The Medium and High Frequency Telescopes of LiteBIRD

## Team

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=> 211 researchers

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MHFT Instruments

The European collaboration is responsible of the sub-K stage of the cryo-chain, and of the Mid- and High-Frequency Telescopes (MHFT), covering a large frequency range from 89 to 224 Hz and 166 to 448GHz, respectively. Both refractive telescopes are cooled down at 4.8K, with two half-wave plates rotating continuously. The two focal planes, cooled down at 100mK, consist, respectively, in 2074 and 1324 detectors delivered by the US.

Overview of the MFT and HFT telescopes

Frequency bands

The cryocahin design is based on passive cooling and mechanical coolers. A 4K stage is cooled with a ^{4}He Joule Thomson cooler from JAXA, precooled by a Stirling coolers. The current baseline of the sub-5K stage is based on a Multi-stage ADR (Adiabatic Demagnetization Refrigerator) which will be optimized to provide continuous cooling at 1.8 K, 300 mK and 100 mK. 7 ADR stages provided by NASA and CEA/CNES are required.

Overview of the cryo-chain
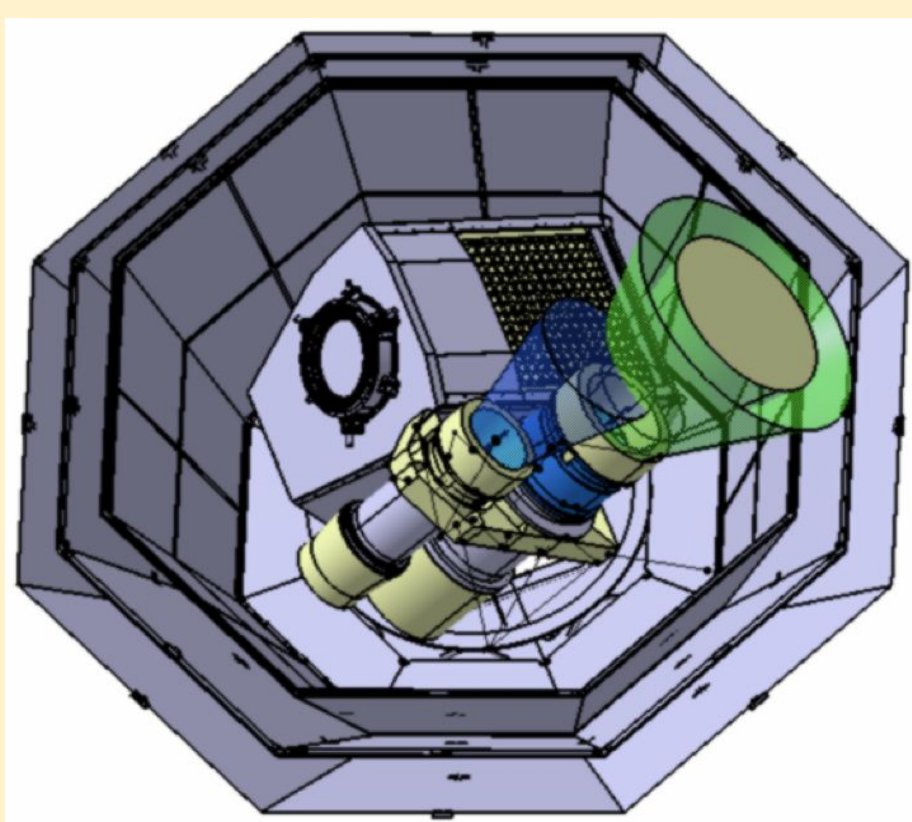
Mechanical Structure

Cooled down to 5 K a thermoelastic study is performed to estimate the thermal contractions and reach the constraints on the optical alignements. Made of Aluminum, the mechanical structure of the telescopes ensure the thermal link between the MHFT's subsystems anf the cryo-chain.
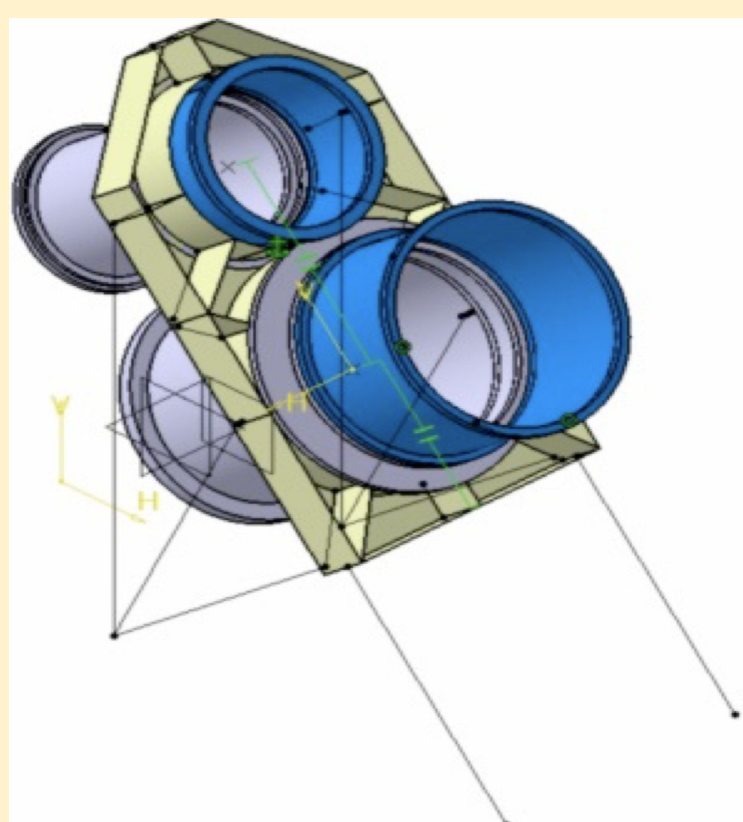
Mechanical structure
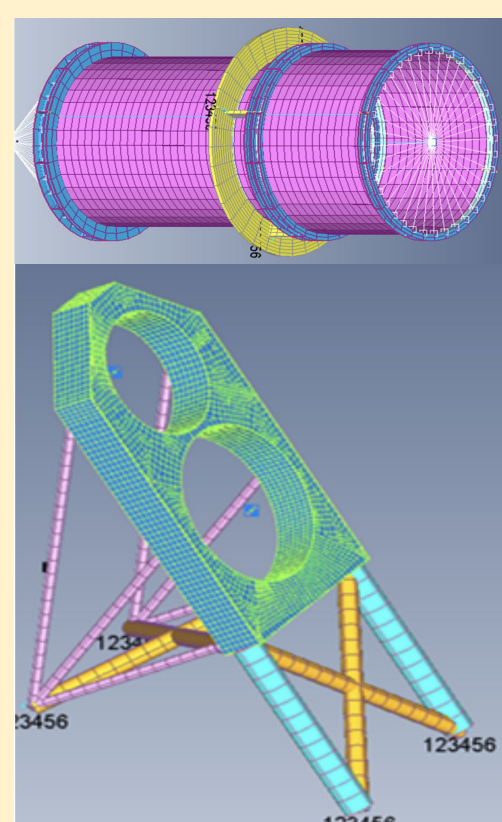
Finite Element Modeling

MHFT implantation on the PLM

HWP rotator

The HWP diameters of MFT and HFT are 320mm and 220mm, respectively. The *Sapienza* proposal is to have two scaled polarization modulators with the HWP mounted on a nearly frictionless bearing. This is obtained via the magnetic levitation of a permanent magnet rotor ring (cream grey) above a stator ring hosting an array of super-conducting bulks (black). The magnet ring is sandwiched between an Aluminum grooved ring, coupled with 3 actuators (and 3 launch locks), and an encoder ring.
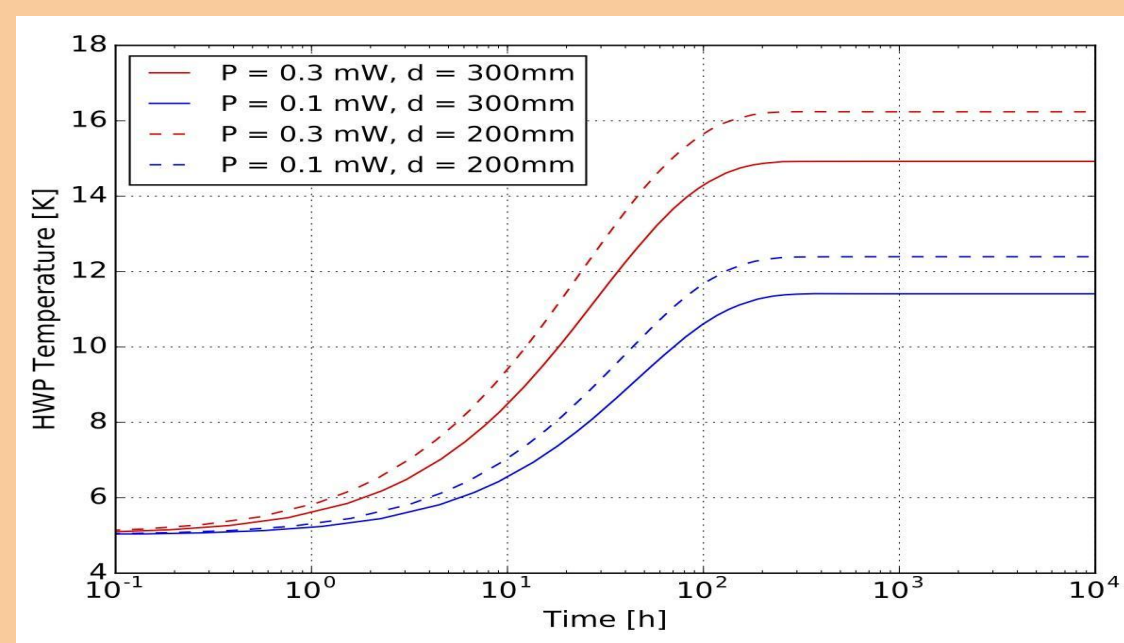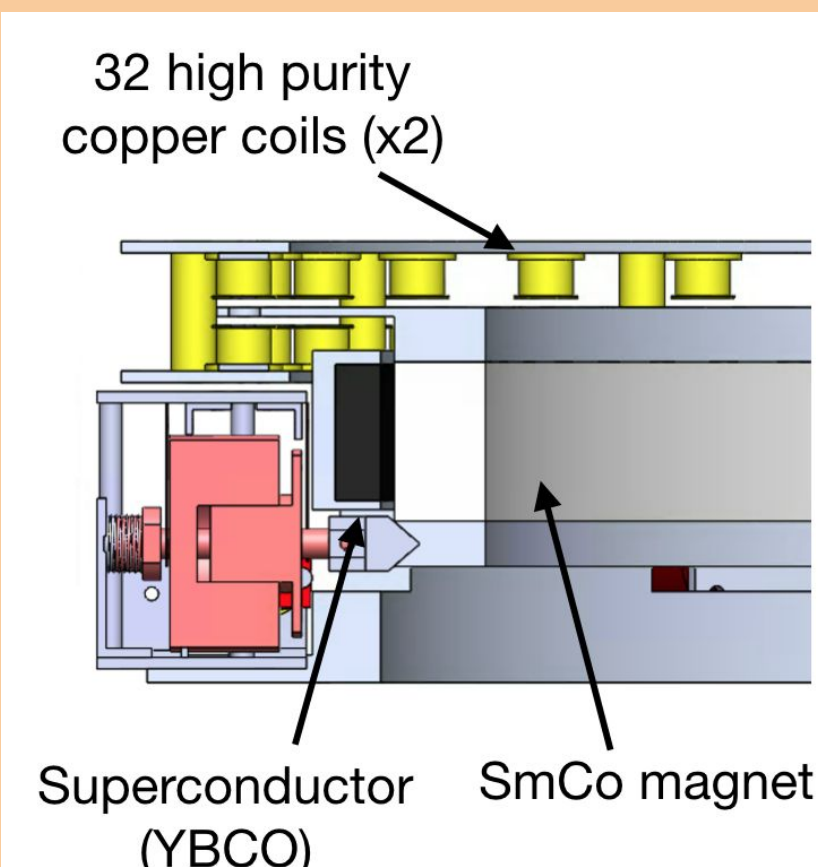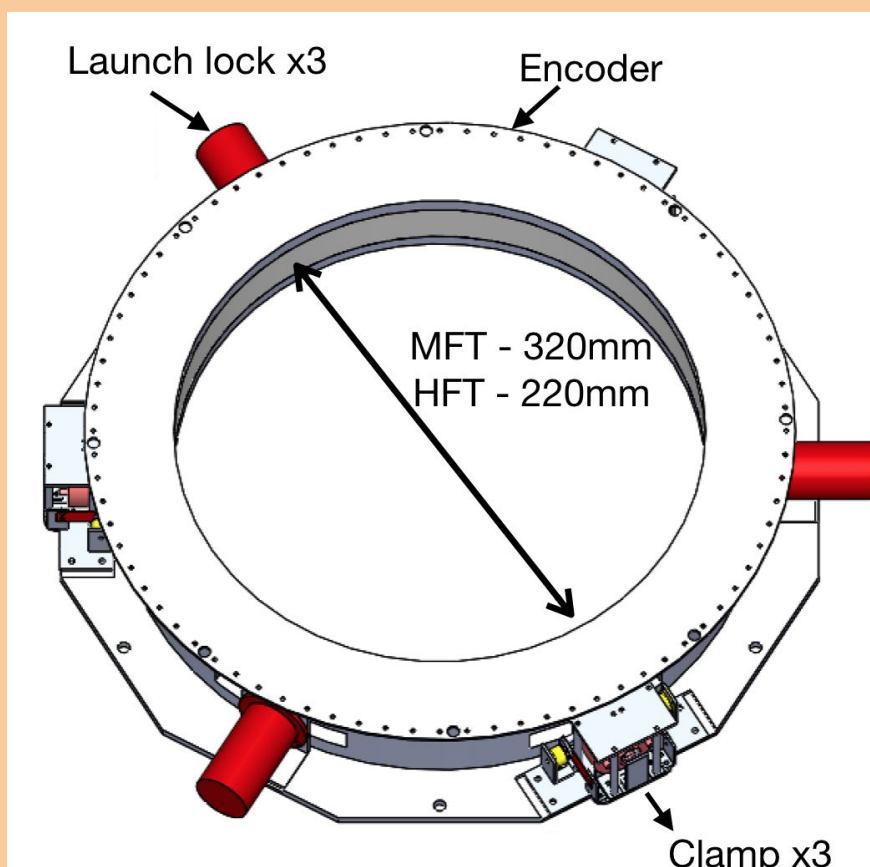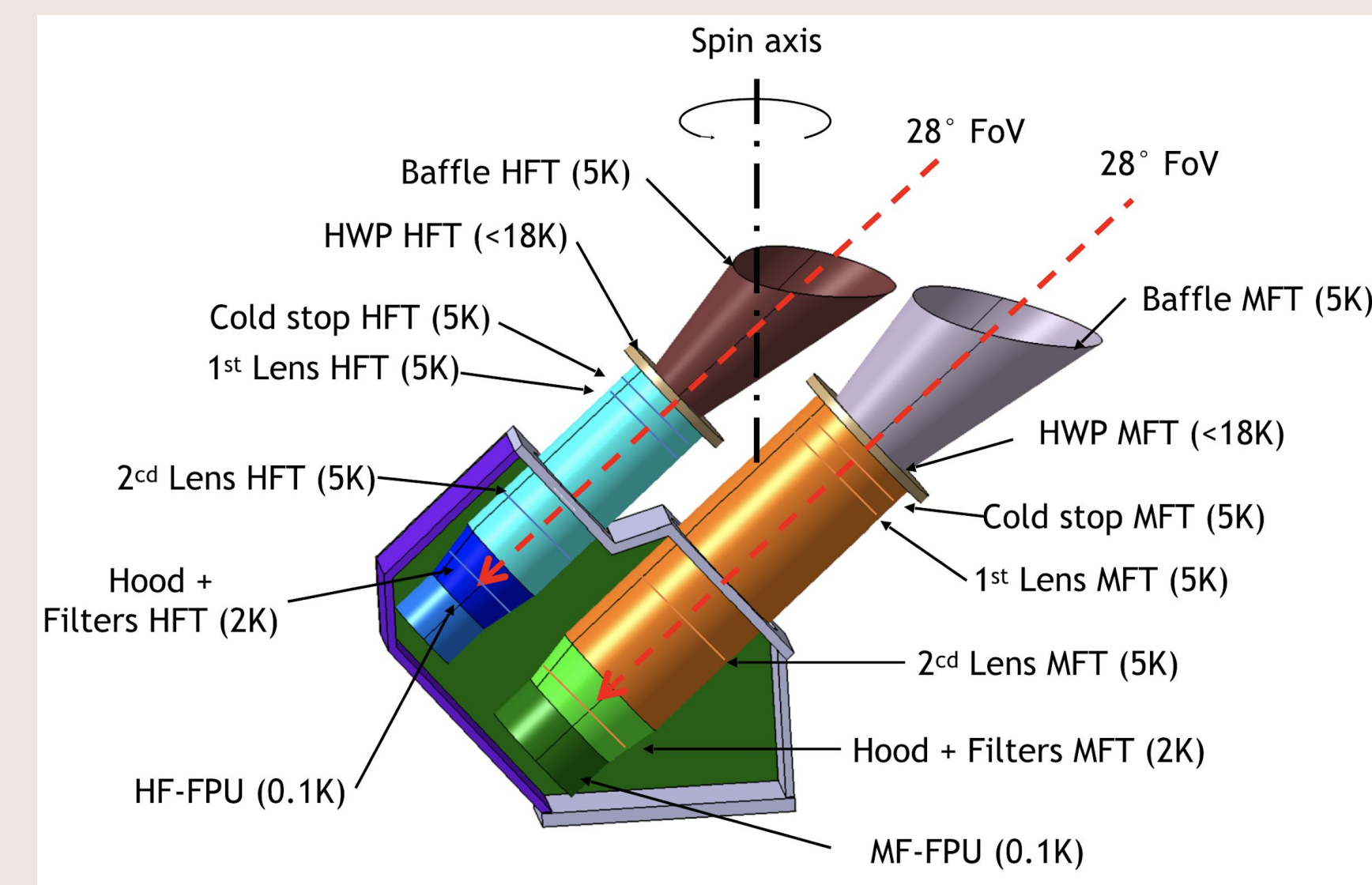
The rotation is performed thanks to 32 coupled coils on the stator, paired with 8 small SmCo magnets on the rotor. Eddy currents produced on the rotor will heat up the HWP. For its thermal model we assumed:

- motor composed by 32 coupled copper coils (RRR > 100)
- ~10 mA current needed in the motor
- ~0.1 mW dissipated during operation on the rotor
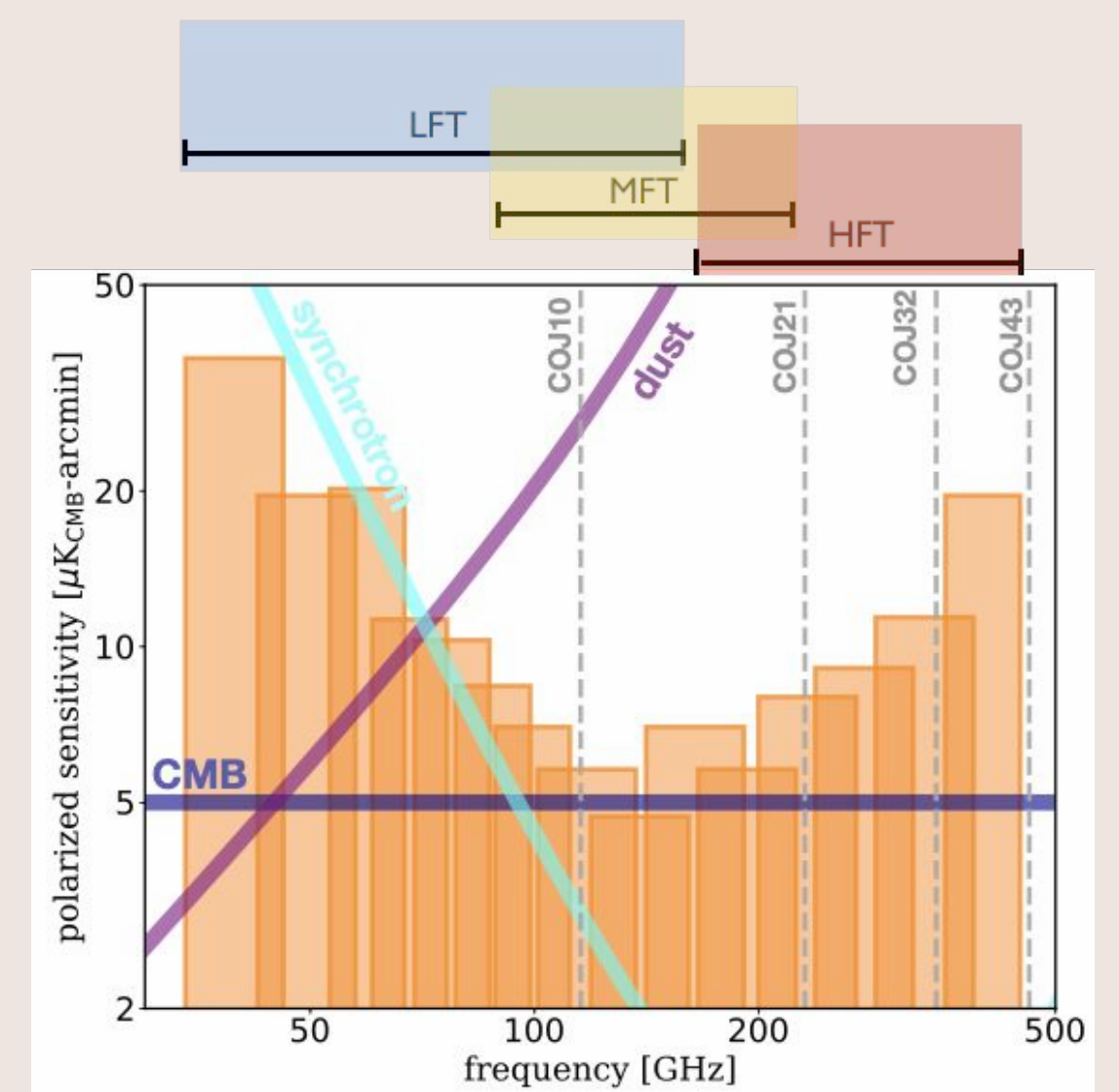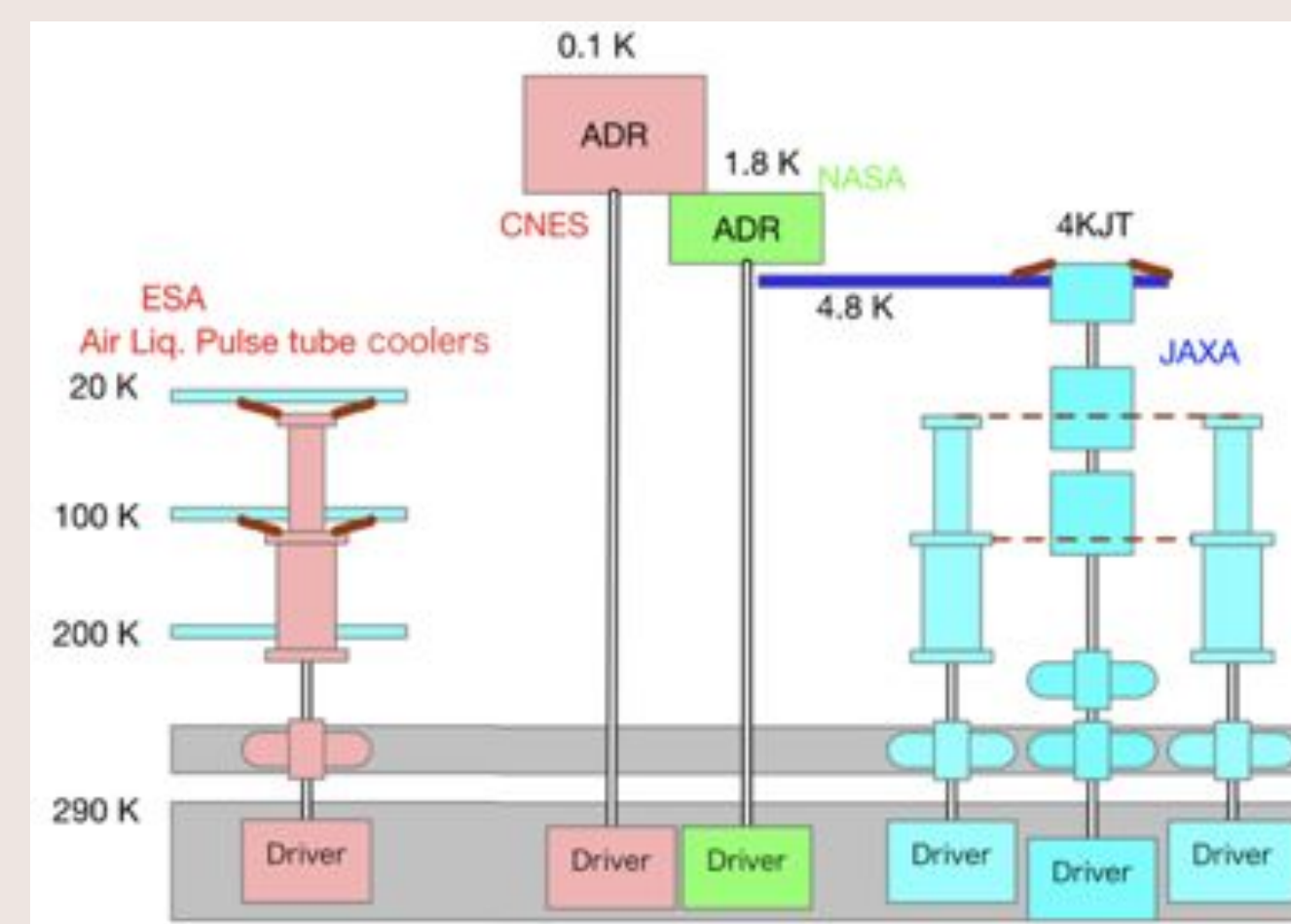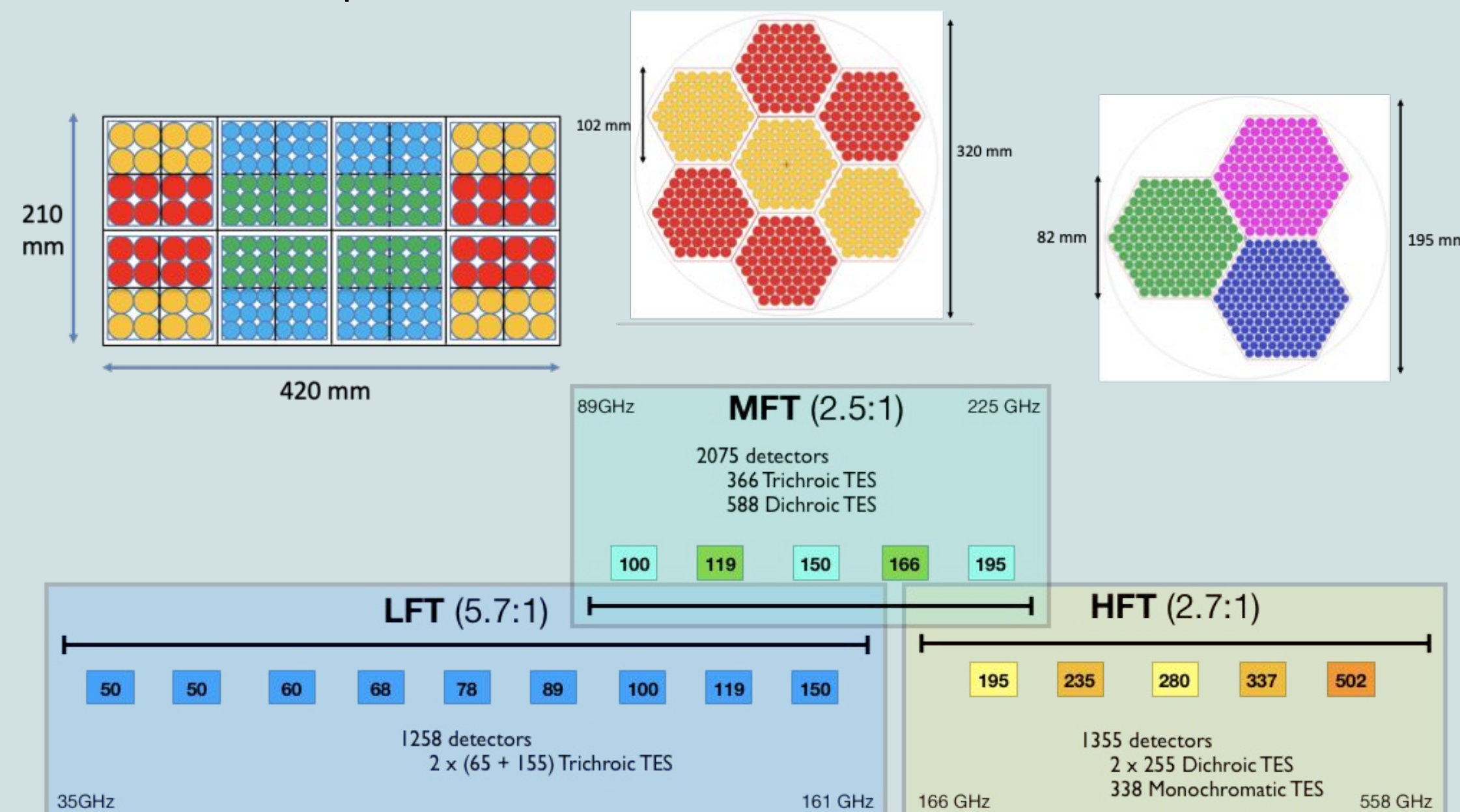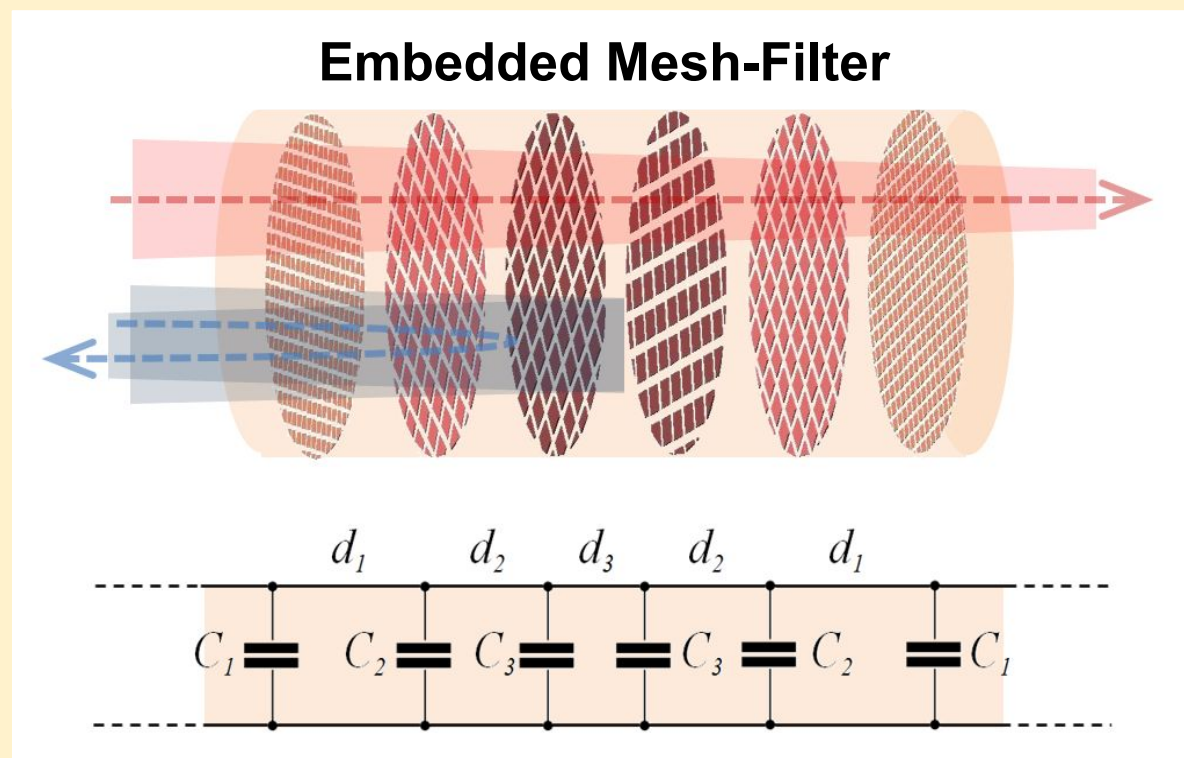- Emissivities: HWP = 0.03 and Al = 0.4.

After a drift of a few hours, the expected temperatures are both below 20K
A similar concept is being used for the LSPE-SWIPE mission.

Focal Plane Units

More than 4600 detectors cooled down to 100mK (more than 3400 for both MHFT & HFT).
Focal planes are made of TES bolometers coupled with a silicon lenslet & a sinuous antenna for MFT and coupled with silicon platelet for HFT. Each focal plane is composed of Monochromatic, Dichroic and Trichoic pixels sensitive to the polarisation.
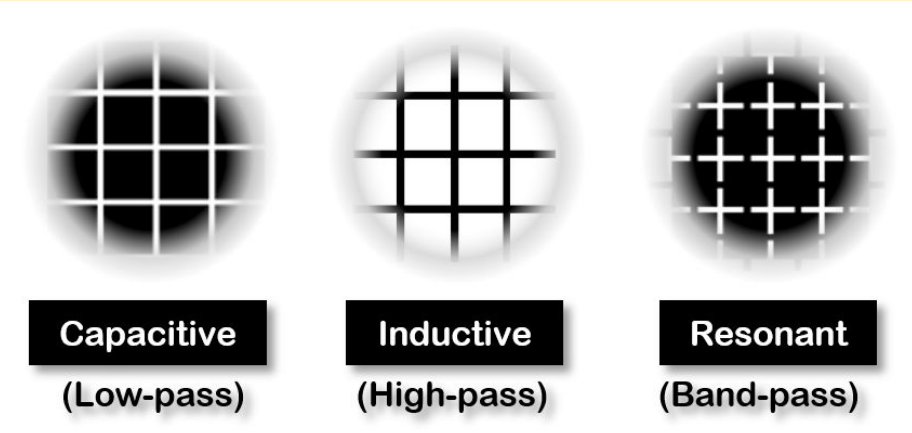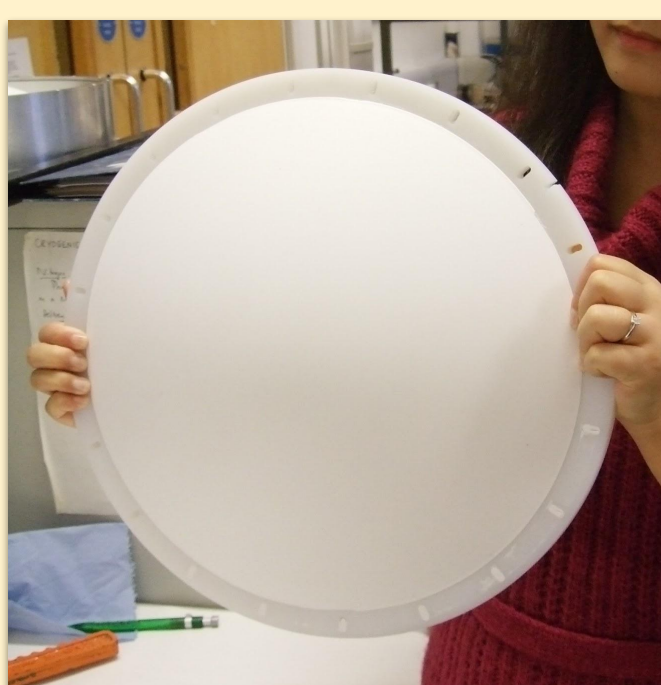
LFT (5.7:1)	MFT (2.5:1)	HFT (2.7:1)
50 50 60 68 78 89 100 119 150	89GHz ... 225 GHz, 100 119 150 166 195	195 235 280 337 502
1258 detectors 2 x (65 + 155) Trichroic TES	2075 detectors, 366 Trichroic TES, 588 Dichroic TES	1355 detectors, 2 x 255 Dichroic TES, 338 Monochromatic TES
35GHz ... 161 GHz		166 GHz ... 558 GHz

Quasi-optical components

Filters

Embedded Mesh-Filter

$$d_1 \quad d_2 \quad d_3 \quad d_3 \quad d_2 \quad d_1$$
$$C_1 \quad C_2 \quad C_3 \quad C_3 \quad C_2 \quad C_1$$

Large diameter embedded mesh filters (30 cm)

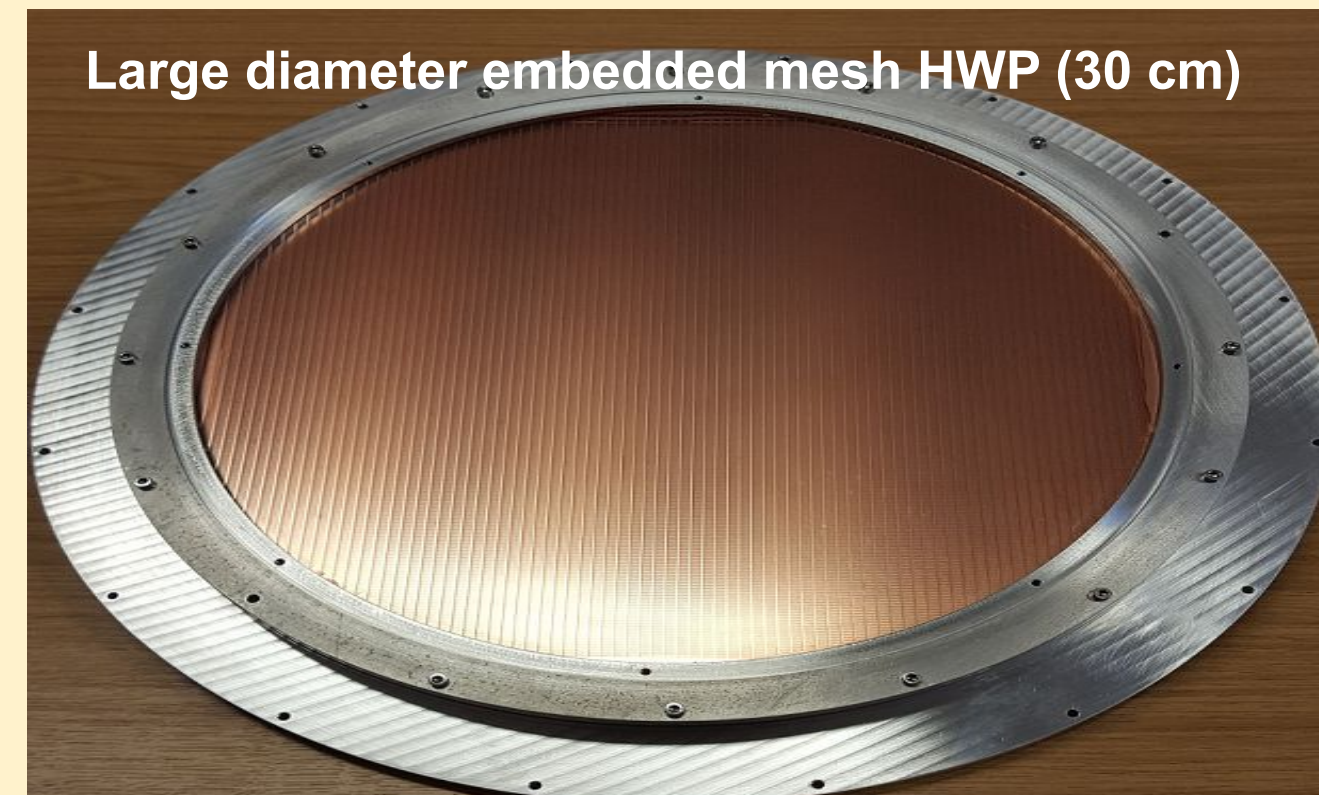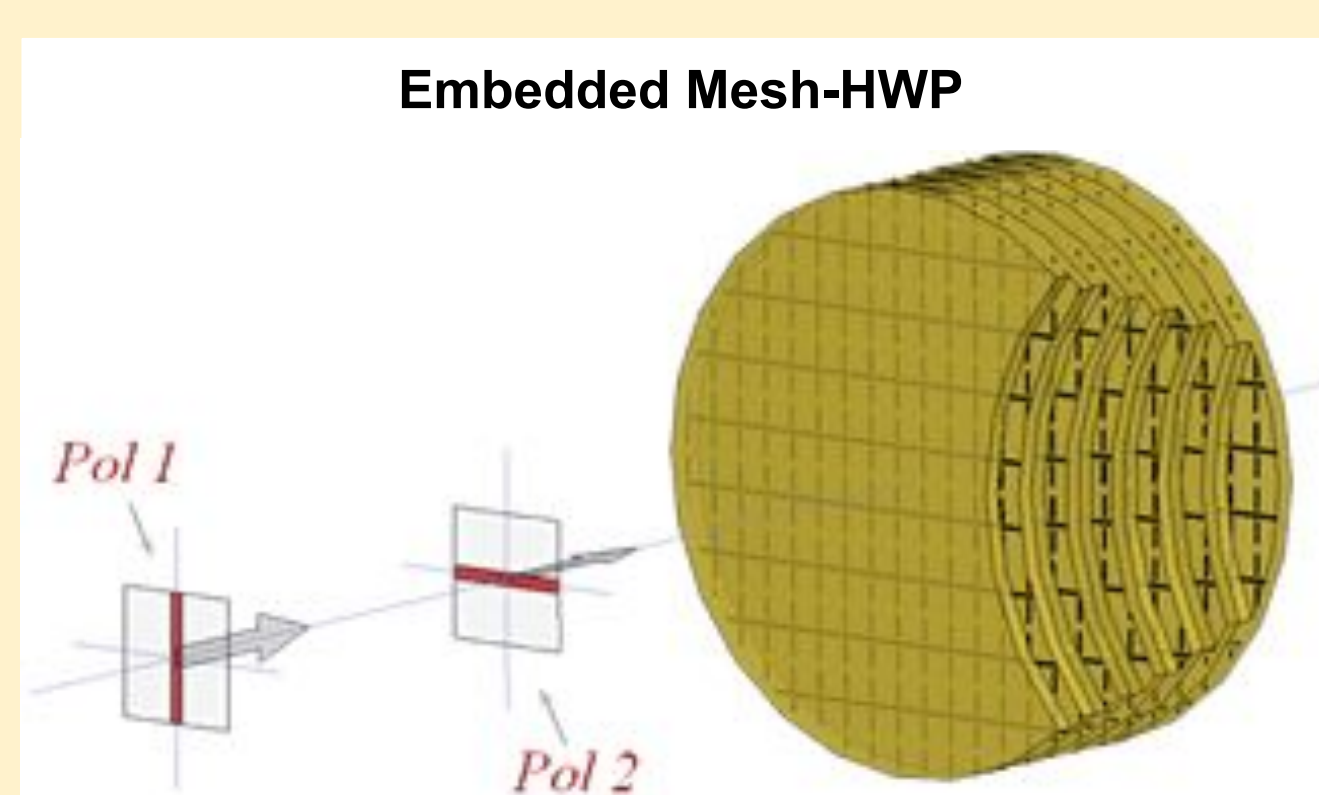| Capacitive (Low-pass)	Inductive (High-pass)	Resonant (Band-pass)

- Polypropylene embedded mesh-filter technology.
- Thermal shielding and spectral bands definition.
- Space qualified technology employed in many other ground-based, balloon-borne and satellite instruments.
- Filter diameters up to 500mm

Lenses

- Millimetre-wave Anti-Reflection Coated dielectric lenses
- Coating made with ¼ wave Porous PTFE
- Process developed and refined under ESA contract
- Deployed on several ground & balloon-based experiments
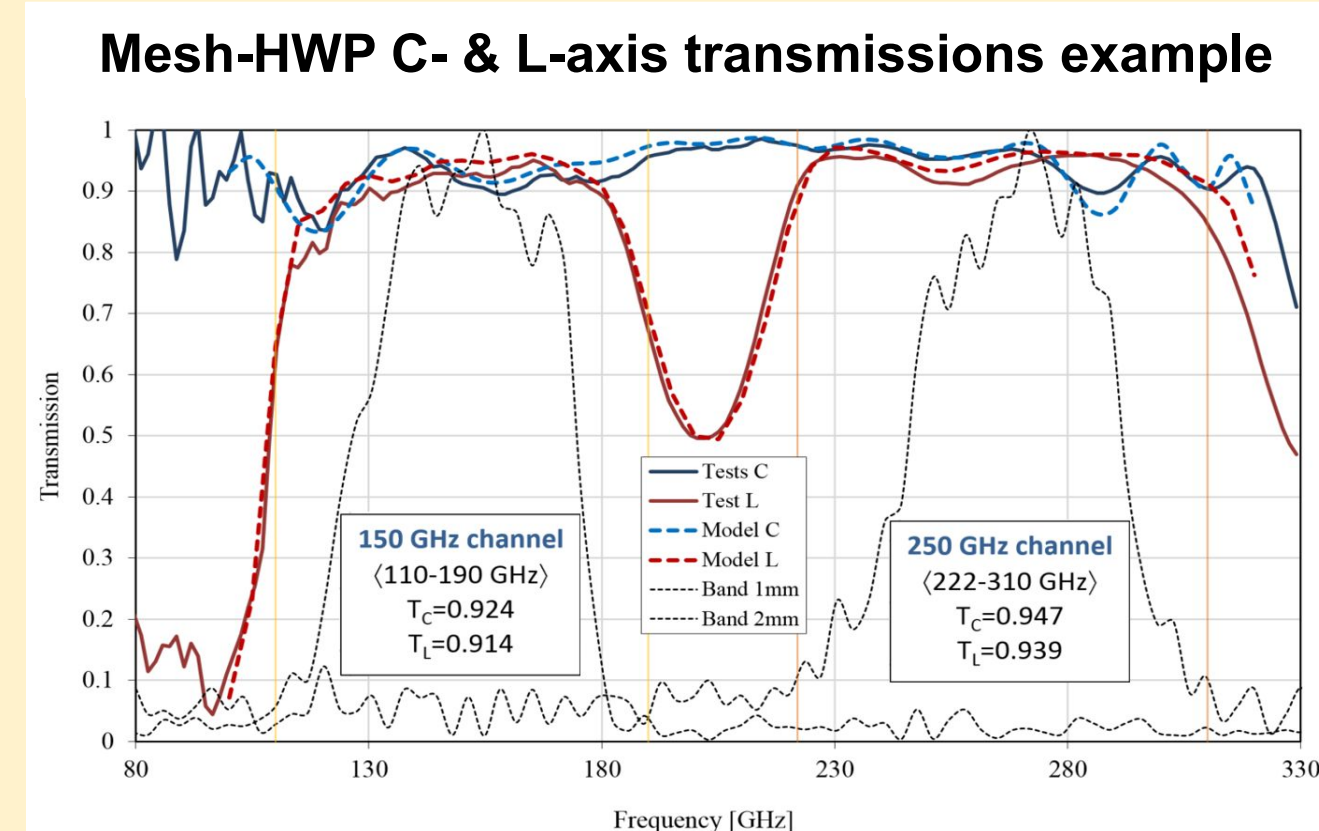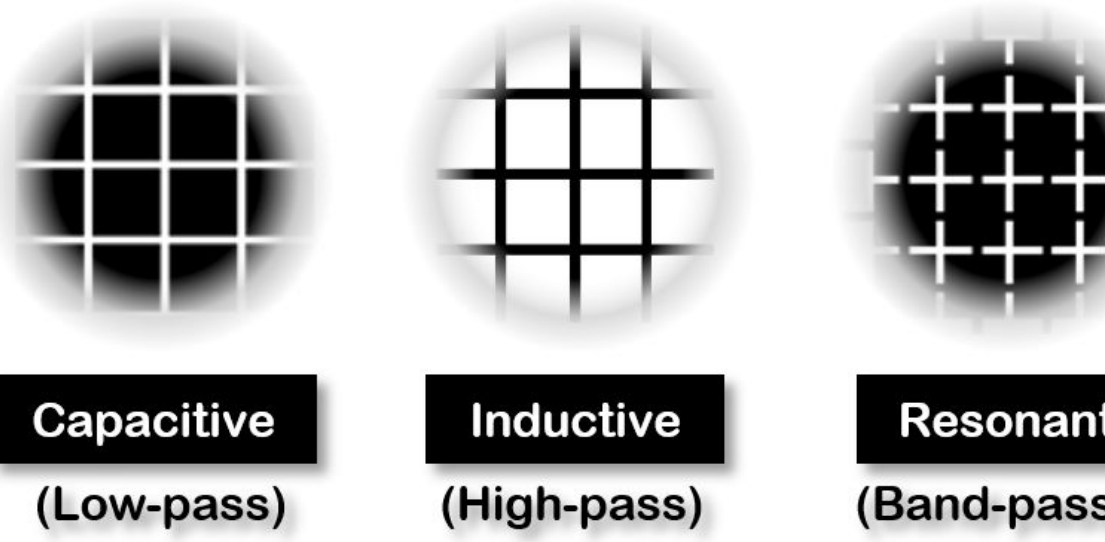- MFT and HFT telescopes based on two A/R coated polypropylene lenses

Mesh-HWPs

Embedded Mesh-HWP

Pol 1
Pol 2

Large diameter embedded mesh HWP (30 cm)

Basic Frequency Selective Surfaces (FSSs)

Capacitive (Low-pass)	Inductive (High-pass)	Resonant (Band-pass)

Mesh-HWP C- & L-axis transmissions example

150 GHz channel (110-190 GHz) $T_C=0.924$ $T_L=0.914$

250 GHz channel (222-310 GHz) $T_C=0.947$ $T_L=0.939$

- Solution based on polypropylene embedded mesh-filter technology
- Anisotropic grids providing phase-shifts in opposite directions
- Employed in ground-based and balloon-borne instruments
- Further performance developments funded by ESA contract