AMSTAR+

Advanced Mm and Sub-mm Techniques for Astronomical Receivers

Large Format FPAs of heterodyne receivers at mm/sub-mm wavelengths

RadioNet FP7 2nd Engineering Forum Workshop
Bonn, November 16/17th 2009

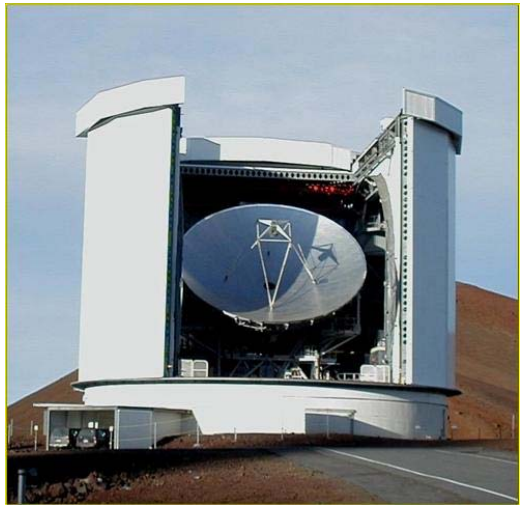
The AMSTAR+ Community

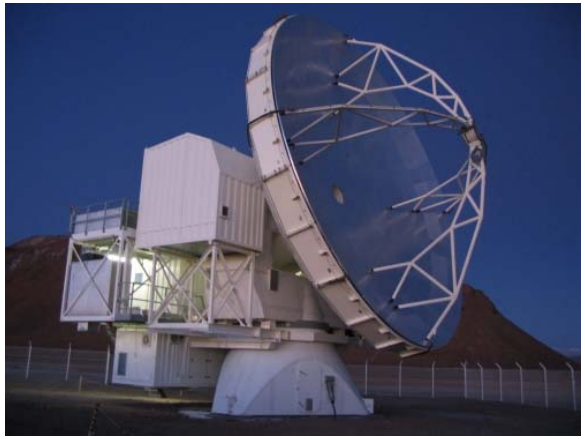
- It includes the **FP6-AMSTAR** community (9 labs: IRAM, RAL, GARD-Chalmers, SRON, TUDelft, FG-IGN, ObsParis, KOSMA, MPIfR) **+ 3** more participating labs (IAF + UOXF + OA Cagliari) **+** UCAM as an observer .

- In total, it involves in 7 countries **almost ALL European laboratories working on mm/sub-mm technology for astronomical research**

Outstanding Facilities:

European mm/sub-mm telescopes



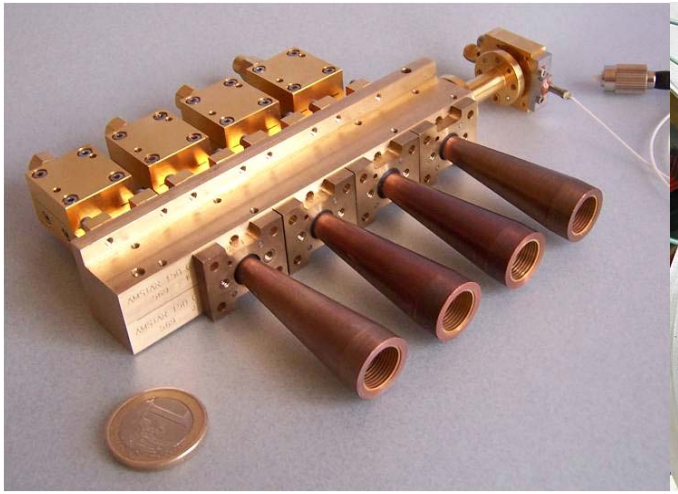


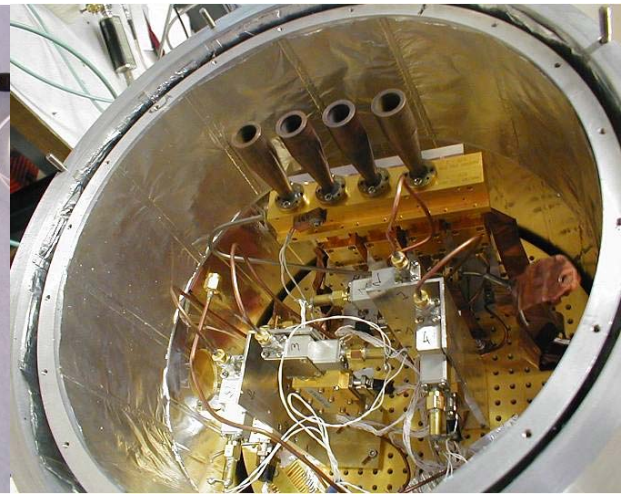
Critical part: Receiver Front ends

- No industrial solution available
- Problem of low noise + large IF band was very successfully addressed by FP6-AMSTAR from 80 GHz to 1.4 THz for single pixel heterodyne receivers (several devices with world-record performances, 90 publications, 4 instruments installed on telescopes).
- Question of Focal plane array heterodyne receivers only touched in FP6 (e.g. WP 2.1.2 & 2.4.1). **Yet this question is crucial for imaging efficiency**.

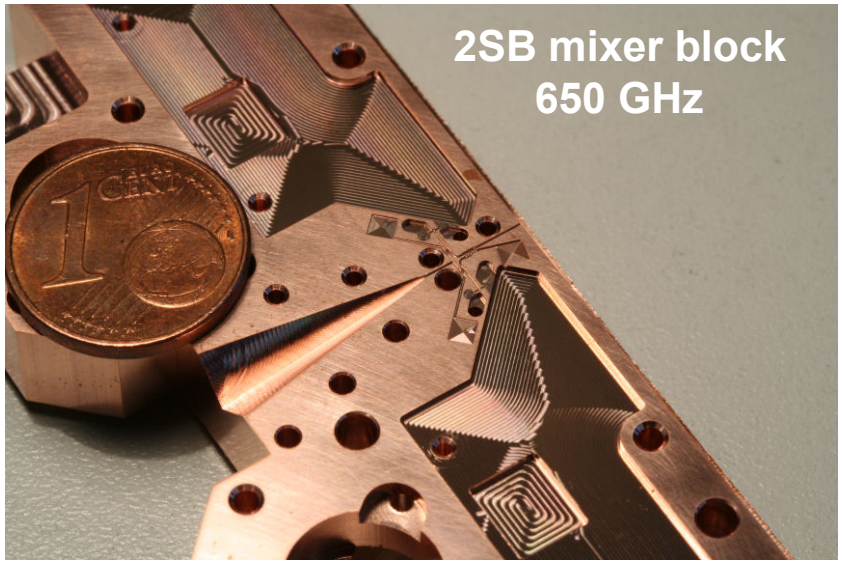
FP6 AMSTAR WP.2.4.1: Array of 2 mm SIS mixer receivers driven by photonic LOs

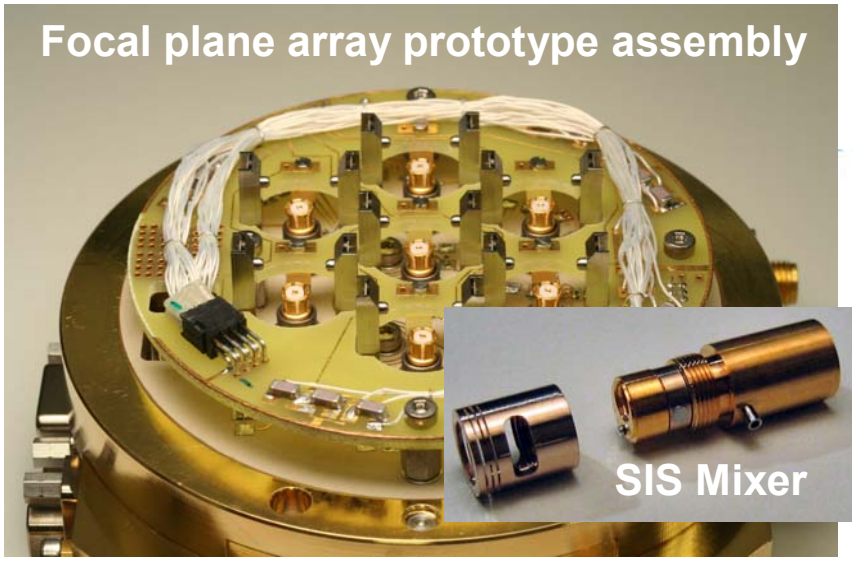
(IRAM-RAL)



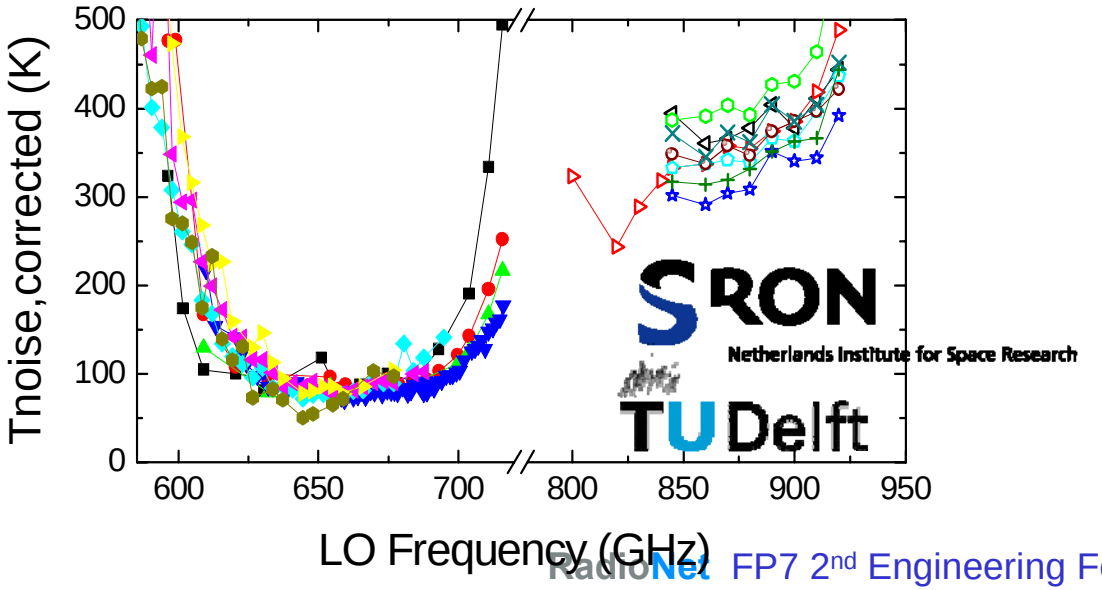


Four pixel-RF module, comprising corrugated horns (front), LO coupler (middle), DSB mixer blocks (left rear) and photomixer (rear right).
Right: 4-pixel module inserted in the demonstration cryostat





AMSTAR WP 2.1.3→ CHAMP



Goals of the new JRA AMSTAR+

Develop State of the Art Methodologies for the construction of:

1. **Large format** mm and sub-mm **focal plane Heterodyne arrays**
2. Extension of technology **deep into the THz region,** the new frontier in astronomy

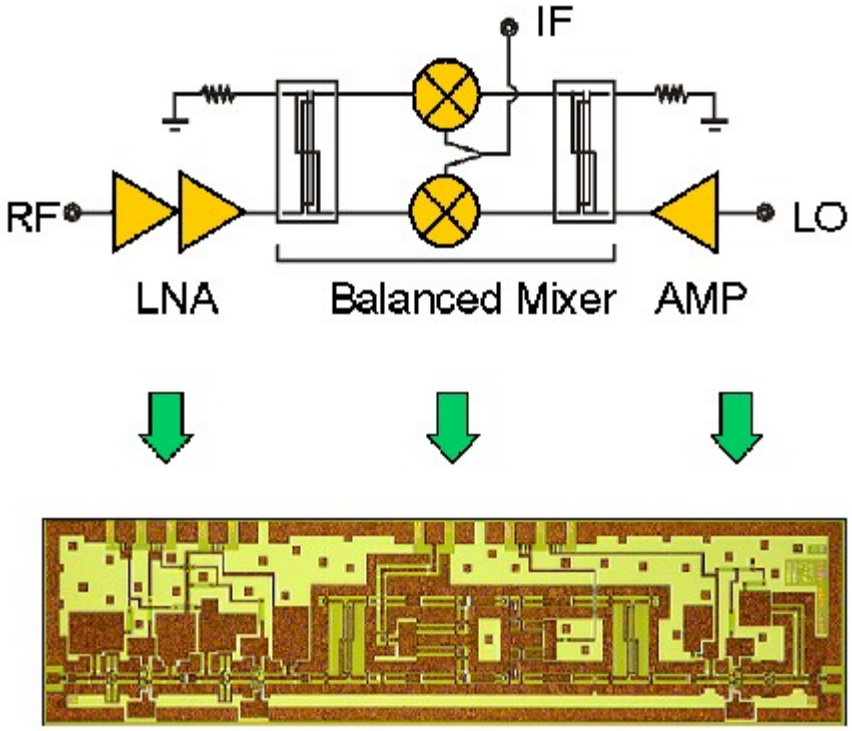
What differentiates heterodyne FPAs at mm/submm wavelengths from single-pixel receivers?

- In addition to ***low noise*** and ***wide IF band***, they ask for ***compactness***, ***low fabrication cost*** and ***high reproducibility, easy integration***.
- Moreover, stringent constrains exist on ***LO power*** generation and distribution, **IF amplification & matching, cryogenic cooling**.
- Without doubt, these requirements present new and demanding technical challenges. **Novel technical solutions will need to be developed as part of the JRA.**

Proposed innovative solutions

- Develop a highly integrated W-band cryogenic prototype heterodyne pixel using the low cost IAF **metamorphic HEMT** process **on GaAs**
- Develop **integrated on-chip** mixer elements (SIS mixers, LO injection system, antennas)
- **Integrate** the IF **LNA** to mixer (no circulator)
- Develop novel solutions for **LO generation and distribution** (e.g. photonic mixer)

Example of innovative solutions: Ia



chip-size: 1 x 4 mm^2

Room temperature W-band receiver MMIC designed with IAF's metamorphic HEMT process. Long term goal of WP1 is to enable such designs at cryogenic temperatures.

Example of innovative solutions: Ib

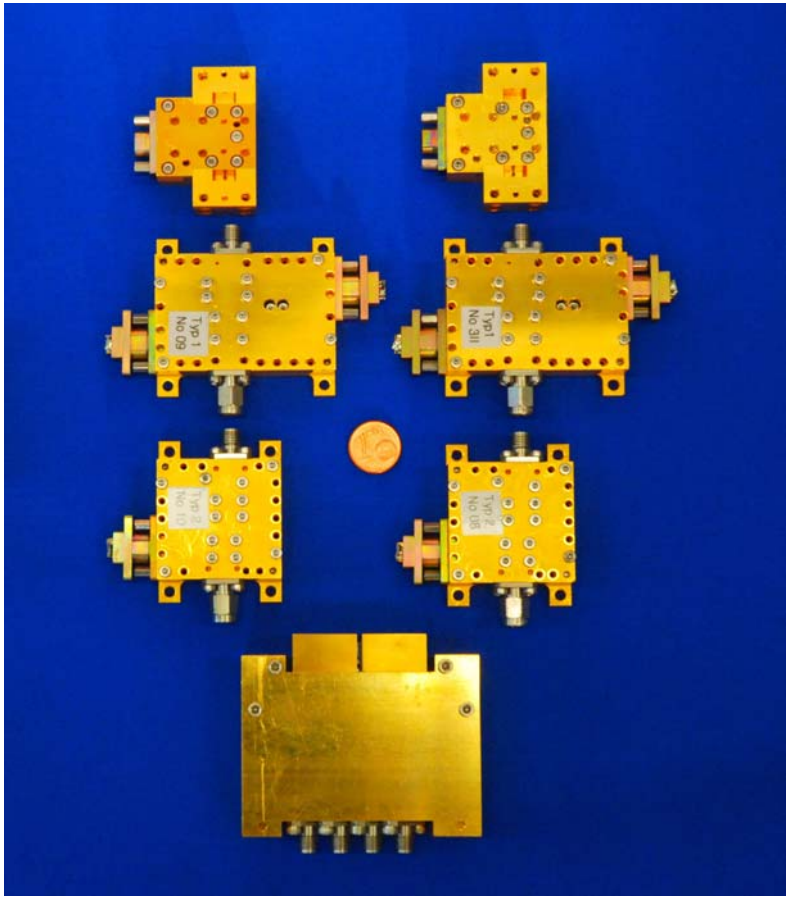
Comparison: **2 polarimeter RF channels for 1 horn at different levels of integration**

Cryogenic LNA
(2 MMICs)

300K Module 1
(3 MMICs)

300K Module 2
(2 MMICs)

Polarimeter
at **300K**

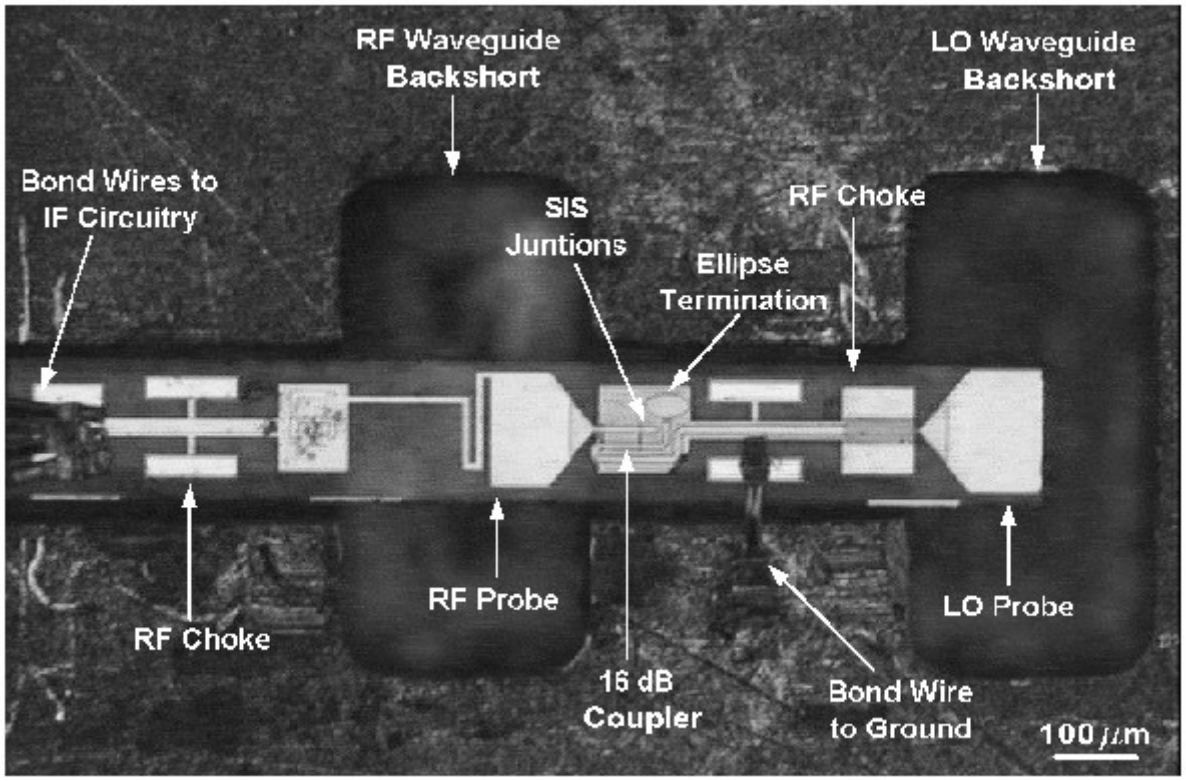


8 MMICs

40GHz **cryogenic** module designed
by JPL / QUIET collaboration
for QUIET CMB experiment
in Chile

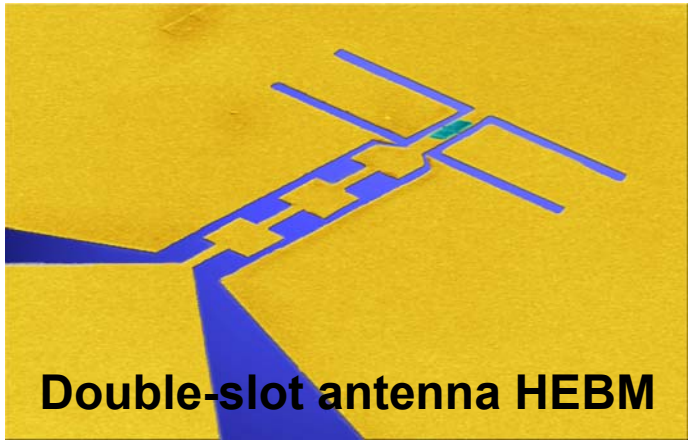
RF–modules of MPIfR 9mm Rx

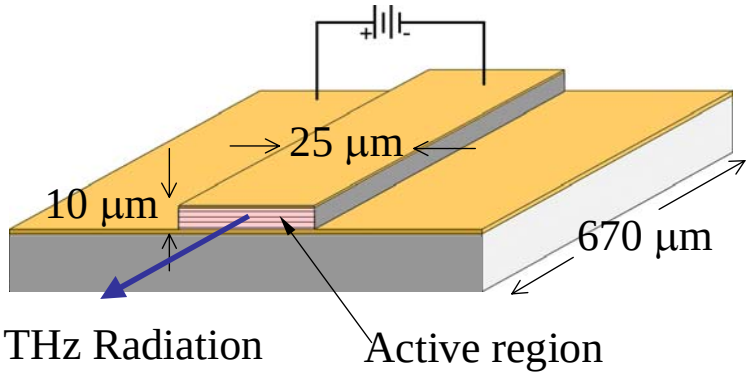
Example of innovative solutions: II



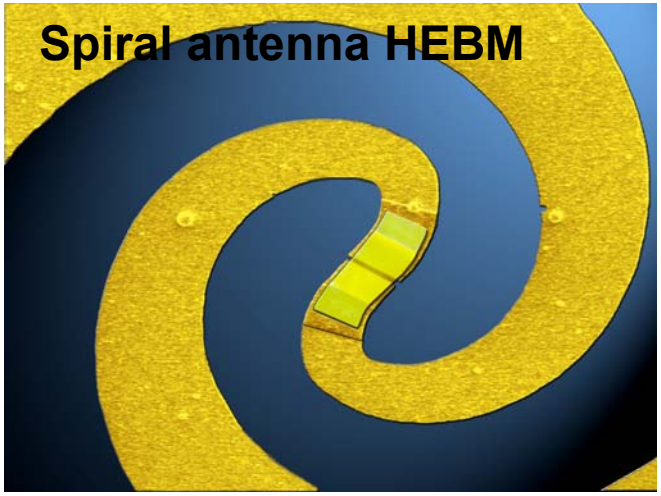
Mixer chip developed in AMSTAR WP 2.1.2 (OSO) with LO injection circuit integrated on chip

Example of innovative solutions: III

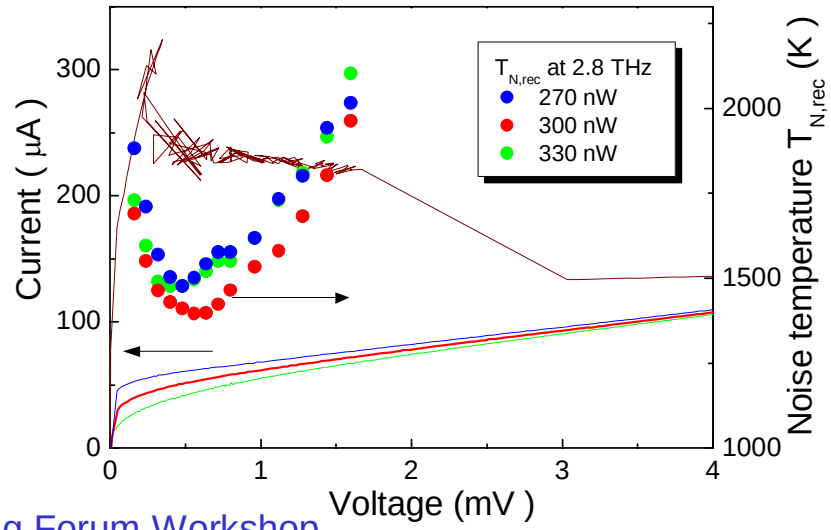




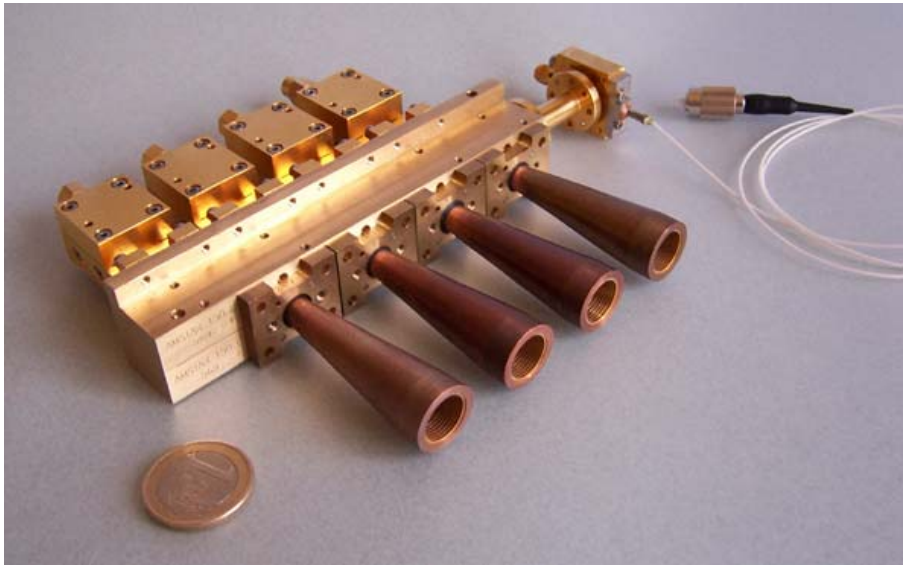
Quantum Cascade Laser (QCL)

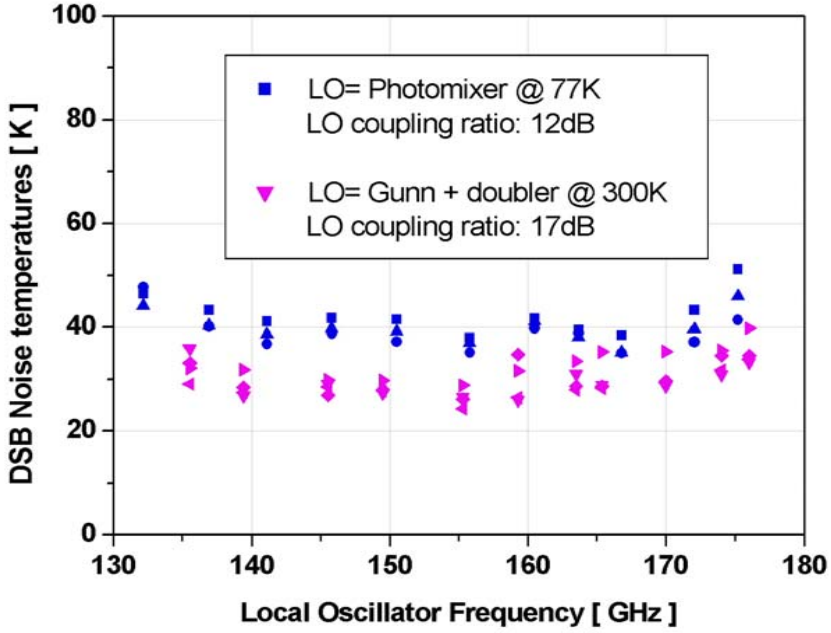


HEBM with QCL as LO



Example of innovative solutions: IV





Mixers driven by a Photonic Local Oscillator WP 2.4.1 (RAL-IRAM)

4 Tasks of AMSTAR+

1. W-band prototype array module using metamorphic HEMT technology (MPIfR, IAF, IRAM, OA-Cagliari)
2. Advanced receiver pixels and LOs for large FPAs in the near mm domain (IRAM, RAL, FG-IGN)
3. Sub-mm FPAs (SRON, TuD, GARD, FG-IGN, KOSMA, Oxford)
4. Low noise mixers for FPAs in the 1-2 THz range – **HEBs *and* SIS** (TuD, SRON, GARD, ObsParis, KOSMA)