X-IFU Aperture Cylinder and FPA Filters

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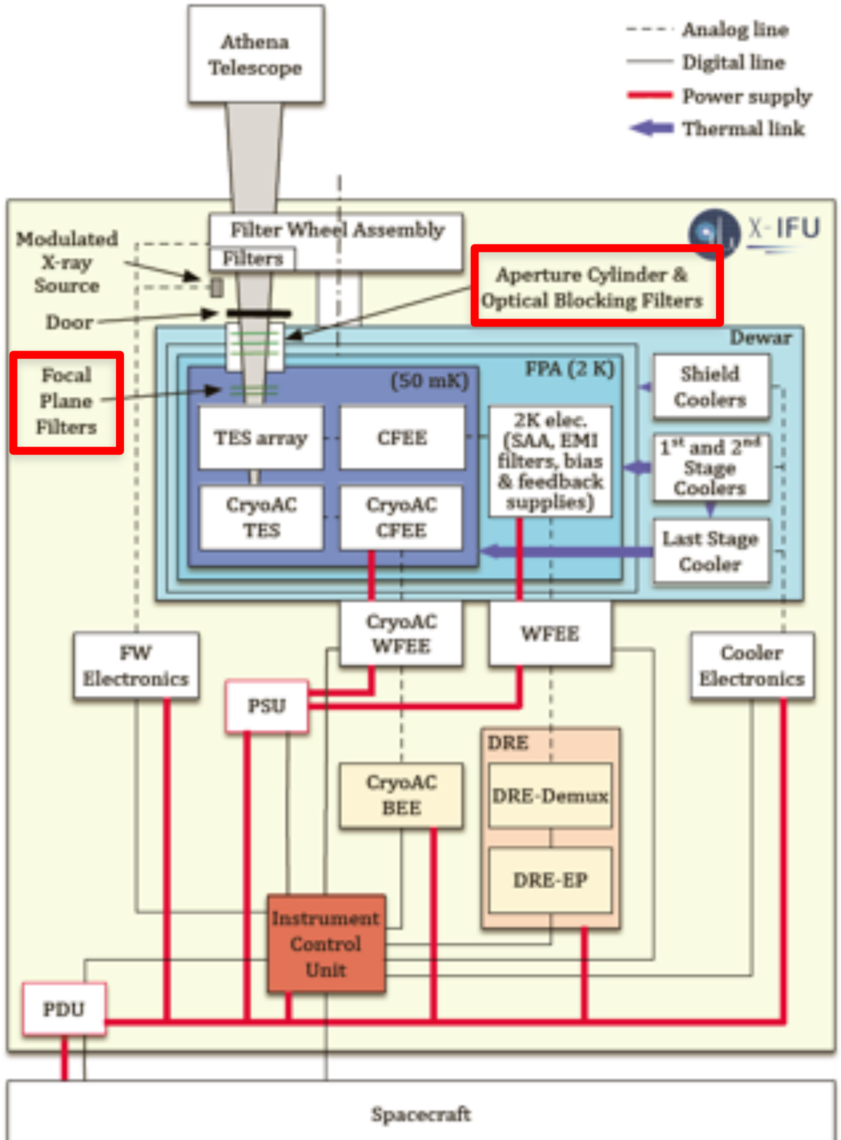
and the ATHENA Italian Consortium

OUTLINE

- Quick intro on X-IFU Aperture Cylinder and FPA Filters
- Assessment Phase 0-A1 On-going Activities
- Assessment Phase A1-A2 Activity Planning

Filters in the X-IFU Functional Block



Why X-IFU needs Filters

1) Radiation Heat Load

The cryostat provides a cooling power of approx 1 μW at the cold stage to dissipate conduction heat load and detector bias power. The IR radiation from the cryostat thermal and structural shields provides an additional heat load.

Radiation Heat Load < 1 % of Conduction Heat Load and Bias Power

2) Photon Shot Noise

The micro-calorimeters are also sensitive to photons at lower energies than X-rays. Although the detector does not trigger on individual low energy photons, the statistical fluctuation of the absorbed energy during the detection time interval, can introduce a degradation of the energy resolution of the detector (photon shot noise).

Photon Shot Noise < 0.2 eV FWHM

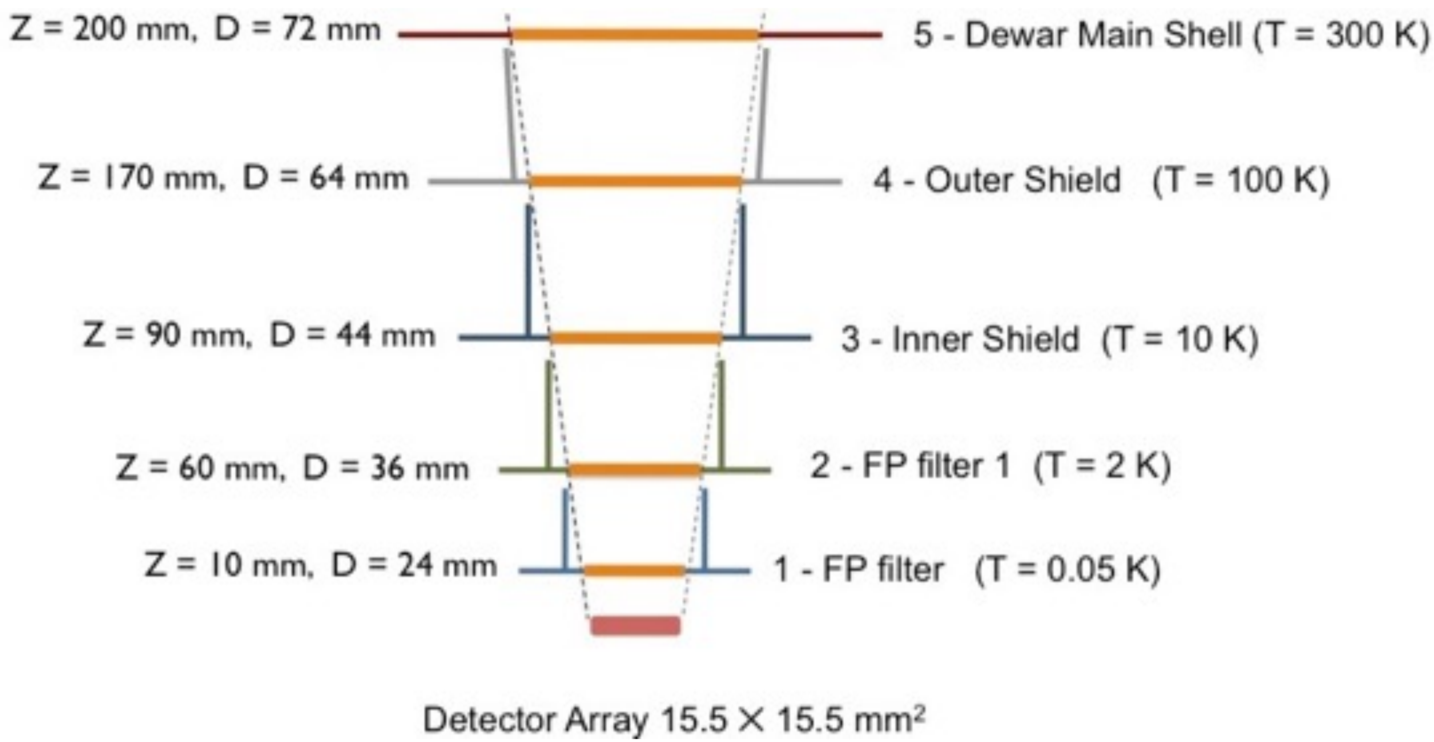
3) EMI (up to 10 GHz)

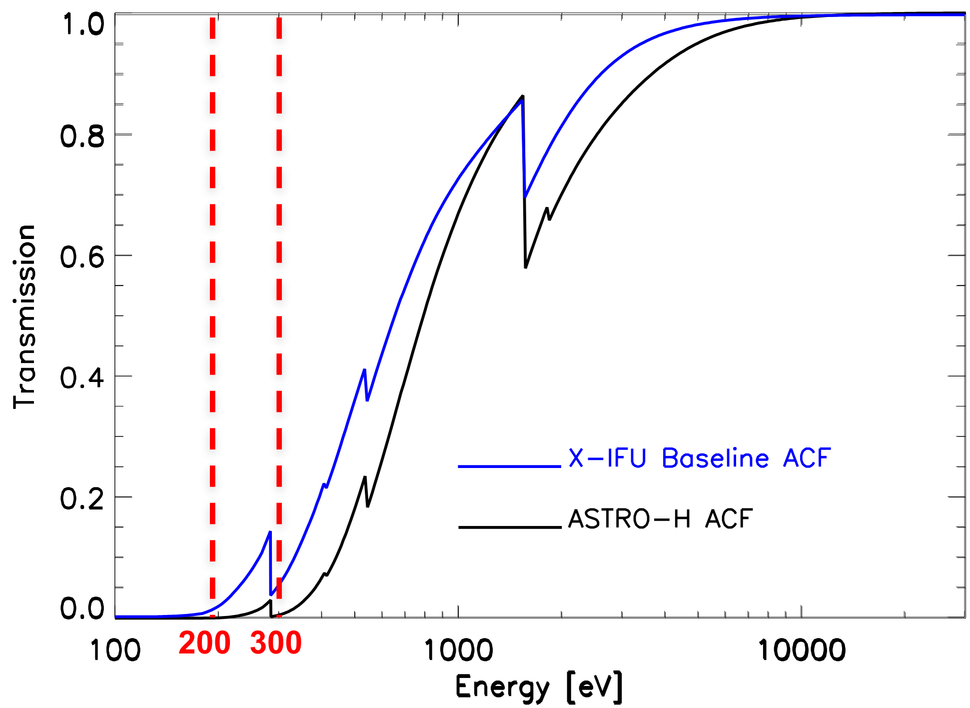
Cryostat shields should also operate as Faraday cages to protect the detector from EMI coming from the read-out electronics and spacecraft environment (telemetry).

Attenuation level TBD

Baseline Design

The baseline design adopted in the ATHENA proposal, based on the IXO-XMS study, consists of 5 identical filters with a total of 2800 Å of polyimide and 2100 Å of aluminum with integrated Polyimide support meshes 10 μm thick (93% open area) on the two outer and larger diameter filters.





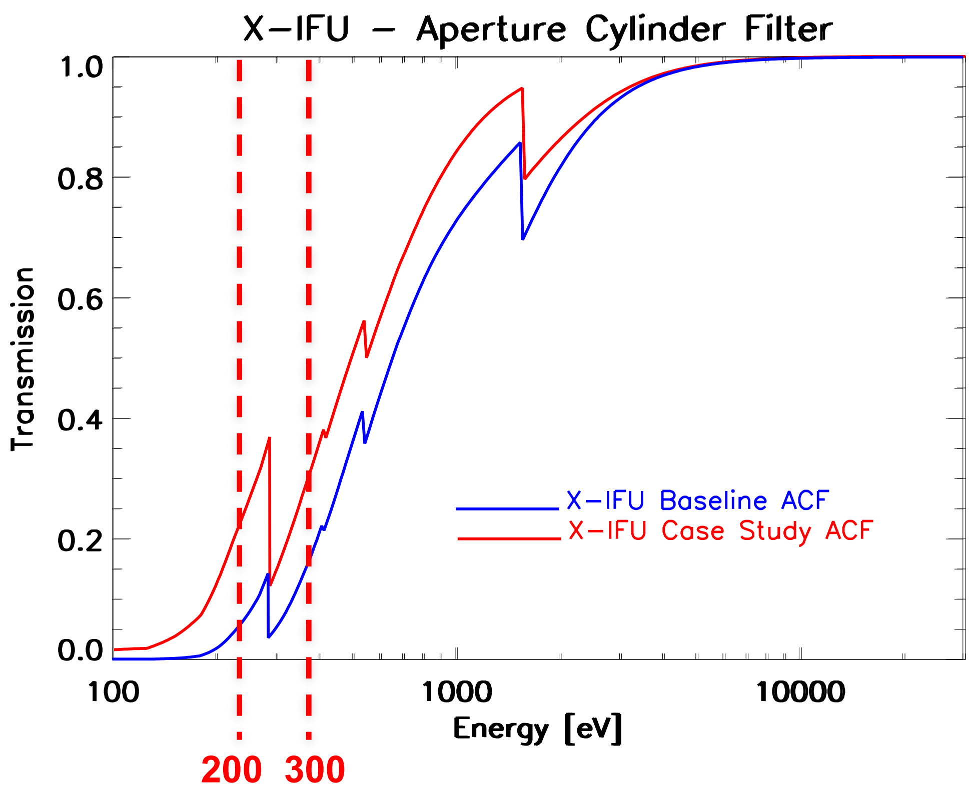
ASTRO-H 5 filters: Polyimide 4600 Å + Al 4000 Å total, Si mesh on three filters

X-IFU – Baseline 5 filters: Polyimide 2800 Å + Al 2100 Å total, mesh 93% on the two outer filters

The low energy response of the X-IFU is essentially defined by the AC and FPA filters

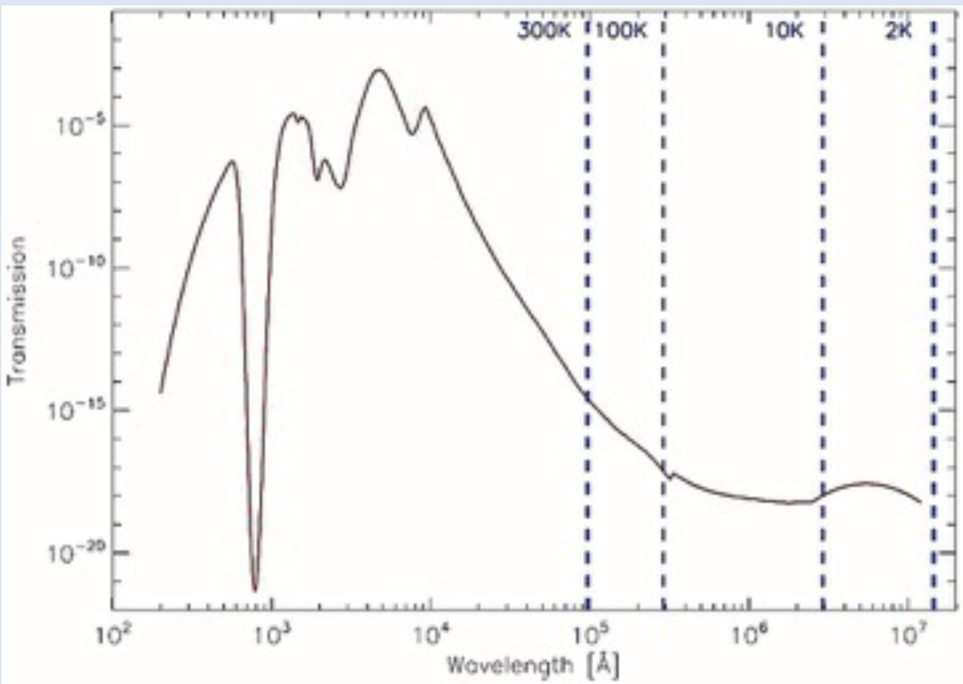
Ongoing activities: Design Optimization

A more efficient design, currently under investigation, consists of 5 identical filters with a total of 2250 Å of polyimide and 1000 Å of aluminum. The two outer and larger diameter filters are supported by an Al lithographic mesh 2 μm thick with > 93% open area.

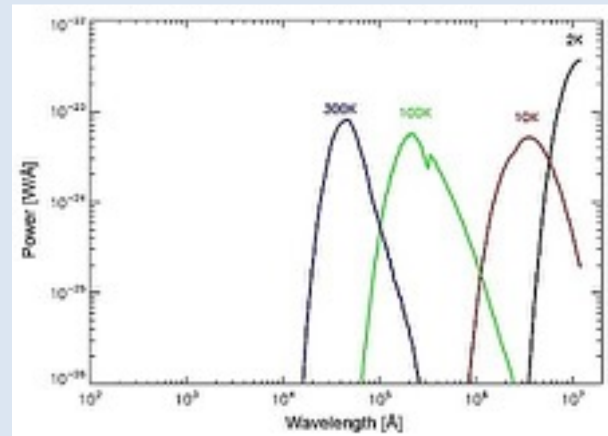


On-going Activities: Simulations

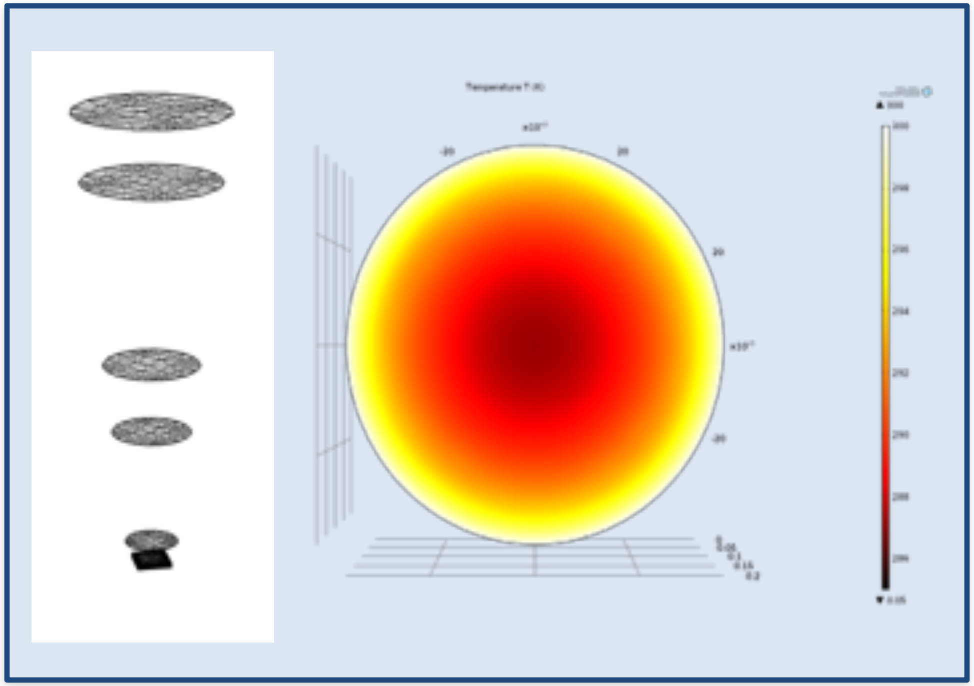
IR transmission



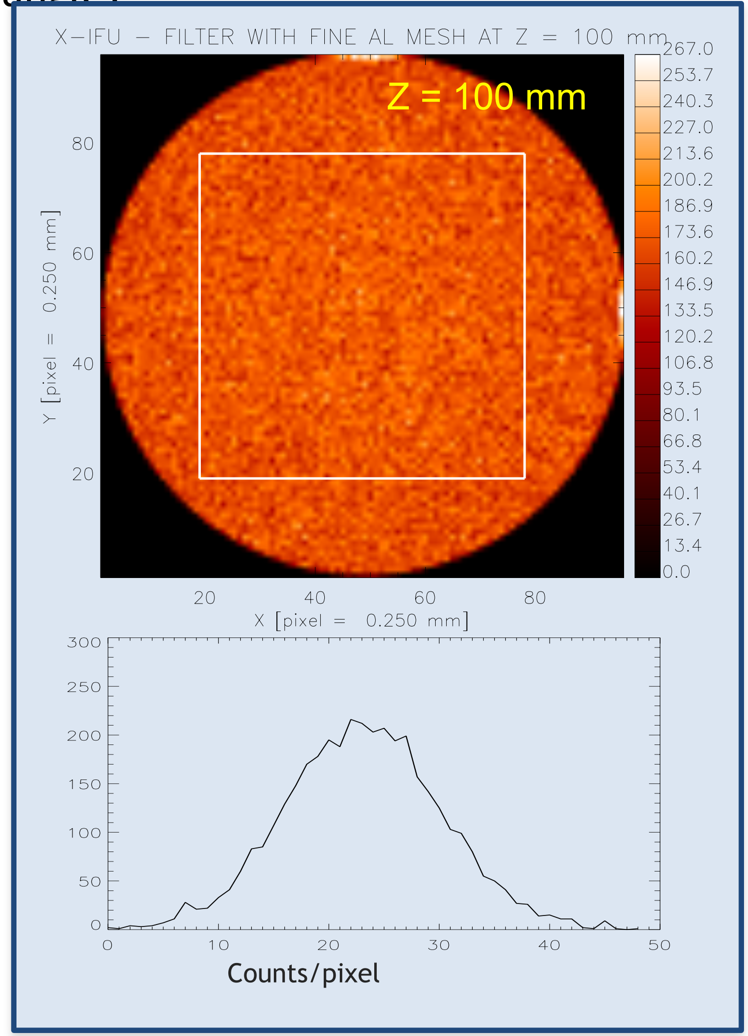
Radiative power onto the detector array



Thermal modeling of the filters inside the cryostat (COMSOL multiphysics)

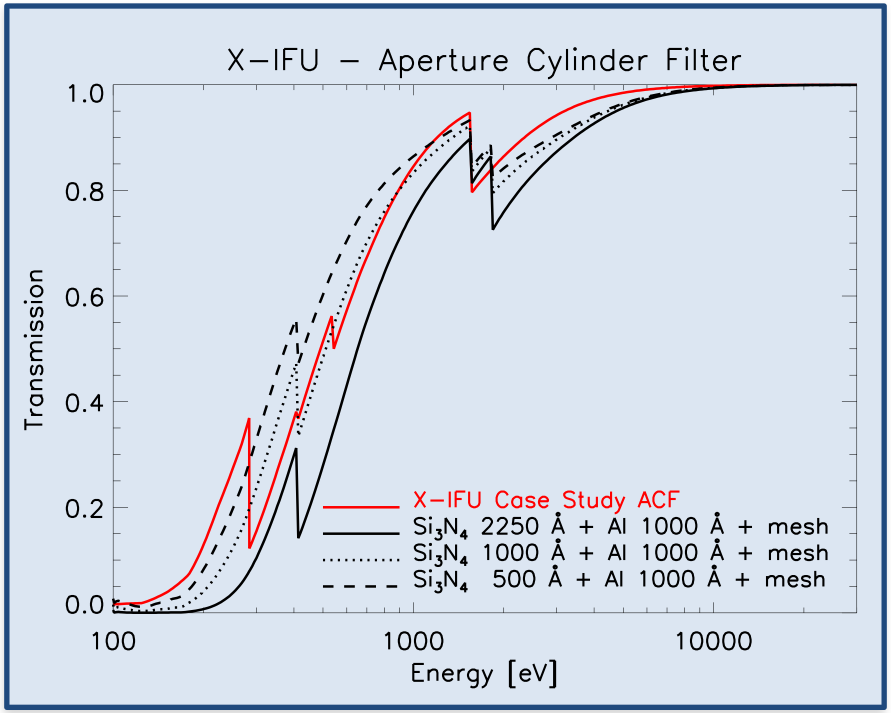


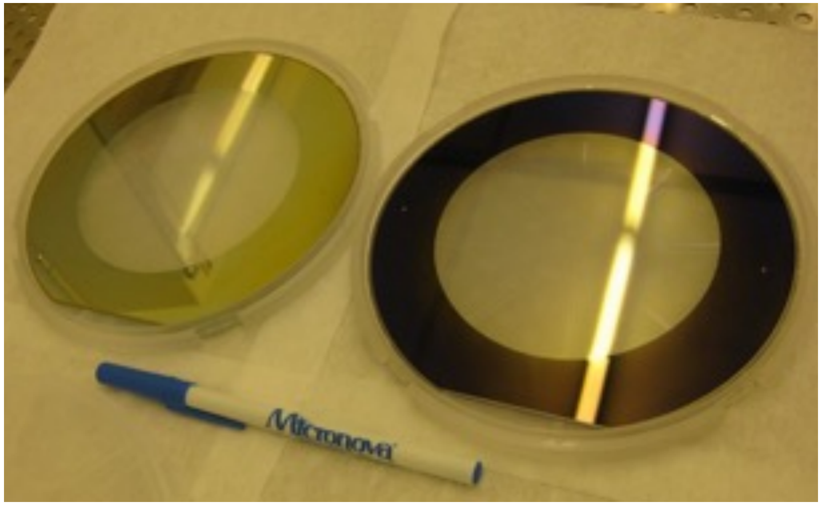
Ray tracing (mesh imaging, filter tilt angle)



On-going Activities: Material Investigations

Thin foil (Polyimide, Si_3N_4)



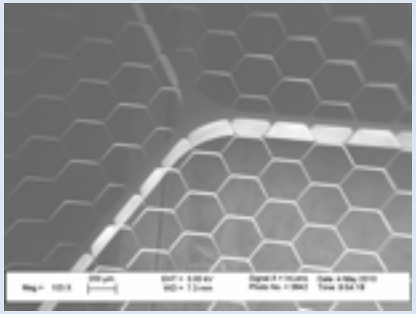


Si_3N_4 membranes
Mesh open area 85%,
Filter diameter 100 mm, thickness 650 Å
[Courtesy of HS foils, Finland]

Si_3N_4 membranes 500 Å thick can also be built with diameter up to 20 mm mesh-less, or larger than 50 mm with mesh.
[Courtesy of LUXEL, USA]

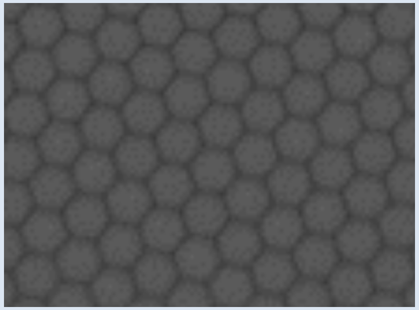
Mesh for the larger diameter filters (Al, Si, Polyimide)

Lithographic Si
Support mesh: 200 µm thick, 3.2 mm pitch
Fine mesh: 8 µm thick, 200 µm pitch
Mesh Open Area: 93%



[Mc Cammon et al., JLTP (2008) 151, 715–720]

Lithographic Al
Fine Mesh: 8 µm bar width, 1.4 µm thick, 200 µm pitch
Mesh Open Area: 92.4% (Optical Measurement)



[Courtesy of LUXEL]

On-going Activities: Test samples procurement

1. **45nm Polyimide / 20nm Al film**, **supported by Al lithographic mesh**, with **ID > 50mm.**

   - Mesh to have nominal 92% transmission (Optical Measurement)
   - Mesh Pitch = 200 microns
   - Calculated Mesh Bar Width = 8 microns
   - Mesh Bar Thickness = 1.4 microns

2. **45nm Polyimide / 20nm Al film**, **meshless**, with **ID < 50mm.**

Witness filters (taken from same lots as Item 1 and 2) mounted on ring frames with ID < 10 mm for Synchrotron X-ray transmission measurements and IR transmission measurements.

Witness filters (taken from same lots as Item 1 and 2 on) mounted on solid frames for X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy.

Assessment Phase 0-A1 Activity Planning

Technology Development

Q1-2015

Q4-2015

Main Activities

Performance simulations

- Thermal modeling to derive temperature profile on each filter at equilibrium.
- IR transmission, Radiative load onto detector and NEP
- EM attenuation (Al foil and mesh)

Material investigation

- Thin foil (Polyimide, Si_3N_4, ….)
- Mesh type (Al, Si, Polyimide, …)

Samples procurement

Preliminary tests

- X-ray transmission - XANES and EXAFS vs. T
- Aluminum oxidation (EXAFS and XPS)
- IR transmission vs. T
- EM shielding (< 10 GHz) at T=300 K and T < 1.2 K (TBV)

Required Inputs

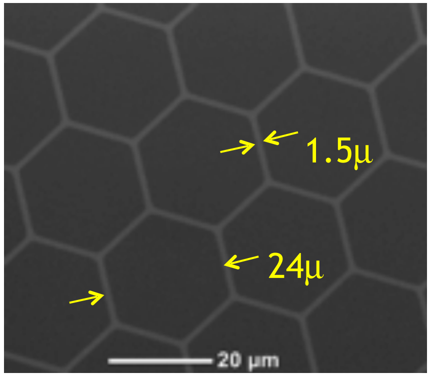
Thermal/Mechanical IF (Cryostat, Aperture Cylinder)

Required EM attenuation in X-band

Assessment Phase A1-A2 Activity Planning

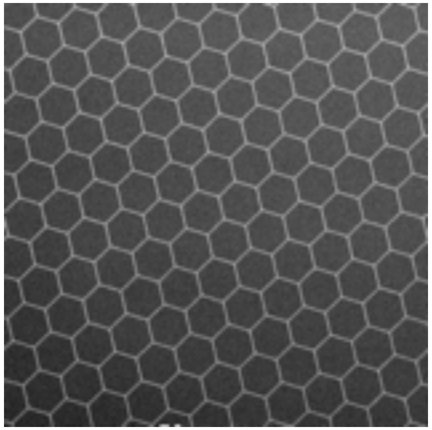
Phase	Period	Main Activities	Required Inputs
Technology Development	Q1-2016 → Q4-2016	**Filters and Frames preliminary design** **Inspection, handling and storage procedures** (procurement/construction of shipment boxes, storage cabinet, handling tools, …) **Filters procurement (**1 set representative of the current flight design + witness samples**)** **Test measurements** •Environmental: cooling, vibration, ageing (e.g. atomic oxygen, micro-meteoroids, TBC) •Vis/IR transmission, XPS, AFM, … •X-ray transmission	**Thermal/mechanical IF** **EM attenuation in X band** **Vibrational load**
DM Development	Q1-2017 → Q3-2017	**DM filters and frame design** **DM filters procurement (**2 sets + witness samples**)** **Visual Inspection** **Shipment for integration in the DM** **Test measurements on back-up filters and witness samples**	TBC Not covered in present budget

Lithographic Aluminum fine mesh



Example of previously built lithographic Al Mesh by LUXEL:

Mesh Bar Width = 1.5 µm
Mesh Pitch = 24 µm
Mesh Bar Thickness = 0.306 µm
Open Area = 88%



Proposed Al Mesh:

Mesh Bar Width = 10 µm
Mesh Pitch = 600 µm
Mesh Bar Thickness = 2 µm
Open Area = 95%

Model predicts the proposed mesh raises the burst strength of 50 nm polyimide by > 2X