### Introduction
- Lynx is a large mission concept under development by NASA for the Astro 2020 Decadal survey.
- One of the key Lynx instruments is an imaging spectrometer called the Lynx X-ray Microcalorimeter (LXM) which comprises of a very large detector array with over 100k pixels.

- Metallic magnetic calorimeter (MMC) technology is a leading contender for detectors for the LXM.
- MMCs can be used to measure the energy of individual X-ray photons with high precision by sensing changes in the magnetic susceptibility of a paramagnetic metal film (Au:Er) as its temperature rises in response to the absorbed photon energy.

### Fabrication Summary
- All buried wiring and sensor meander coil layers are processed as follows:
  - Nb deposition by dc magnetron sputtering
  - Patterning of Nb by deep UV (DUV) lithography (248 nm)
  - TiO$_2$/SiO$_2$ interlayer dielectric (ILD) deposition by PECVD
  - Chemical Mechanical Planarization of ILD to desired thickness
  - Patterning of ILD by DUV lithography and plasma etch
  - MMC sensor (Au:Er) deposition by sputtering and patterning by lift-off
  - Au hydrid link deposition by e-beam evaporation and patterning by lift-off
  - Au heat sink deposition by e-beam evaporation and patterning by lift-off
  - Stems electroplating through photoresist mold on Au seed layer
  - Absorbers electroplating and etch by ion milling

### Motivation
- Design and fabrication challenges for large size arrays
  - As array size increases, stray inductance of the wiring increases both between pixels and in the fanout to amplifiers
  - Routing of wiring between pixels and readout, on a planar scheme, becomes technologically challenging due to requirements of low inductance, low crosstalk, high critical currents and high yield
  - MMCs can be scaled to large array sizes by
    - Maximizing sensor inductance by decreasing sensor meander coil pitch
    - Maximizing magnetic coupling by scaling sensor (Au:Er) and sensor insulator thickness with pitch
    - Maximizing Nb thickness with pitch in order to keep sufficient critical current/width
  - Buried layers can be used to achieve large scale, high density wiring
    - Well suited for connecting thousands of pixels on a large focal plane to readout chips
    - Planarization allows top surface of wafer to be exclusively available for pixels and heat sinking, opening up the possibility for new pixel geometries
    - Can alleviate crosstalk between high density, fine pitch wiring

### MMC Arrays with Four Buried Nb Layers

#### Fabricating High Inductance MMCs
- Sensor meander coil pitch is reduced to 800 nm to increase sensor inductance
- To maintain good magnetic coupling with the reduced pitch, thickness of Au:Er is scaled to 128 nm
- To maintain a large critical current per unit width in the wiring and the sensor meander coils, Nb is anisotropically etched to produce vertical edges, resulting in an approximately square cross section
- By using multiple layers of buried wiring, larger wiring linewidths are maintained, resulting in a decrease in the wiring inductance

#### UH array
- Square annulus shaped sensor with non-hydra design
- Superconducting vias at the center of the sensor connect sensor meander coils on the topmost Nb layer to twin microstrip wiring on the bottom most Nb layer
- Au thermal link connects sensor to absorber stem in order to control size of slew rate at readout

#### Prototype Highlights
- 55800 pixels thermally linked to 5688 sensors
- 4 buried Nb layers
- High yield, low inductance, high density wiring
- Reduced cross-talk through the use of shielding ground planes
- Precludes need for aggressive packing of wiring on one layer by allowing the fanout of wires from sub-arrays under Main array pixels

#### Main and Enhanced arrays
- Arrays of waffle shaped, multi absorber sensors in a 5 x 5 hydra configuration

#### Test Results
- Measured critical current at 4K on pixels with 400 nm wide sensor meander coils is better than 30 mA
- Issues with cooling system limited operating temperature to 50 mK
- Each sensor is not coupled to an optimized SQUID
- NEP at T = 50 mK

<table>
<thead>
<tr>
<th>Array Type</th>
<th>NEP (μW/K)</th>
<th>Critical Current (mA)</th>
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</thead>
<tbody>
<tr>
<td>Enhanced Array 800 nm pitch pixel</td>
<td>1.96 eV – 1.99 eV</td>
<td>15 mA</td>
</tr>
<tr>
<td>Main Array 800 nm pitch pixel (with noisy SQUID)</td>
<td>10.5 eV – 12.5 eV</td>
<td>15 mA</td>
</tr>
<tr>
<td>Main Array 800 nm pitch pixel (noise corrected)</td>
<td>2.8 eV – 3.7 eV</td>
<td>15 mA</td>
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