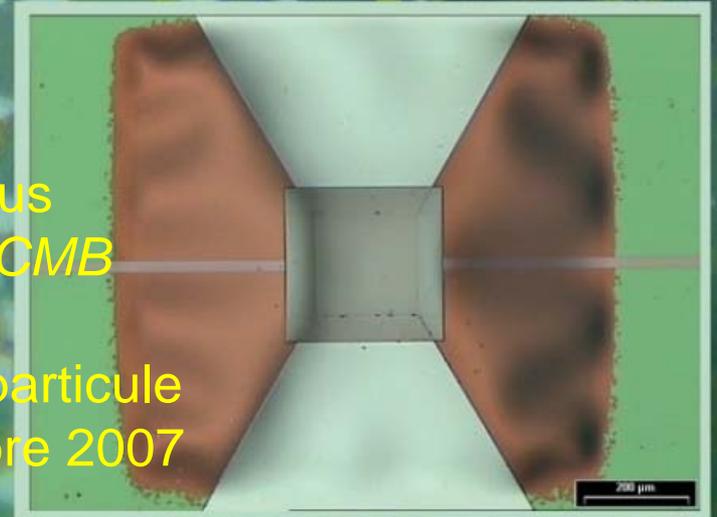


Développement de matrices de bolomètres



Philippe Camus
Collaboration DCMB

Journée de l'Astroparticule
Paris, le 7 septembre 2007



Plan

- **La collaboration DCMB**
 - Motivations
 - Participants
 - Financement
- **Etat d'avancement**
 - Points clés
 - Résultats
- **Perspectives**

La collaboration DCMB

Contexte / motivations

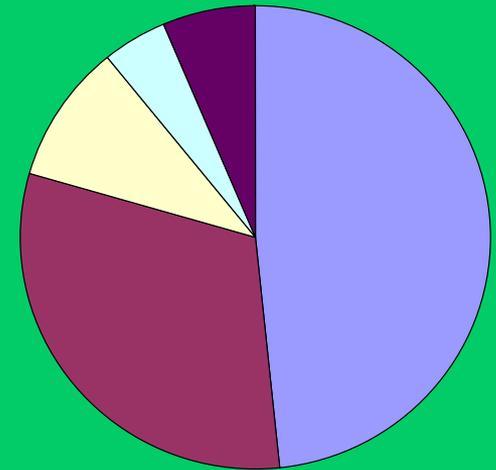
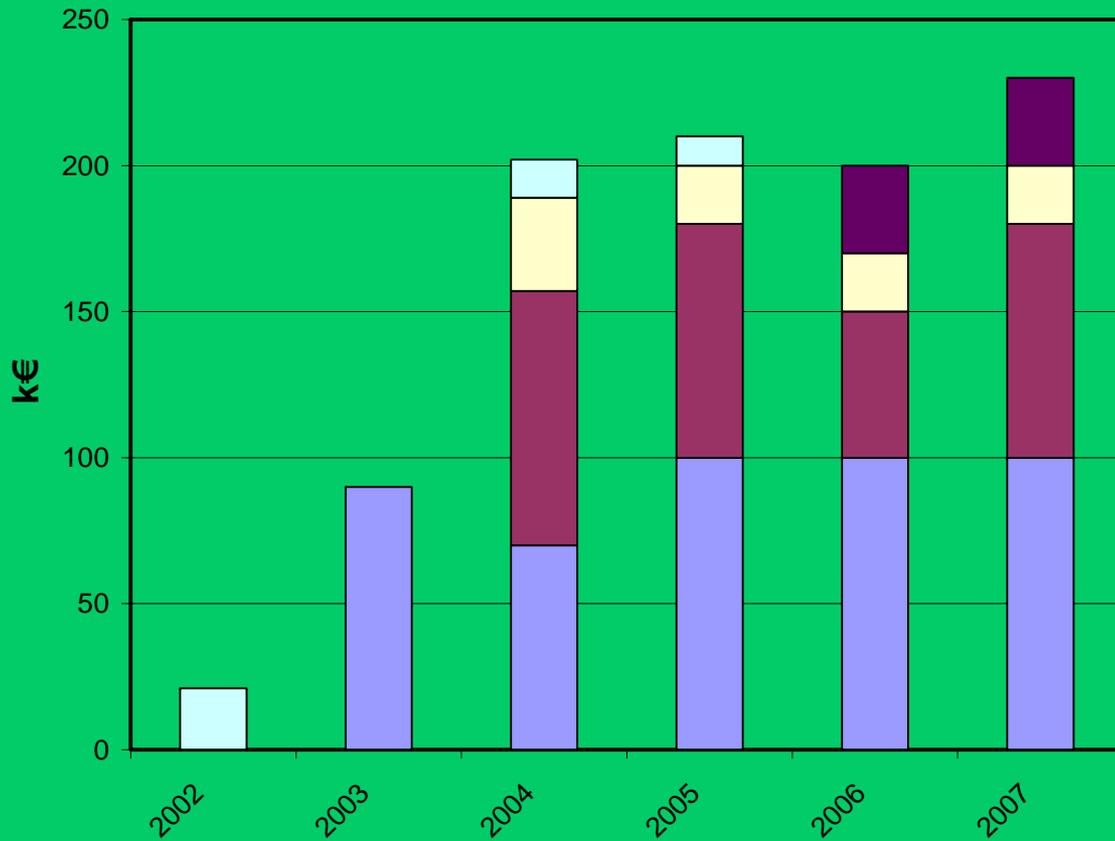
- Environnement scientifique de Planck / HFI
- Lacunes dans le développement des bolomètres en France (méthodes de microfabrication)
- Evolution des besoins vers les matrices de bolomètres à très basse température (< 0.3 K)

Labo	Tâches
CSNSM	Couches thermométriques (semiconductrices, supra)
IEF	Architecture bolométrique, Réalisation SQUIDs
LPSC	Antennes, MPI
APC / LISIF / LERMA	Antennes, traitement GHz-THz, ampli SiGe
Inst. Néel / LAOG	Multiplexage haute impédance, cryogénie, MPI
LPN	Réalisation HEMTs
IAS	Tests échantillons supra
APC	Tests échantillons supra, réalisation SQUIDs (avec IEF), multiplexage SQUIDs
CESR	Electronique, étude CEB

Implication de ~50 personnes (chercheurs, ITA)

Site internet : http://crtbt.grenoble.cnrs.fr/astro/dcmb_pub

Financements



- ANR Artemis
- PNC
- INSU
- Prg AstroParticules
- R&T CNES

Points clés

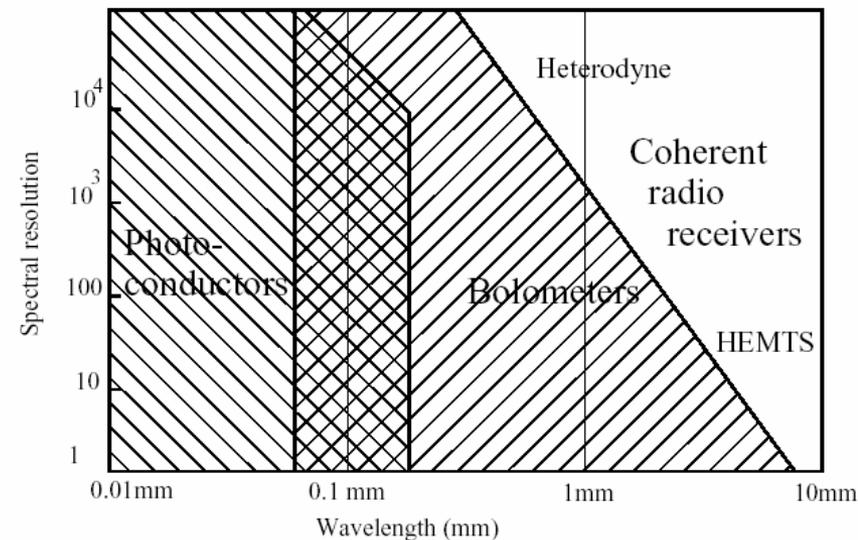
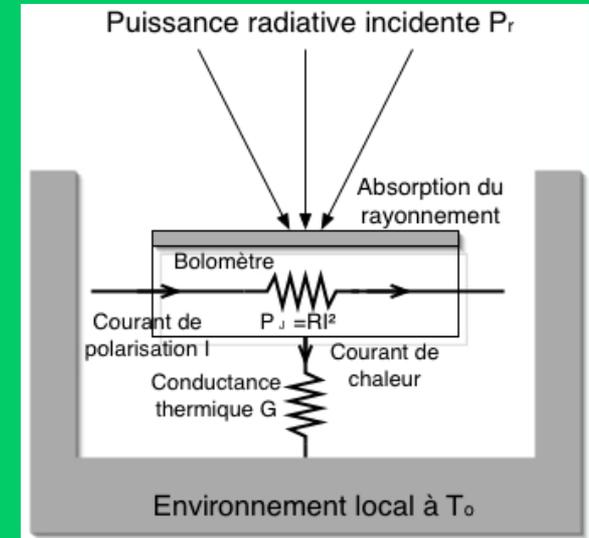
- **Technologie des détecteurs**
 - Choix du senseur thermométrique (HI, TES)
 - Microfabrication, compatibilité pour construire de grandes matrices
- **Multiplexage**
 - Version haute impédance
 - Version basse impédance
- **Démonstration**
 - Matrices ‘classiques’ (OLIMPO)
 - Matrices de bolomètres à antennes

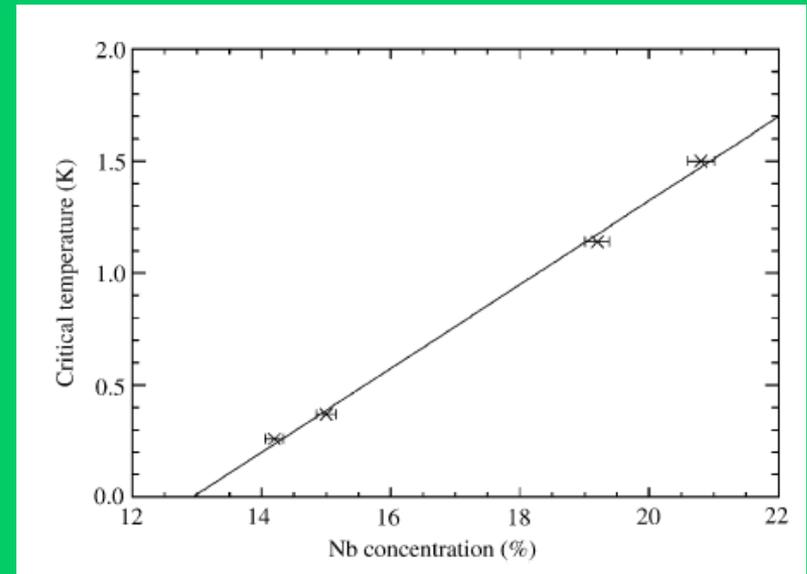
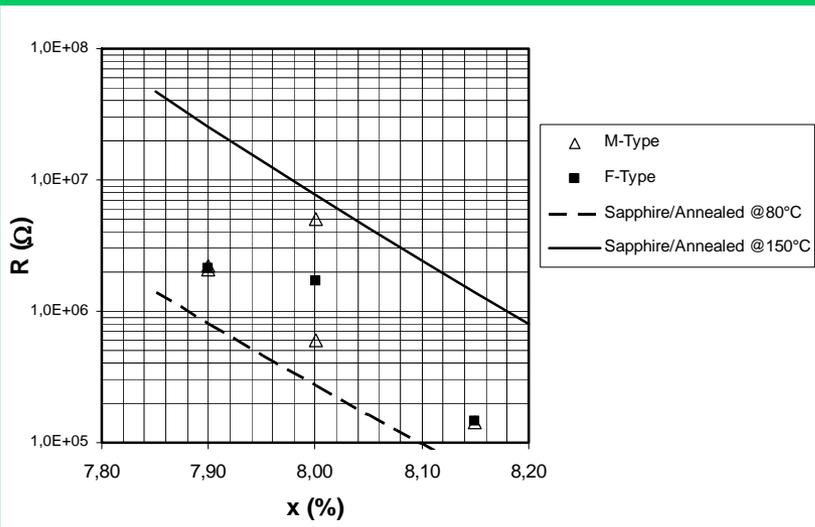
Principe du bolomètre

- Détecteur thermique

- Système macroscopique
- Mesure de l'échauffement résultant de l'absorption du rayonnement
- Thermomètre = élément résistif

- Meilleur détecteur large bande dans la gamme 200 μm -3mm





TES : critical temperature

High impedance case :

- Order influence : thermal annealing / ion irradiation
- Sizing with electron-phonon and electrical field effect
($L_{LOC} \sim 10\text{-}20 \text{ nm}$, $E_c \sim 3000\text{-}5000 \text{ V/m}$, $g_{e-ph} \sim 100 \text{ W/cm}^3/\text{K}^5$)

$$\rho(T_{el}, E) = \rho_0 \cdot \exp \left[\left(\left(\frac{T_0}{T_{el}} \right) \cdot \left(1 - \frac{E}{E_c} \right) \right)^n \right]$$

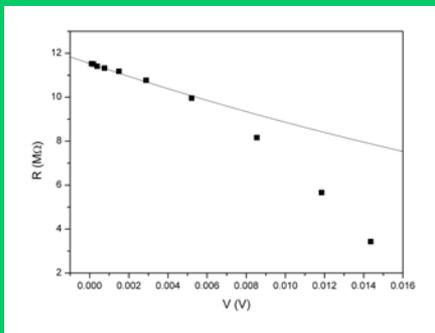
$$E_c = \frac{2 \cdot k_B \cdot T_{el}}{q \cdot L_{LOC}}$$

$$\frac{E^2}{\rho} = G_{e-ph} \cdot (T_{el}^5 - T_{ph}^5)$$

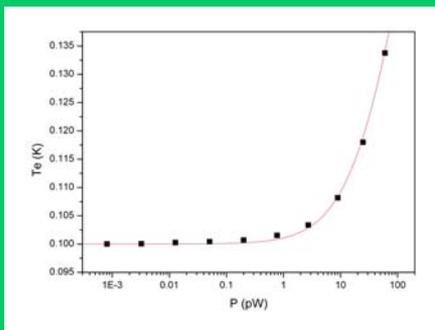


$$\Omega \geq 10 \cdot \frac{P_{el}}{G_{e-ph} \cdot T_{ph}^5}$$

$$l \geq 20 \cdot \frac{P_{el}}{I \cdot E_c}$$



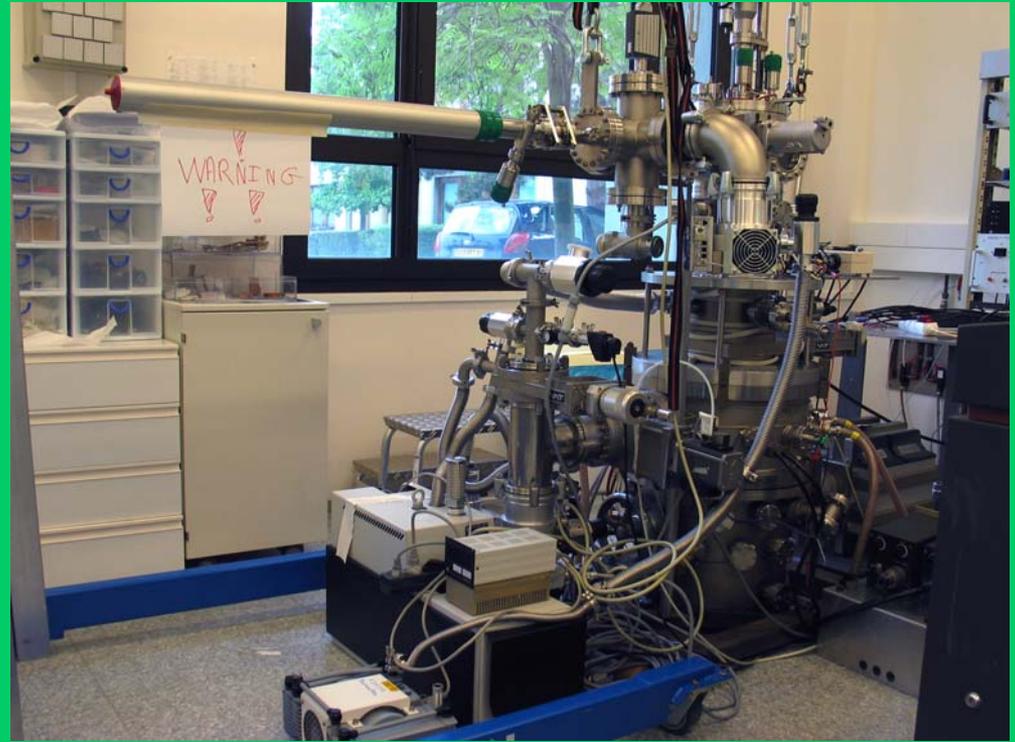
Electrical field effect



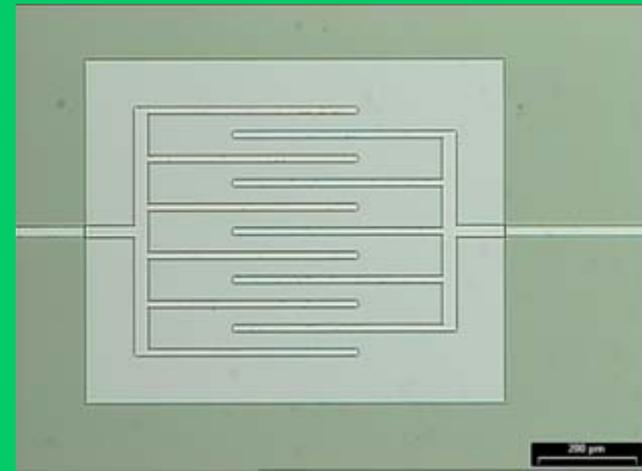
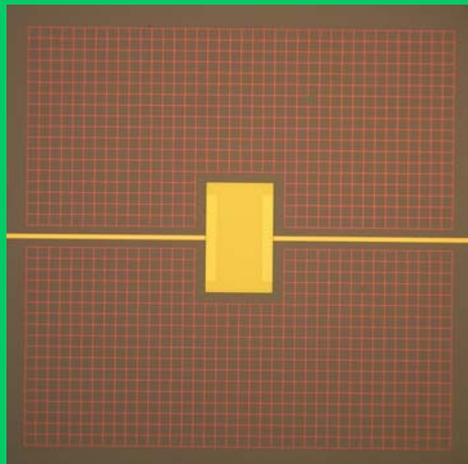
E-field + e-ph coupling

NbSi alloy fabrication

- ❑ Co-evaporation of pure Nb and Si
- ❑ Sample rotation at 3 RPM
- ❑ Evaporation rate 3 \AA s^{-1}
- ❑ Composition reproducibility $< 0.1\%$
- ❑ Sample size :
2 inches – 4 inches
- ❑ Thermal control

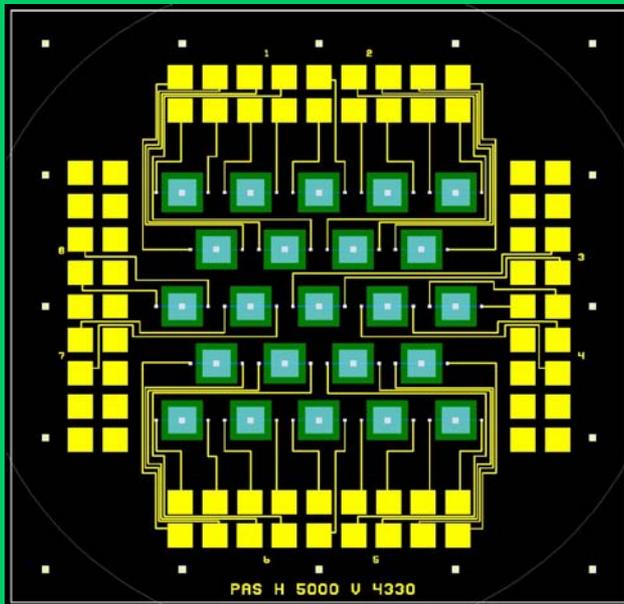


NbSi co-evaporation at CSNSM / Orsay



- High impedance NbSi sensor
(200 μm X 400 μm X 100 nm)
- Grid absorber 2X2 mm² (Z_C = 377 Ω)

TES NbSi sensor
(x = 15%, T_c = 335 mK , R_n ~0.8Ω)



- ❑ Classical architecture on full or structured LS-Si₃N₄ membranes
- ❑ Deep etching process developed at IEF / Orsay or standard wet etching can be used (KOH, TMH)
- ❑ NbSi thermometers :
 - Anderson insulator for Nb < 9%
 - TES for Nb > 12% (adj. T_c 50 mK – 1K)

23 Pixels prototype array, 45 X 45 mm²

Echantillons OLIMPO

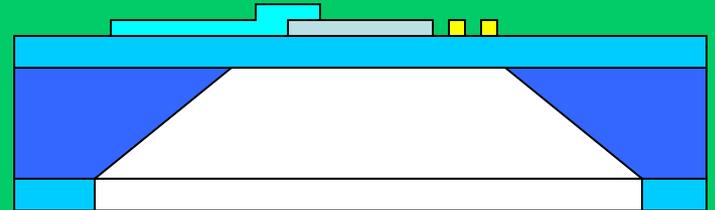
Membrane SiN LS Lionix ou IEF

Litho NbSi + électrodes

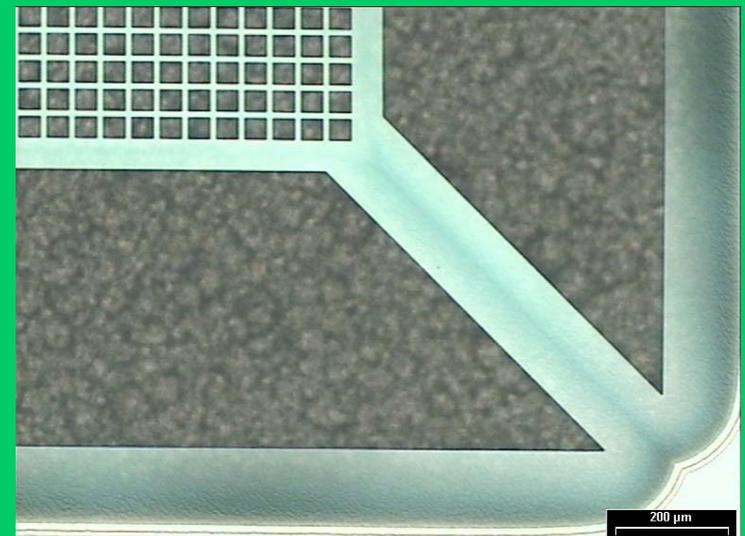
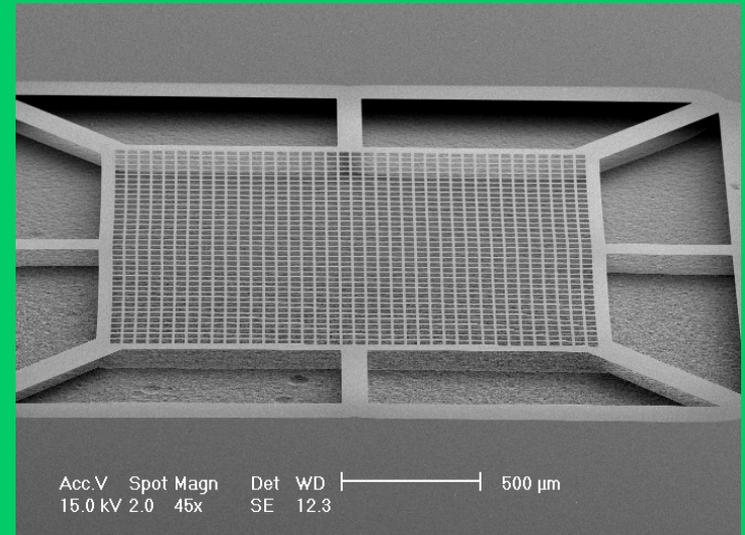
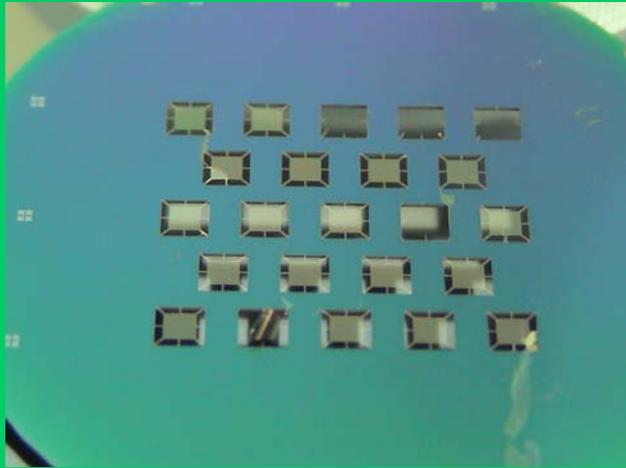
Litho Grille Absorbante

Gravure humide

23 Pixels Membranes pleines

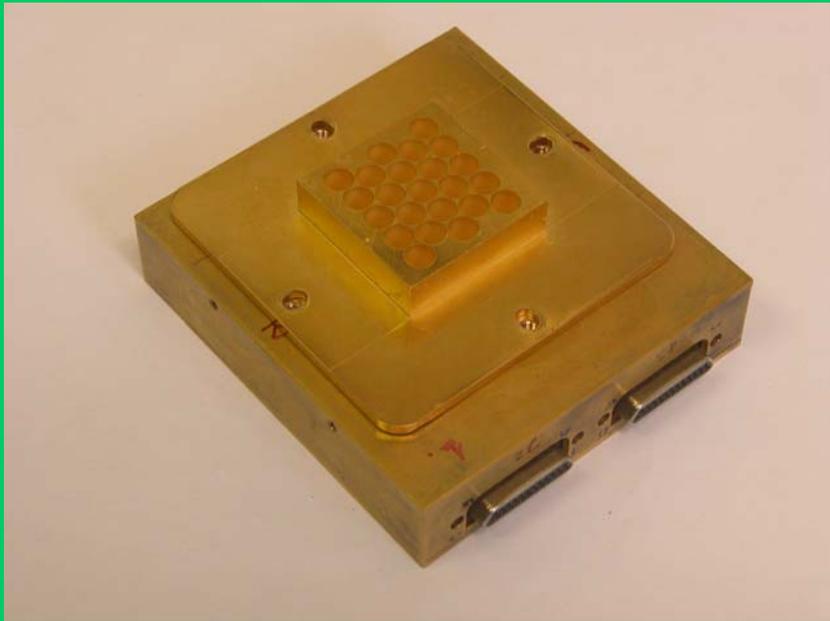


Structuration des membranes

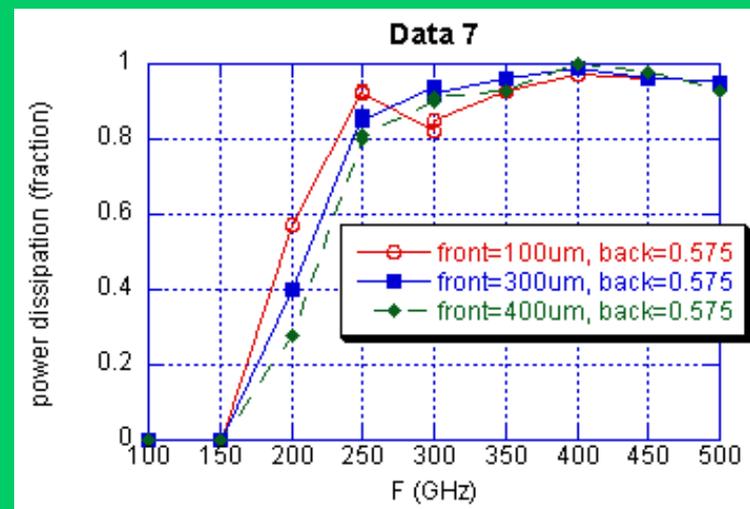
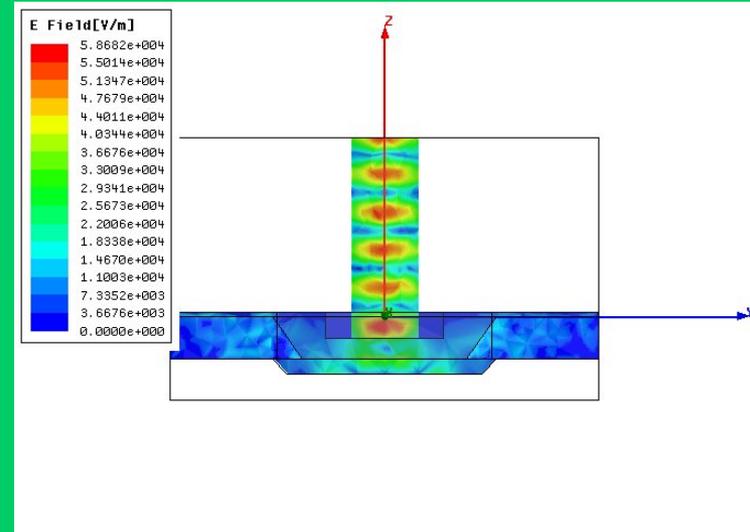


- RIE + gravure profonde
- gravure XeF_2 (phase gazeuse)

Matrices OLIMPO

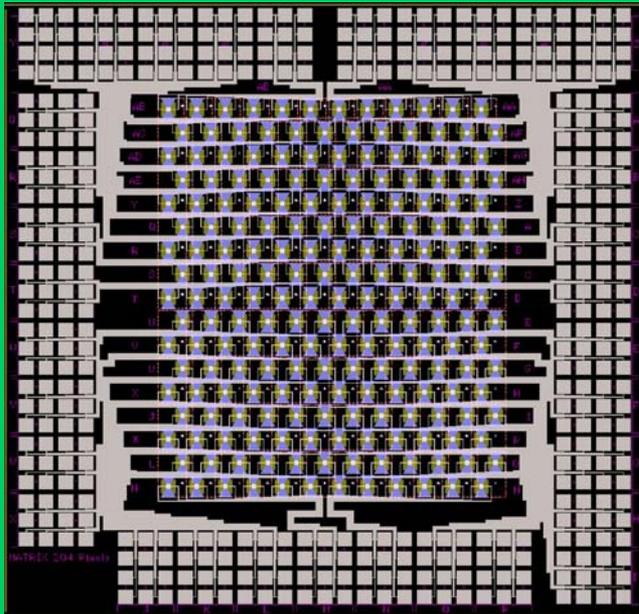
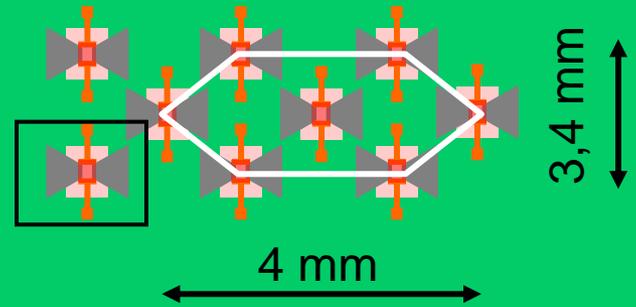


- Small prototype arrays of 23 pixels @ 300mK
- Frequency channels 500-600 GHz and 380-440 GHz (TBC)
- Resonant cavity design
- Backshort / front distances $\lambda/4$ (2nd wafer)
- Crosstalk < 1%

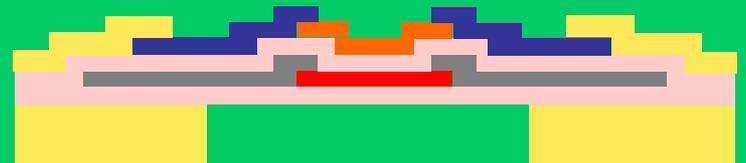
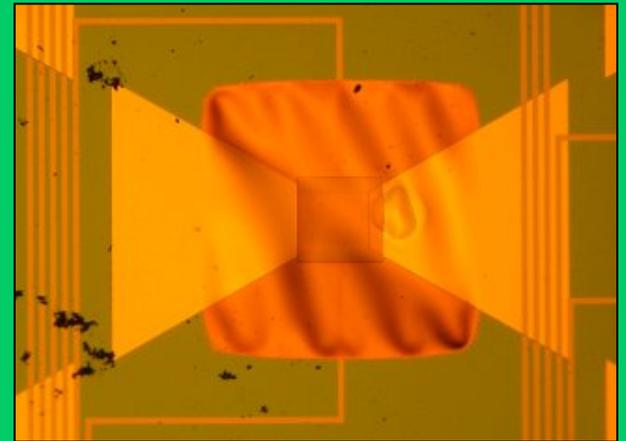


Matrice de bolomètres à antenne

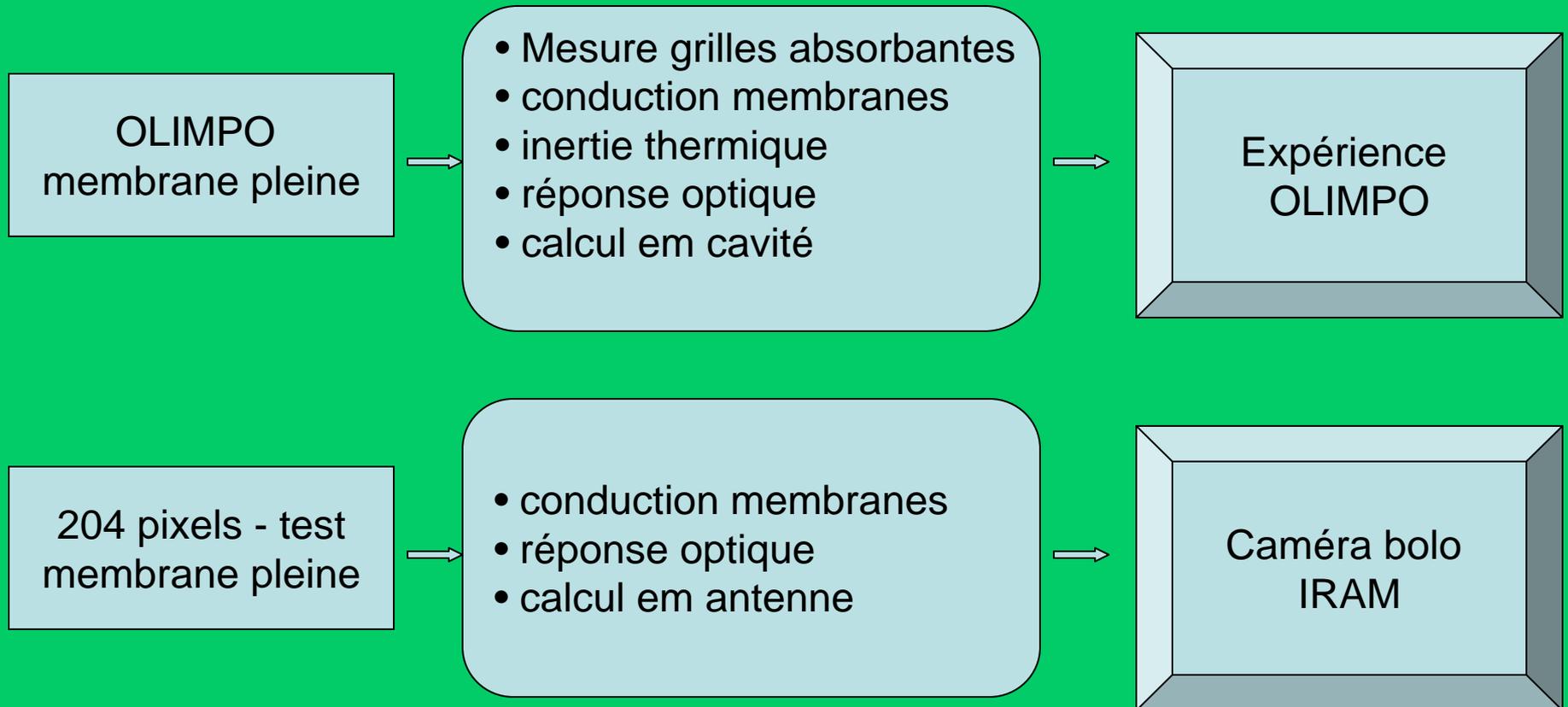
- Planar antenna array for imaging in millimeter wavelength
- optical cryostat with dilution developed for IRAM 30m telescope
- versatile fabrication process for future applications :
 - Polarisation sensitive detectors
 - Integrated frequency selection on the pixels



204 pixels test array

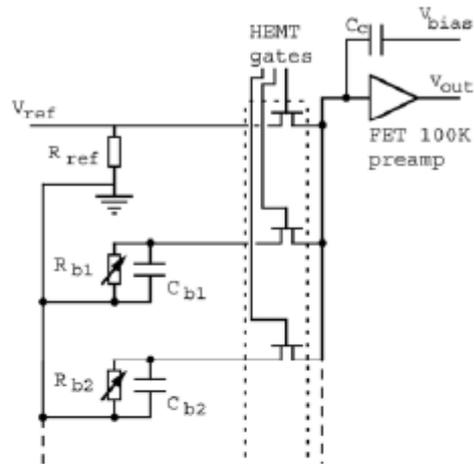


Logique de validation / application

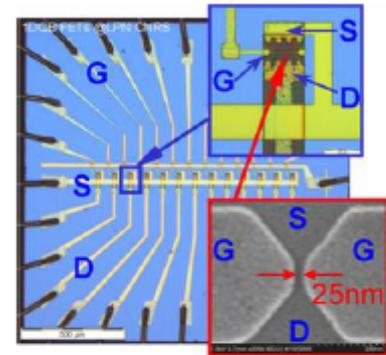


Multiplexeur haute impedance

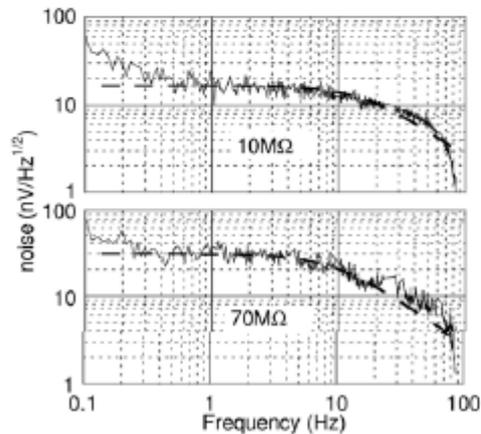
Principal constituents and operating mode



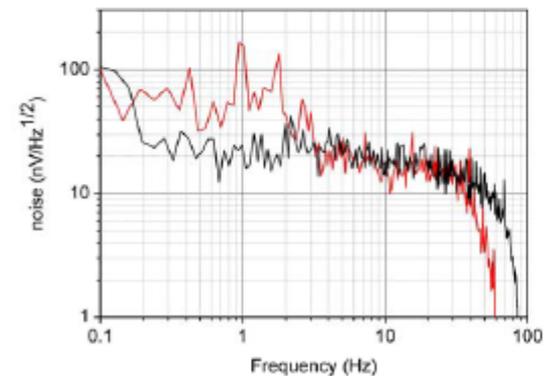
Quantum Point Contact High Electron Mobility Transistors (QPC-HEMTs)



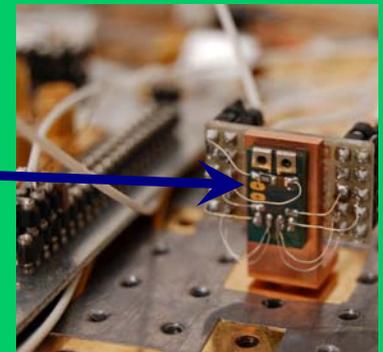
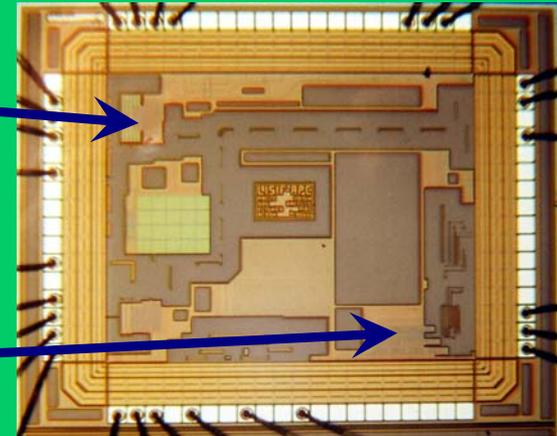
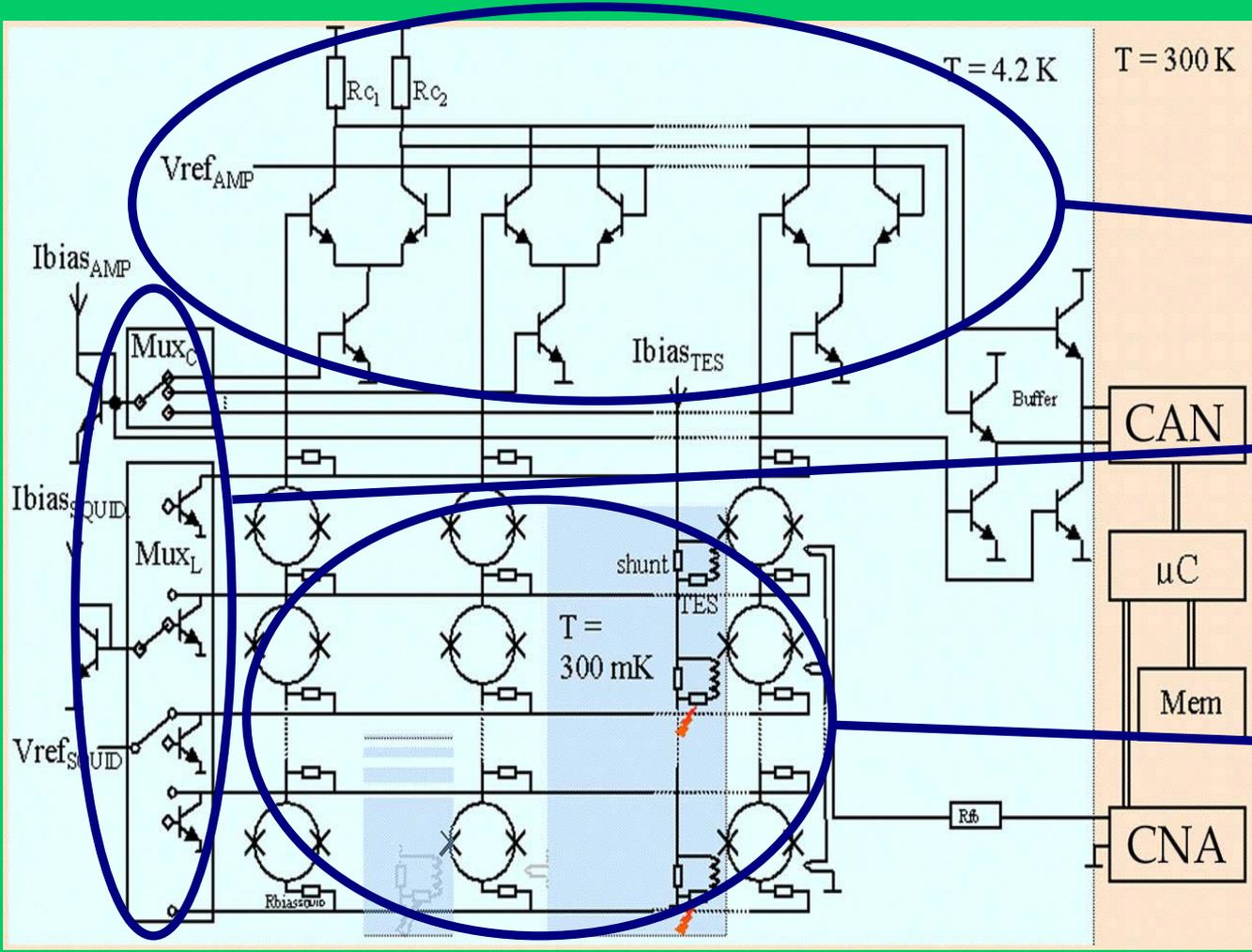
Results



Work in progress



Multiplexeur TES (APC / Lisif)

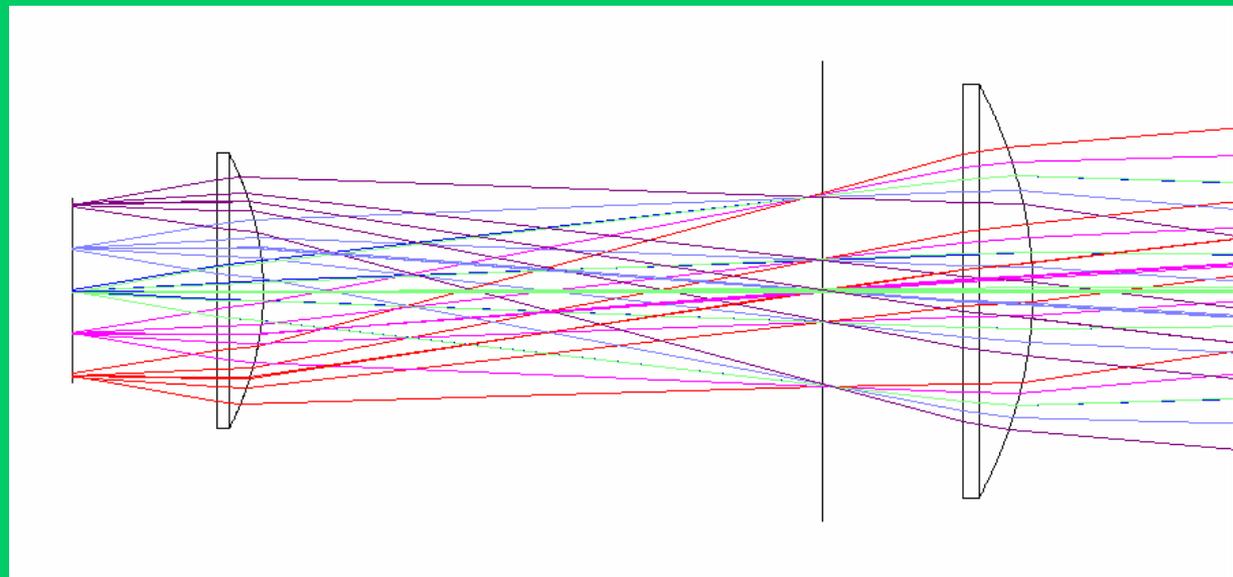
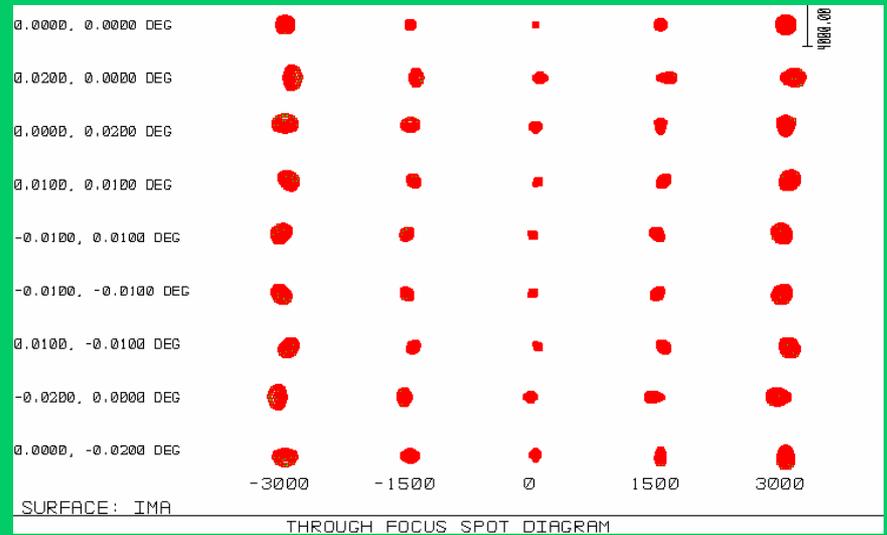
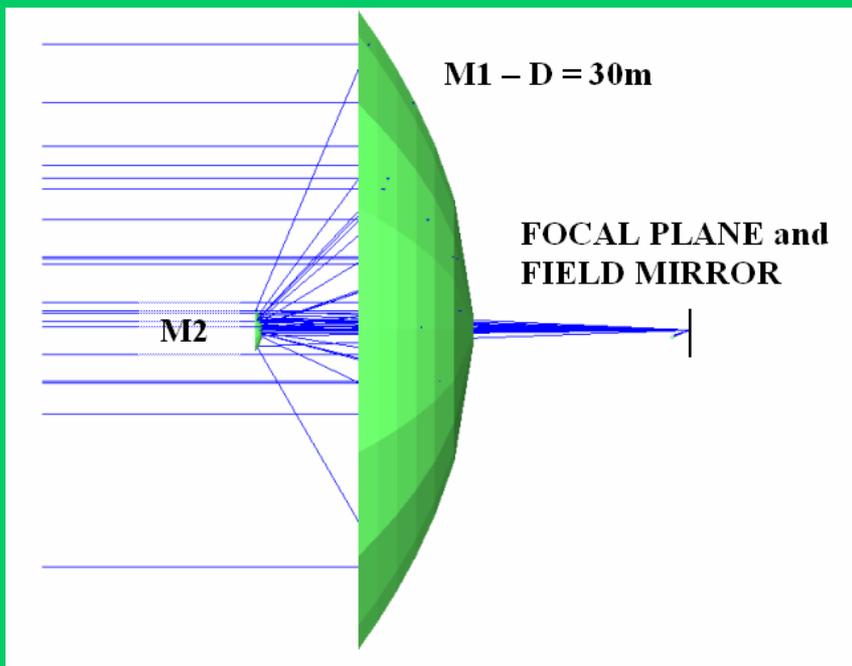


Bilan provisoire

- Mise en place des compétences (conception, fabrication des matrices)
- Moyens de fabrication disponible au Csnsm / IEF
- Moyens de validation (MPI, Caméra bolo)
- Méthodes de multiplexage
- ***Détecteurs pour Olimpo (vol été 2008)***
- ***Matrice + multiplexeur TES***
- ***Démonstration d'une matrice de bolomètres à antenne***

Perpectives

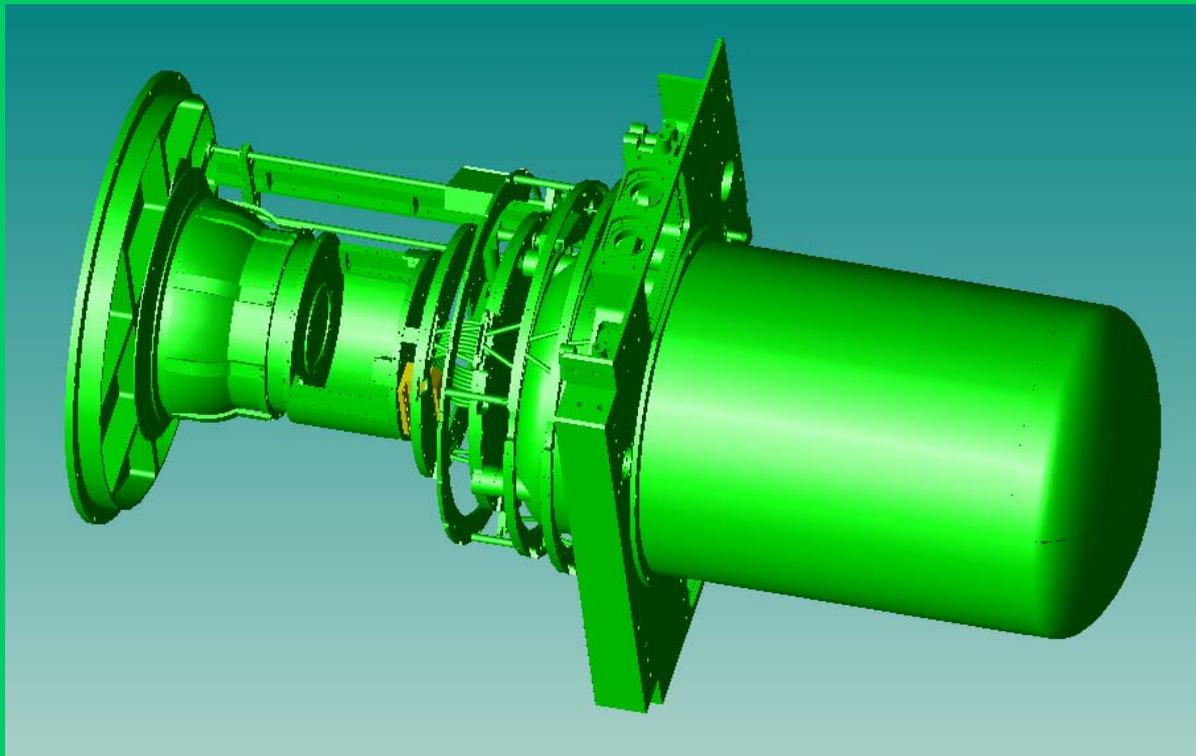
- Préparation d'expériences pour la mesure de la polarisation du CMB (voir M.Piat)
- Instrument bolométrique pour IRAM 30m (CEA / CNRS) (2012)
- Collaboration européenne pour le développement de KIDs (SRON, Cardiff)
- Projet d'investissements à l'IEF (Minerve) pour la production de composants :
 - Dépôts de matériaux supra
 - NbSi sur wafer 4 pouces
 - Gravure XeF₂ des membranes

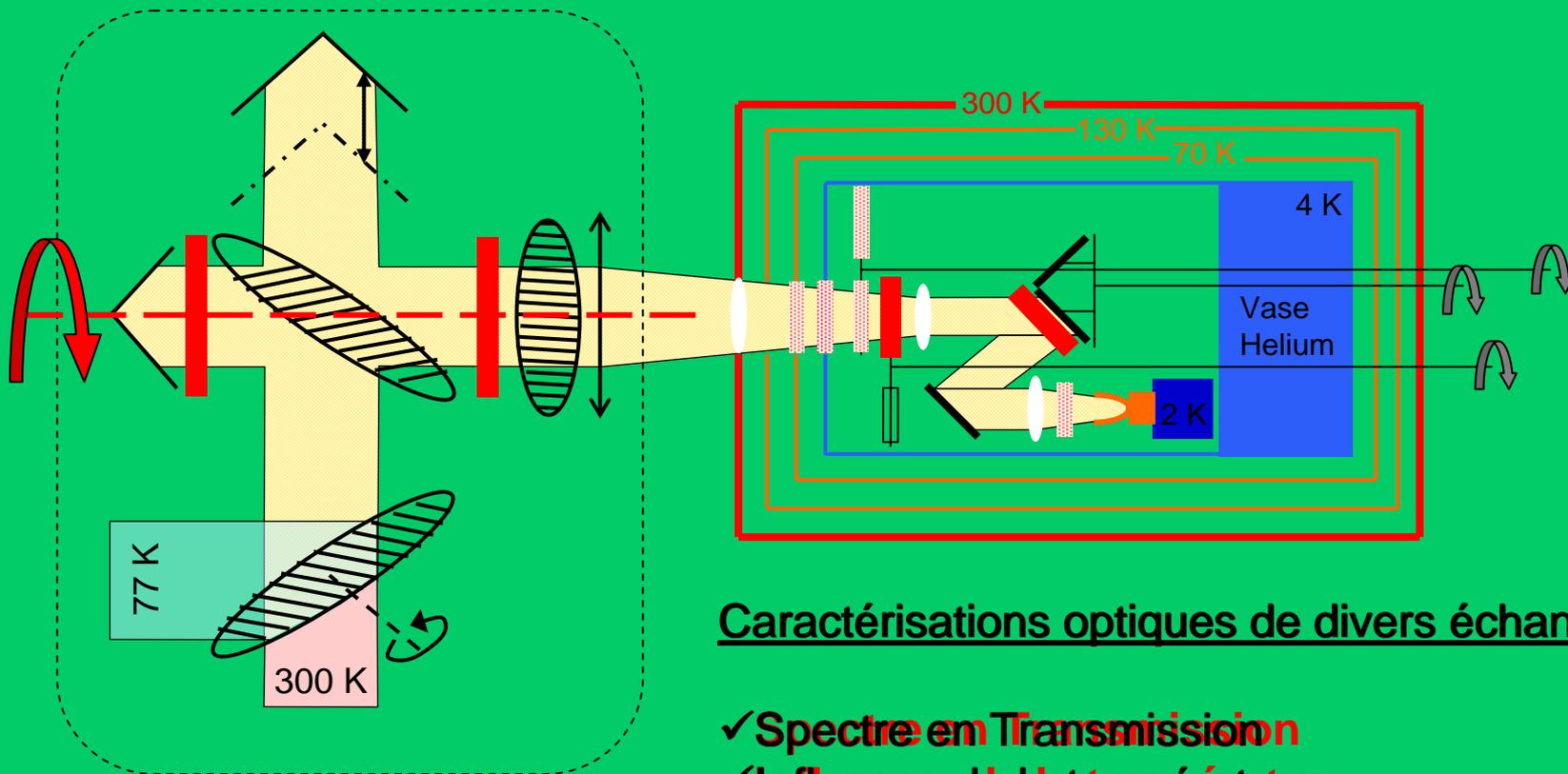


Caméra / Optique 'télécentrique', 2 lentilles HDPE

Cryostat optique :

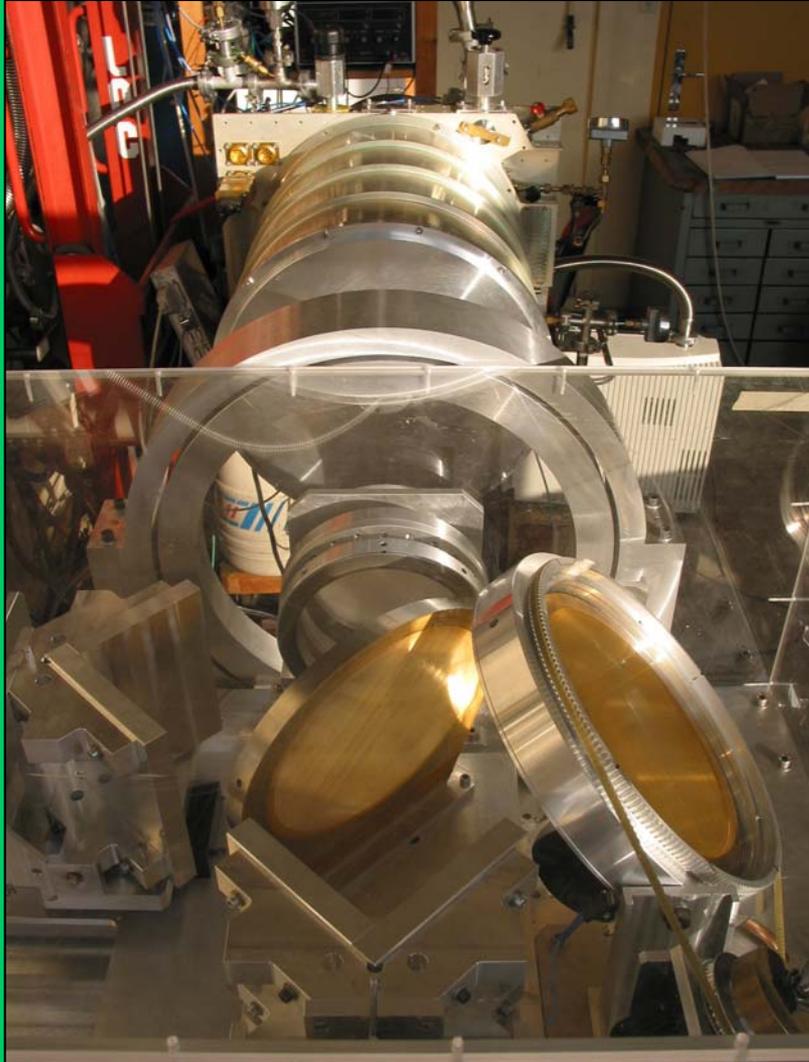
- version avec bain d'hélium
- version avec Pulse-tube
- complètement opérable à distance (Internet)





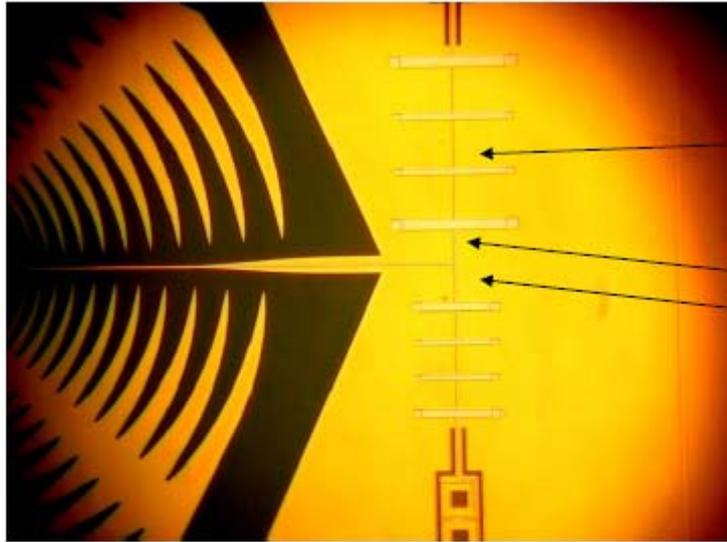
Caractérisations optiques de divers échantillons:

- ✓ Spectre en Transmission
- ✓ Influence de la température
- ✓ Spectre en absorption
- ✓ Influence de la polarisation
- ✓ Indice optique
- ✓ épaisseur



- ✓ Etendue spectrale: **50 – 3000 GHz**
- ✓ Résolution: **0,6 GHz**
- ✓ Signal sur Bruit: **6000**
- ✓ Durée pour obtenir un spectre: **2 min**

150-220 GHz Diplexer



- 4 bolometers
- 4-pole $\lambda/4$ shorted-stub filters define bands
- Impedance & length of input lines chosen so one filter looks open in the other's band.

IE3D Simulations

