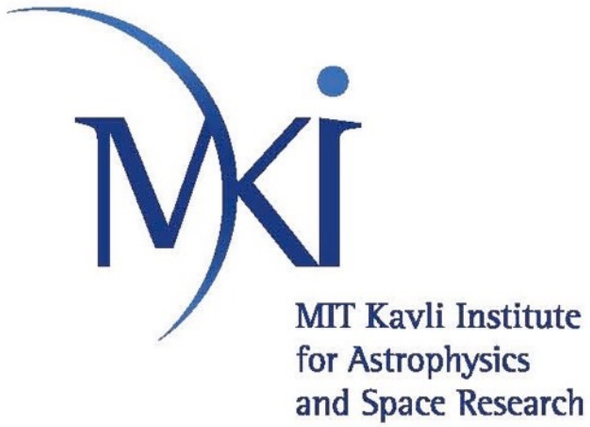
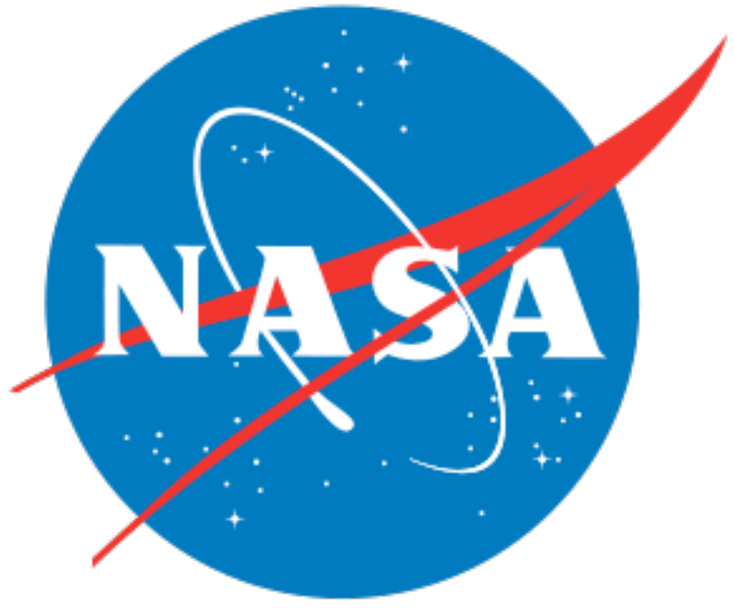




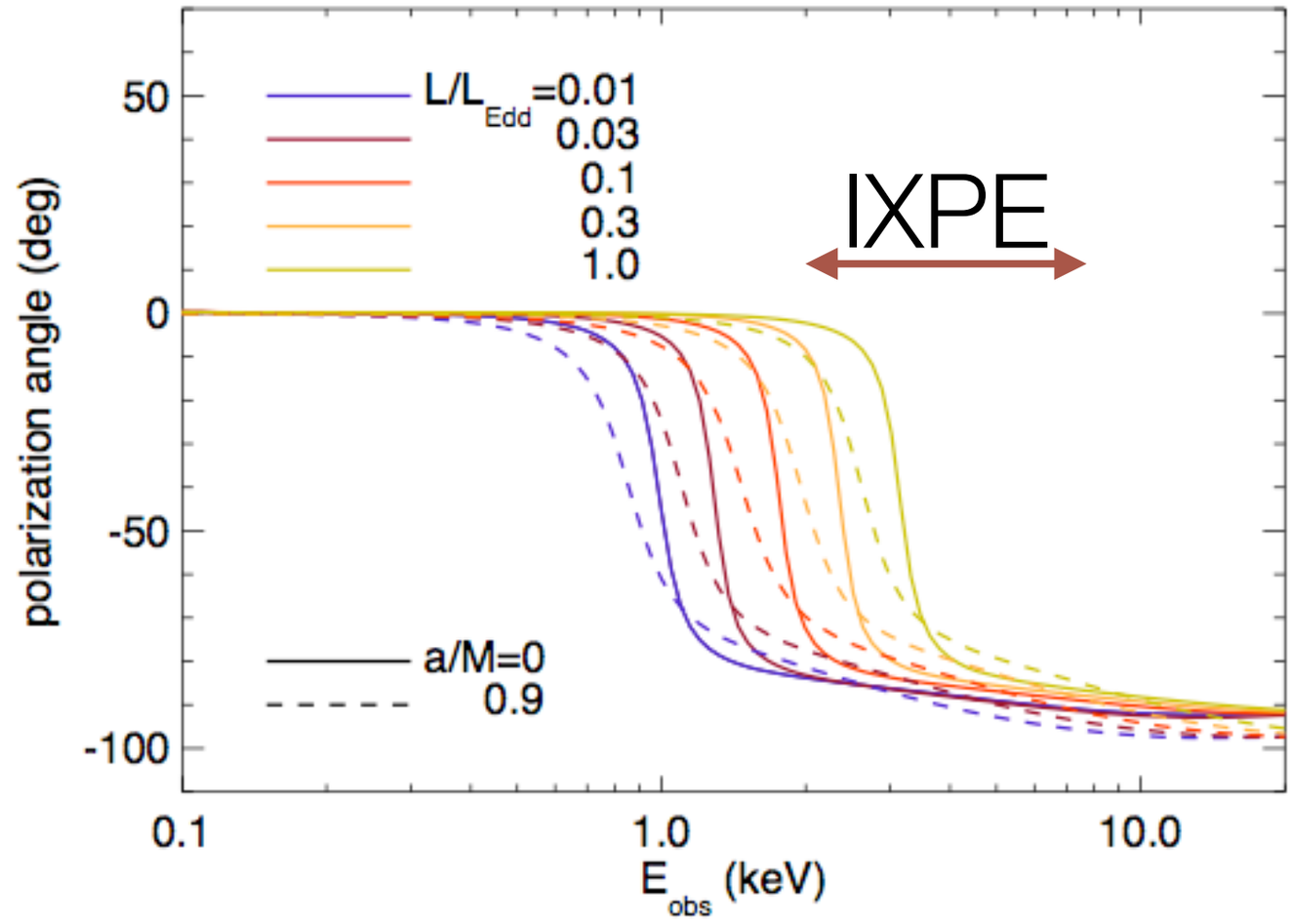
A Sub-keV X-ray Polarimeter

Herman L. Marshall

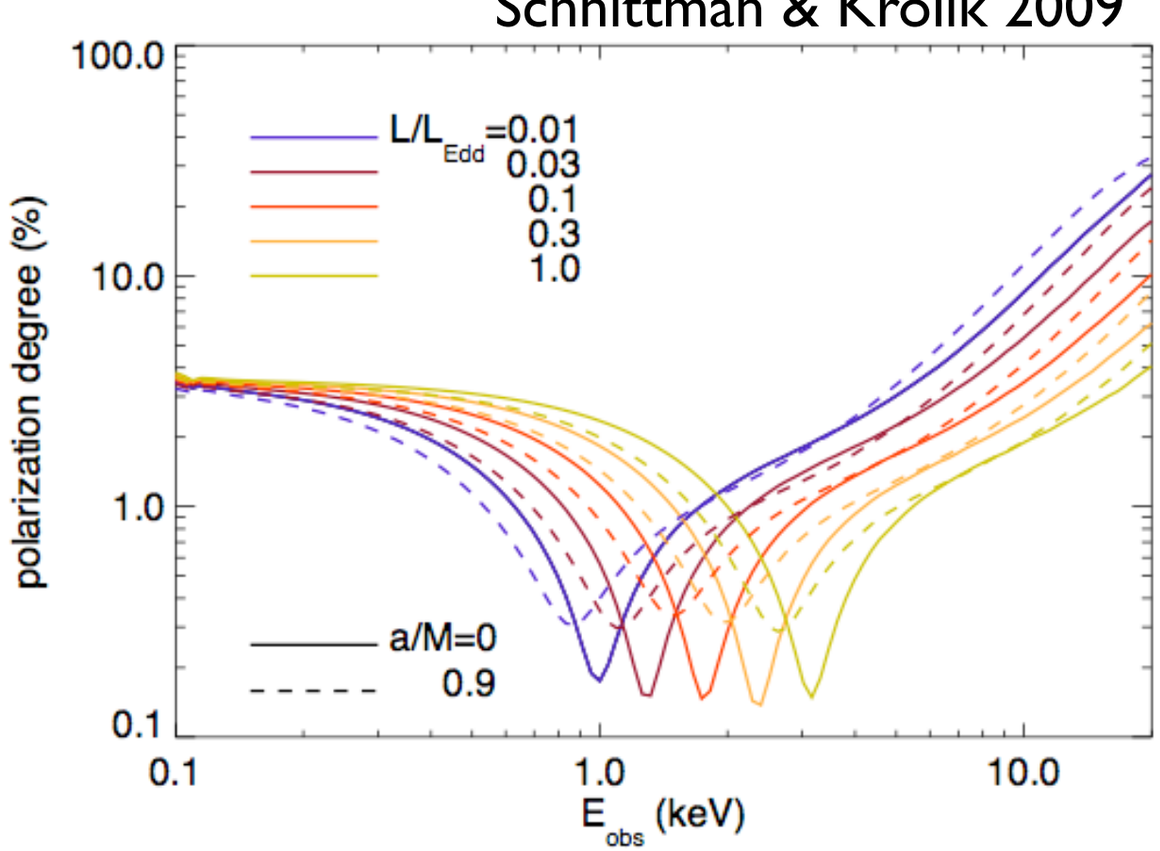
Norbert S. Schulz, Ralf Heilmann, Sarah Heine (MIT)
David L. Windt (Reflective X-ray Optics)
Eric M. Gullikson (LBL)
Brian Ramsey (MSFC)

A Science Goal: Polarimetry of AGN

- Scattered return radiation will be polarized
- Polarization fraction and angle depend on a/M, L/L_{Edd}
- Soft and Hard X-ray measurements are needed

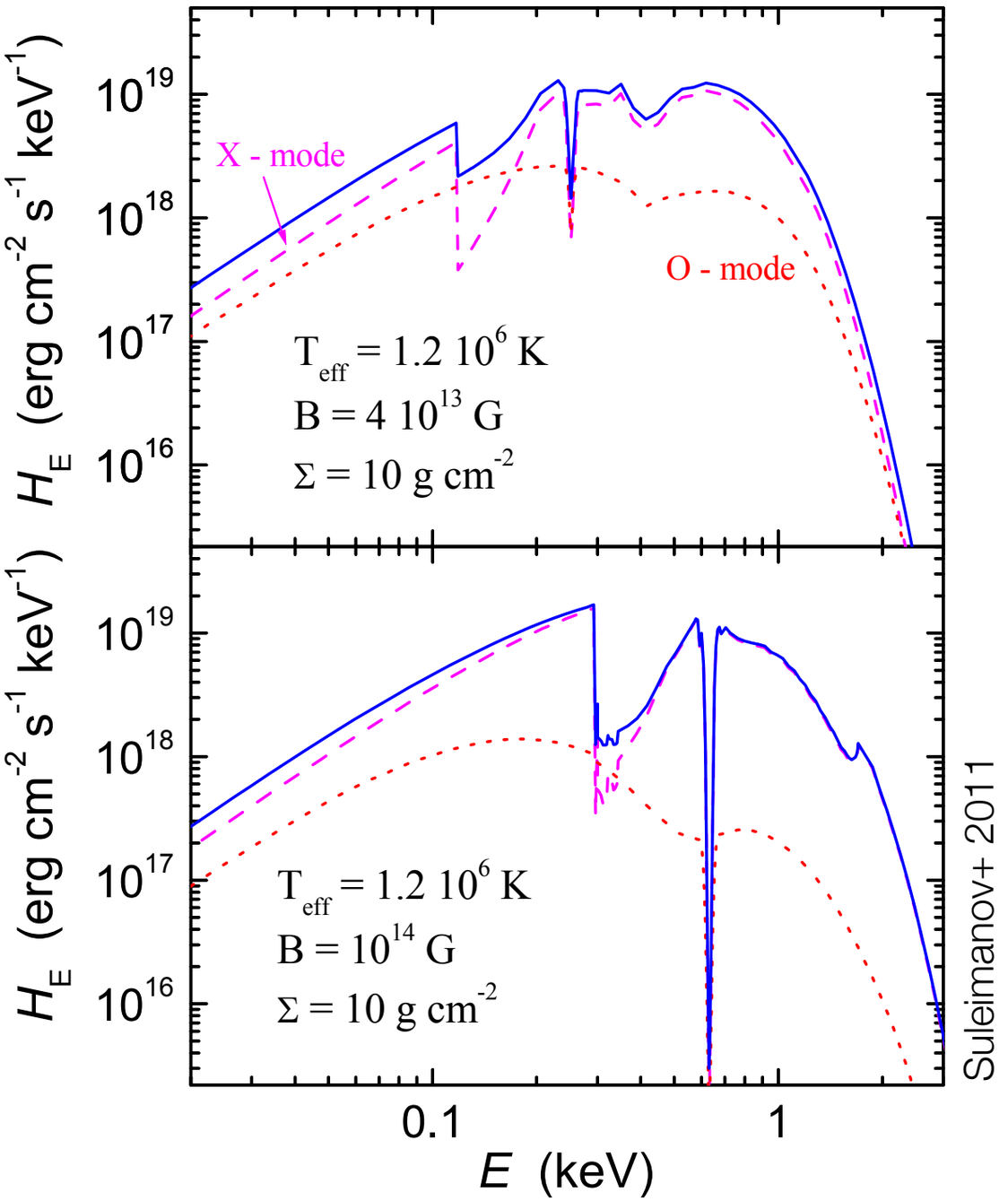


Schnittman & Krolik 2009



A Science Goal: Neutron Star Atmospheres

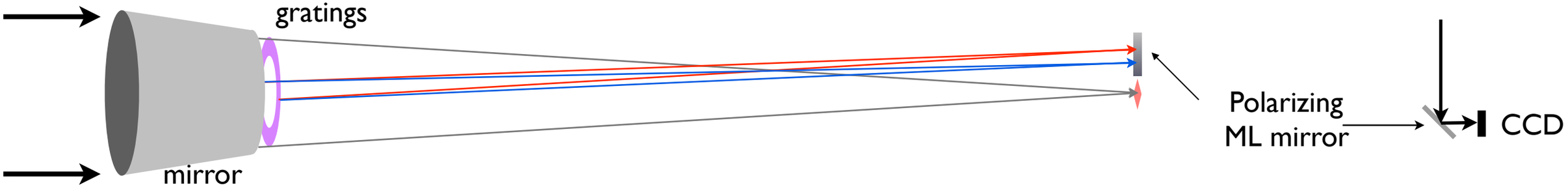
- Isolated neutron stars are often soft, emit below 1 keV
- Polarization amplitude and angle v. rotation phase depends on B-field direction and N-star orientation
- Atmospheres show features now found in spectra of isolated N-stars
- Polarization data would distinguish features in spectra
- Atmosphere models are used to determine R^2, g to give M,R
- Best target is ~10 mCrab

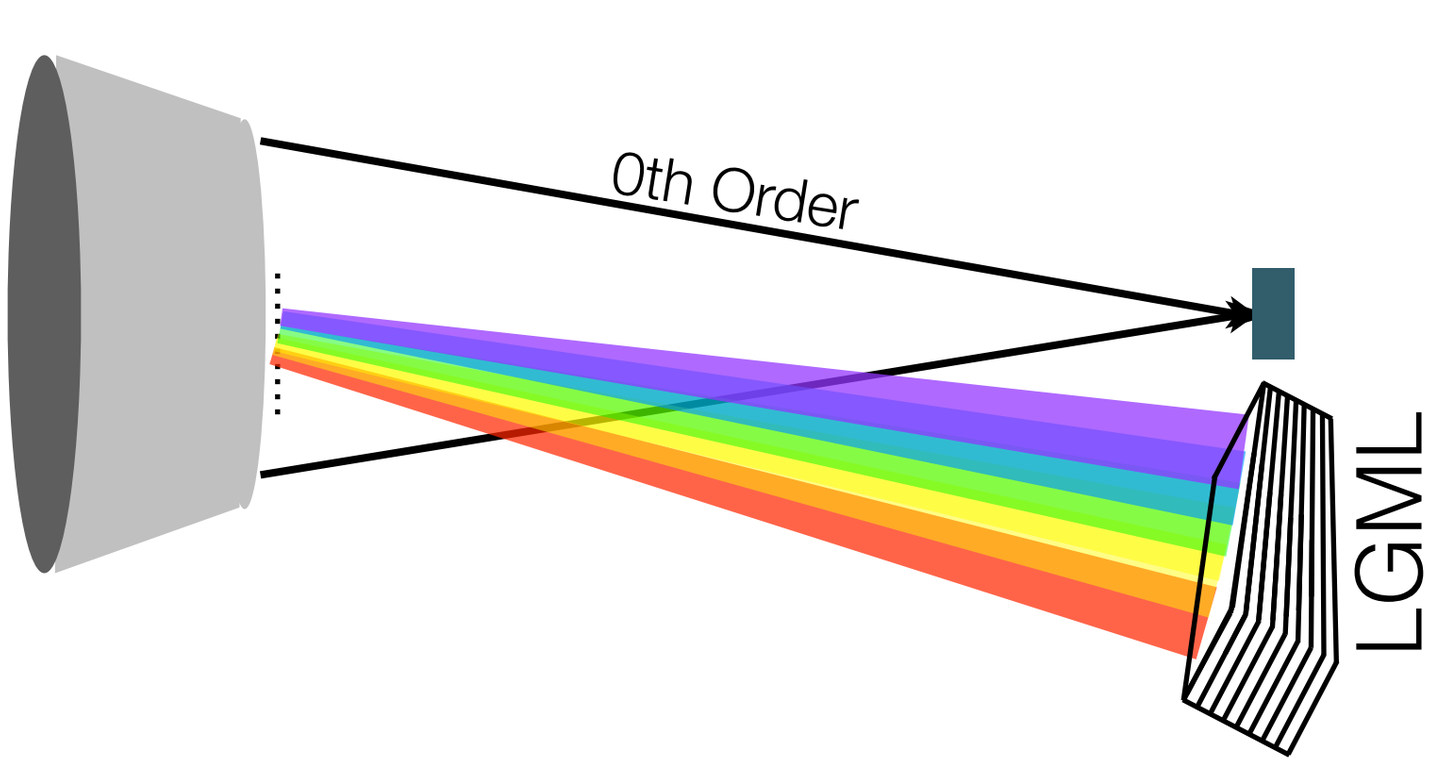


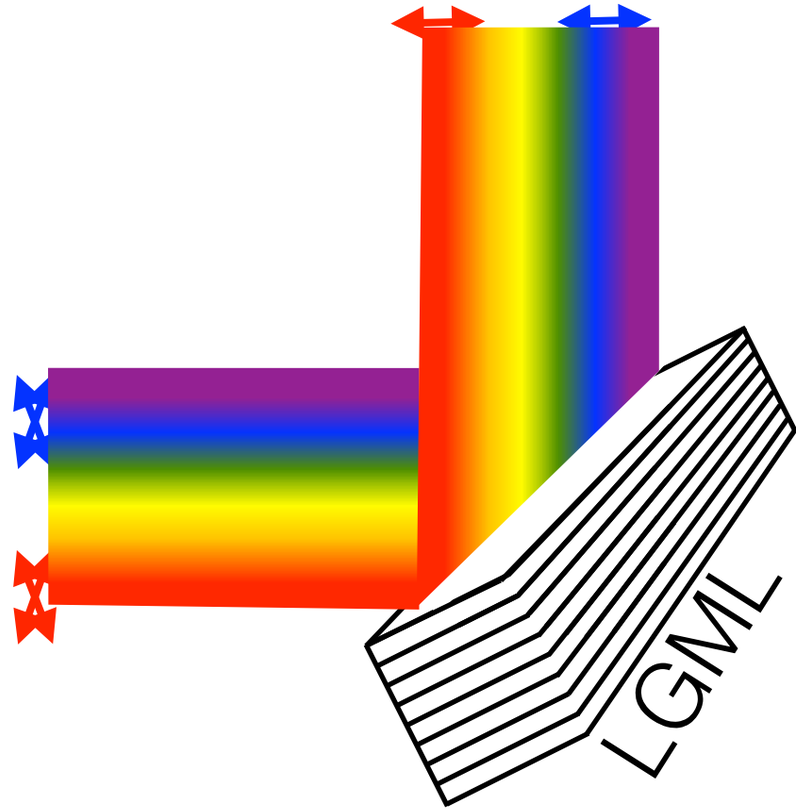
Soft X-ray Polarimetry

- Start with general use broad-band focusing mirror
- Use gratings to disperse X-rays: Critical Angle Transmission (CAT) gratings
- Add Bragg reflector: multilayer coated, flat mirror
  - Period is laterally graded (LGML) along mirror to match dispersion
  - Set at 45±5° angle (Brewster angle) for >95% selection of s-polarization
  - Useful bandpass: 0.15-0.7 keV
  - Components verified at MIT Polarimetry Beamline
  - Designed a sounding rocket instrument
    - Rocket Experiment Demonstration of a Soft X-ray Polarimeter (REDSoX Polarimeter)
    - Received funding for raytracing and mechanical engineering
    - Resubmitting to NASA APRA

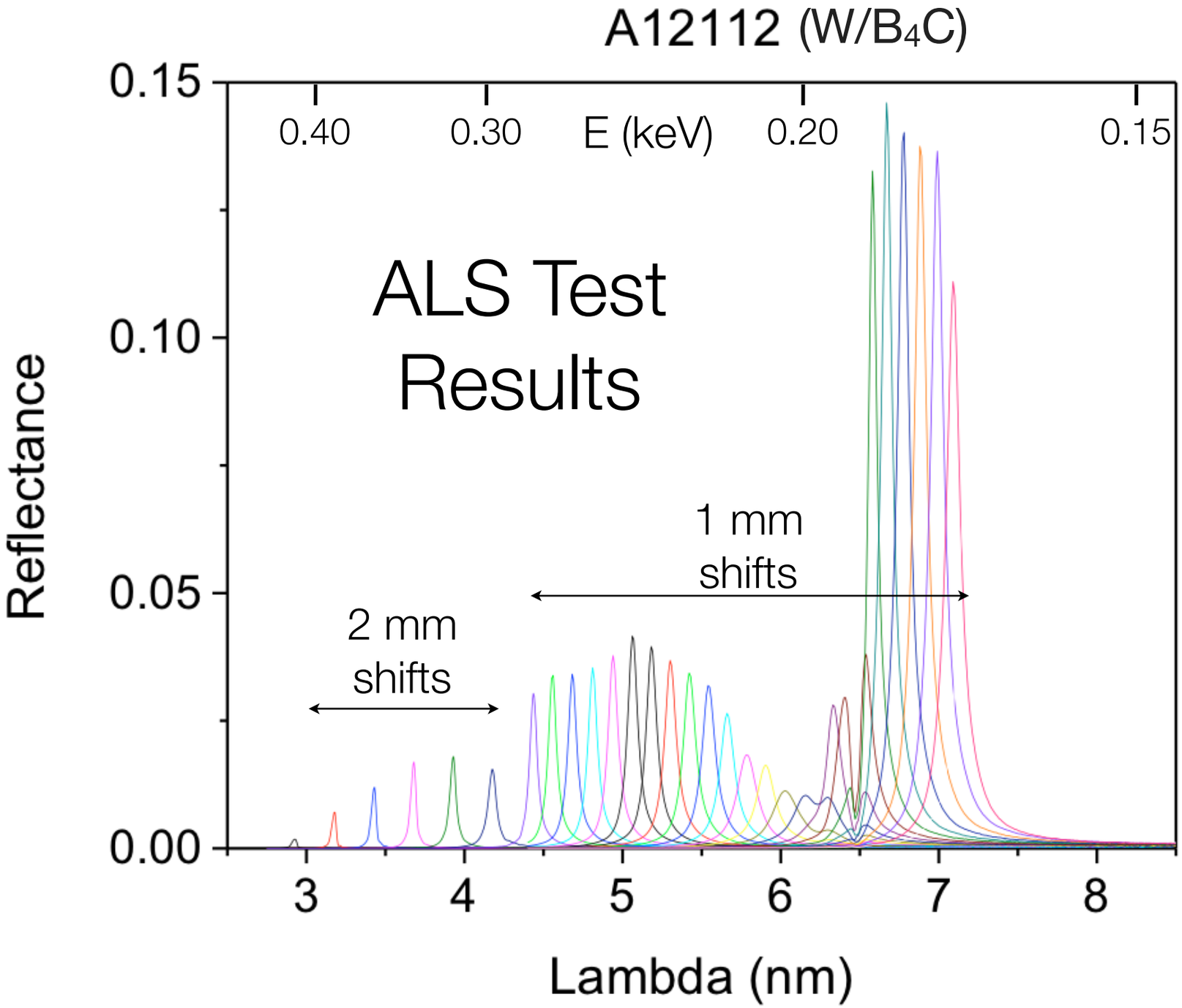
Multilayer Polarimeter Schematic Layout

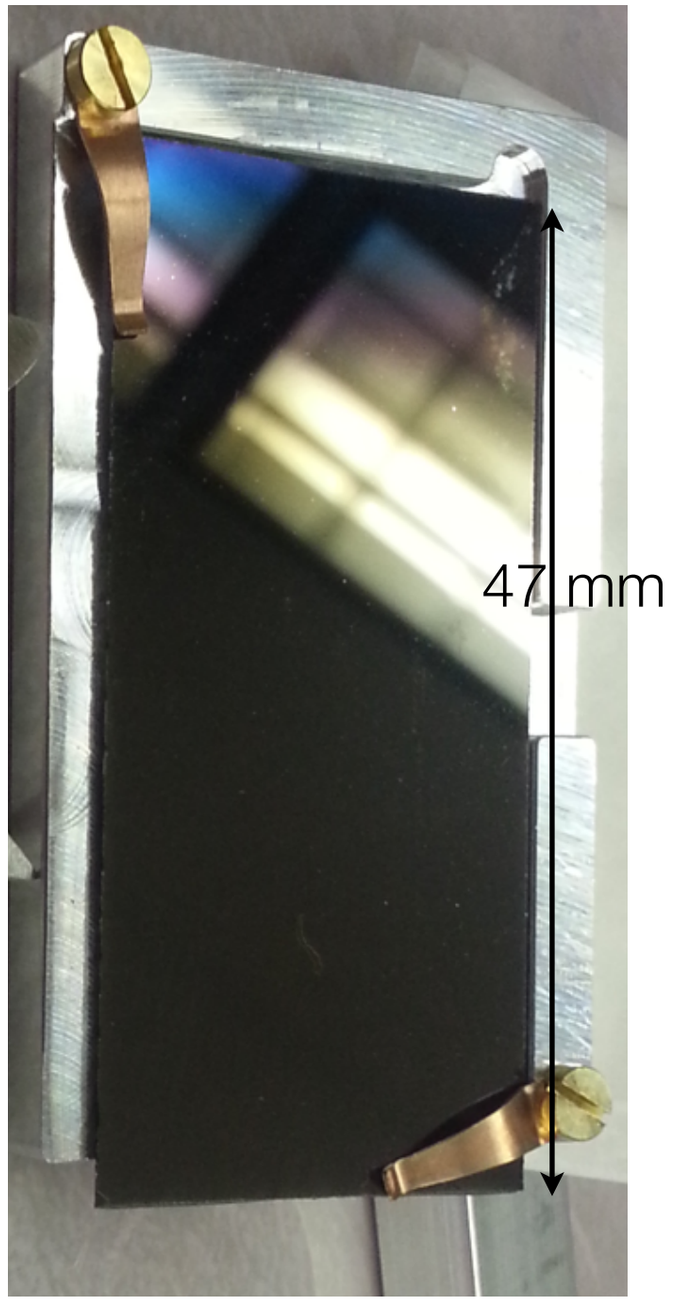




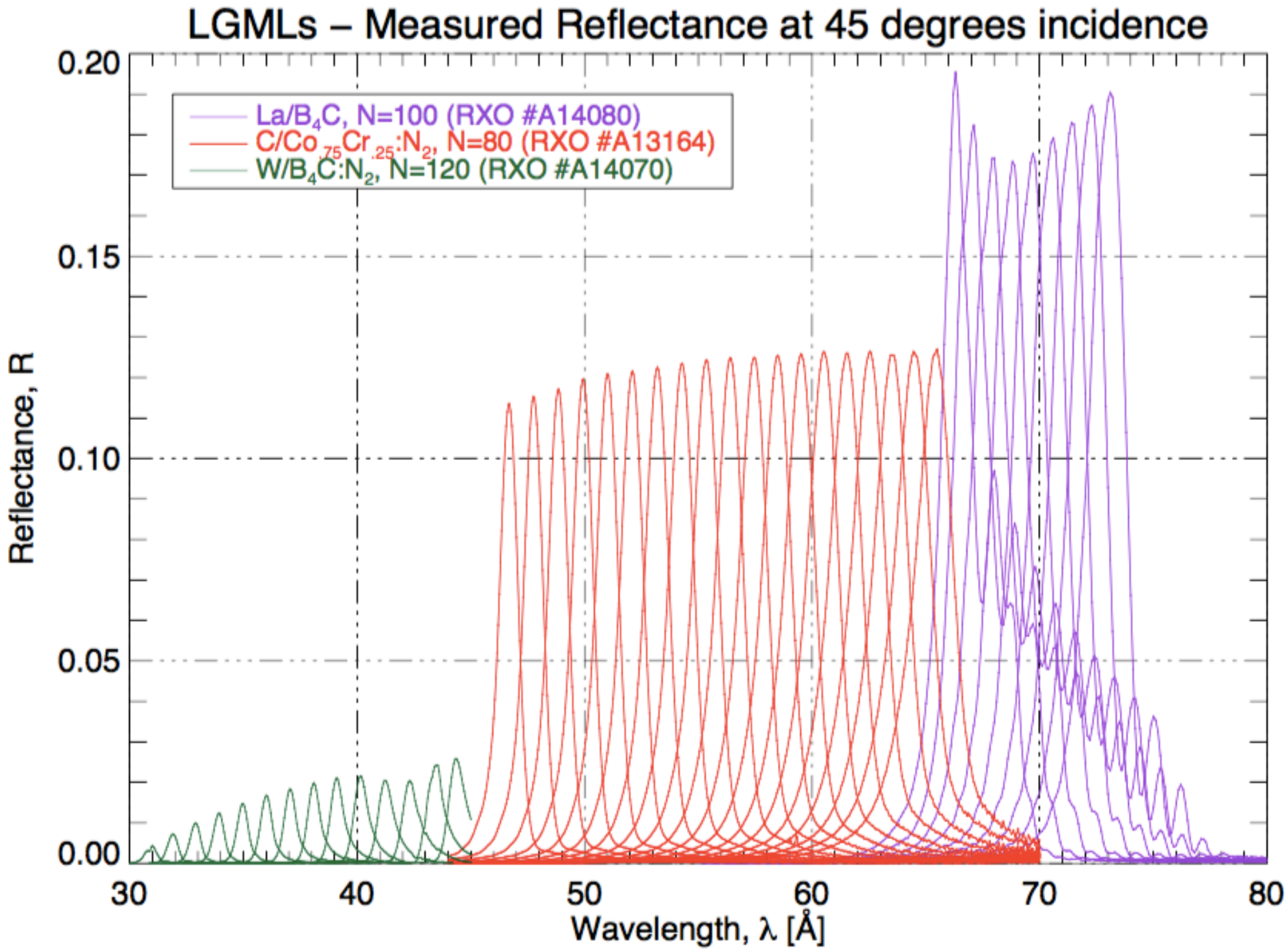


Laterally Graded Multilayers (LGMLs)



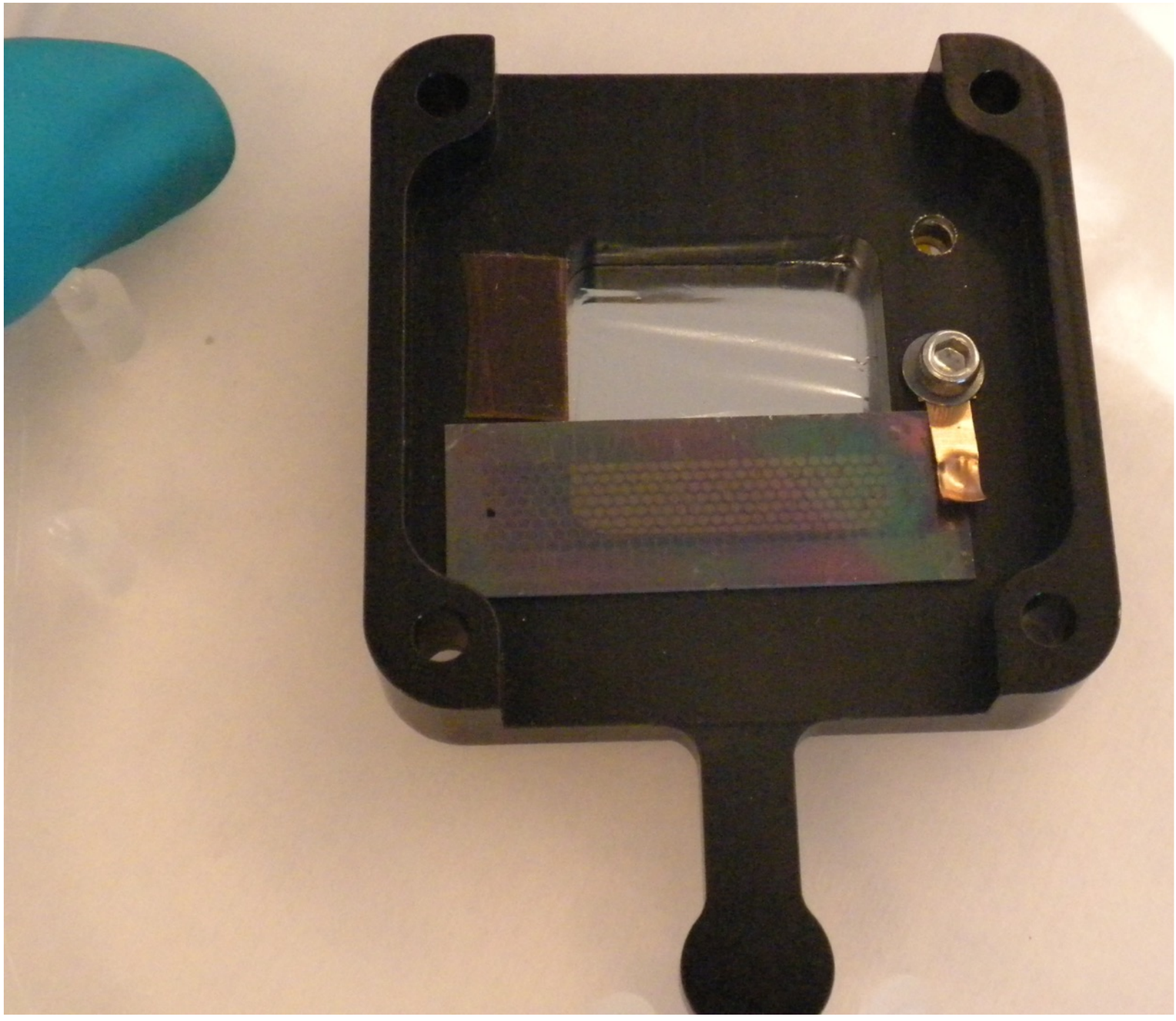


Current Reflectivities of LGMLs



CAT Gratings

- MIT/SNL CAT gratings are now available
- Gratings etched from Si wafers
  - 5 gratings are in lab, others tested at MSFC
  - Efficiencies are as expected, up to 25%
  - Gratings are light



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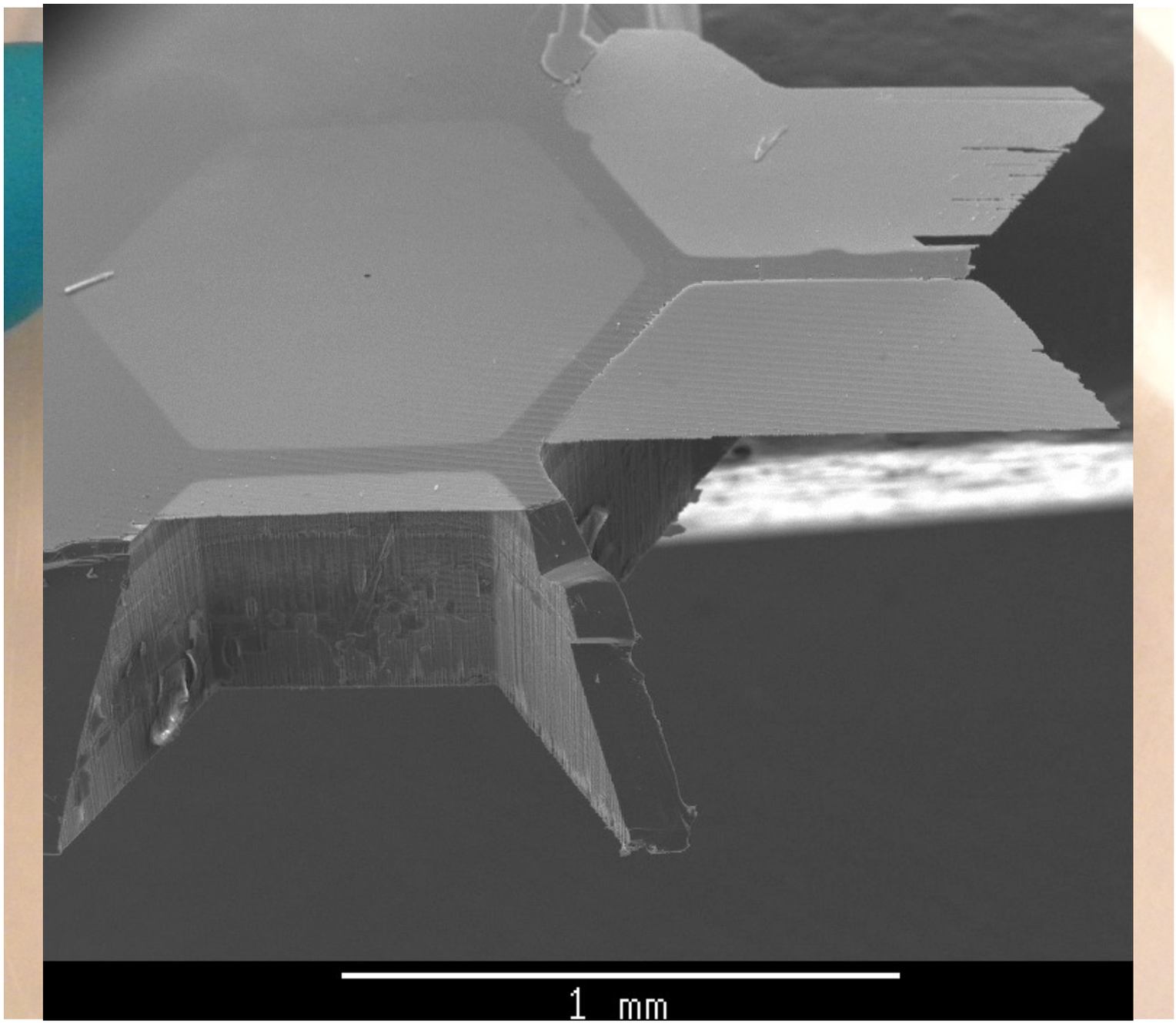

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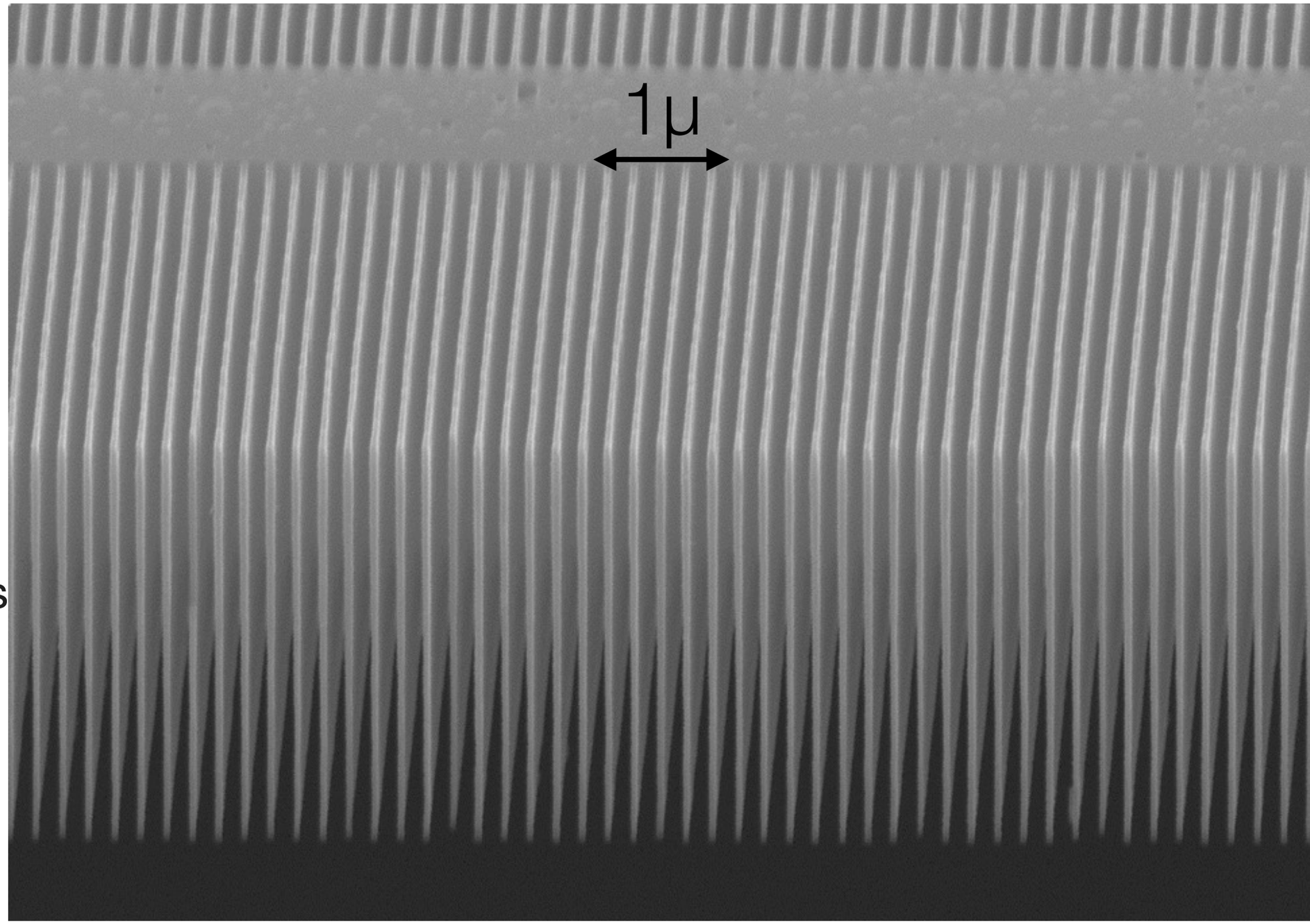
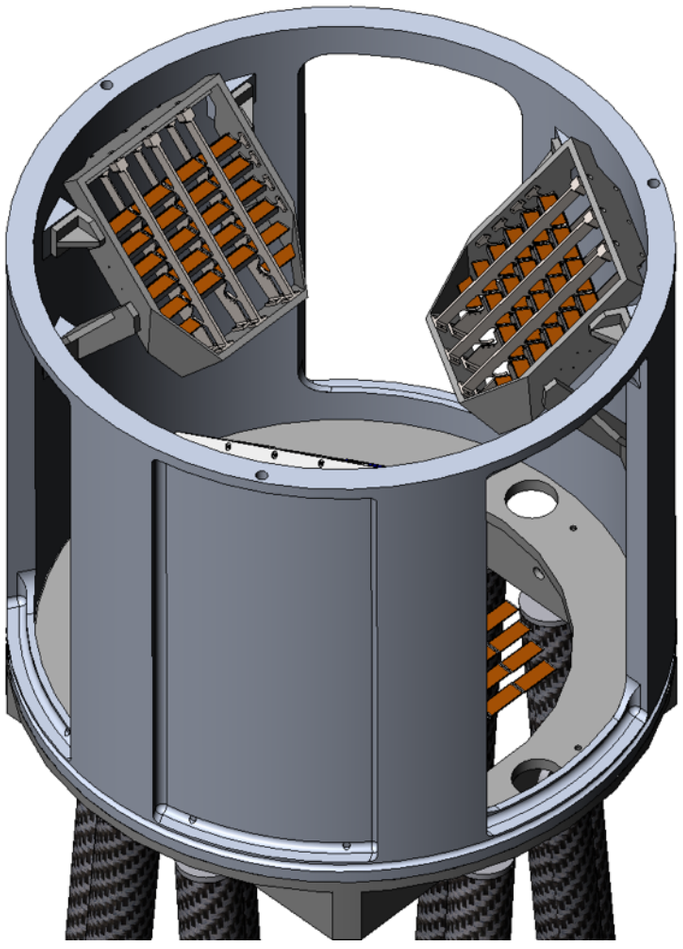
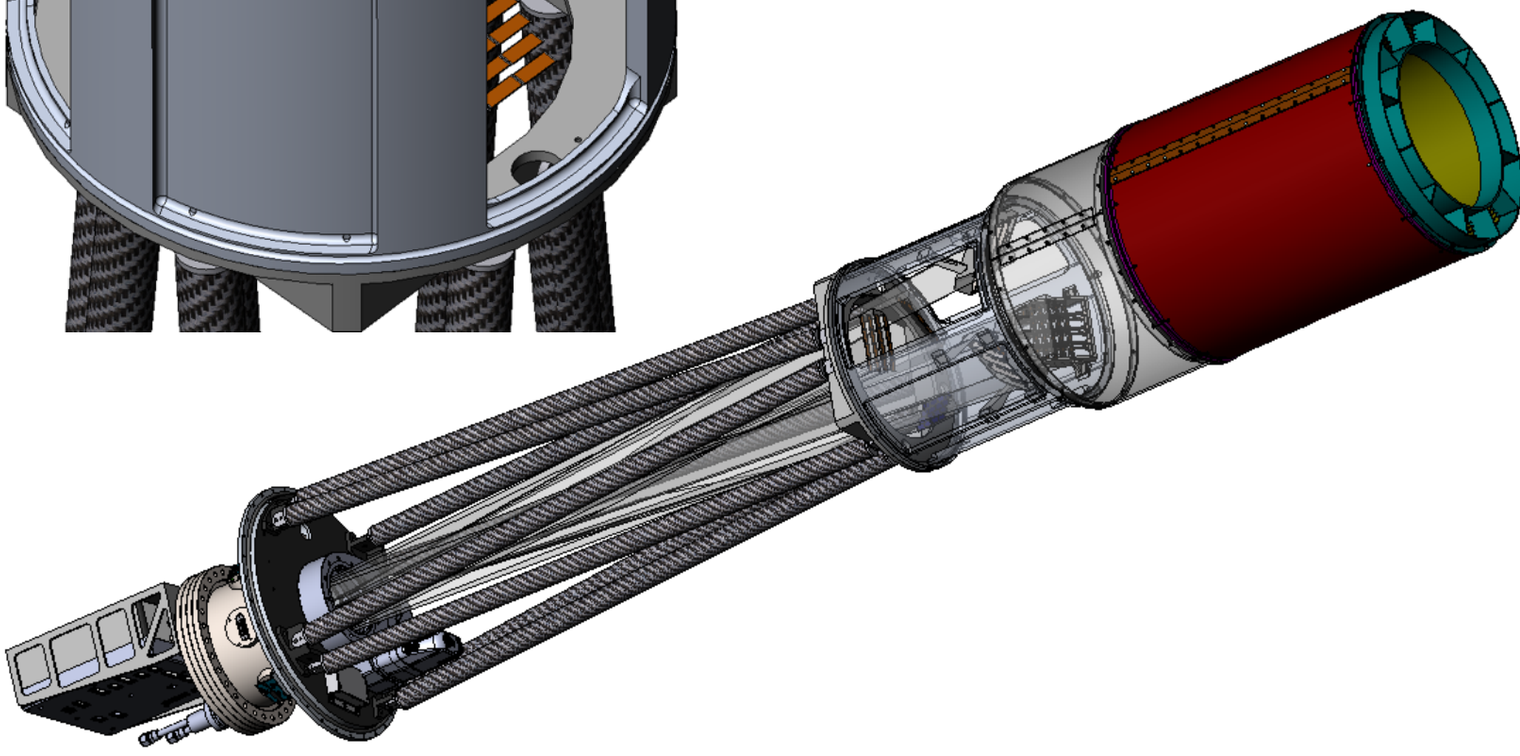


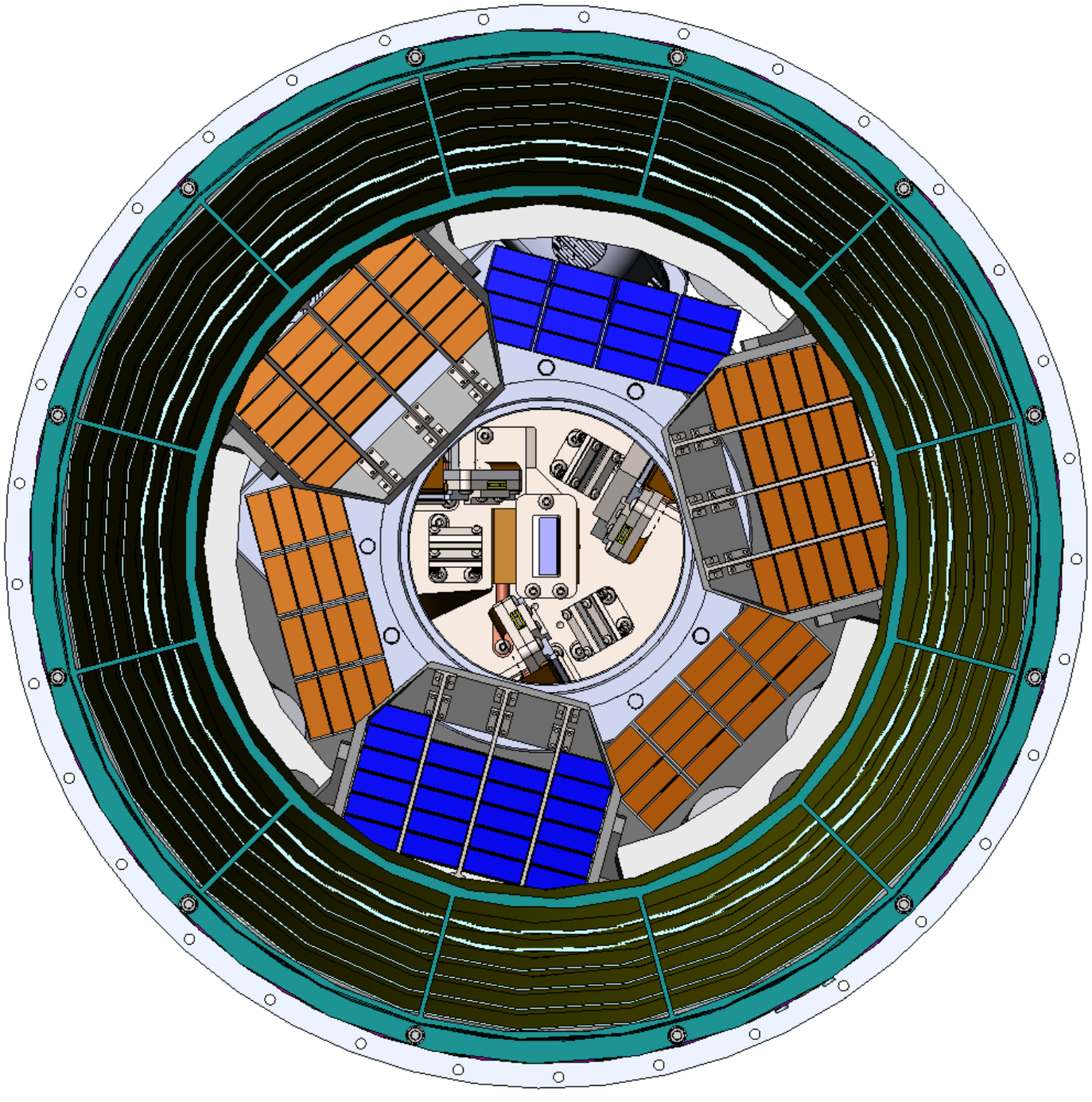
Sounding Rocket Experiment

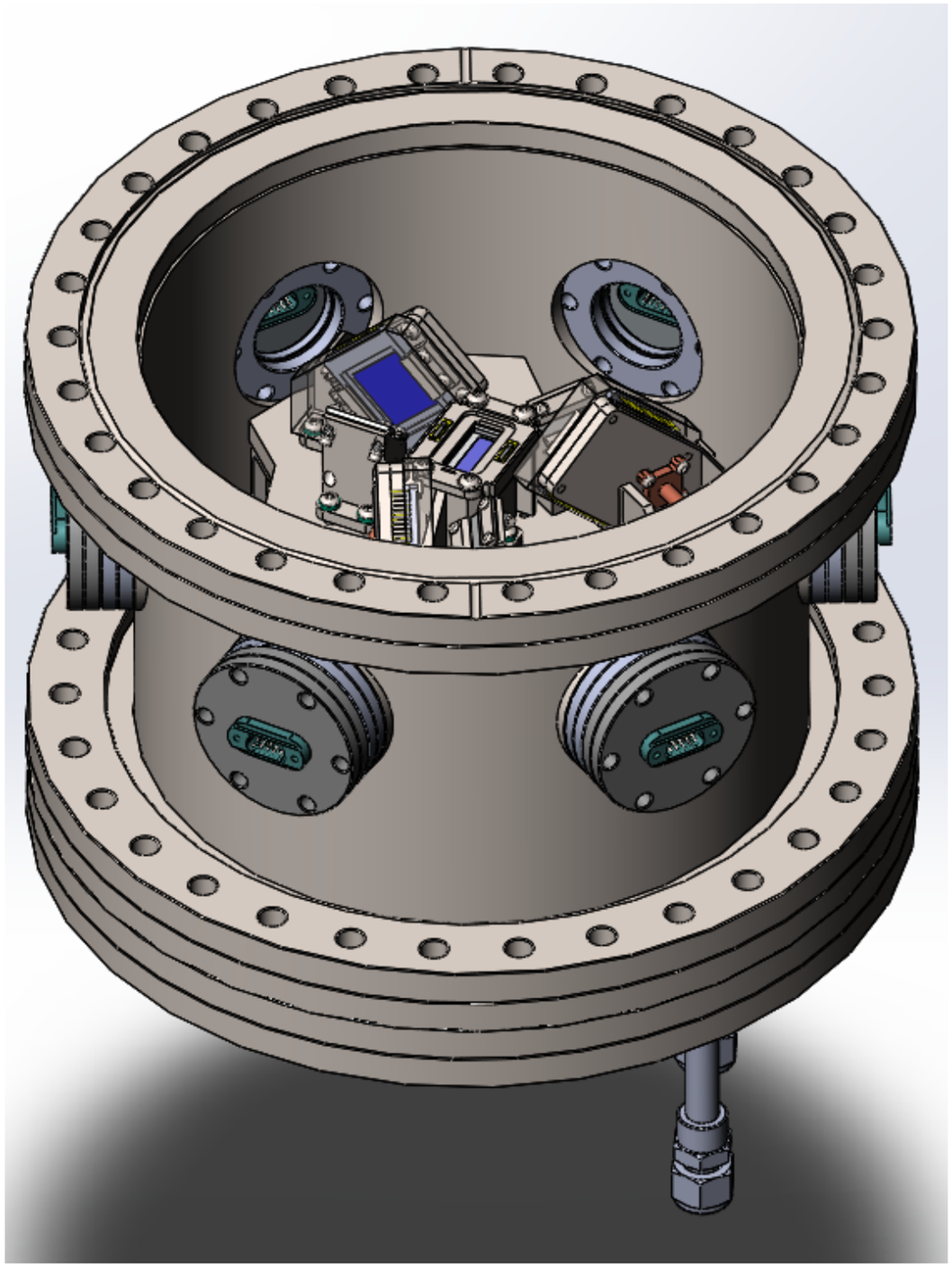
- Focusing optics from MSFC
  - 500 cm^2 mirror
  - 25” HPD
  - F = 2.5 m, 44 cm diam.
- CAT gratings (MIT SNL)
  - in 60° sectors
- 1 direct imaging EMCCD (XCAM)
- 3 LGMLs (RXO) & EMCCDs
- Achieve MDP = 10% for Mk 421 in 300 s exposure





Suborbital Mission:
Entrance Aperture & Focal Plane

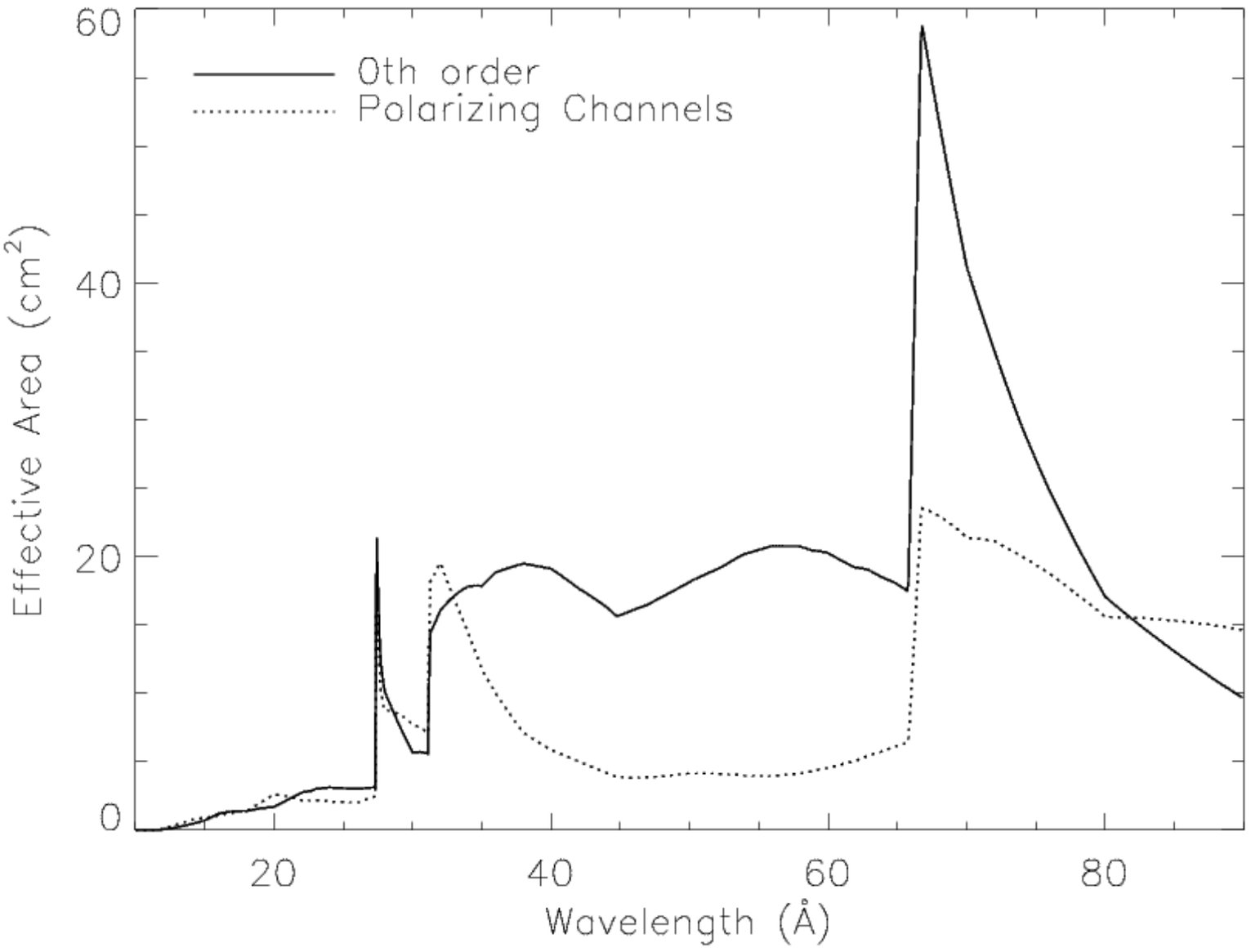




Prediction for eXTP version

- Same focal plane
- Added improved LGML
- Added mirror shells
- 200 ks exposure on 3C 273

- MDP = 2% in 10Å bands (30-70 Å, 0.18 to 0.4)
  - Total rate: 2.3 cps
- PFA in 200 ks: MDP = 2% (2-8 keV)



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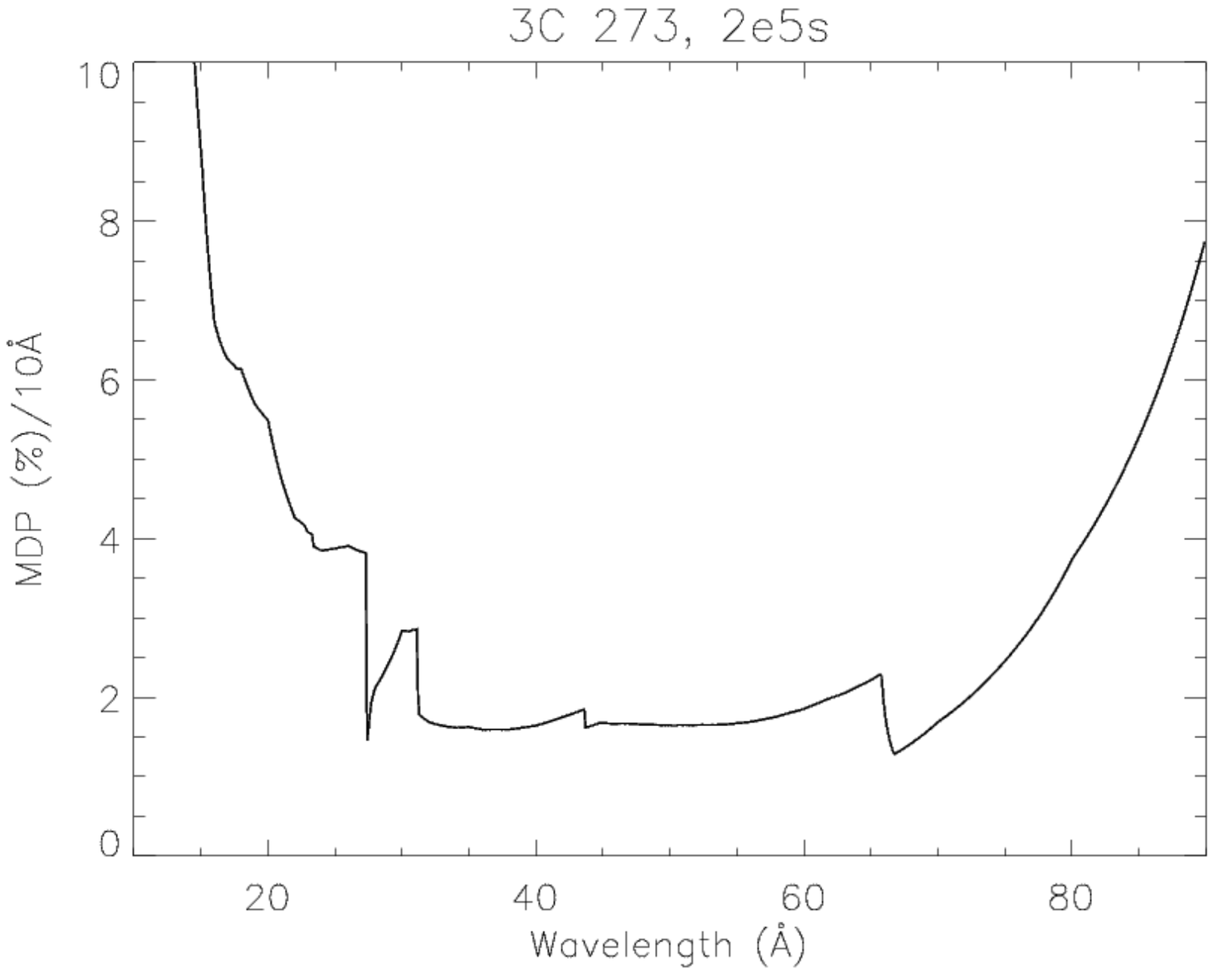
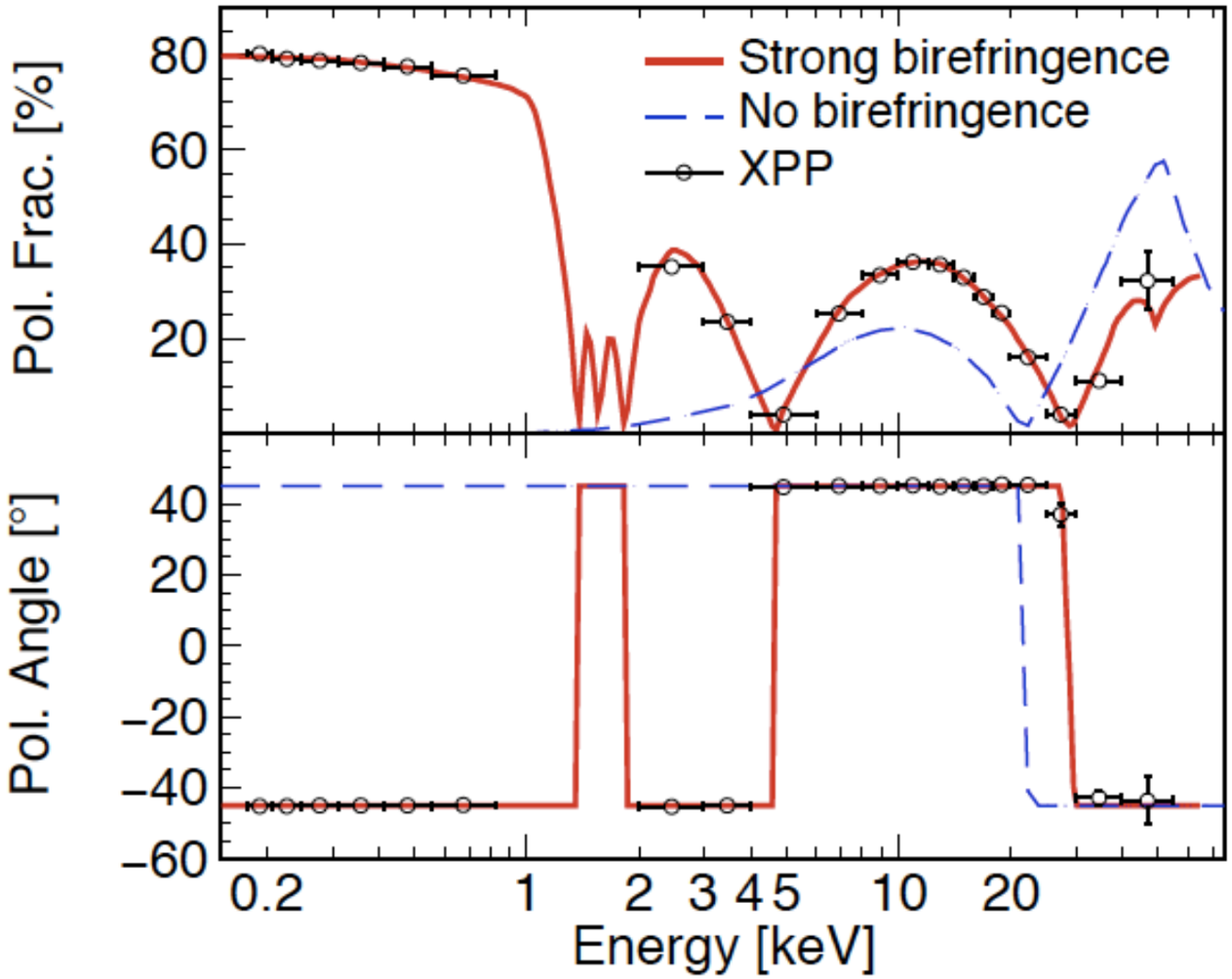
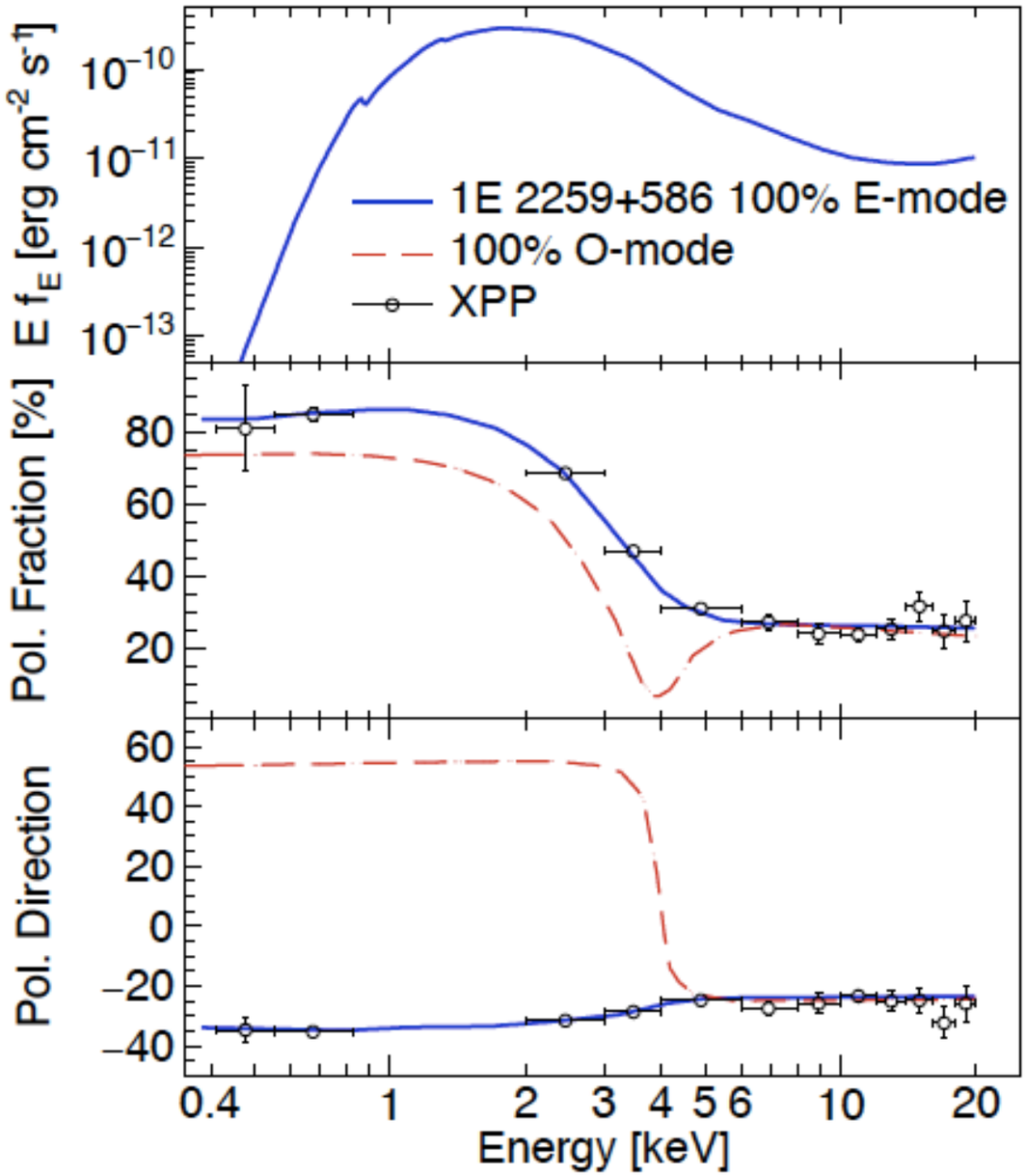


Polarimetry Probe Science

(Krawczynski+ proposal)



Her X-1, 22 ks



1E 2259+586, 1 Ms, 1/4 phase

Summary

- Soft X-ray (0.15 - 0.7 keV) polarimetry is feasible
  - Suborbital flight proposal: REDSoX Polarimeter (1st launch: 2021)
  - Mech. eng. & raytracing validates approach & achievable tolerances
- NASA probe concept study submitted (Krawczynski+): 0.2-50 keV
- For eXTP: add an instrument of the REDSoX design
  - Replace a SFA? Optics diameter same as SFA and PFA telescopes
  - Add to PFA? Add gratings, 3 LGMLs, & 3 detectors, leave GPD
  - Adds 0.15-0.7 polarimetry to PFA's 2-8 keV band
  - Adds low E imager, spectrometer, and flux monitor
- New/improved eXTP science
  - Blazar jets, quasar cores: polarization over x50 in E
  - Nstars below 1 keV: QED (RX J0720-31), pulsars (Her X-1, PSR 0656+14)
  - AGN disk orientation & GR effects, supporting PFA modeling
  - XRB jets for low NH in BH transients (XTE J1118+480)