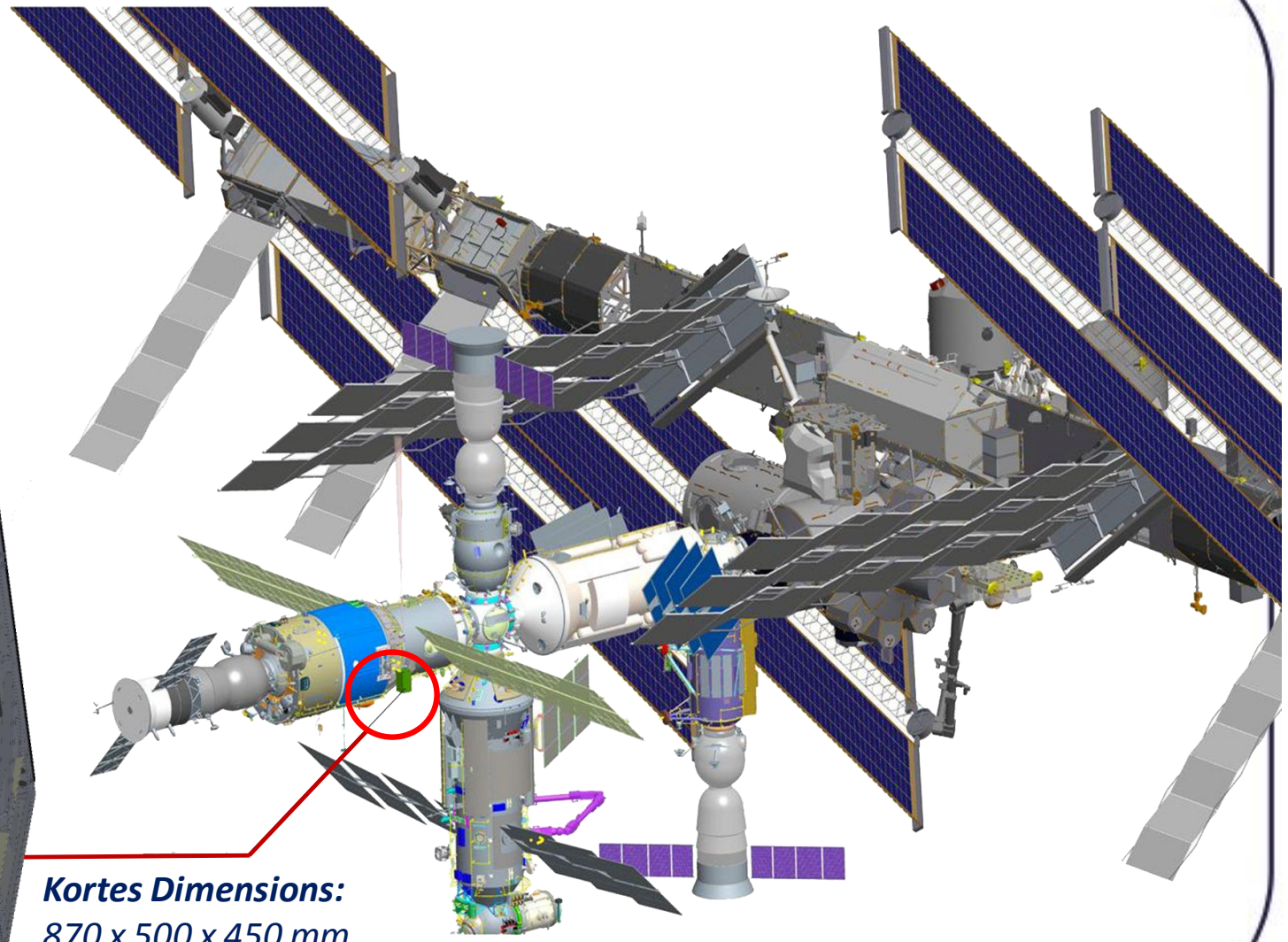
# CURRENT STATE OF MECHANICAL SOLUTIONS OF TWO INSTRUMENTS DEVELOPED AT SOLAR PHYSICS DIVISION OF SRC PAS

Jarosław Bąkała, Janusz Sylwester, Marek Stęślicki, Żaneta Szaforz, Mirosław Kowaliński, Stefan Płocieniak, Zbigniew Kordylewski, Daniel Ścisłowski, Piotr Podgórski, Anetta Owczarek

17th Ukrainian Conference on Space Research, August 21-25, 2017, Odessa, Ukraine

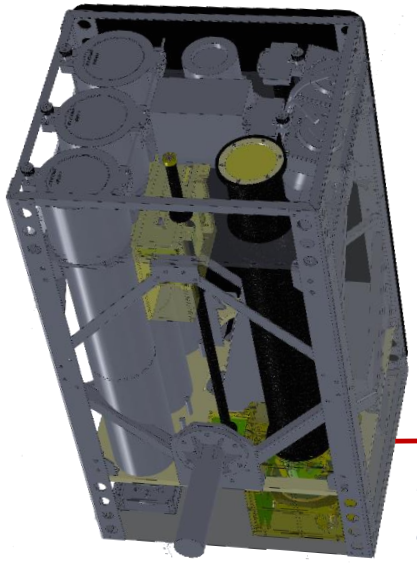
# International Space Station



**Block of FIAN detectors:**

- 3 telescopes – 195, 304 and 584 Å
- 2 spectroheliographs 170-210 Å & 280-330 Å
- X-ray spectropolarimeter SOLPEX (0.5-23 Å)

**KORTES**



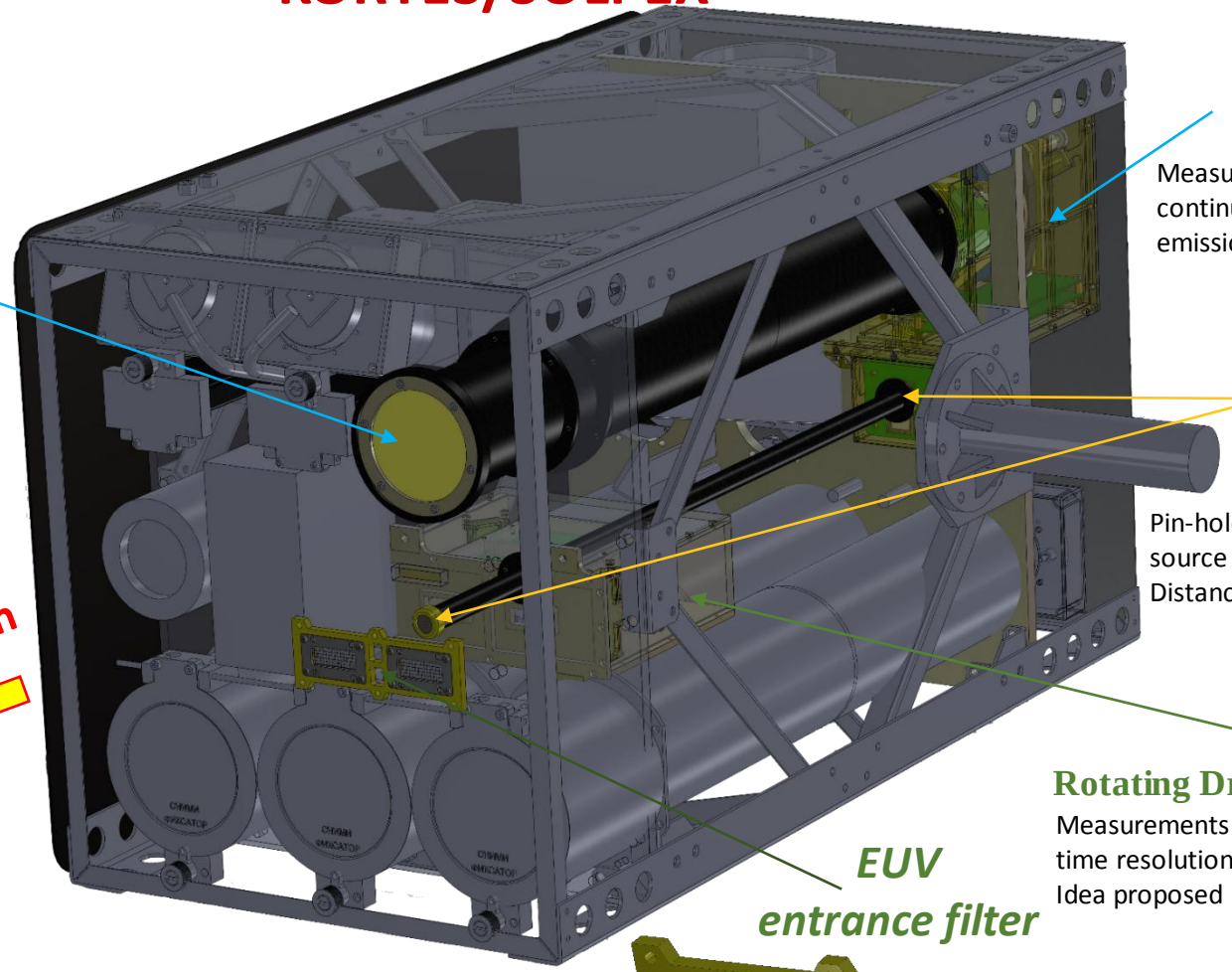
Perigee 409 km
Apogee 416 km
Orbital inclination 51.65 degrees
Orbital period 92.69 minutes

Kortes will see the Sun
only by 10-12 min/orbit.

***Kortes Dimensions:***
*870 x 500 x 450 mm*

# KORTES/SOLPEX

***EUV***
**entrance filter**



***B-POL***
**Bragg Polarimeter**

Measurements of polarization in soft X-ray continuum emission and possibly in selected emission lines (1-2% detection limit).

**System**
**Pinhole & Detector**
**(colimator with 1mm$^2$ pinhole)**

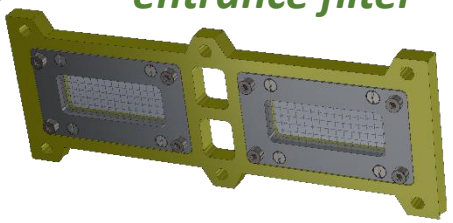
Pin-hole imager- will provide location of the source on the disk.
Distance between filter and detector is 600 mm

**Toward Sun**

***RDS***
**Rotating Drum Spectrometer**

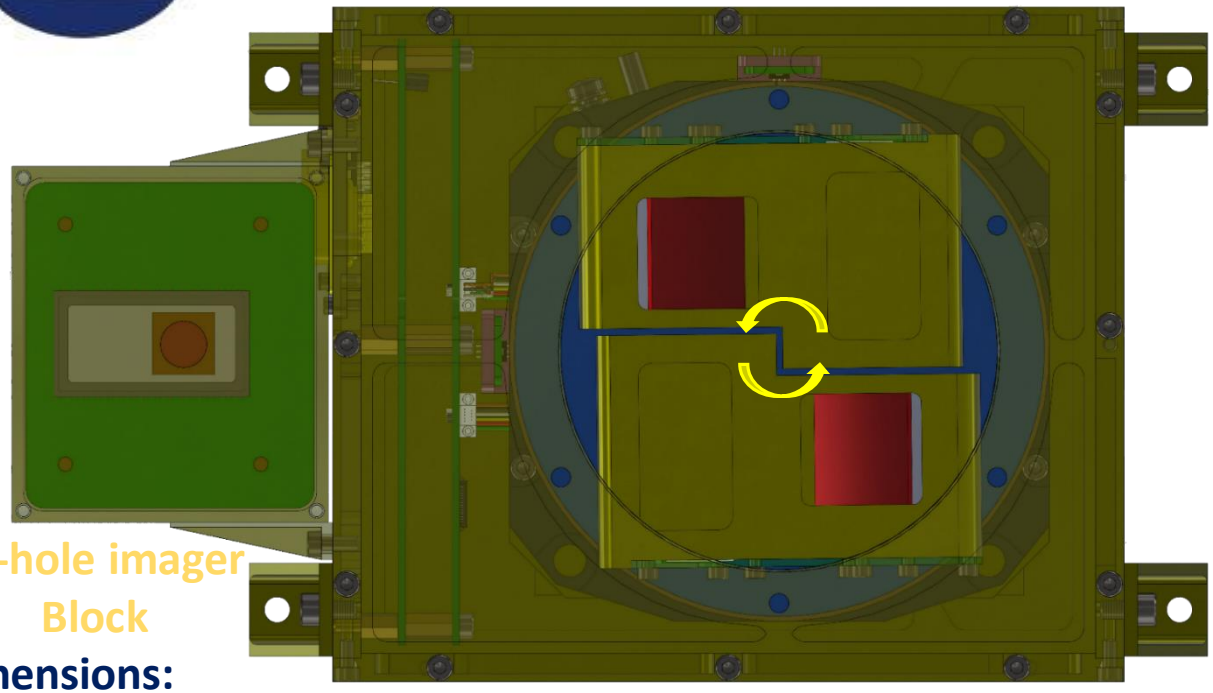
Measurements of X-ray spectra evolution with very high time resolution (0.1 s) rotating drum spectrometer.
Idea proposed by Stefan Płocieniak

***EUV***
***entrance filter***



# B-POL
# Bragg Polarimeter

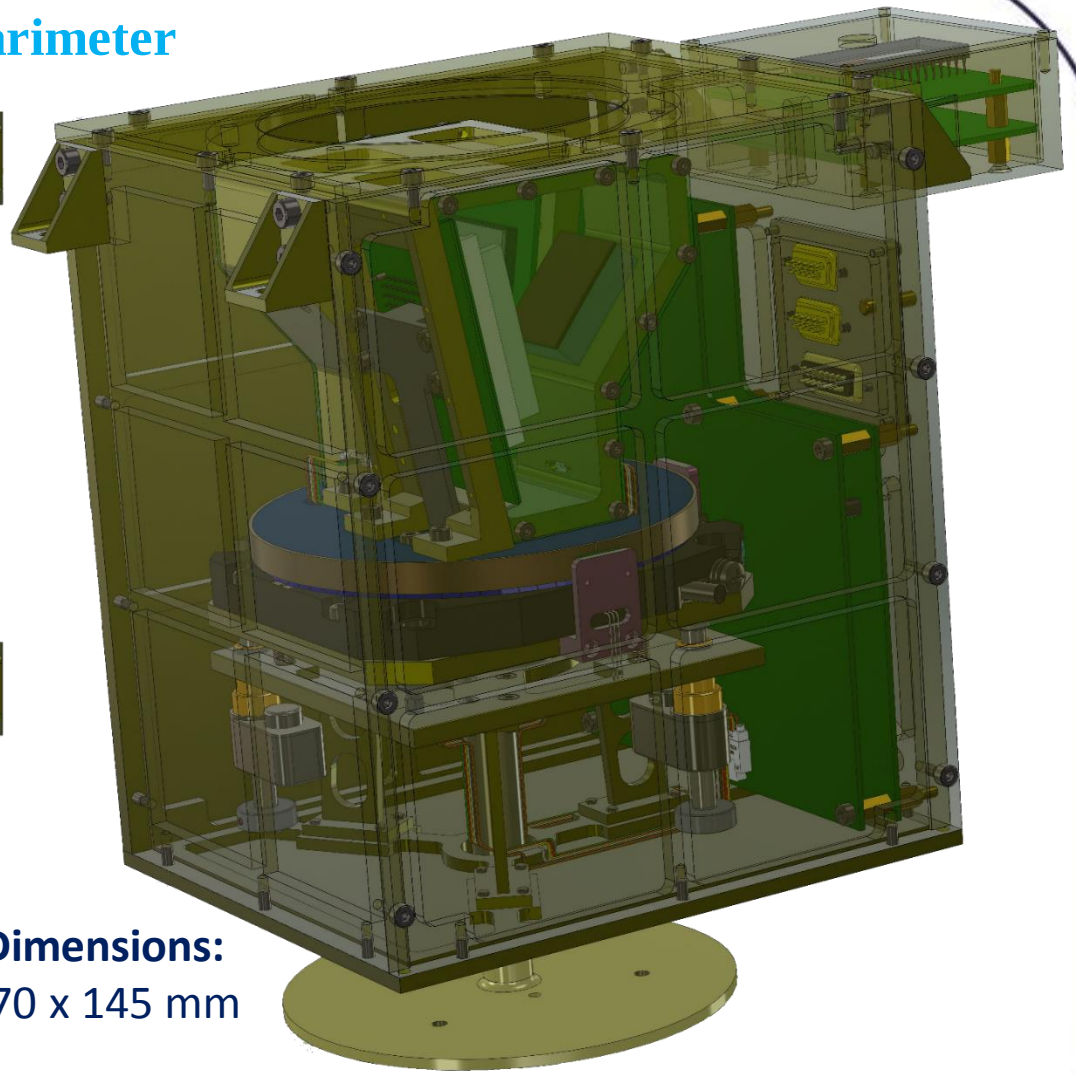
*Viewof B-POL from the direction of the Sun.*



Pin-hole imager Block

**Dimensions:**
77x70x38 mm

Polarimeter block



- The unit rotates 1 rotation per second,
- Spectral range 3.9 Å – 4.1 Å
- Maximum supply power is 5W

**B-POL Dimensions:**
200 x 170 x 145 mm

The total mass ~3kg

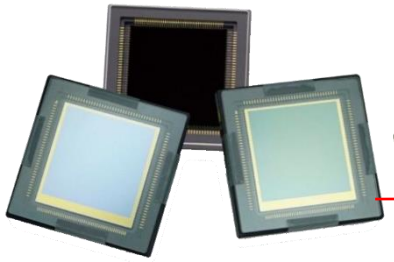
# Instrument concept

**Main science task:**

- detect polarisation in flare soft X-rays by means of Bragg spectroscopy

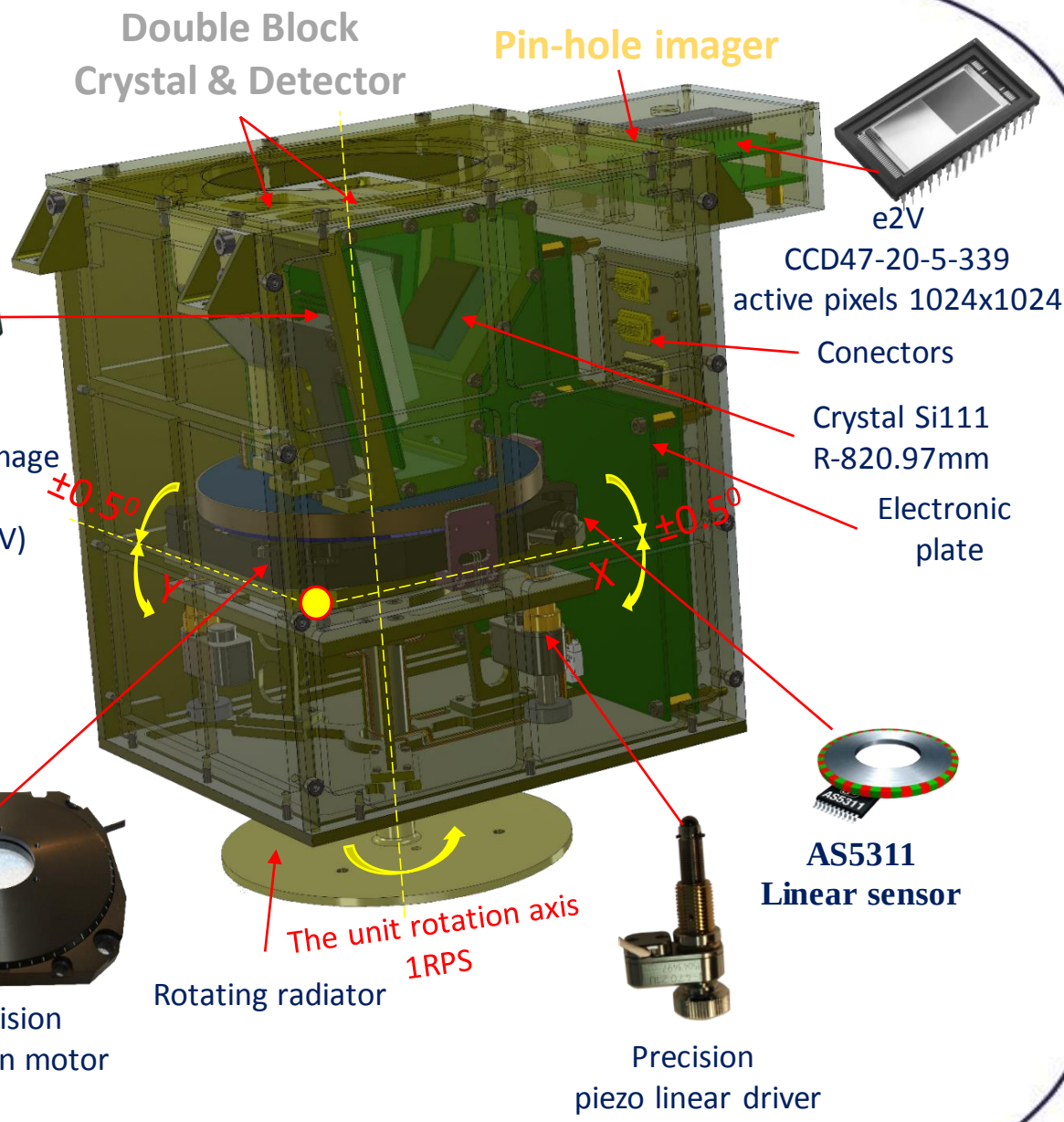
**Secondary:**

perform high resolution spectroscopy in the vicinity of Brewster angle at ~4.3Å



The GSENSE400 is backside Illuminated Scientific CMOS Image Sensors:

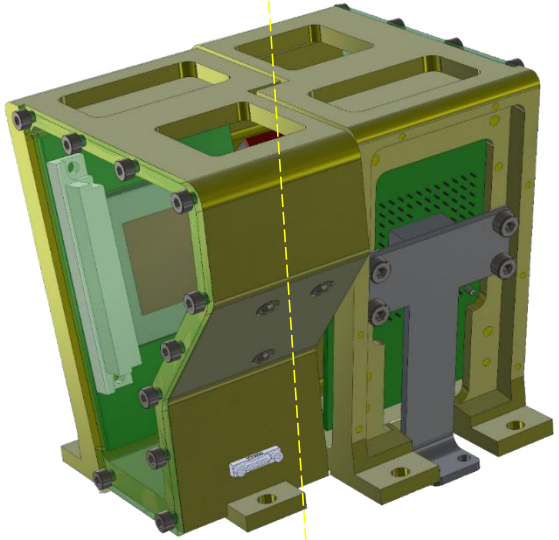
- Resolution : 2048(H) x2048(V)
- 11µm Square Pixels



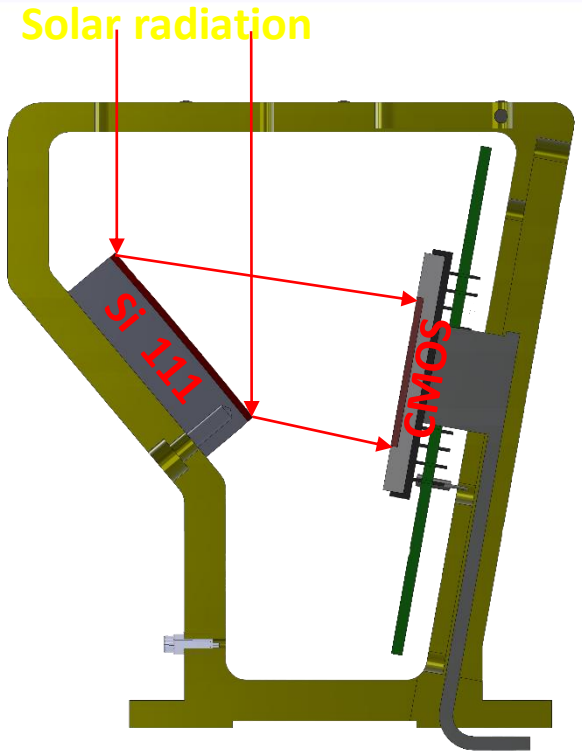

**Purposes of the Pinhole System/ CCD:**

1. Locating the X-ray sources on the Sun
2. Detecting & tracing active phenomena on the disk, analyzing individual AR X-ray light curves
3. Image readout: each 0.2 s
4. Focal length of the imager is about 60 cm and the image will be projected on CCD detector.

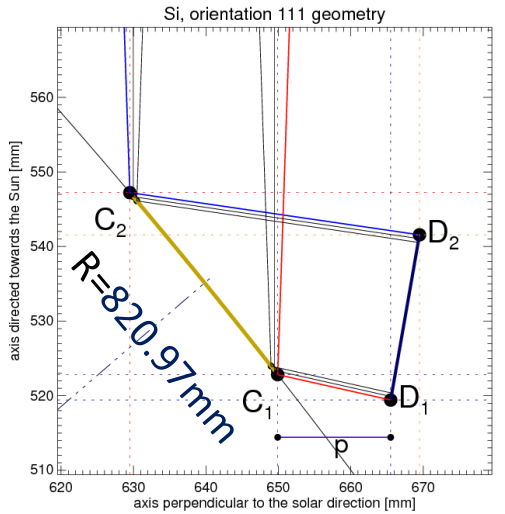
## Double Block Crystal & Detector

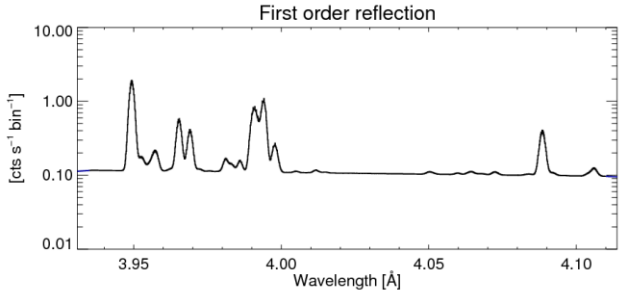


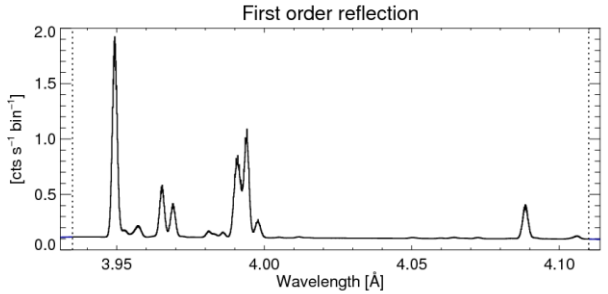
Rotation axis




Si 111 bent crystal
at the Brewster angle ~45°



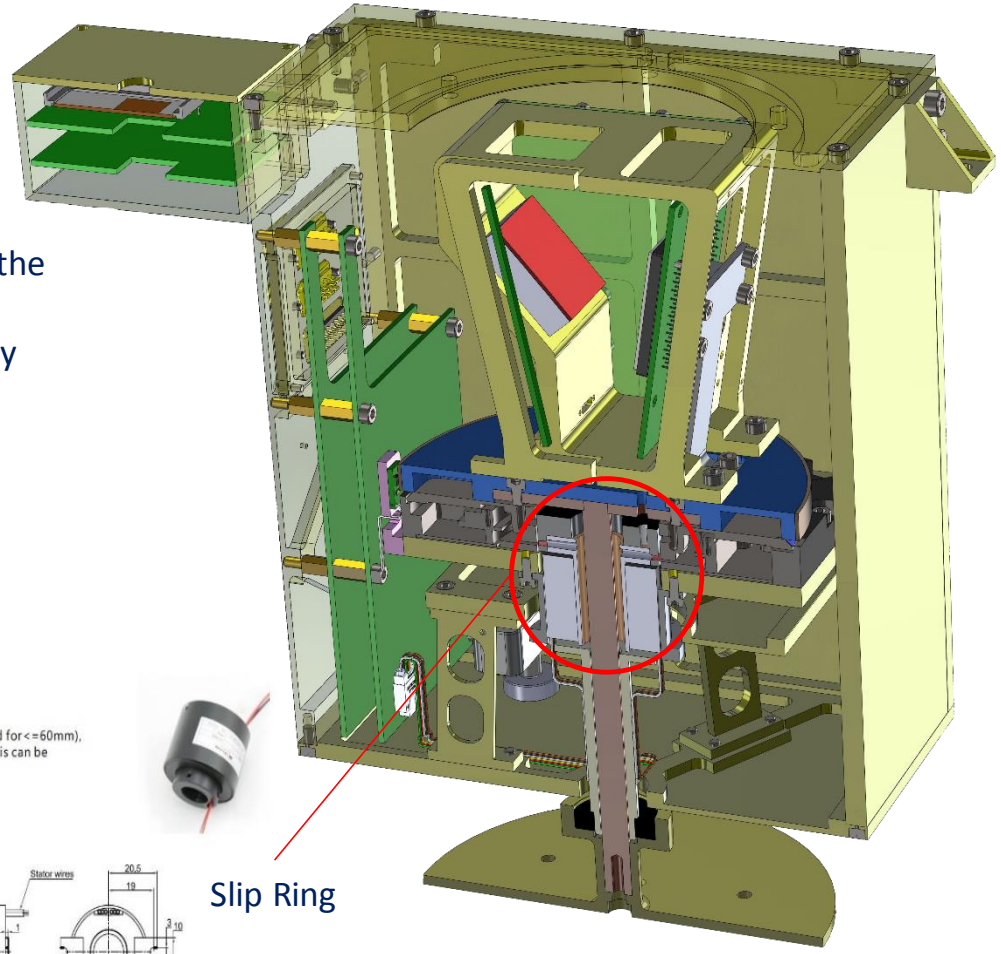




Crystal geometry& Synthetic spectra
for 1st order reflaction M5.0 Goes class flare

The instrument will measure the degree of linear polarization of solar flares impulsive phase in the soft X-ray range. Measurements will be carried out in a narrow range of the spectrum by using a bend silicon monocrystal wafer, with reflective plane 111 and a curvature radius of 820.97 mm.

# Power/ Data Transfer System

Slip ring can be used in electromechanical device where required. Its role is the transfer of electrical signals & power to the rotating components.
The signals transmitted by the slip rings are transmitted continuously, for any number of turns in each direction.



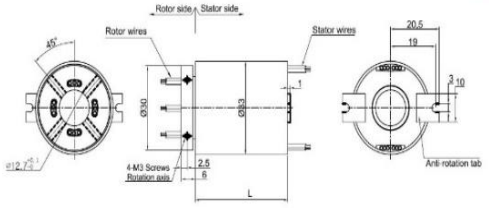
Slip Ring

Transmission coils

MT1233 Series

Standard compact slip ring with bore size 12.7mm(1/2" ,used for<=60mm), OD 33mm.*Attention: if required through bore <12.7mm, this can be solved by adding a sleeve inside the bore.



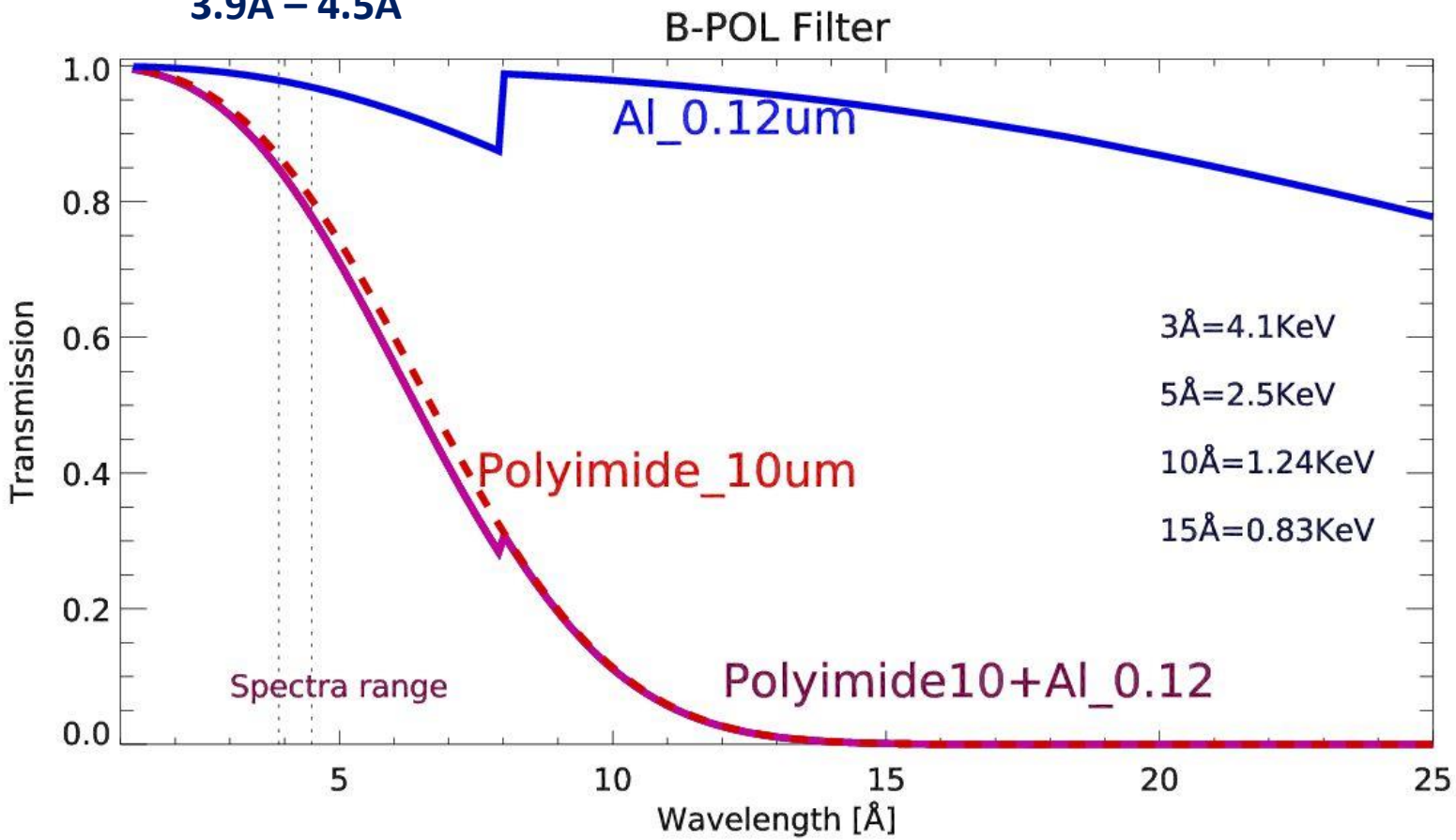


# Filter Transmission For B-POL instrument

***EUV***
**entrance filter**

Filter dimension- Ø80mm

**Spectral range**
**3.9Å – 4.5Å**



# RDS

## Rotating Drum Spectrometer

### RDS scanning modes

- The spectral line scanning mode

  During a periods of low solar X-ray flux the instrument will be scanning only prominent emission lines. It will “wobble” the crystal around positons where a spectral lines are reflected and will periodically change the crystal to observe different selected spectral lines.

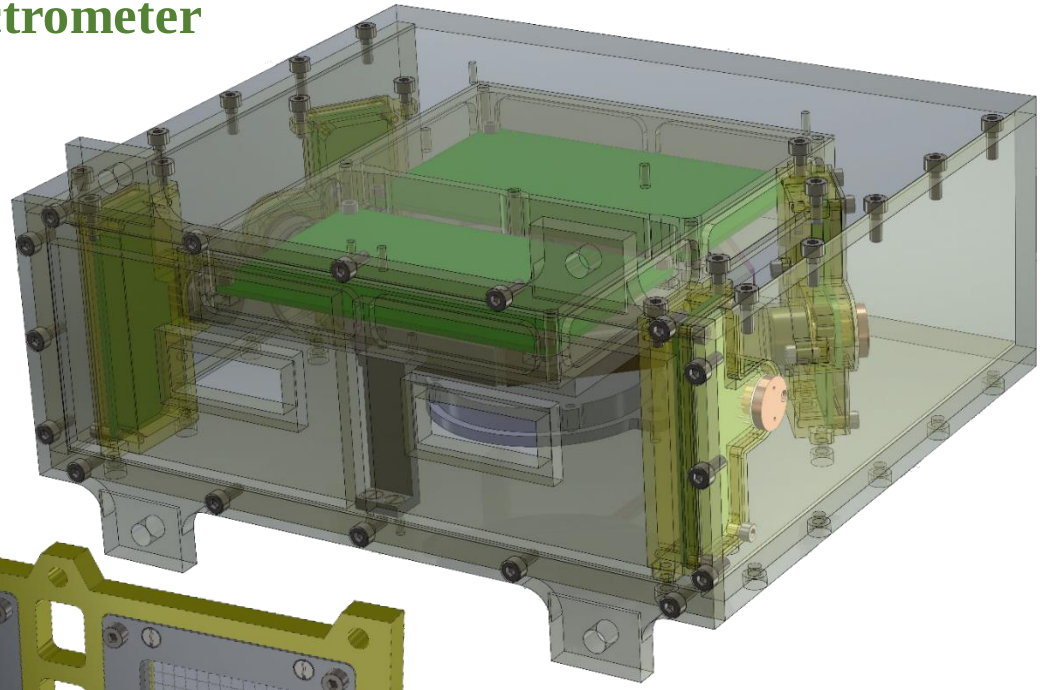
- Whole spectra scanning mode

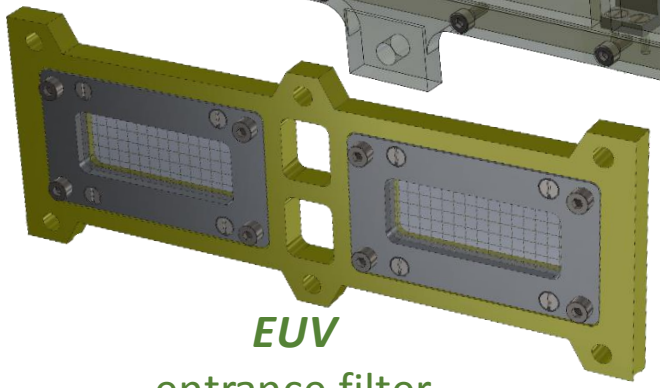
  During a periods of high intensity of solar x-ray flux the instrument will be scanning entire spectral ranges. It will rotate the drum with constant frequency of 10 rev/s scanning entire available spectra from **0.5 Å** to **23 Å**.

**Bragg's law**

$$2dsin\theta = n\lambda$$

$\theta$ - the incidence grazing angle
$d$ – separation between crystal lattice planes
$\lambda$ - the wavelength of incident photon





***EUV***
entrance filter

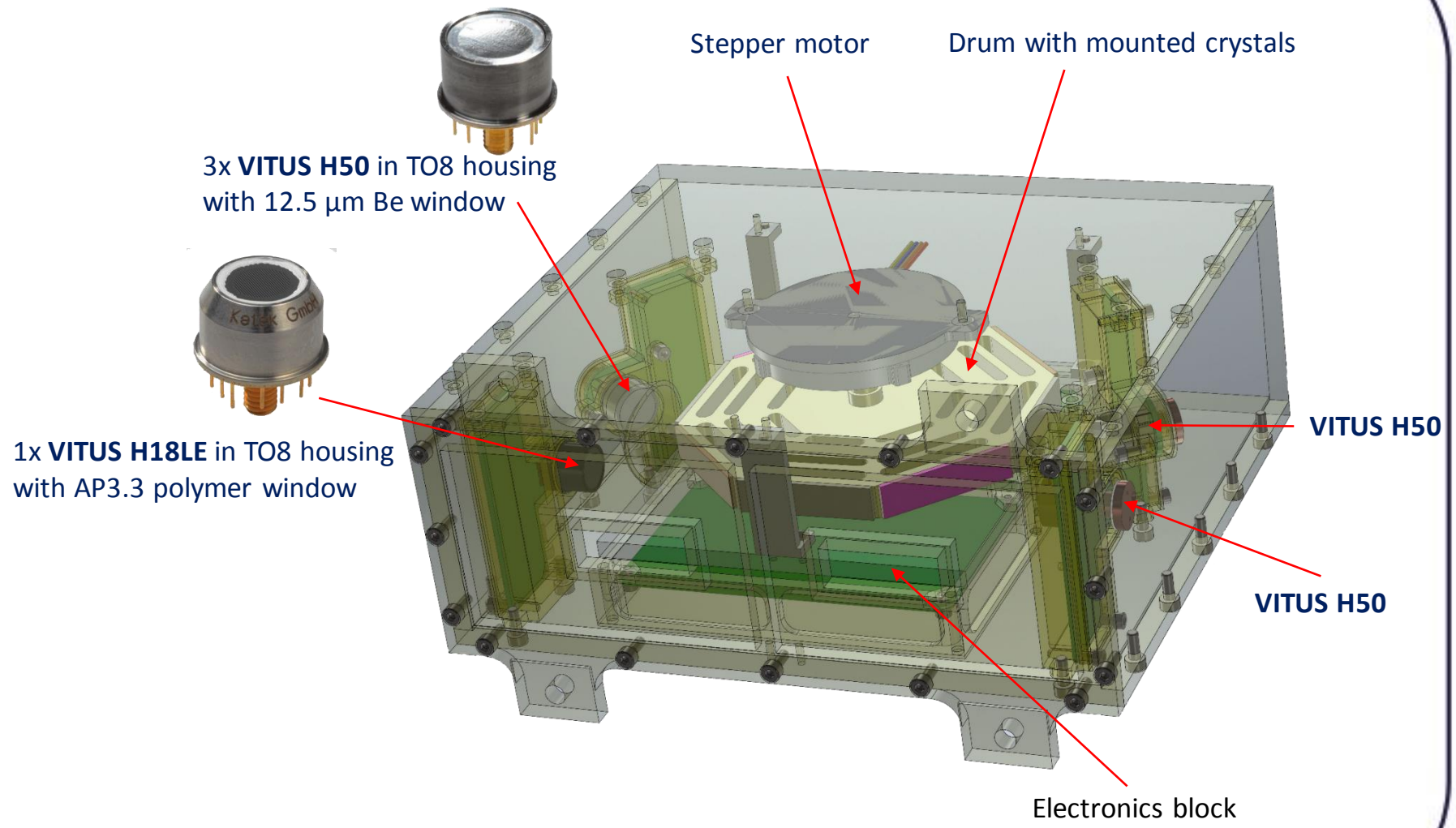
**RDS Dimensions:**
200 x 175 x 76 mm
Approximate Mass: 2 Kg
Approximate power consumption:
1 W electric motor
1 W per detector, 4 detectors
1 W Electronics

- Changing the angle of incidence allows scanning different wavelengths
- Different crystals reflect different wavelengths at the same angle if incidence

# The RDS main components

Main Components :

- 4 Silicon drift detectors
- 8 Flat crystals
- 1 Stepper motor



# Optical Design

Two pairs of detectors (two front and two rear) are placed around rotating drum with crystals placed in locations that broaden the wavelength range covered.

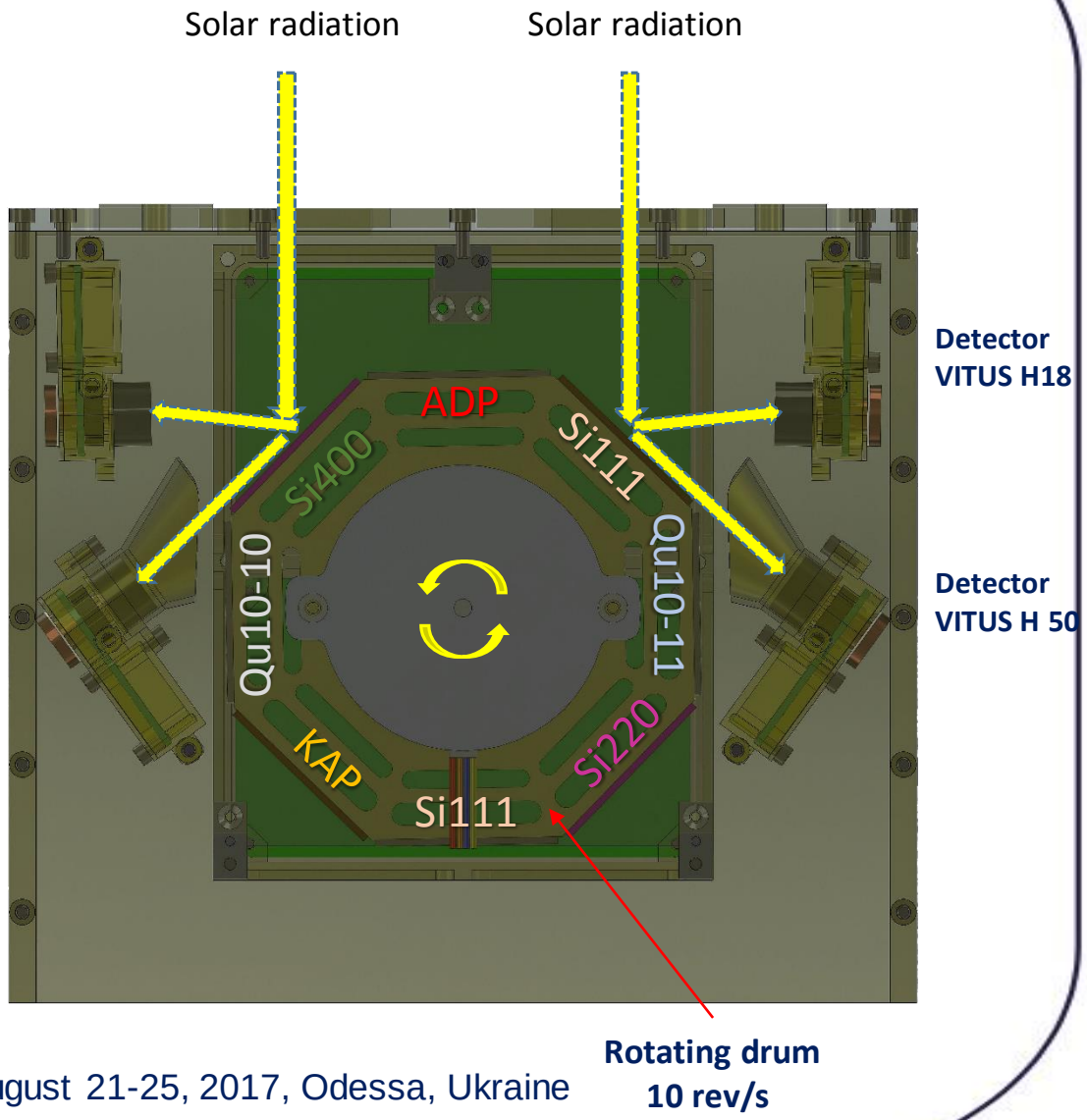
Wavelength range scanned by the instrument for different crystals

Front detectors

| Crystal | Min Wavelength [Å] | Max Wavelength [Å] |
|---|---|---|
| Si111 | 3.878 | 5.381 |
| Si220 | 2.375 | 3.295 |
| Si400 | 1.678 | 2.330 |
| Qu10-10 | 5.265 | 7.306 |
| Qu10-11 | 4.133 | 5.735 |
| ADP101 | 6.585 | 9.137 |
| KAP001 | 16.474 | 22.859 |

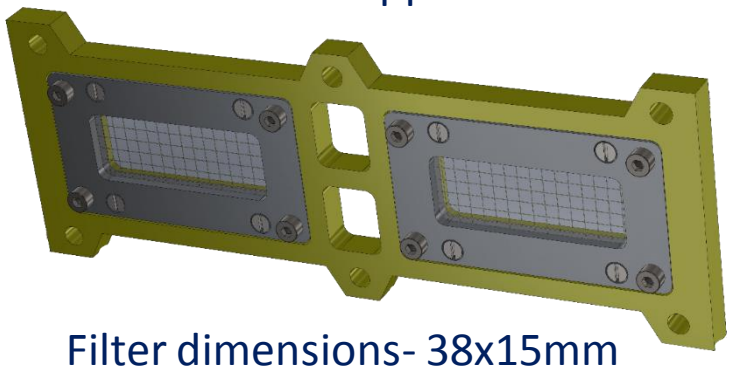
Rear detectors

| Crystal | Min Wavelength [Å] | Max Wavelength [Å] |
|---|---|---|
| Si111 | 1.021 | 3.737 |
| Si220 | 0.625 | 2.288 |
| Si400 | 0.442 | 1.618 |
| Qu10-10 | 1.386 | 5.073 |
| Qu10-11 | 1.088 | 3.983 |
| ADP101 | 1.734 | 6.345 |
| KAP001 | 4.337 | 15.875 |



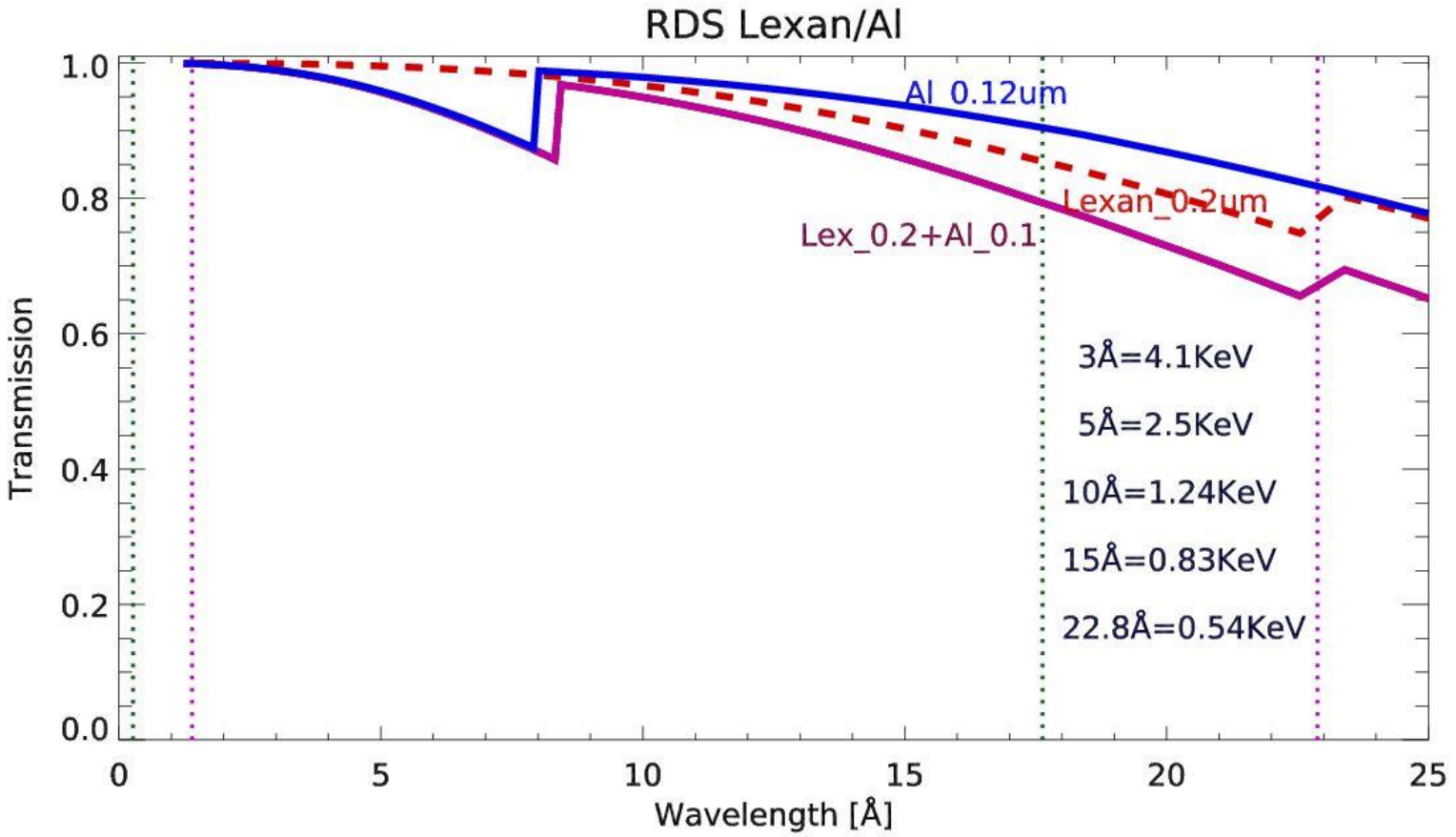
# Filter Transmission For RDS instrument

Polycarbonate (Lexan) 2000Å
Aluminum 800Å, 400Å
Mesh- Kevlar thread for mechanical support



Filter dimensions- 38x15mm

***EUV***
**entrance filter**



# Papers published/submitted

*Polarimetry: From the Sun to Stars and Stellar Environments*
*Proceedings IAU Symposium No. 305, 2014*
*K. N. Nagendra, S. Bagnulo, R. Centeno & M. J. Martínez González, eds.*
© International Astronomical Union 2015
doi:10.1017/S1743921315004627

## SolpeX: the soft X-ray flare polarimeter–spectrometer for the ISS

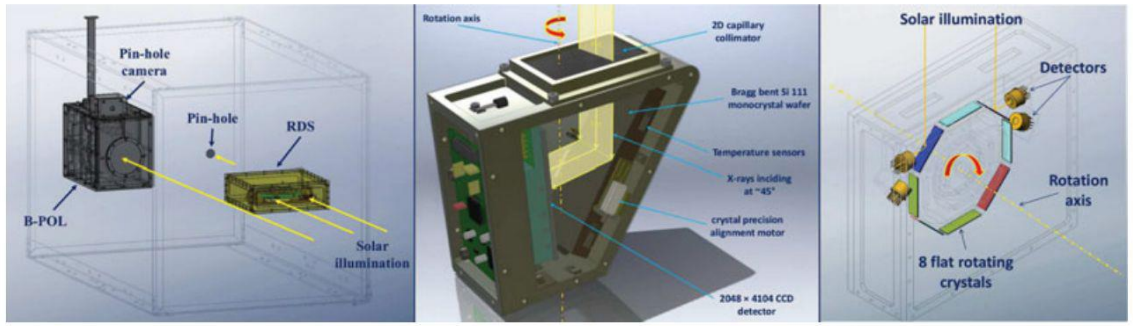
**Janusz Sylwester[1], Stefan Płocieniak[1], Jarosław Bąkała[1], Żaneta Szaforz[1], Marek Stęślicki[1], Daniel Ścisłowski[1], Mirosław Kowaliński[1], Piotr Podgórski[1], Jose Hernandez[1] and Sergey Shestov[2]**

[1]Space Research Centre, Polish Academy of Sciences,
51-622 Wrocław, ul. Kopernika 11, Poland
email: `js@cbk.pan.wroc.pl`

[2]P.N. Lebedev Physical Institute, Russian Academy of Sciences,
53 Leninskij Prospekt, 119991, Moscow, Russia
email: `sshestov@sci.lebedev.ru`

https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S1743921315004627

*SolpeX: the soft X-ray polarimeter–spectrometer for the ISS*




*Solar and Stellar Flares and their Effects on Planets*
*Proceedings IAU Symposium No. 320, 2015*
*A.G. Kosovichev, S.L. Hawley & P. Heinzel, eds.*
© International Astronomical Union 2016
doi:10.1017/S1743921316002106

## Soft X-ray polarimeter-spectrometer SOLPEX

**Marek Stęślicki[1], Janusz Sylwester[1], Stefan Płocieniak[1], Jarosław Bąkała[1], Żaneta Szaforz[1,2], Daniel Ścisłowski[1], Mirosław Kowaliński[1], Jose Hernandez[1], Sergey Kuzin[3] and Sergey Shestov[3]**

[1]Solar Physics Division, Space Research Centre Polish Academy of Sciences
Kopernika 11, 51-622 Wrocław, Poland
email: `sm@cbk.pan.wroc.pl`

[2]Astronomical Institute, University of Wroclaw
Kopernika 11, 51-622 Wrocław, Poland
email: `zs@cbk.pan.wroc.pl`

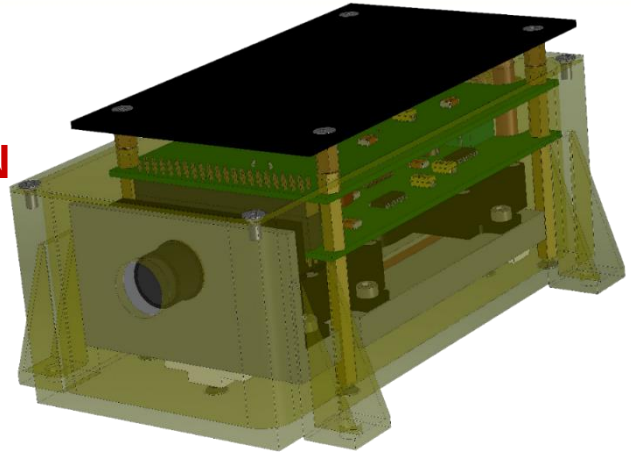
[3]P.N. Lebedev Physical Institute, Russian Academy of Sciences
Moscow, Russian Federation
email: `kuzin@sci.lebedev.ru`

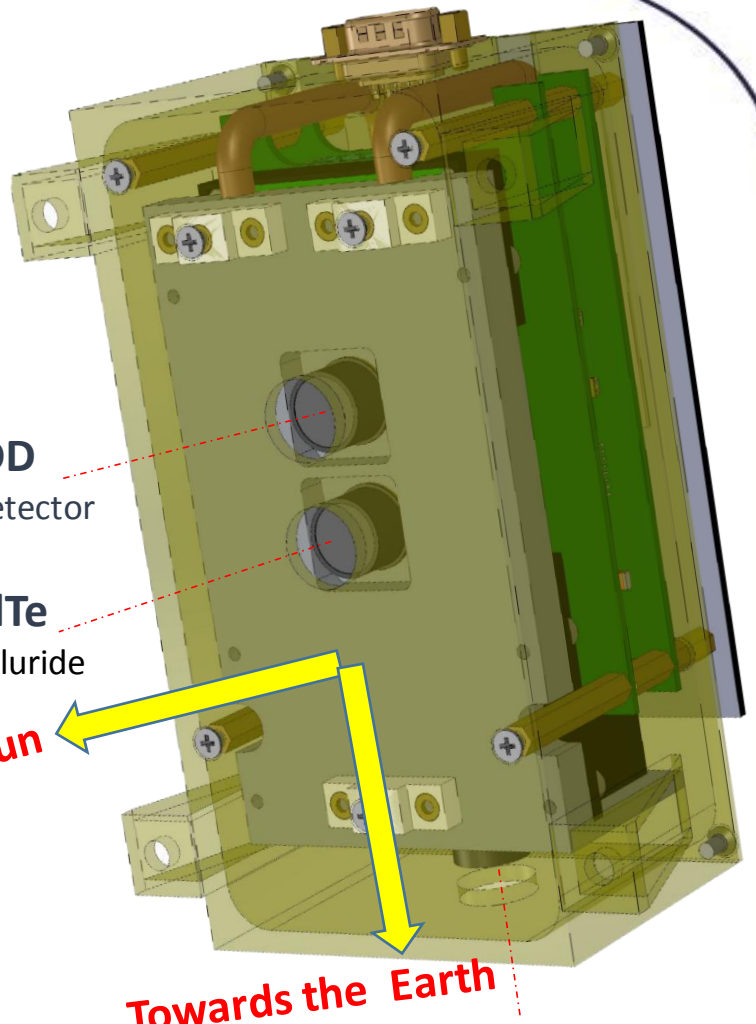
http://sun.stanford.edu/~sasha/IAUS320/iau_1600210_PRF.pdf


**Figure 2.** Simulated X-ray image of the Sun, with a C5 class flare in progress, projected on the pinhole CCD camera (left). The signal profile "observed" along the dashed line cut is shown to the right.

# SphinX-NG

## PROJECT DESCRIPTION






### Description of the SphinX-NG research project

**Solar X-ray monitoring:**

- Temperature and differential emission measure studies
- Long-term solar flux variability
- Studies of non-active corona
- Active regions' physics
- Solar flares' energy release physics
- Coronal sources plasma abundances

**Terrestrial X-ray and particle observations:**

- X-ray signatures of Terrestrial Gamma-ray Flashes (TGFs)
- Auroral X-ray spectra while in transit
- Orbital particle environment fluctuations

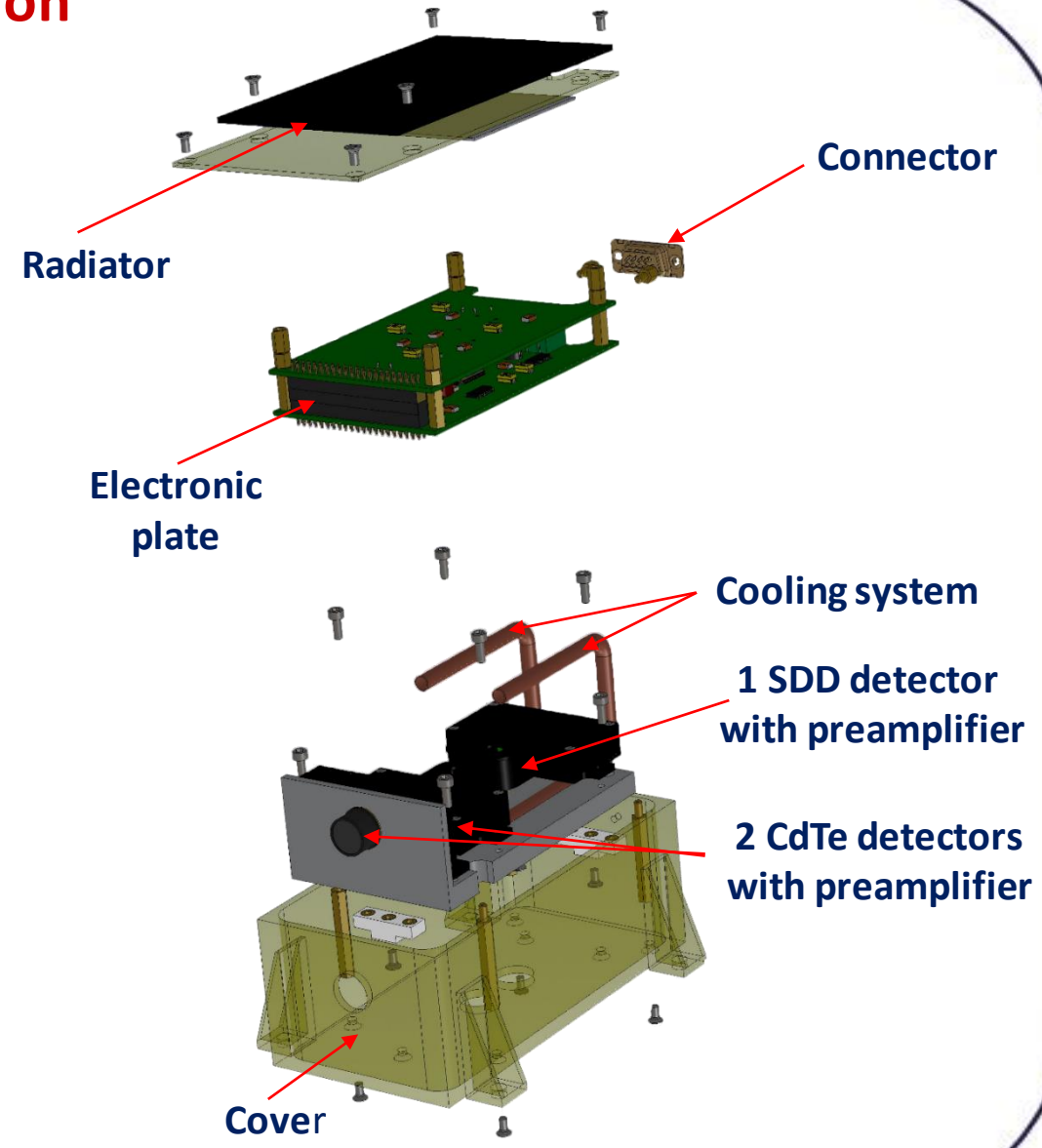
- Spectral range 0.5 keV – 150 keV
- Resolution: 200 eV

# Detailed Construction RDS

**SphinX-NG** instrument will be equipped with three multi-channel X-ray detectors-analyzers (256 energy channels each) for the soft (0.5-15 keV) and harder (5-150 keV) photon energy domains. A modern type of high-sensitivity silicon drift detectors (SDD) and Schottky diode detectors CdTe sensitive to radiation in the softer and harder X-rays respectively will be used. The detectors are available from the US-based Amptek or German KETEK companyies, and have proven space heritage in astrophysical and planetary missions (SOXS - Jain et al., 2006, Pathfinder, SphinX -Sylwester et al., 2008).

**Two detectors** will look towards the Sun.

**One detector** will be directed towards the Earth to search for X-ray signatures of terrestrial gamma-ray flashes (TGFs) that have been observed from powerful thunderstorms. Low-energy threshold for TGF will be investigated




Approximate Mass: ~1 Kg
Approximate power consumption:
1 W per detector
1 W Electronics

**SphinX-NG Dimensions:**
*150 x 76 x 67 mm*

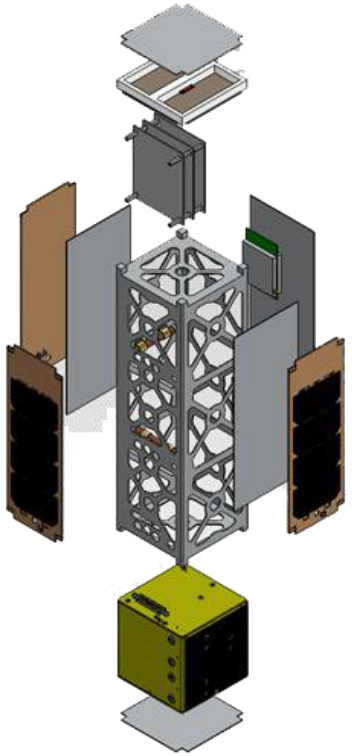
# Possible common venture between SRC-PAS and other Institutes

**Satellite and orbit:**

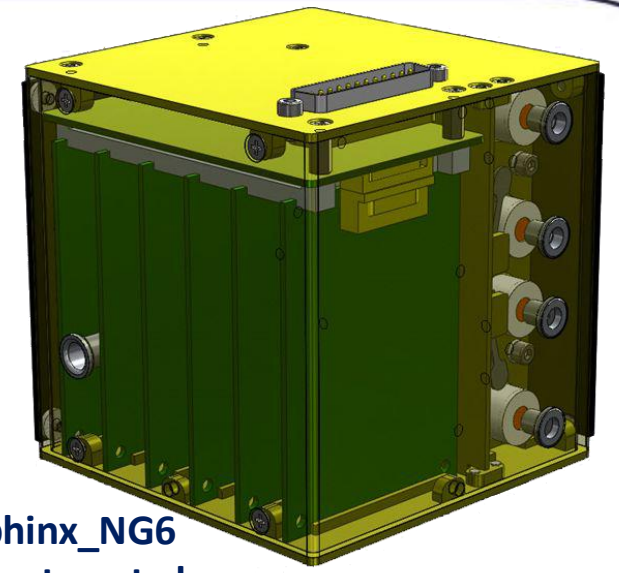
- CubeSat or Firefly type

**Orbit:**

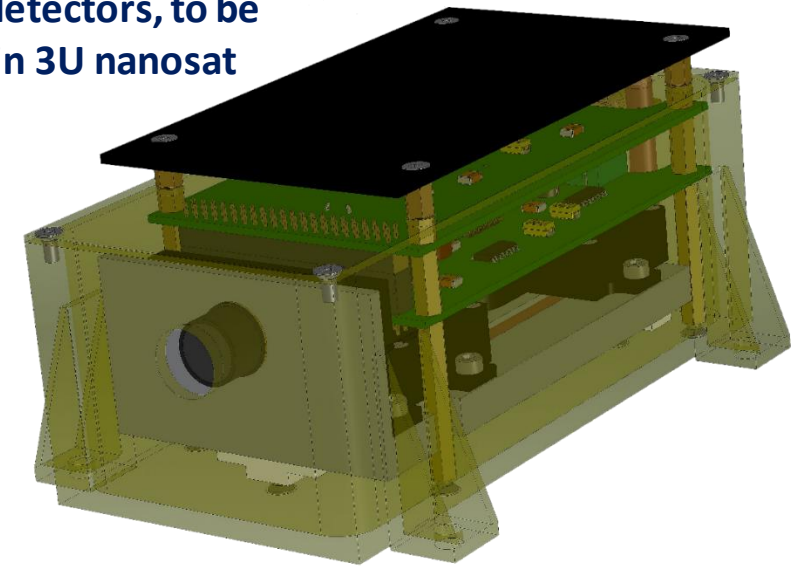
- Sun synchronous
- One-axis directed towards solar disc
- Pointing within ±1 degree on every axis
- Liftime depends on the orbit



**CubeSat 3U model**



**CubeSat 1U Sphinx_NG6 Box with 6 detectors, to be placed within 3U nanosat**

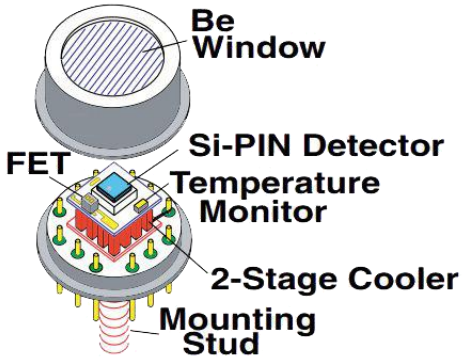


**SphinX-NG3 Box version with 3 detectors**

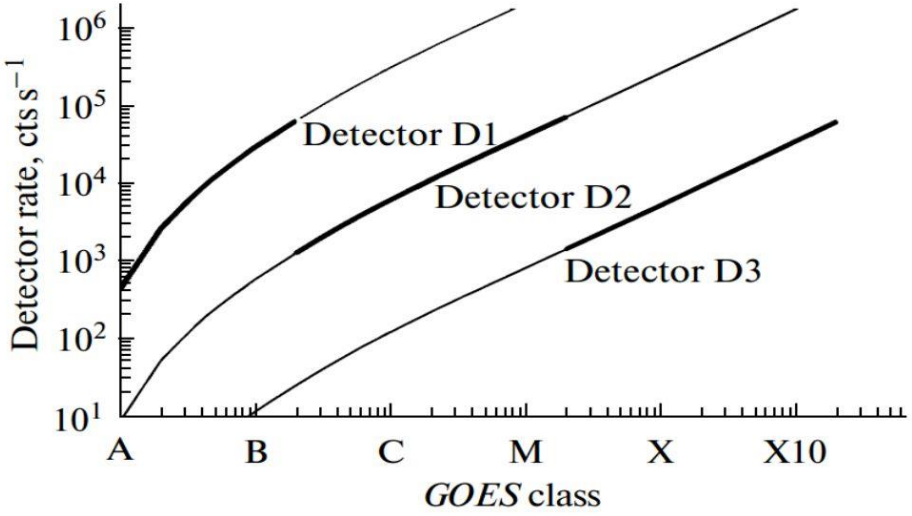
# SphinX: Solar Photometer in X-rays
# CORONAS- Photon satellite
# February – November 2009


**Spectral range:**
**0.8-15 keV (0.8 – 20 Å) in 256 channels**

**Amptek PIN detector XR 100-CR**




A single, unobscured, XR-100CR detector measured correctly the solar flux at low activity levels only, below the X-ray class B5.0, corresponding to count rates of 10^4




In order to extend the range of measurements, the other SphinX detectors were equipped with collimators of reduced apertures. In the flight configuration the SphinX X-ray detector assembly came up with one detector (D1) of the entrance aperture of 21.50 mm2 (the nominal factory entrance window area), the second one (D2) with aperture limited to 0.495 mm2 for measuring moderate X-ray fluxes and the third (D3) with aperture of 0.01008 mm2 for measurements of the strongest flares. This configuration of aperture setting allowed to cover seven orders of expected variability of the solar X-ray flux.

## SphinX data catalogue

http://156.17.94.1/sphinx_l1_catalogue/SphinX_cat_main.html


# THANK YOU !