Soft X-ray polarimeter-spectrometer SOLPEX

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SolPEX: **Sol**ar **P**olarimetry **Ex**periment

Motivation

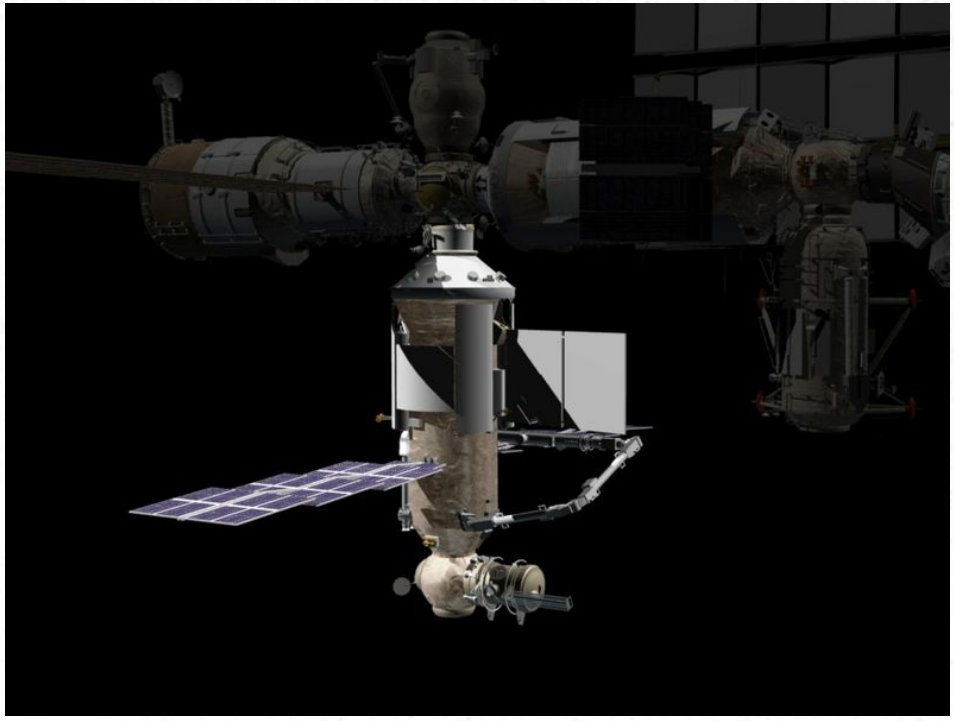
- Reliable detection of X-ray polarisation provides unique, yet unexplored tool of studying non-isotropic distribution of particles in the solar corona
- Ubiquitous presence of collimated non-thermal electron beams during flare impulsive phase is indispensable in order to explain observed patterns of hard X-ray flare emission

Opportunity

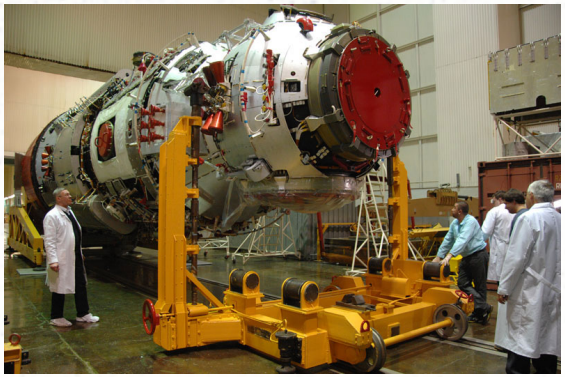
- Russian Academy of Sciences P.N. Lebedev Institute (FIAN) recently became involved in design of the Kortes Package of instruments to be put on the solar pointed platform attached to the Russian Module aboard the ISS. Expected launch 2015-2016.
- FIAN (Professor Sergey Kuzin: Head) offered SRC-PAS Solar Laboratory in Wrocław a possibility to place an instrument for testing new measurement concepts.
- Our Team decided to take this opportunity and designed the SolPEX instrument intended for measurements of solar soft X-ray spectra, simple imaging and line polarization detection through Bragg crystal spectroscopy.
- Official Collaboration bi-lateral protocols have been signed between SRC-PAS and FIAN on 15th November 2012.

ISS Nauka module

- Nauka (Russian: Нау́ка; lit. Science), also known as the Multipurpose Laboratory Module (MLM) or FGB-2, (Russian: Многофункциональный лабораторный модуль, or МЛМ), is the major Russian laboratory module which will take the place of Pirs.



- Nauka is expected to be launched in 2014/2015.
- SUN-pointing platform will be attached to NAUKA



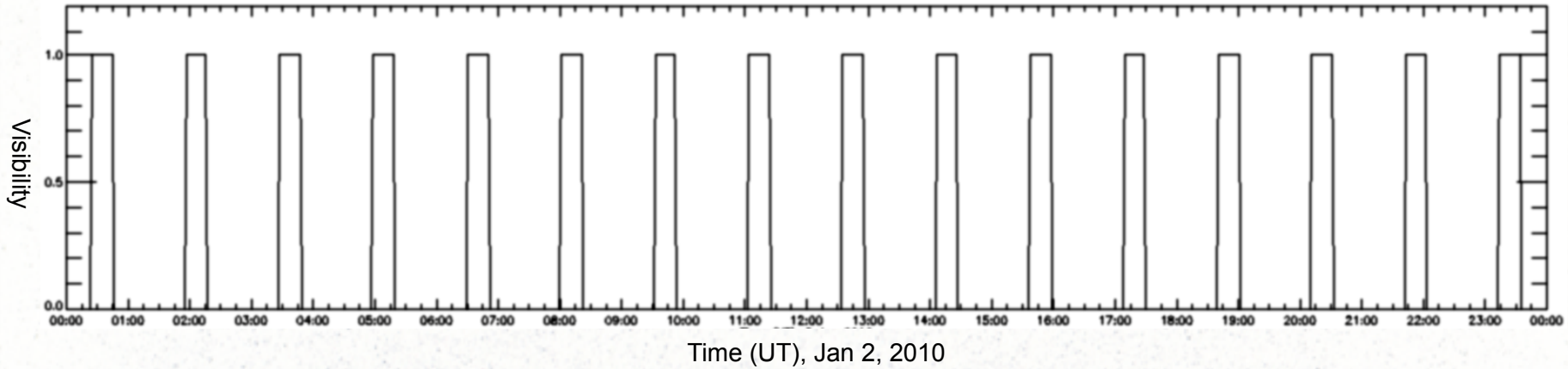
MLM Nauka module arrives to RKK Energia's KIS test facility in Korolev on Dec. 14, 2012. Credit: RKK Energia

Is ISS a good observing platform?

- Easy access to ISS, instrument mounting by cosmonauts
- Possibility of using large instruments
- No substantial limitation on power
- Large volumes of data storage on „popular" media
- Possibility of „repairs" and memory module transport to the ground

- Rough Pointing- few arcmin due to ISS motions
- Spacecraft day/night shifts (16 nights/24h)
- Vignetting by various ISS structures: only ~10 min of uninterrupted measurements per orbit possible

Sun visibility from Nauka



- The ISS orbits the Earth at 51.6° to the Equator, following the direction of the Earth's rotation from west to east.
- The Earth itself is tilted at 23.4° to the plane of its orbit around the sun (sun vector)
- The ISS's altitude varies between 320 to 410 km, and it takes 92 minutes to circle the Earth.

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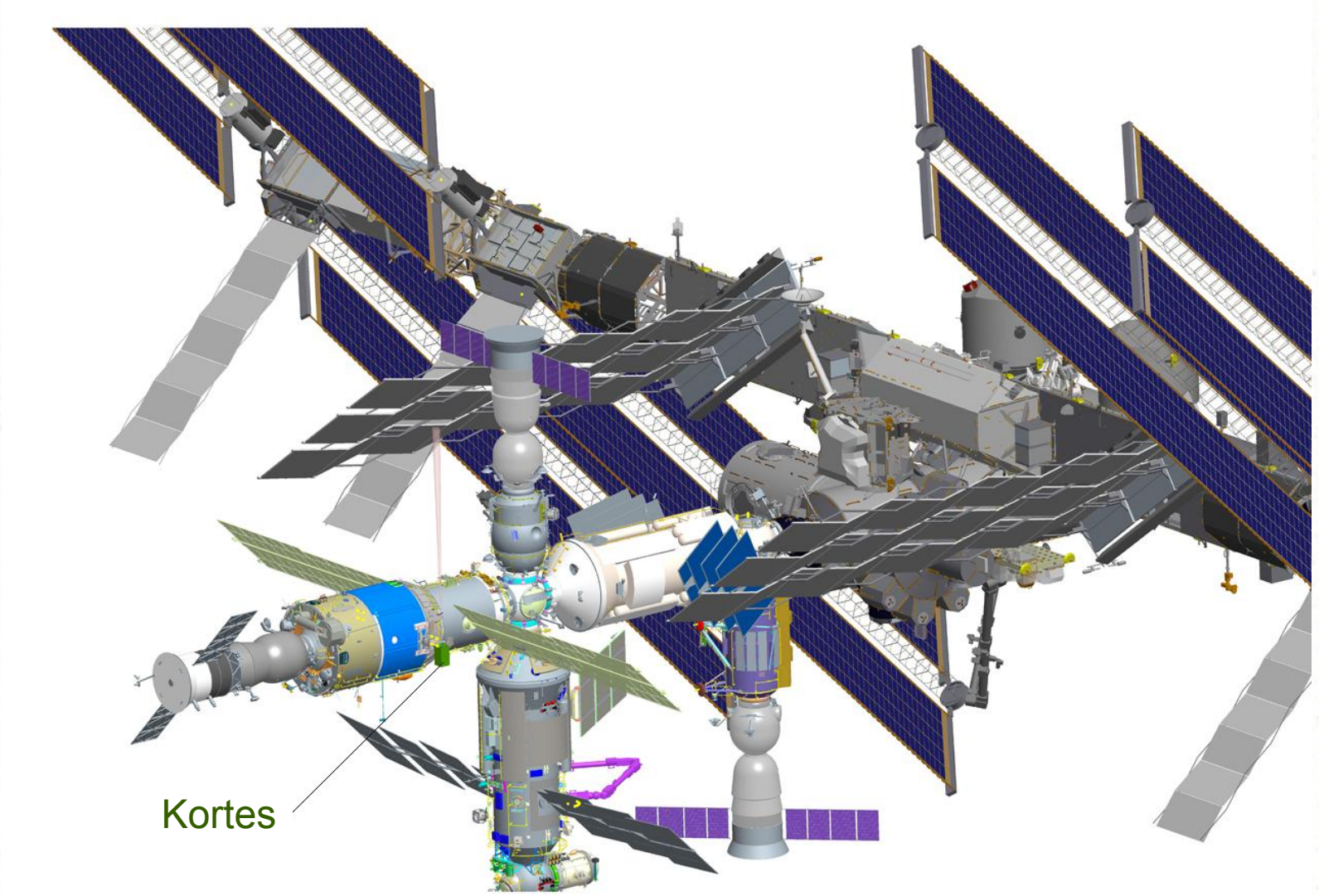
ISS suitable for tests of new experimental ideas

SUN-pointing platform - Kortes



Kortes

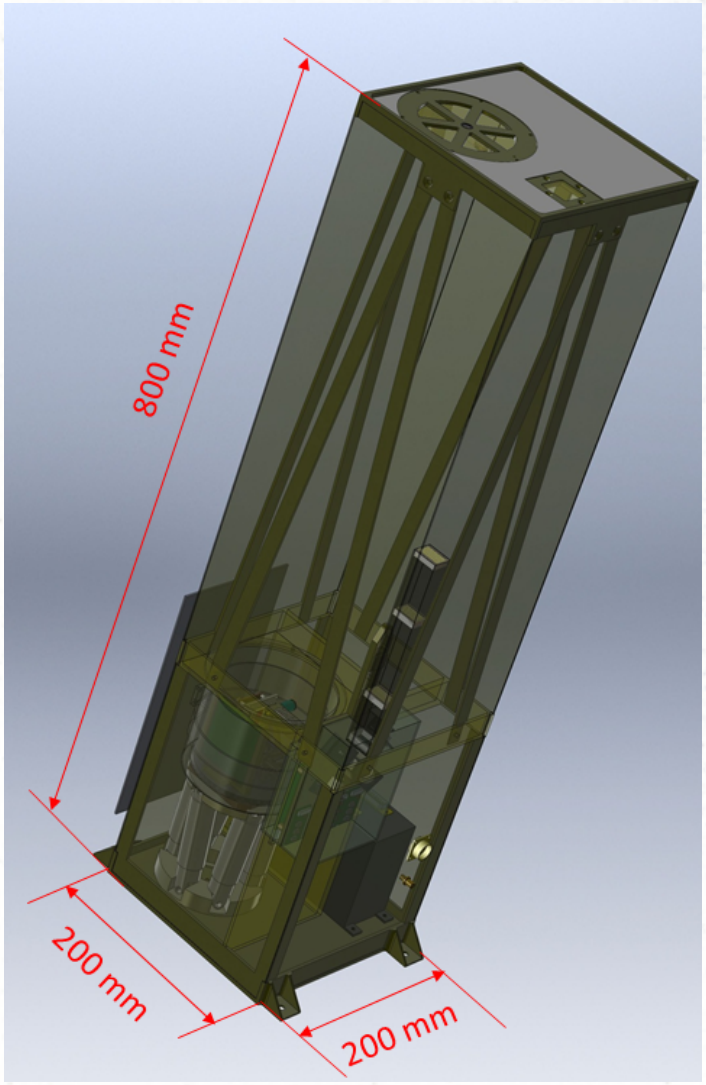
- Block of detectors – vacuum space outside the ISS on 2D-platform
- Block of electronics – inside the ISS

- Block of FIAN detectors:
  - 2 telescopes – 171 and 304 Å (some other channel for technology & science testing)
  - 2 spectroheliographs 180-210 Å & 280-330 Å
  - **X-ray spectropolarimeter SolPEX (0.5-15 keV)**

SolPEX objectives

- Measurements of polarization in soft X-ray continuum emission and possibly in selected emission lines (1-2 % detection limit) (B-POL)
- Measurements of X-ray spectra evolution with very high time resolution (0.1 s) rotating drum spectrometer (RDS) - idea proposed by Stefan Płocieniak
- Imaging the soft X-ray Sun with moderate spatial (~20arcsec) and high time resolution (0.1 s) pin-hole imager (PHI)

General view



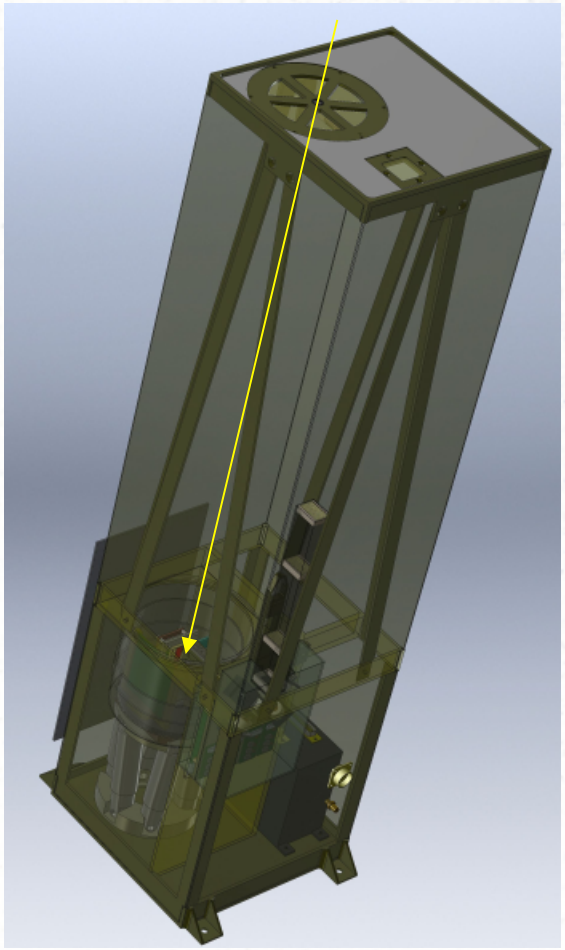
Design: Jarek Bąkała SRC PAS, Solar Physics Div.

- Pin-hole imager
- Rotating, bent-crystal Bragg spectropolarimeter with capillary 2D collimator
- Rotating drum, flat crystal, multiple band Bragg-crystal spectrometer with multi-slit collimator
- 6D Hexapod precision (arcsec) pointing device
- Front-end open-space electronics

Pin-hole imager

Purpose: Locate the X-ray source on the Sun

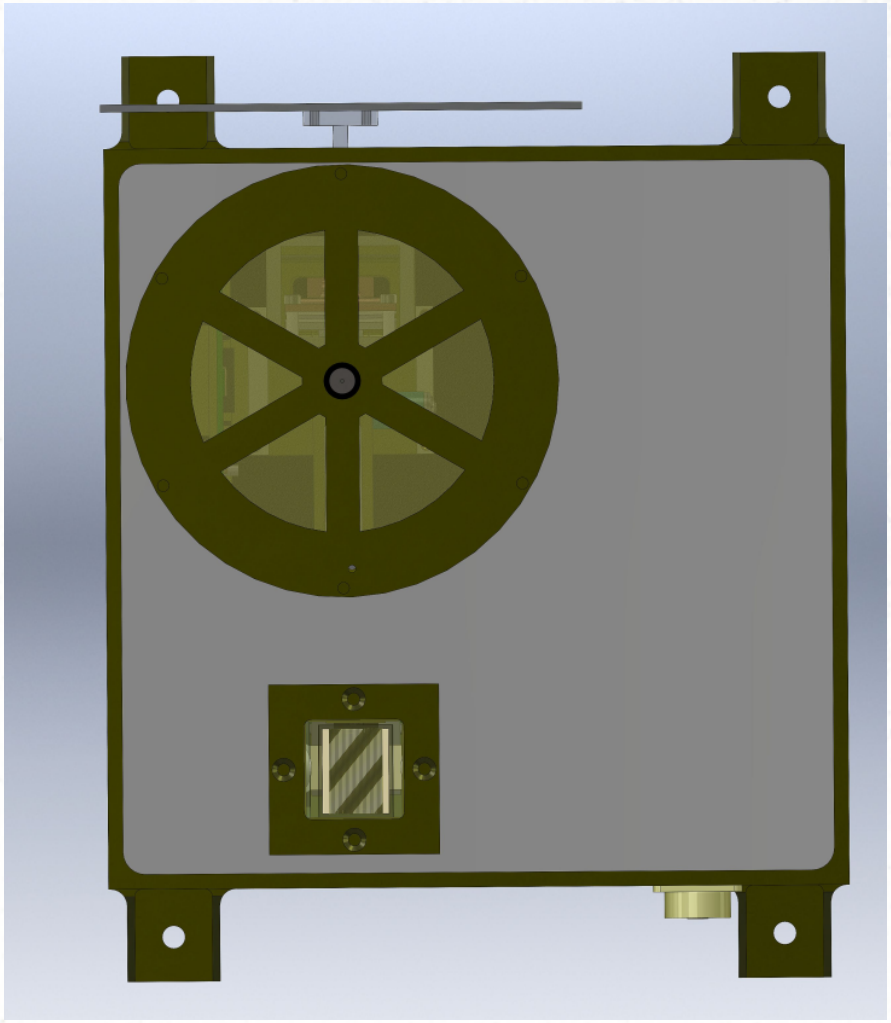
E range: 1-10 keV, dE: ~1 KeV



- Primary role: localize sources (AR & flares) on the disk in the instrument coordinate system
- Secondary: detect active phenomena on the disk, analyse individual lightcurves for separate AR
- Easy concept: pin-hole (adjusted diameter open down to 0.1 mm, can be changed depending on the activity), CCD detector (256 x 1024 pixels 26 μ)
- Image readout: each 0.2 s
- Will provide positions [x,y] of more prominent individual sources (resolution 1.5 arcmin).
- Limited spectroscopy, similar to RHESSI at lower energy range (Fe XXV and Fe/Ni line groups distinguishable)

Pin-hole imager

View from the Sun



- Focal length ~60cm
- Spatial resolution:
  - 0.5 mm hole ~2 arcmin (AR)

    20 x 20 pixel area
  - 0.1 mm hole ~30 arcsec (flare)

    4 x 4 pixel area
- Solar diameter: 200 x 200 pixels
- FoV: 38 arcmin x 150 arcmin

6D Hexapod new precise pointing system

M-811 Vacuum-Compatible

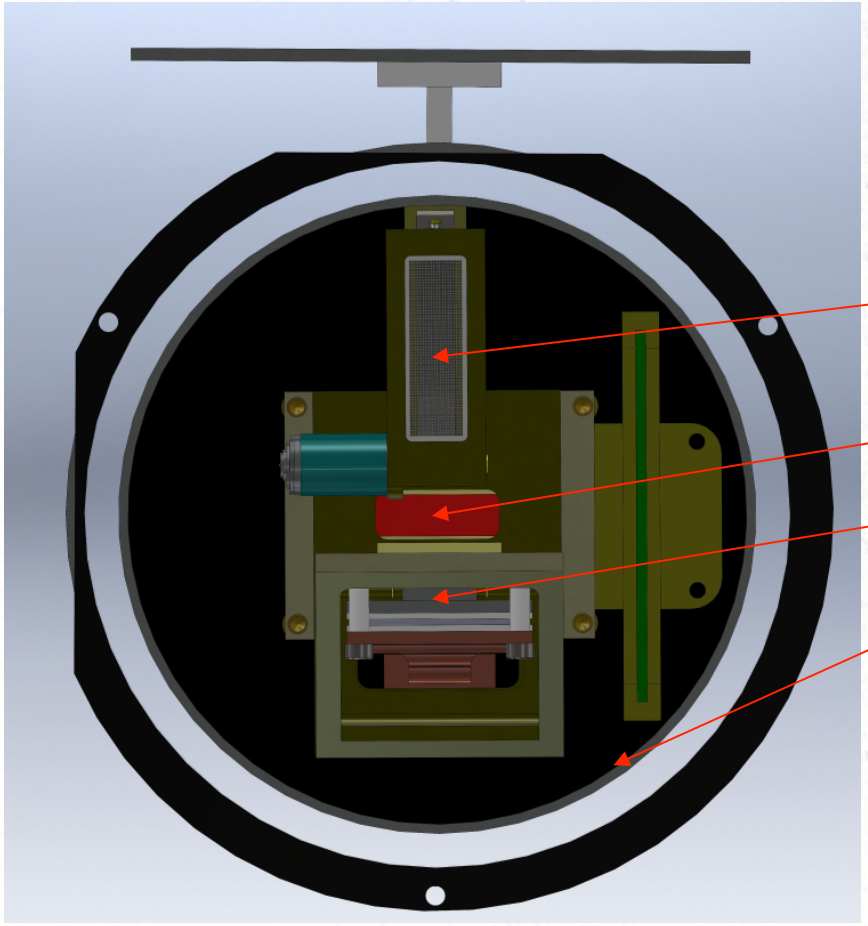
High Precision and Very Versatile

The M-811.STV vacuum-compatible Hexapod comes complete with software and a highly specialized Hexapod controller. It combines small size with high-load capacity and high accuracy.

PIEZO NANO POSITIONING

- Mass 2.2 kg
- Vacuum-Compatible
- Travel ranges 34×32×13 mm
- Rotation to 42°
- Load Capacity to 5 kg
- Actuator Resolution 40 nm
- Velocity to 10 mm/s
- Repeatability up to ±0.2 µm

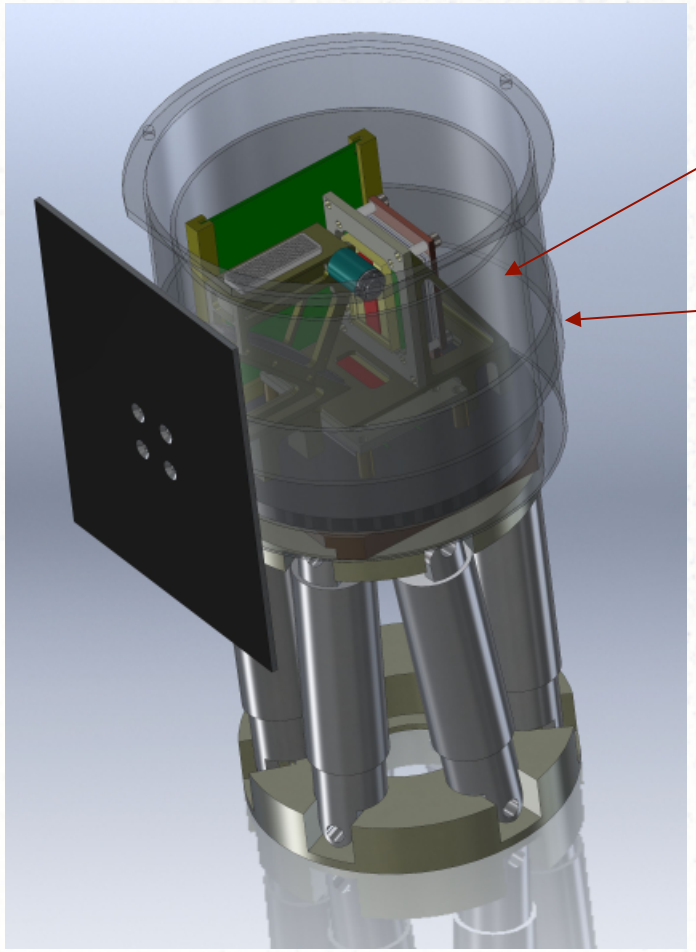
Rotating polarimeter unit



View from the Sun

- Si 111 bent crystal at the Brewster angle ~45°
- Pin-hole image
- CCD detector (1024x256 pixels)
- Rotating at 1 rev./s

Removing heat from the rotating section



- Rotating section connected to the emitting drum
- Still-heat receiving drum connected to external radiator

Heat transfer through radiation between the two

Spectro-Polarimeter monocrystal wafer: cylindrical Si 111

2d=6.271 Å

- Spectral range:

  3.940 - 4.505 Å

- Radius of curvature:

  180.0 mm

- Crystal length & width:

  38.2 & 10 mm

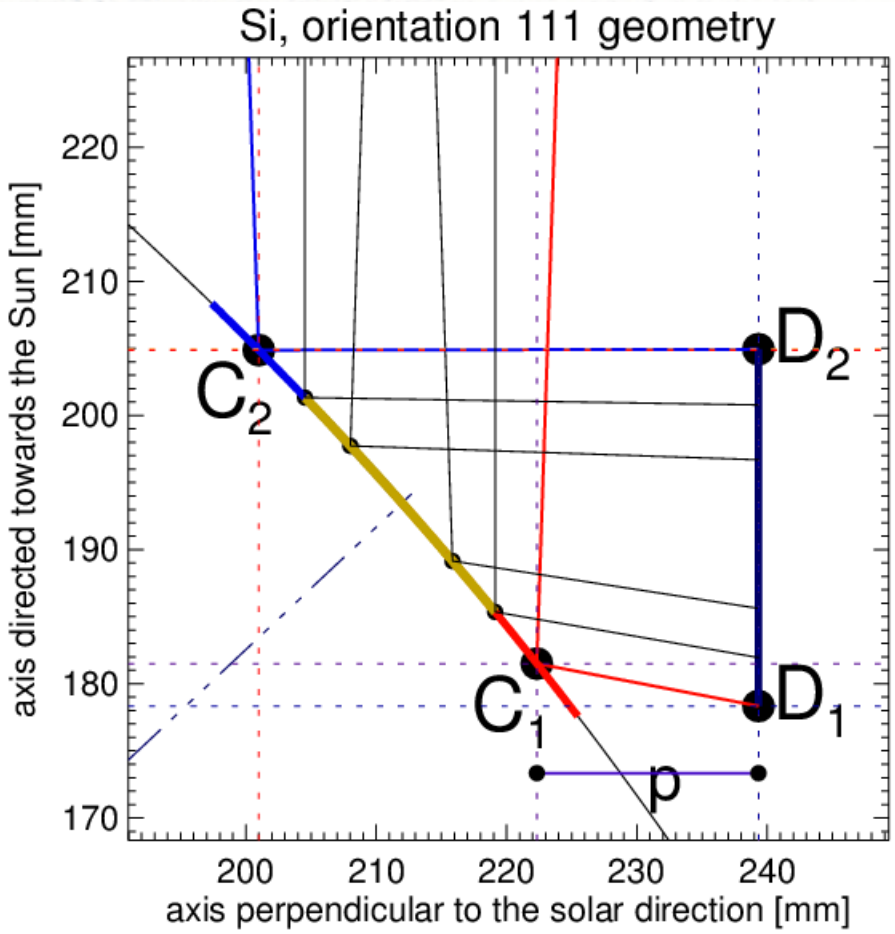
- Calculated ideal

FWHM & Resolution:

4.4 arcsec ~ 0.0005 Å

< line thermal wdths

courtesy Żaneta Szoforz



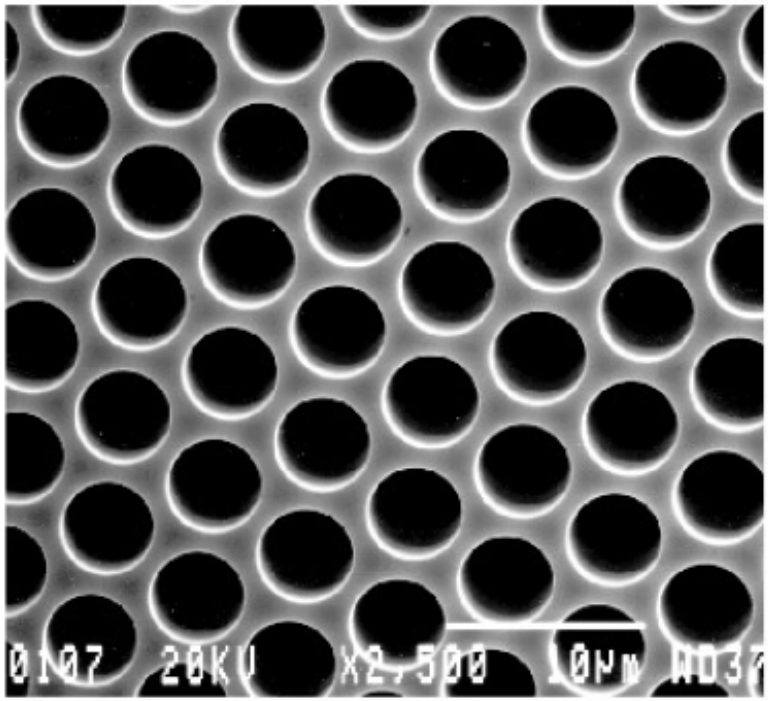
Why this selection?

- Continuum and line emission should be prominent for a wide range of physical conditions on the Sun i.e. AR and/or flares
- Clean spectral range in the vicinity of the lines, allowing for separate measurements for the continuum and line rotationally modulated pattern

The need for isolated source

Selecting isolated AR or flare is crucial to avoid overlapping the spectra

The Capillary collimator (~2 arcmin)



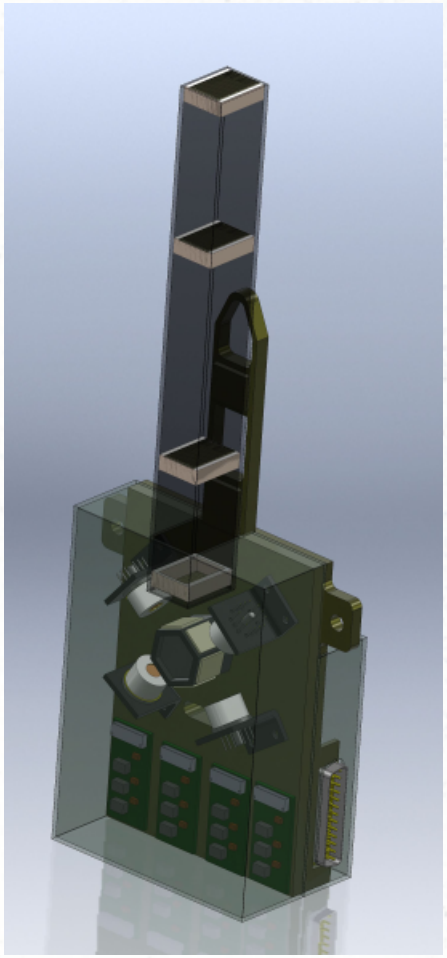
collimatedholes

Microscopic view of a Glass Capillary Array with precision 5 micron pores.

- Glass Capillary Arrays are strong, self-supporting devices;
- Have exceptional thermal and chemical stability;
- Can withstand temperatures greater than 450 °C.

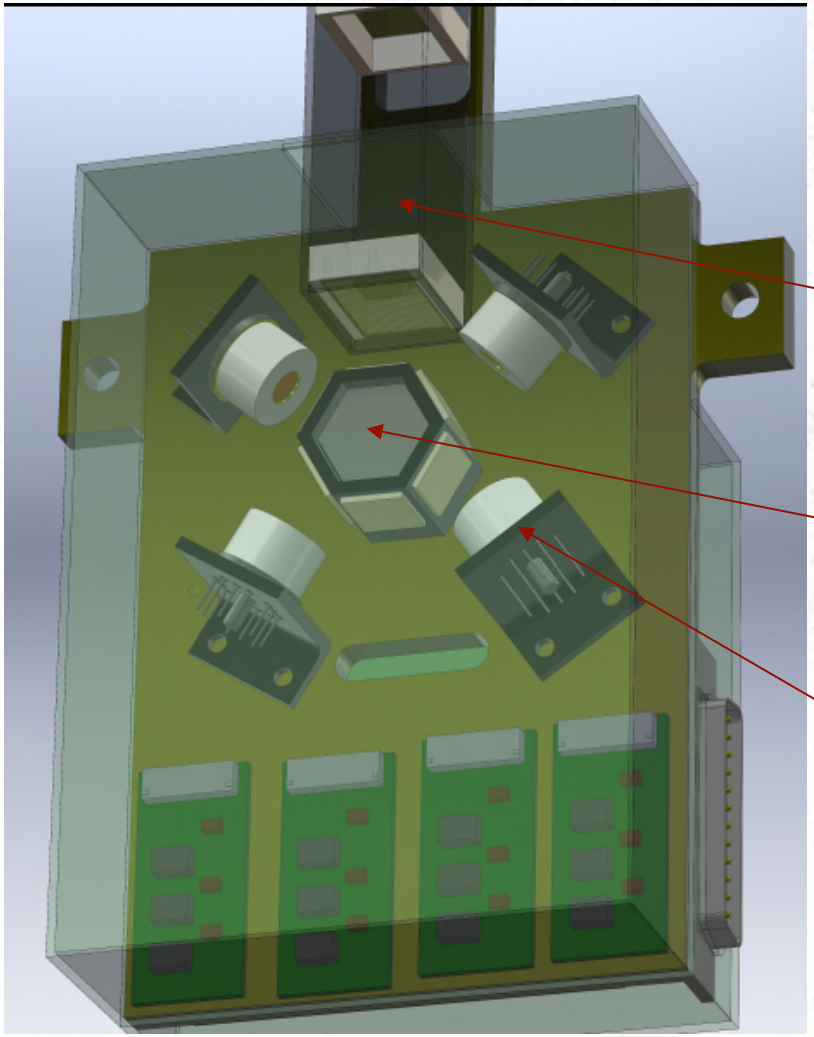
A very high time resolution (0.1s) spectroscopy for flares

New concept: Stefan Płocieniak SRC PAS



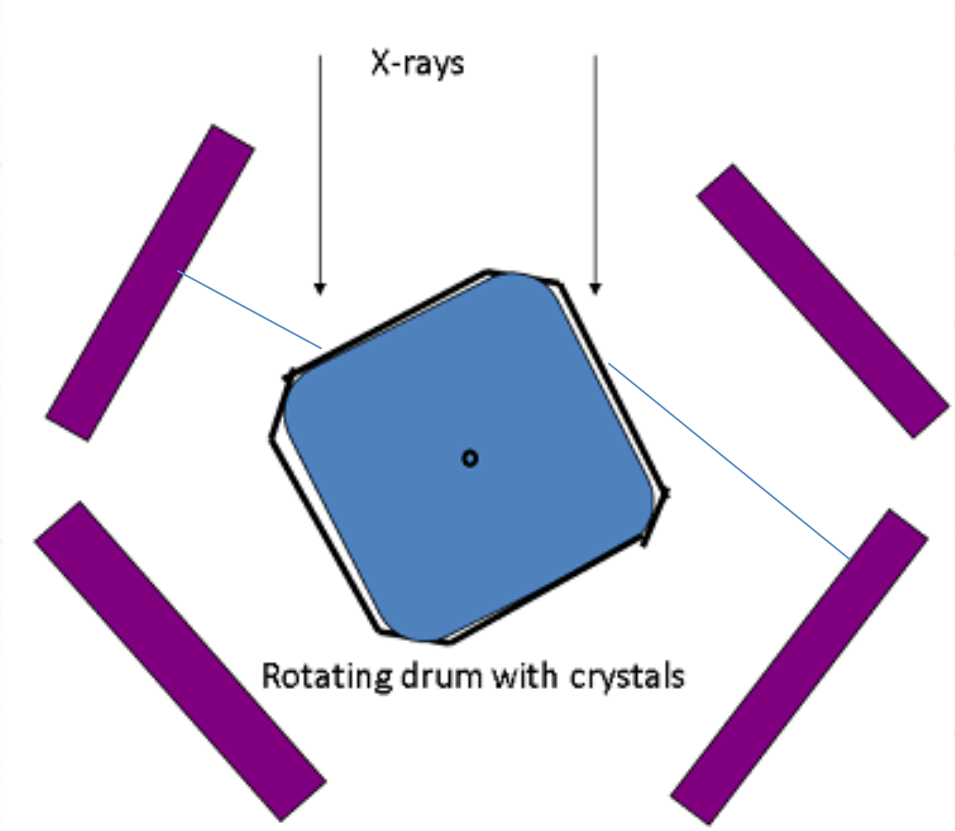
- Fast rotating drum equipped with 3 pairs of identical crystals in the Dopplerometer orientation Bragg-illuminate the ”standard” SDD detectors’
- Thanks to the rotation photons are being „reflected” from the crystal.
- By monitoring the photon arrival time, accurate „intercept” angle can be estimated & converted to wavelength
- Histogram spectrum will be revealed with sufficient amount of detections

Rotating Drum
Flat spectrometer unit



- Single emitting solar AR selected by the multi-slit collimator, based on PHI data
- Fast rotating (10 rev/s) drum with a set of 6 crystals (3 pairs of identical flat monocrystals in Dopplerometer configuration)
- 4 large area ~0.25cm^2 PIN detectors

Spectra reconstruction from a fast rotating crystal drum



- Angular position of the detector event (1 μsec accuracy)
- ~few arcsec angle determination accuracy
- less than line FWHM

Summary

- Kortes opportunity is unique for testing new measurement ideas
- Very short design time is an obstacle, but many components are already at hand & tested at SRC PAS SPD
- Detailed ground calibration & alignment & testing (innovative) procedures are necessary
- New measurement techniques can be tested and interesting flare physics can possibly be revealed