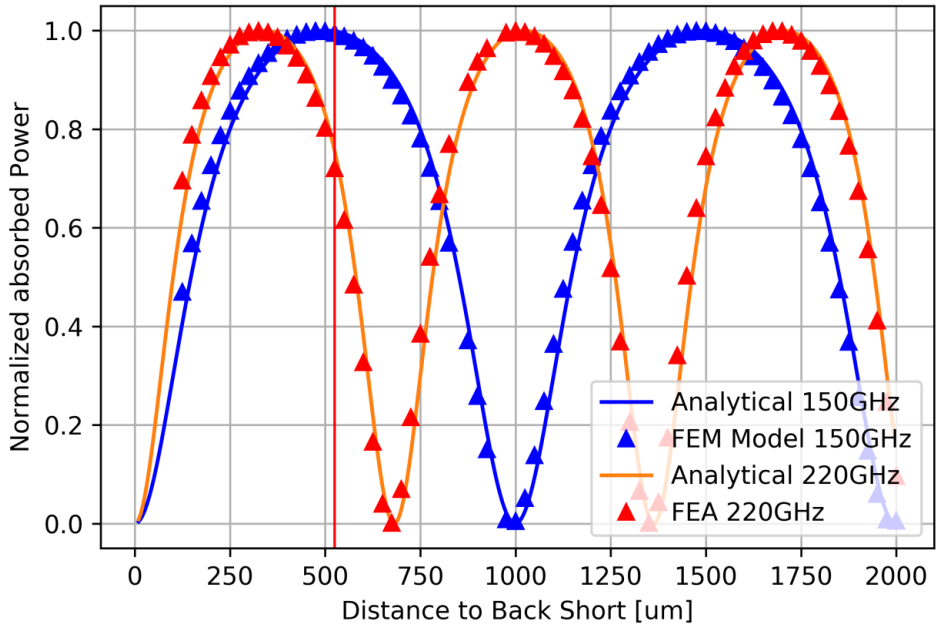
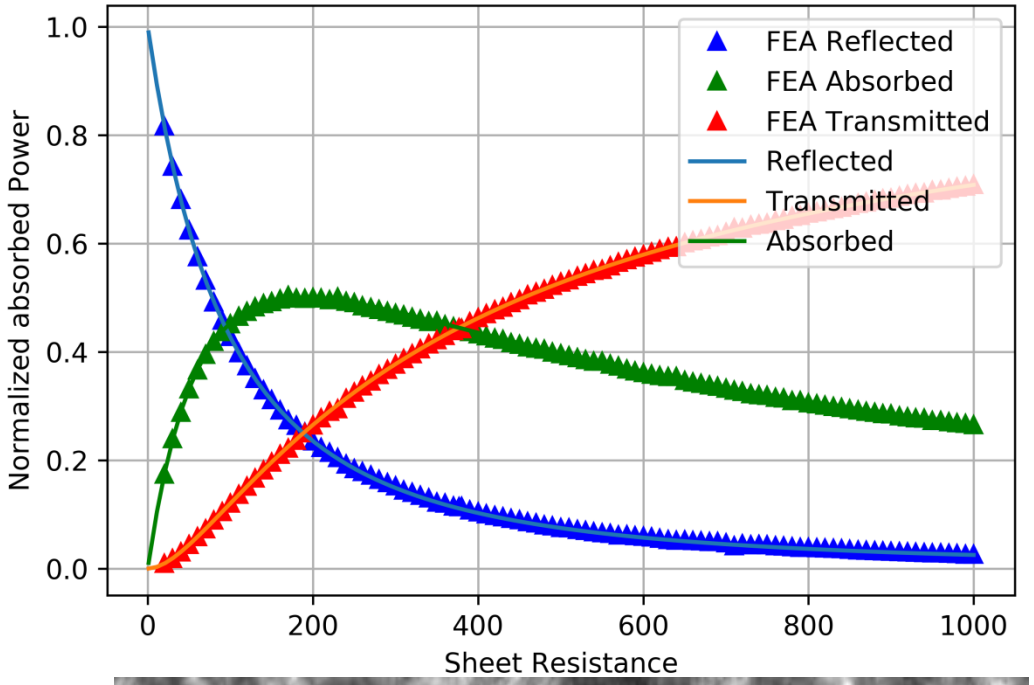
Proceso de Microfabricación
Microfabricación

DESARROLLO




Normalized absorbed Power
Distance to Back Short [um]
0.0
0.2
0.4
0.6
0.8
1.0
0
250
500
750
1000
1250
1500
1750
2000
Analytical 150GHz
FEM Model 150GHz
Analytical 220GHz
FEA 220GHz

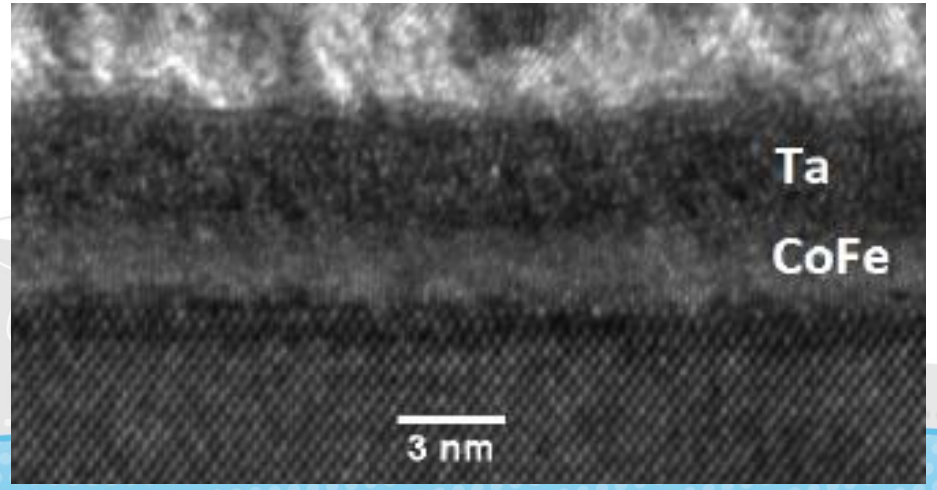
Real world problem



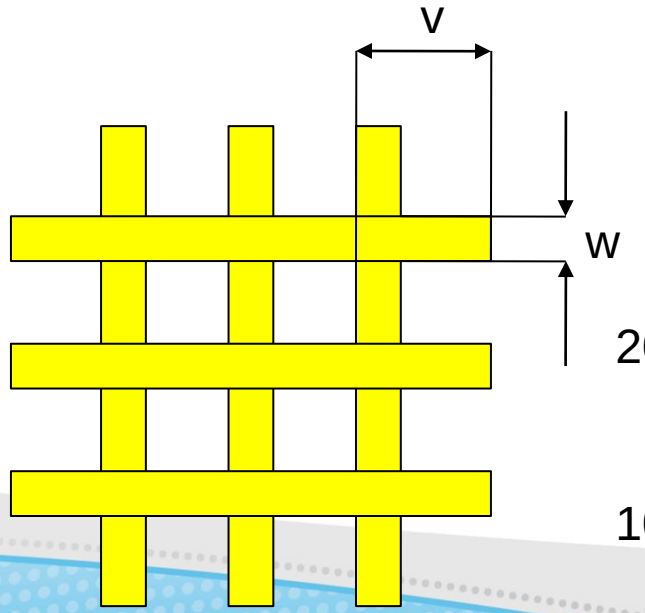
Optimal Sheet resistance=188.5Ω

RF sputtered Pd Resistivity, ρ=25μΩ.cm

Pd thickness to get 188.5Ω : 1.33nm



Possible solution: Material structuring



$$v << \lambda$$

$$Z_{patt} = \frac{v}{w}\frac{\rho}{t}$$

20nm Pd : $\frac{v}{w} = 30.16$

10nm Pd : $\frac{v}{w} = 15.08$

BACKUP CLEANROOM I

Clean room

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

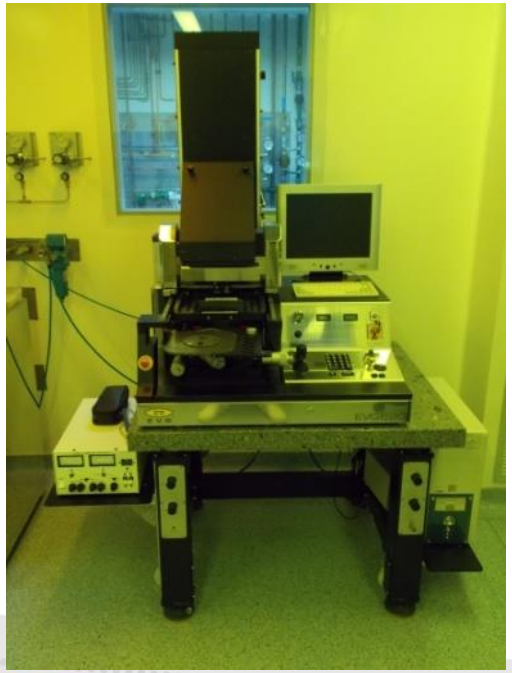
Statistics (Dic. 2018)

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