

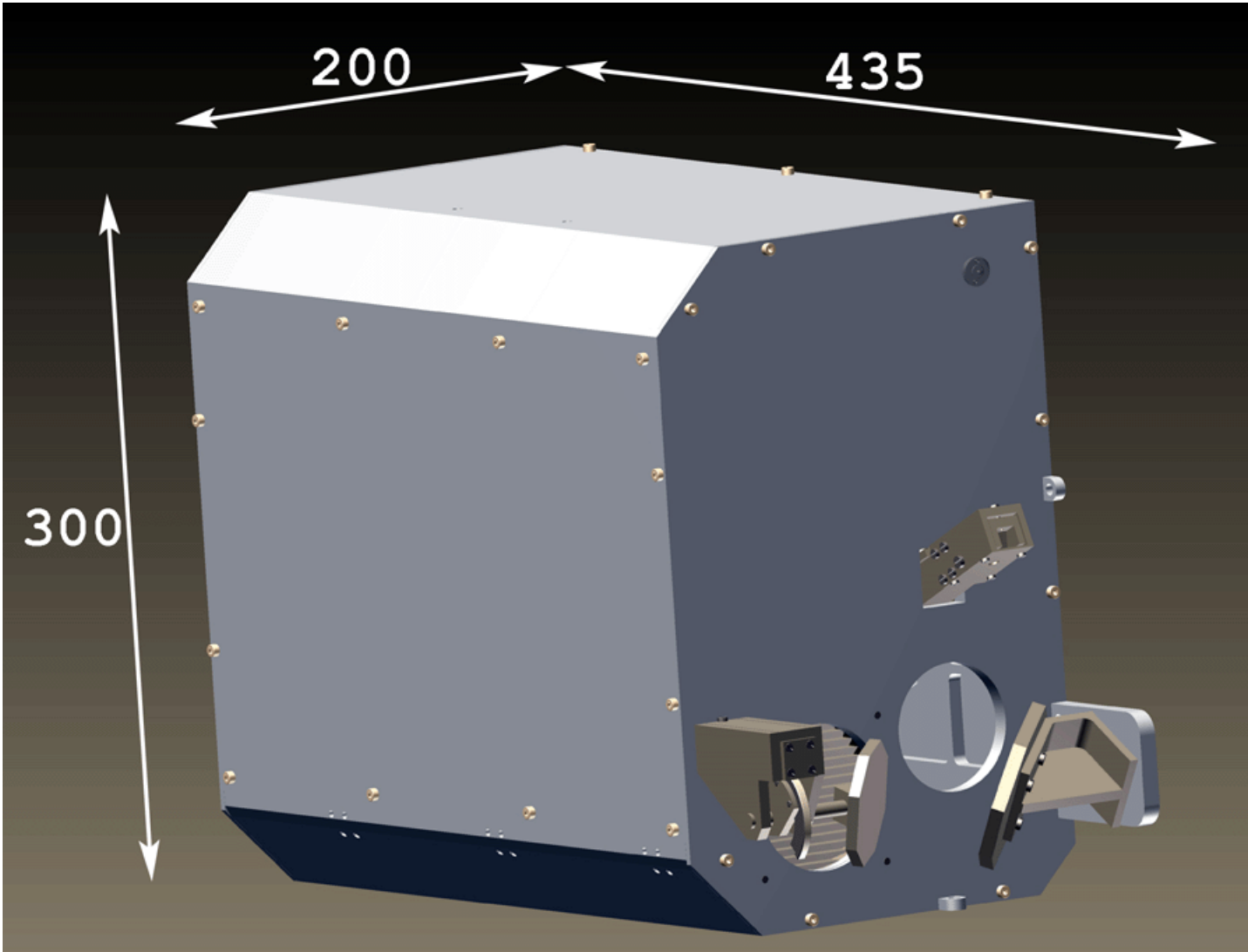
Fourier-spectrometers in ExoMars missions:

TIRVIM/ACS (2016)
and
FAST (2018)

Fourier-spectrometers in ExoMars missions

MISSION	EXPERIMENT	STATUS
Trace Gases Orbiter, “ExoMars-2016” (2 ^h polar orbit)	TIRVIM/ACS: 0.2cm ⁻¹ ; 2-17μ; 12kg; 2”-aperture; single-direction scanner	Is being funded by Roscosmos
Landing Platform, “ExoMars-2018”	FAST: 0.05cm ⁻¹ ; 2-17μ; 4kg; 1”-aperture; bi-directional scanner	Got the top grade at contest, the funding is pending

Instrument overview



Main scientific objectives

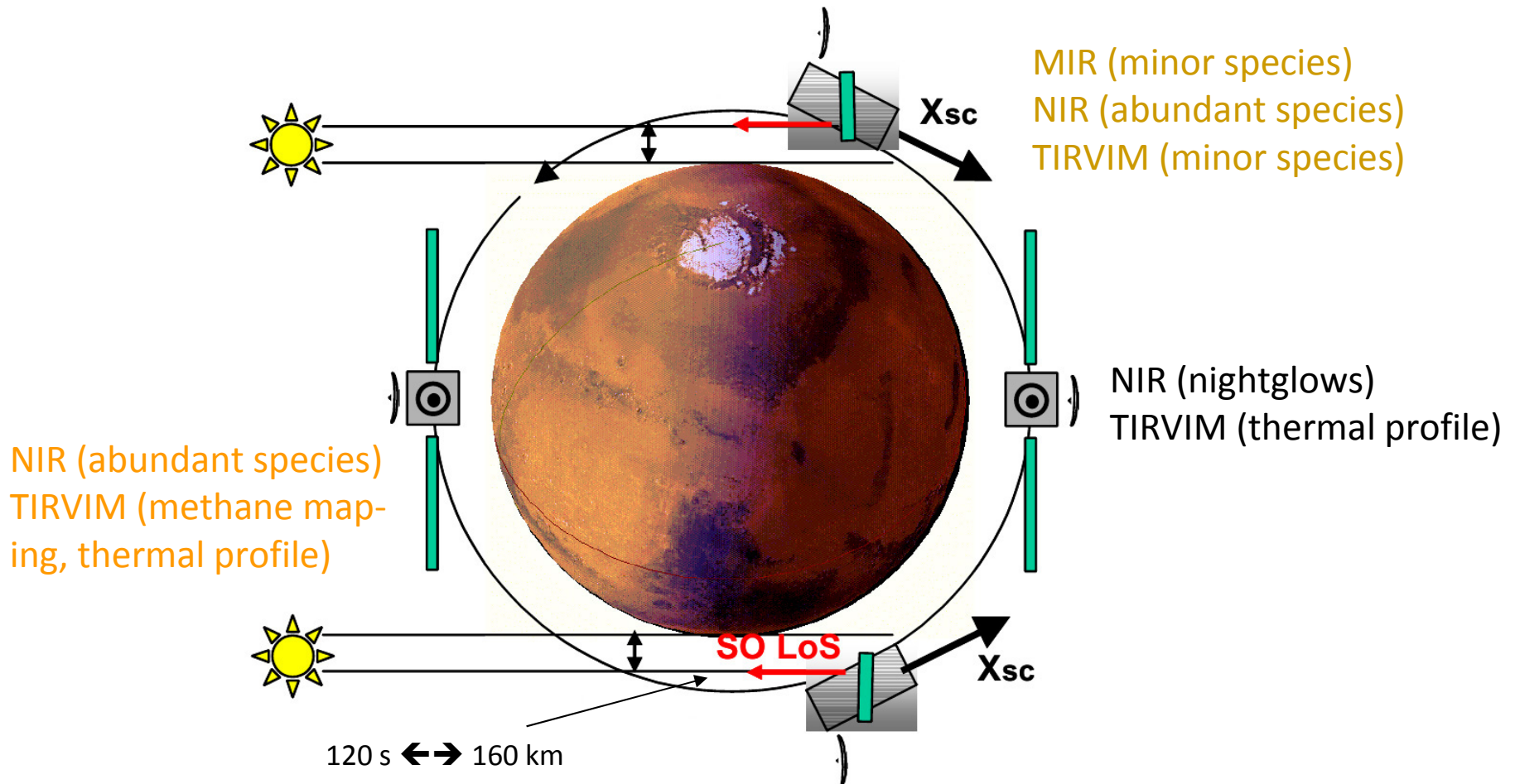
OBJECTIVE	MESUREMENT MODES & PARAMETERS
Methane & other minor atmosphere constituents	Sun occultations, 2-17 μ m, 0.2 cm^{-1} 1) PV-MCT detector @65K, 1 IFG: 2sec, S/N \sim 10 ³ or (redundant channel): 2) Pyro-detector @RT, 1 IFG: 30sec, S/N \sim 3x10 ²
Methane, if any, mapping at day-side	Nadir, 2-4 μ m, 0.2 cm^{-1} PV-PbCdSe detector @200K, 1 IFG: 10sec, S/N \sim 3x10 ²
Vertical thermal profile of the atmosphere, both day-side & night- side	Nadir, CO ₂ band at 15 μ m, 1.6 cm^{-1} PV-MCT detector @65K, 1 IFG: 4sec, S/N \sim 3x10 ²

On-board FFT and scissor mode apply to all modes

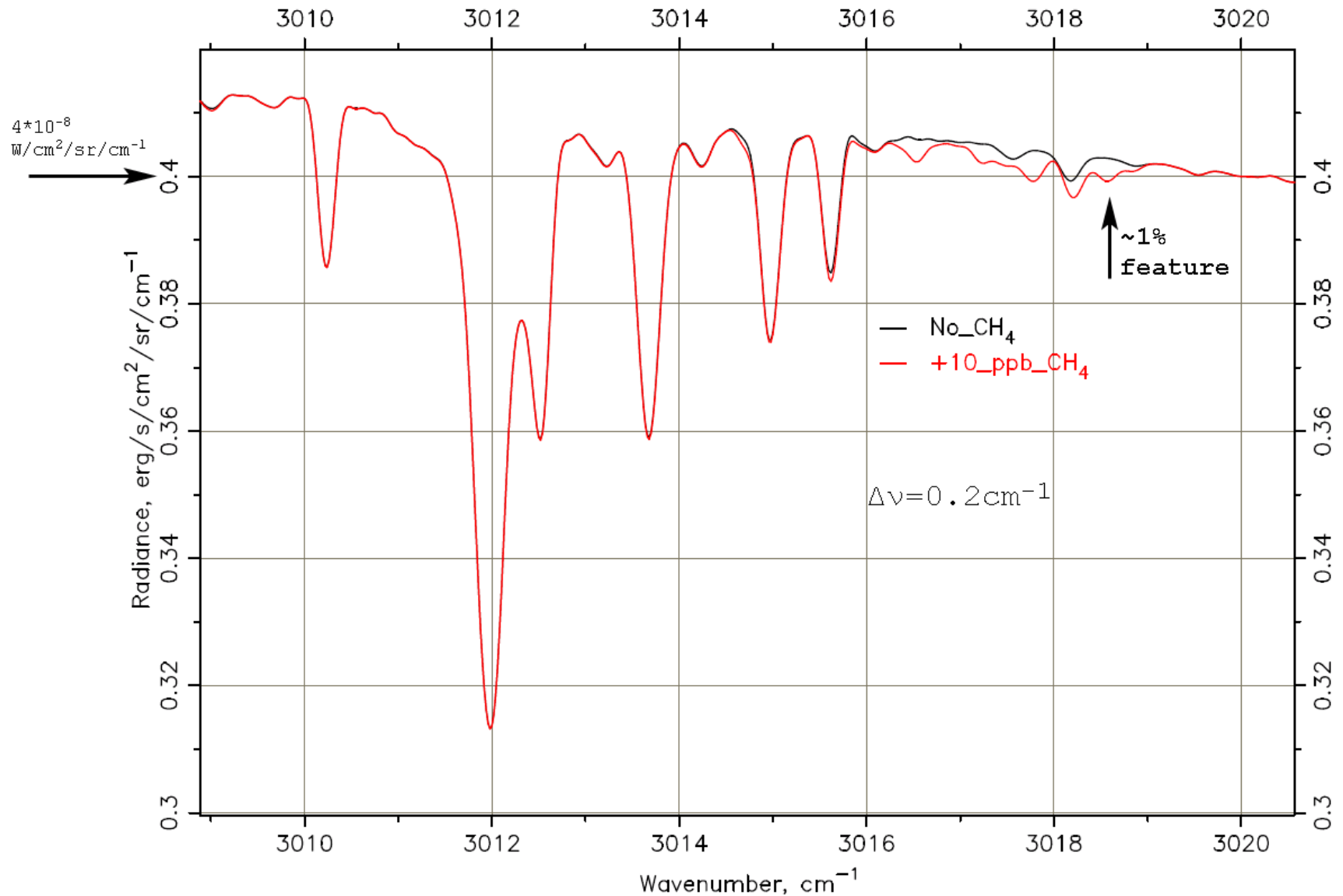
Experiment Operation Plan

TGO operational orbit $T \sim 2$ hr orbital period

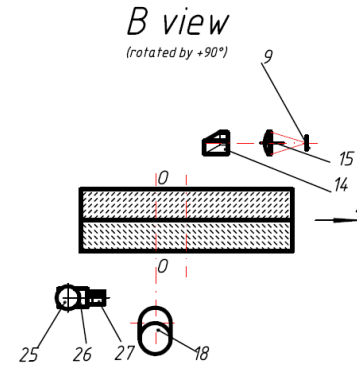
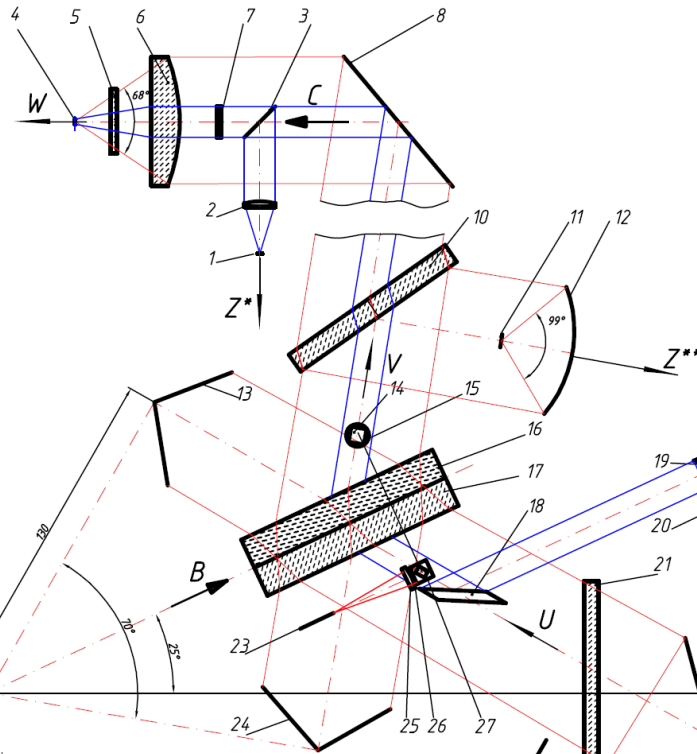
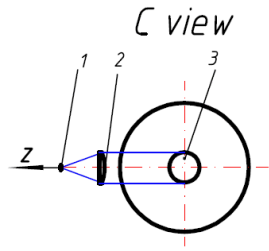
→ 12 orbits per day, 12 sunrises and 12 sunsets – 24 occultation's per day



CH₄ simulated spectra (nadir)



Optical scheme



- 1 Pyro-detector
- 2 Pyro-detector' lens (ZnSe)
- 3 Flip mirror (flat)
- 4 PV-MCT detector (@65K)
- 5 ARC-Ge window (2.5mm thick)
- 6 Aspheric ZnSe lens (Ø50)
- 7 Diverging ZnSe lens (Ø12 R=-150)
- 8 Fixed flat mirror (CA: 50x66)
- 9 Reference Channel (RC) detector
- 10 Dichroic plate
- 11 PV-PbCdSe detector (@200K)
- 12 Parabolic mirror (Ø50 R=50)
- 13 Retro-reflector (CA=Ø51)
- 14 RC-detector mirroring prism
- 15 RC-detector lens
- 16 Compensator (ZnSe Ø88x12)
- 17 Beam-splitter (ZnSe Ø88x12)
- 18 Flat mirror(Sun periscope outlet)
- 19 Sun-inlet mirroring prism
- 20 Sun-inlet filter & field stop
- 21 Nadir-inlet window (TBD)
- 22 Fixed flat mirror (CA: 55x78)
- 23 RC-emitter fiber optic
- 24 Retro-reflector (CA=Ø51)
- 25 RC-emitter collimating lens
- 26 RC-emitter mirroring-prism-big
- 27 RC-emitter mirroring-prism-small
- 28 Calibration Black-Body
- 29 Scanning flat mirror (CA: 58x84)

Mirror 29 scans by rotation around Z axis.

00 - optical axis of the Interferometer.

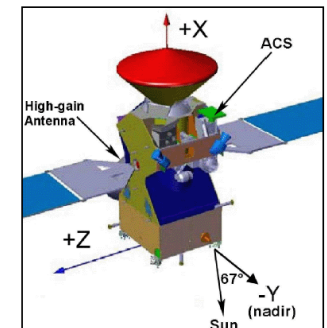
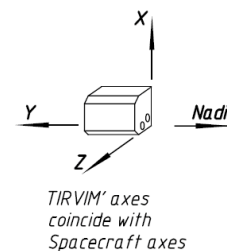
Y^* , Z^* , Z^{**} & Z^{***} - Instrument' axes after conventional rotations.

Elements 1, 2 & 3 at the main view are conventionally rotated by -90° around axis W.

Elements 10, 11 & 12 are conventionally rotated by +90° around axis V.

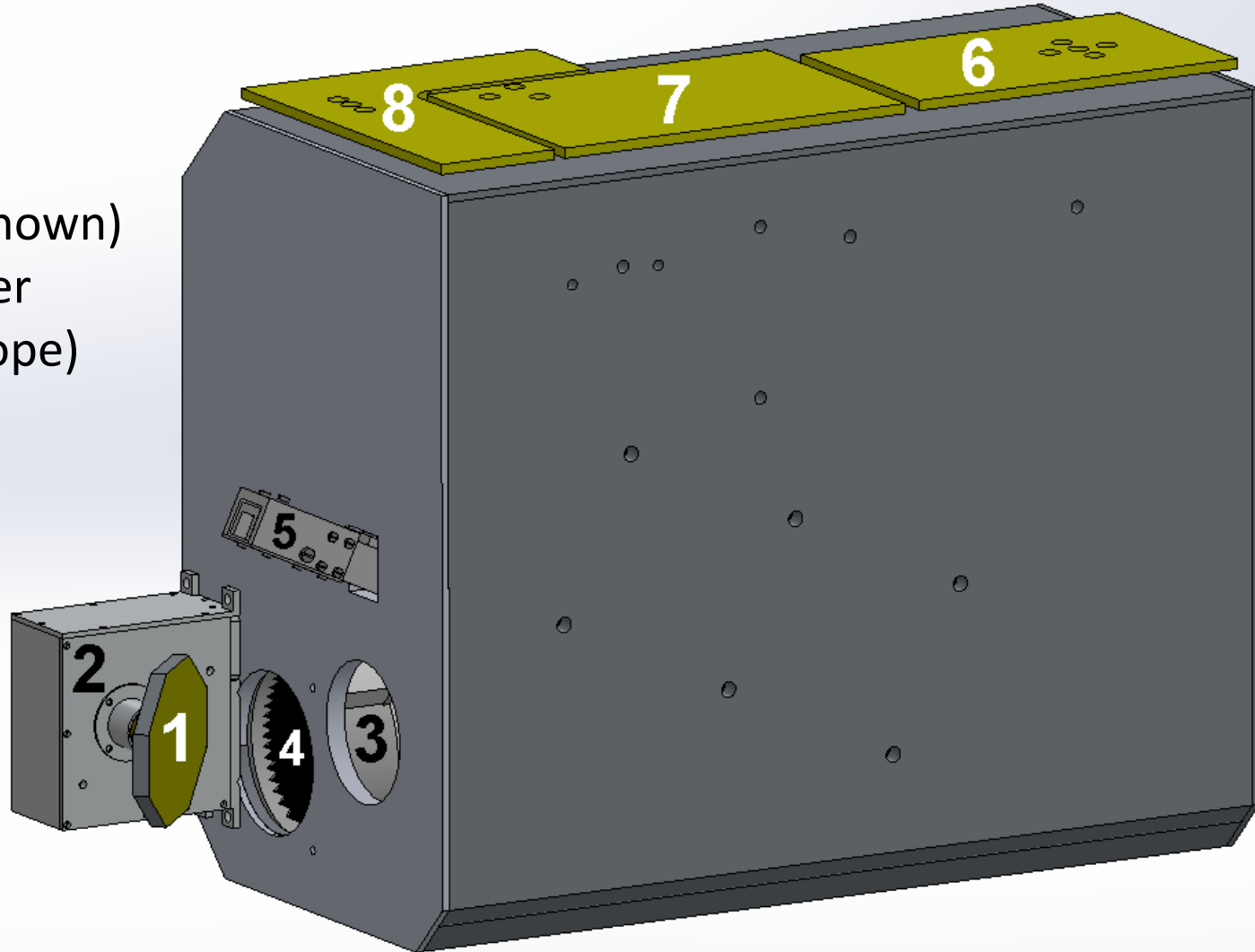
Elements 22, 28 & 29 are conventionally rotated by -90° around axis U, and then elements 28 & 29 are additionally conventionally rotated by -30° around axis Z^{***} .

Elements 1..8 are conventionally moved by 30mm along the V axis.



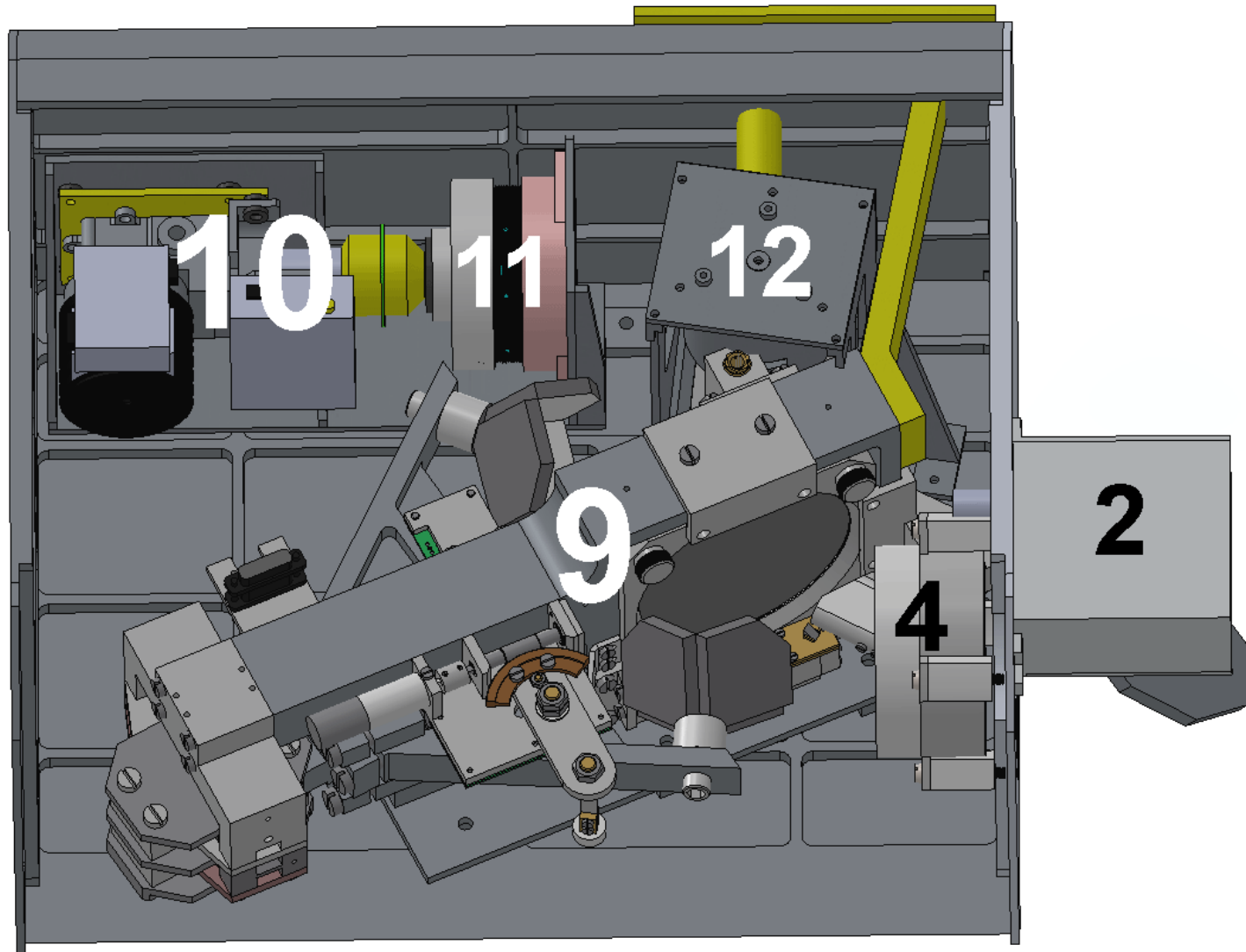
Instrument overview continued

- 1 – Scanning mirror
- 2 – Scanner module
- 3 – Optical inlet
(fixed mirror not shown)
- 4 – Blackbody emitter
- 5 – Sun inlet (periscope)
- 6 – Stirling radiator
- 7 – PbCdSe radiator
- 8 – Interferometer radiator

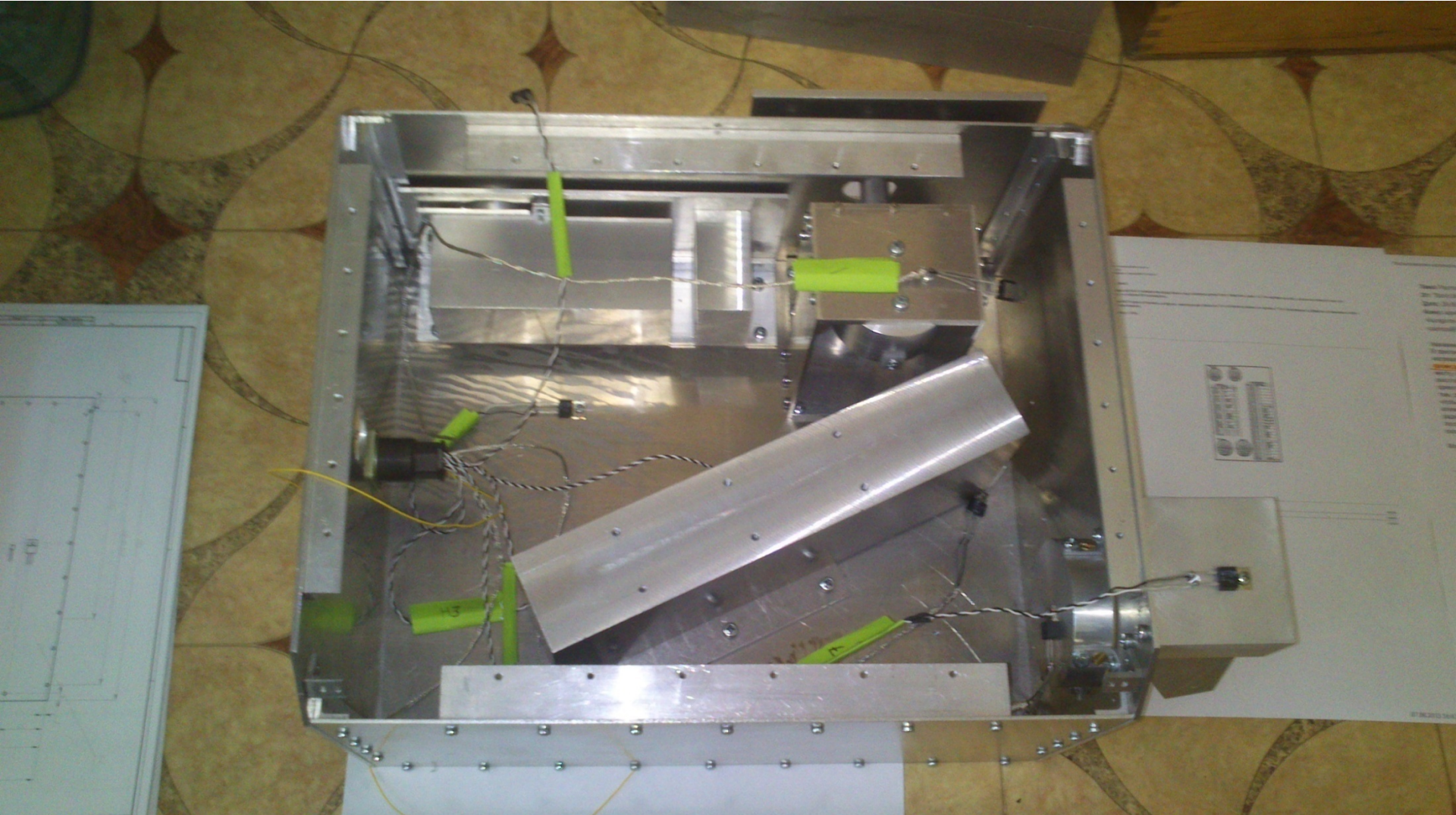


Instrument overview continued

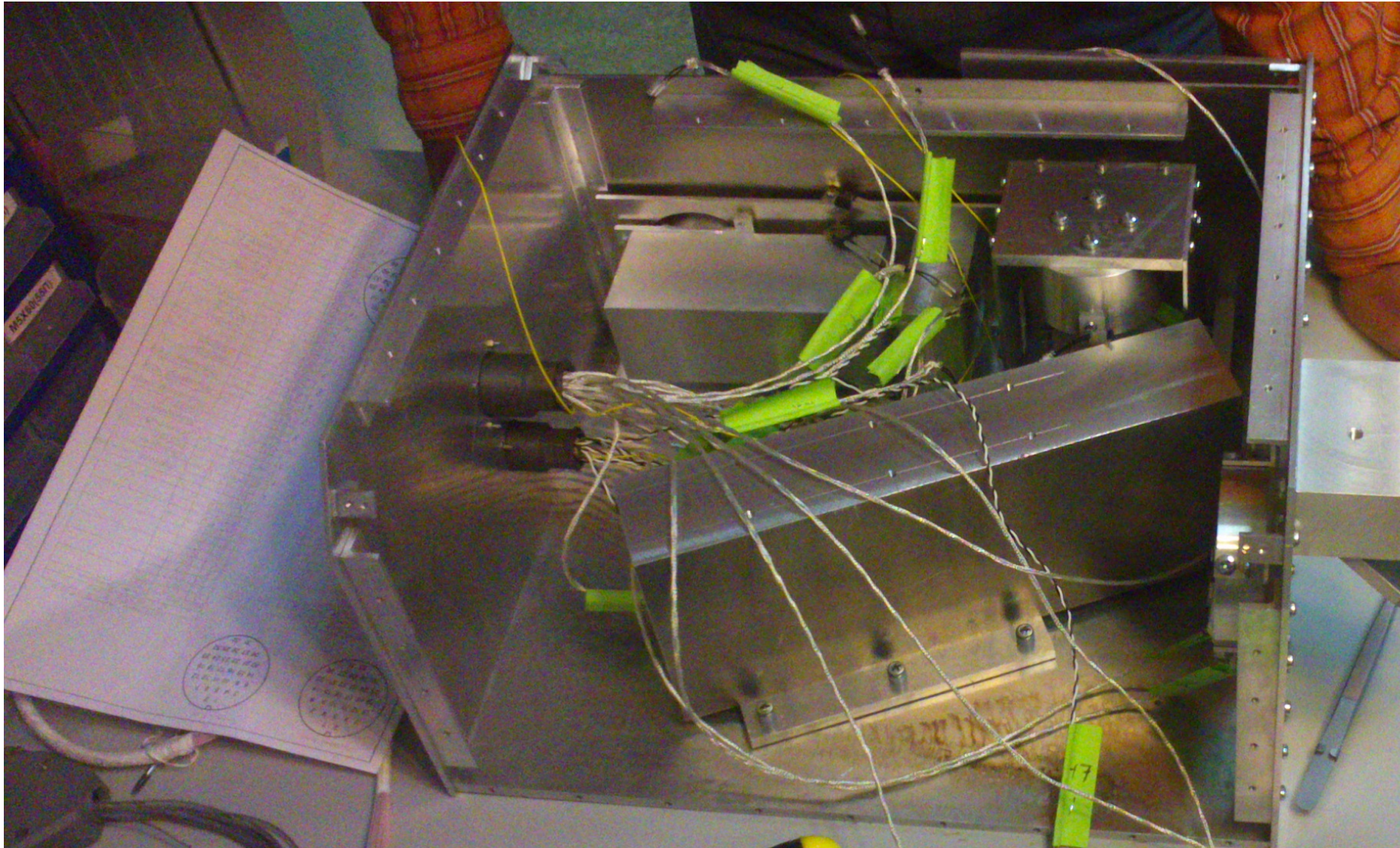
- 2 – Scanner module
- 4 – Blackbody unit
- 9 – Interferometer
- 10 – Stirling cooler
- 11 – ZnSe aspheric lens unit
- 12 – Dichroic & parabolic mirror unit



HW: Thermal Model

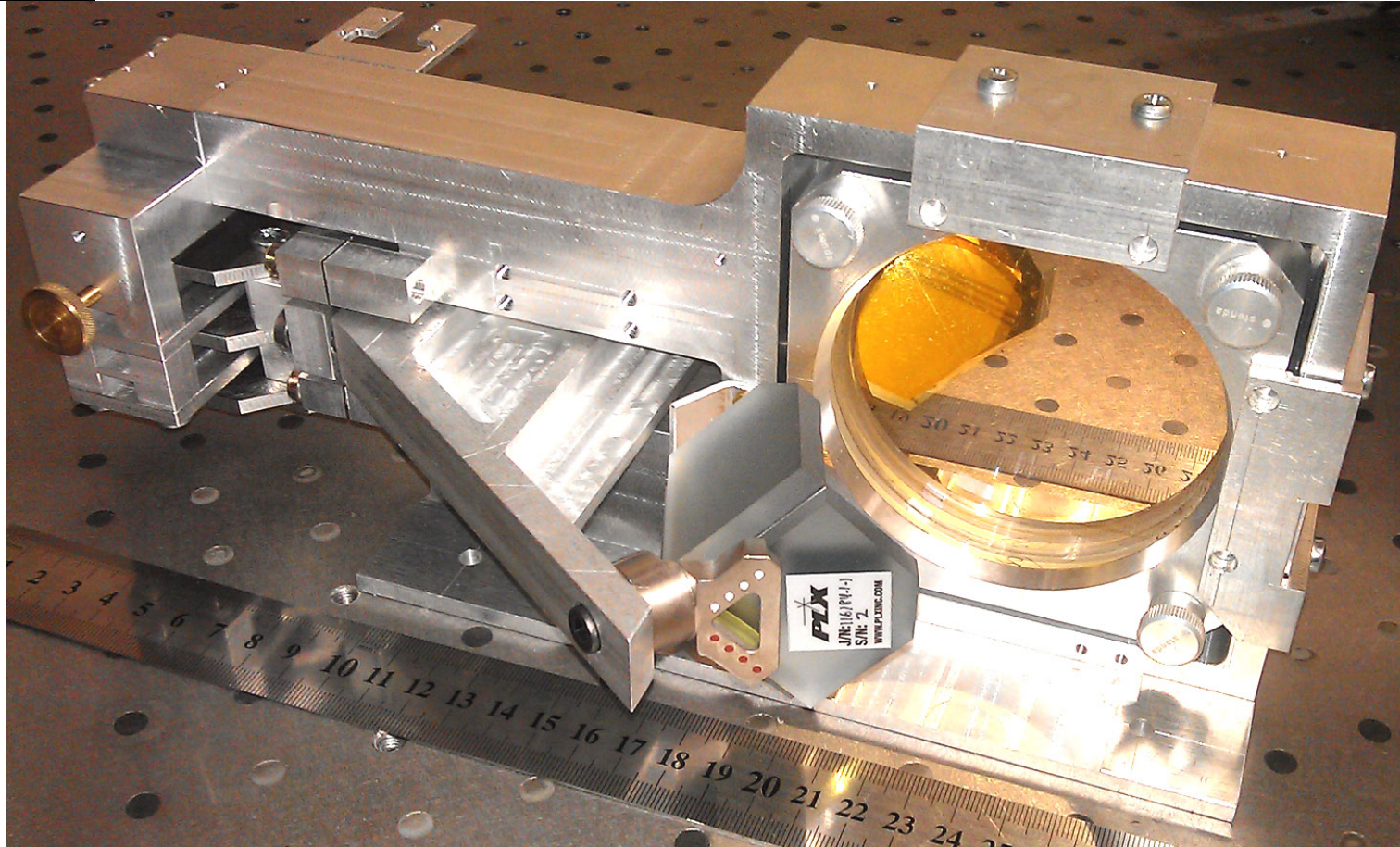


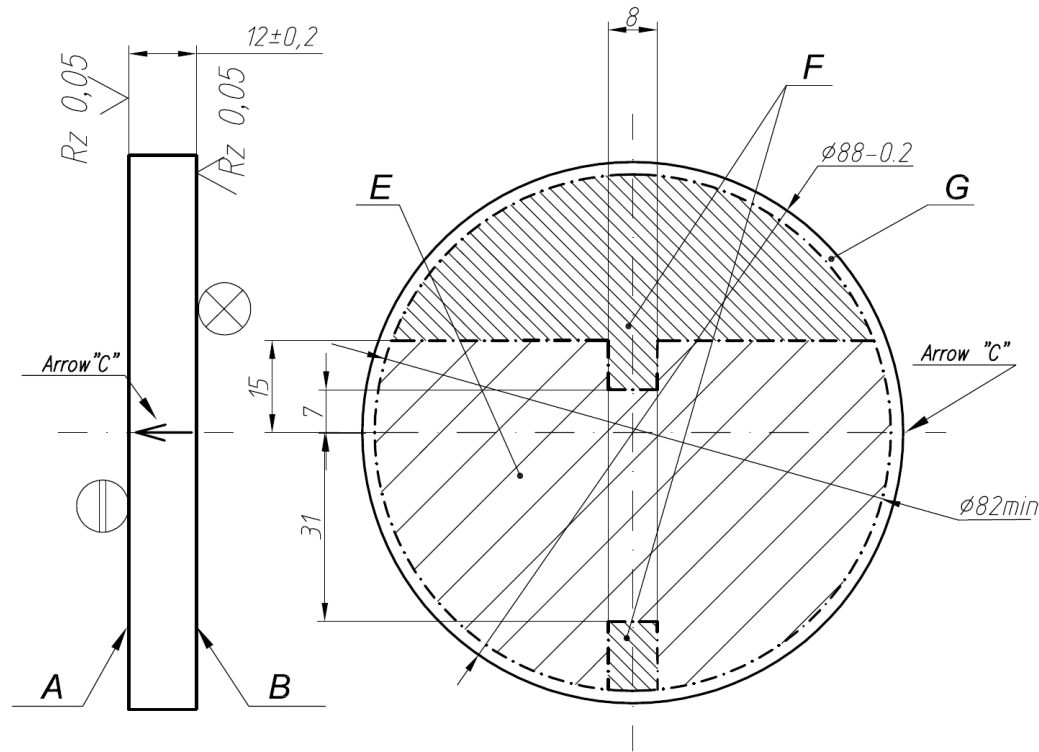
HW: Thermal Model





TIRVIM/ACS (ExoMars-2016)

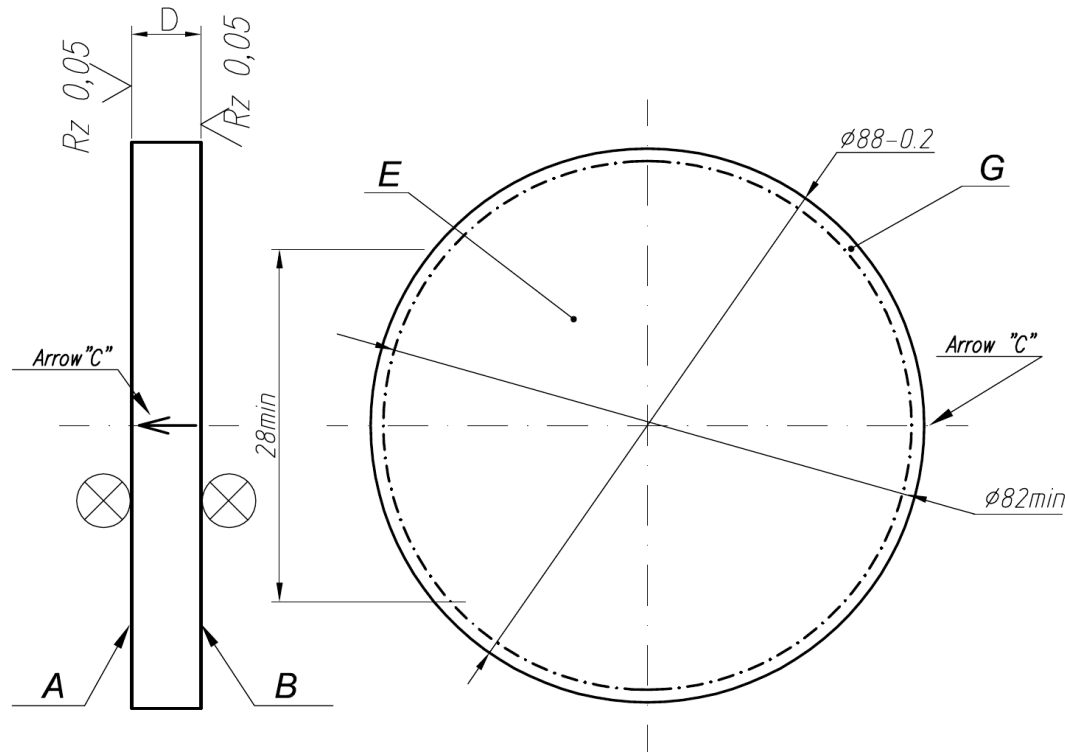
HW: Interferometer





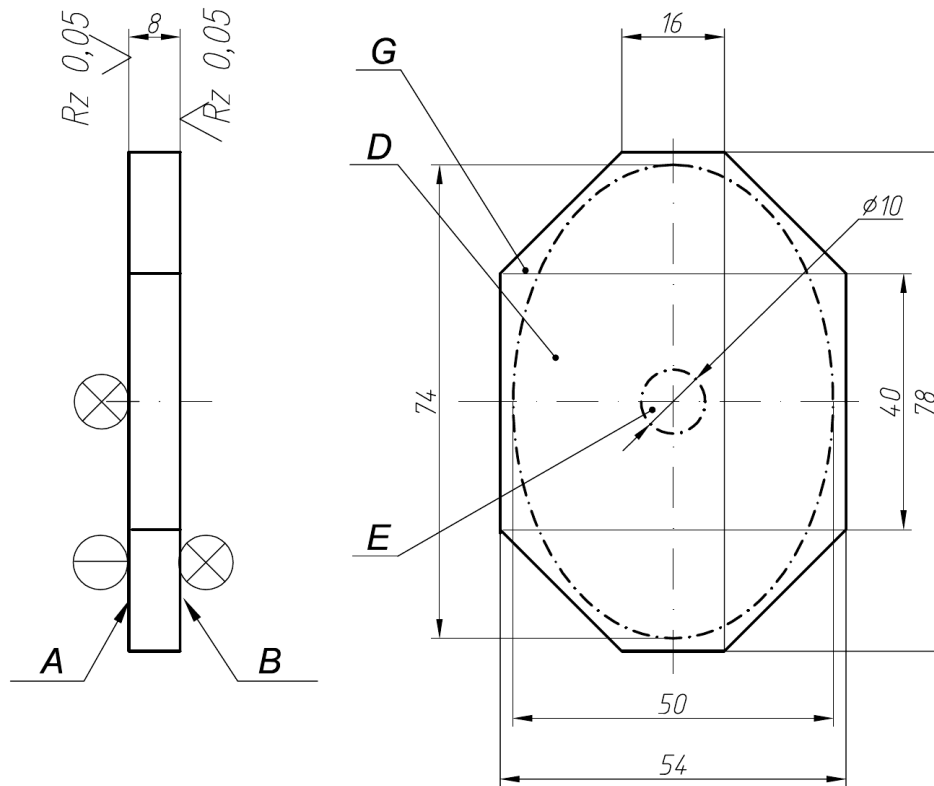
BeamSplitter (preliminary drawing)

1. ALPHA (angle between planes A & B) = 3 ± 1 arcminutes
2. Zones E & F may overlap by 0.5mm max
3. Planarity of planes A & B in zones E & F: $N=0.7$, $dN=0.3$
4. Painted arrow "C" indicates the most thick place with max error ± 2 mm
5.  - BeamSplitting coating:
 in zone E: $R=0.5 \pm 0.05$ for 3.3 & 15 micron;
 $R=0.5 \pm 0.1$ for rest parts of ranges 3.1-3.5 & 14-16 micron;
 $R=0.5 \pm 0.2$ in the rest parts of the region 2-17 micron.
 in zone F: $R=0.5 \pm 0.2$ for 0.76 & 0.63 micron.
6.  - antireflective coating:
 $R < 0.02$ for 3.1-3.5 & 14-16 micron;
 $R < 0.07$ in the rest parts of the region 2-17 micron;
 $R < 0.1$ for 0.76 & 0.63 micron.
7. Reflection must be measured at Angle of Incidence 35 ± 5 degrees.
8. Zone G is a non-working zone.
9. Bevels at sharp edges: $0.5\text{mm} * 45$ degrees.



Compensator (preliminary drawing)

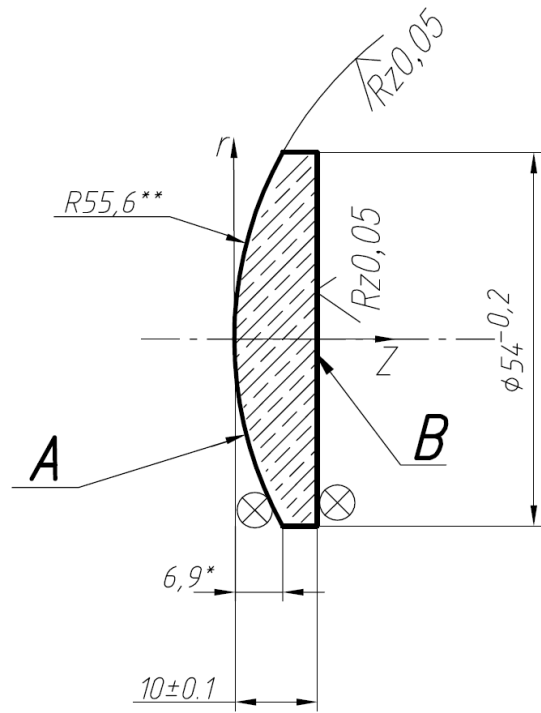
1. The angle between planes A & B must be equal to that of Beamsplitter ("ALPHA") with accuracy $\pm 5arcseconds$
2. The Compensator thickness "D" must be equal to that of Beamsplitter with accuracy $\pm 0.01mm$
3. Planarity of planes A & B in zone E: $N=0.7$, $dN=0.3$
4. Painted arrow "C" indicates the most thick place with max error $\pm 2mm$
5. \otimes - antireflective coating:
 - $R < 0.02$ for 3.1-3.5 & 14-16 micron;
 - $R < 0.07$ in the rest parts of the region 2-17 micron
 - $R < 0.1$ at 0.76 & .63 micron.
6. Reflection must be measured at Angle of Incidence $35 \pm 5degrees$.
7. Zone G is a non-working zone.
8. Bevels at sharp edges: $0.5mm * 45degrees$.



Dichroic

(preliminary drawing)

1. Angle between planes A & B: $<5\text{arcminutes}$.
2. Planarity of planes A & B in zones D & E: $N=3$, $dN=0.5$.
3. \odot - dichroic coating in zone D:
 at 3.3micron $R>0.97$, T is not important;
 in rest parts of range 3.1-3.5micron $R>0.9$, T is not important;
 in rest parts of range 2-4micron $R>0.7$, T is not important;
 at 15micron $T>0.97$, R is not important;
 in rest parts of range 14-16micron $T>0.9$, R is not important;
 in rest parts of range 5-17micron $T>0.7$, R is not important.
4. \otimes - ARC in zone E of plane A and zones D & E of plane B:
 $R<0.02$ in range 14-16micron;
 $R<0.1$ in the rest parts of the region 2-17micron.
5. Reflection must be measured at Angle of Incidence $45\pm 5\text{degrees}$.
6. Zone G is a non-working zone.
7. Bevels at sharp edges: $0.5\text{mm} * 45\text{degrees}$.



Однородность	1
Двулучепрел.	1
Бессвильность	1A
Пузырность	1A
N	5
ΔN	1
P_A	VI
$Z_F(\lambda=15\mu)$	42,8
$\phi_{св}$	50

Aspheric ZnSe lens

(preliminary drawing)

1. Рабочая область 2...17 мкм.
2. * – размер для справки.
3. Фаски на ребрах $0,5\pm 0,2 \times 45^\circ$.
4. \otimes – Просветл, $R < 0,02$ при $\lambda = (14...16)$ мкм. $R < 0,07$ в остальных.

5. Уравнение поверхности A (гипербола):

$$Z = \frac{Gr^2}{1 + \sqrt{1 + 0,8G^2 r^2}} \quad G = 0,02$$

6. ** – радиус исходной описанной сферы.

(макс. разность $Z_{сфер} - Z_{гипер}$ равна 0,24 мм при $r = 18$ мм)

7. Z_F – координата фокуса по оси Z.

**FAST –
Fourier for
Atmospheric
Species and
Temperature**

(0.05cm⁻¹ !)

FAST has won the contest:

FAST (first place in the list): 76 points

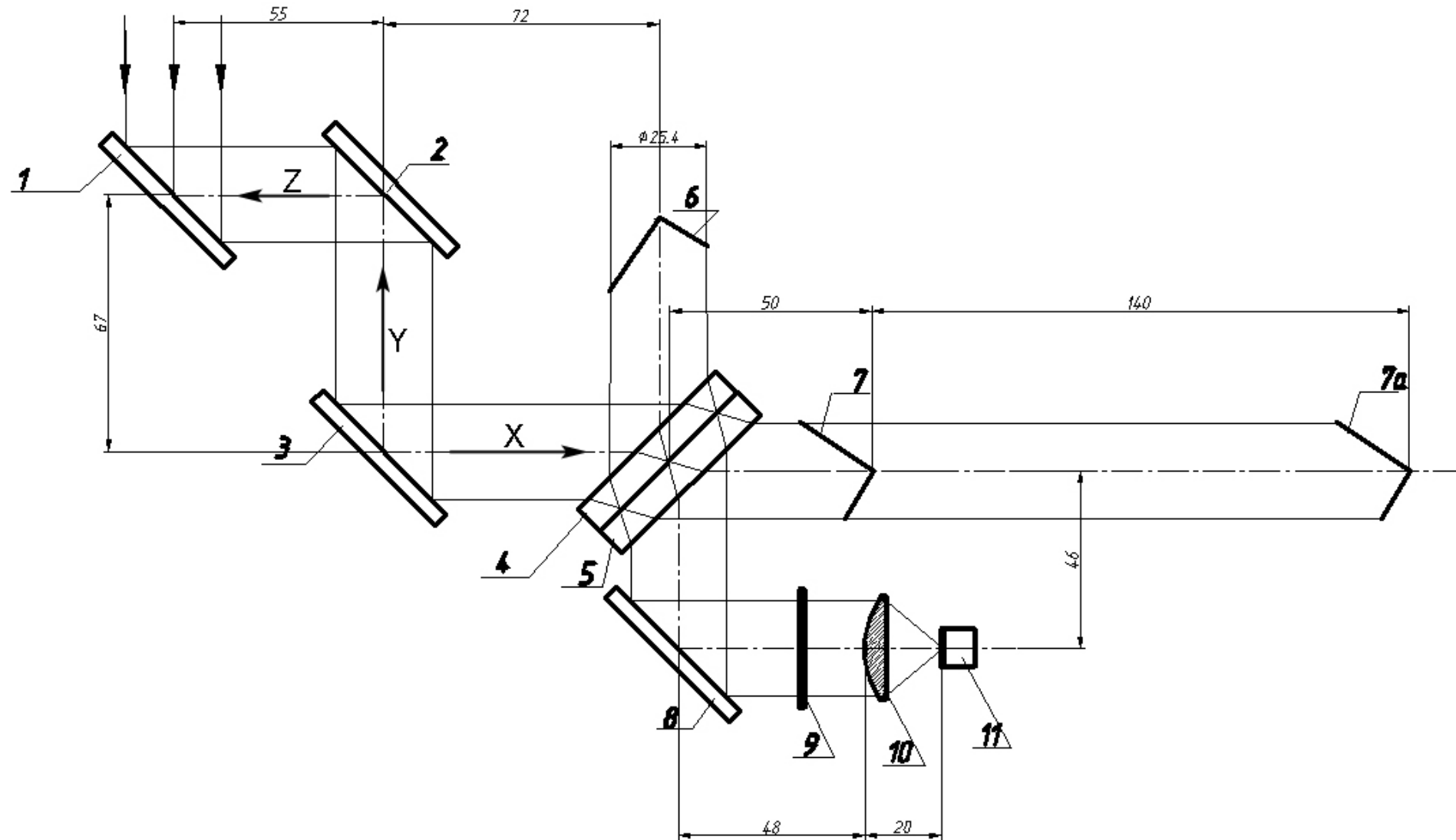
Next after FAST in the list: 68 points

The last in the list : 30 points

Main scientific objectives

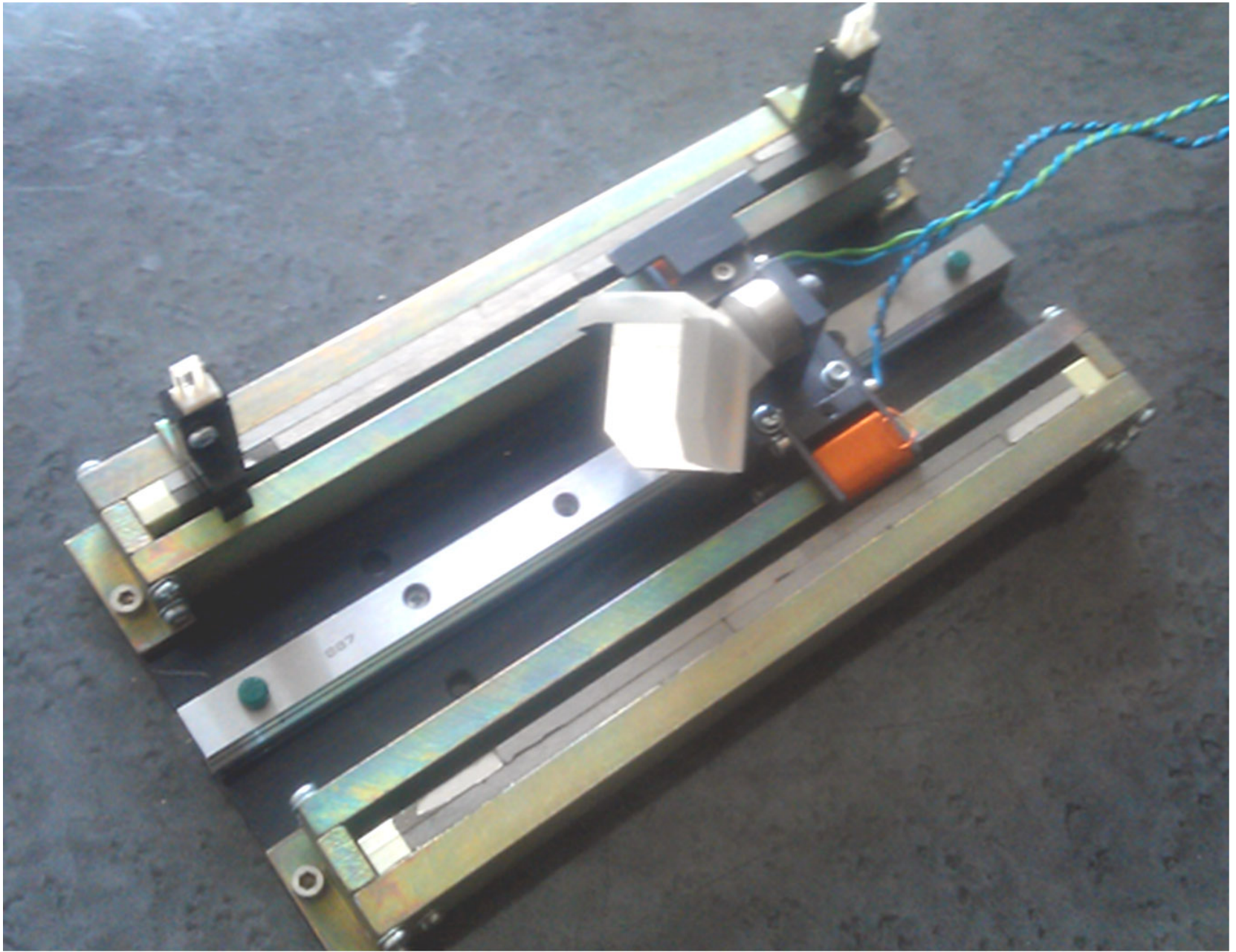
OBJECTIVE	MESUREMENT MODES & PARAMETERS
Methane & other minor atmosphere constituents	Sun tracking, 0.05cm^{-1} 1) 2-4 μm , PV-PbCdSe detector @200K, 1 IFG: 10sec or: 2) Pyro-detector @RT, 1 IFG: 30sec
Vertical thermal profile of the atmosphere, both day & night	Different air masses, CO_2 band at 15 μm , 1.6cm^{-1} Pyro-detector @RT, 1 IFG: 30sec, averaging
Mineral composition of the surroundings	1) 2-4 μm , PV-PbCdSe detector @200K, 1 IFG: 10sec or: 2) Pyro-detector @RT, 1 IFG: 30sec, averaging

Concept



Carriage unit prototype

FAST (ExoMars-2018)

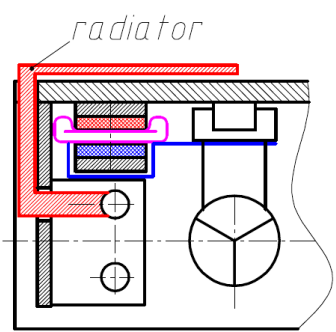
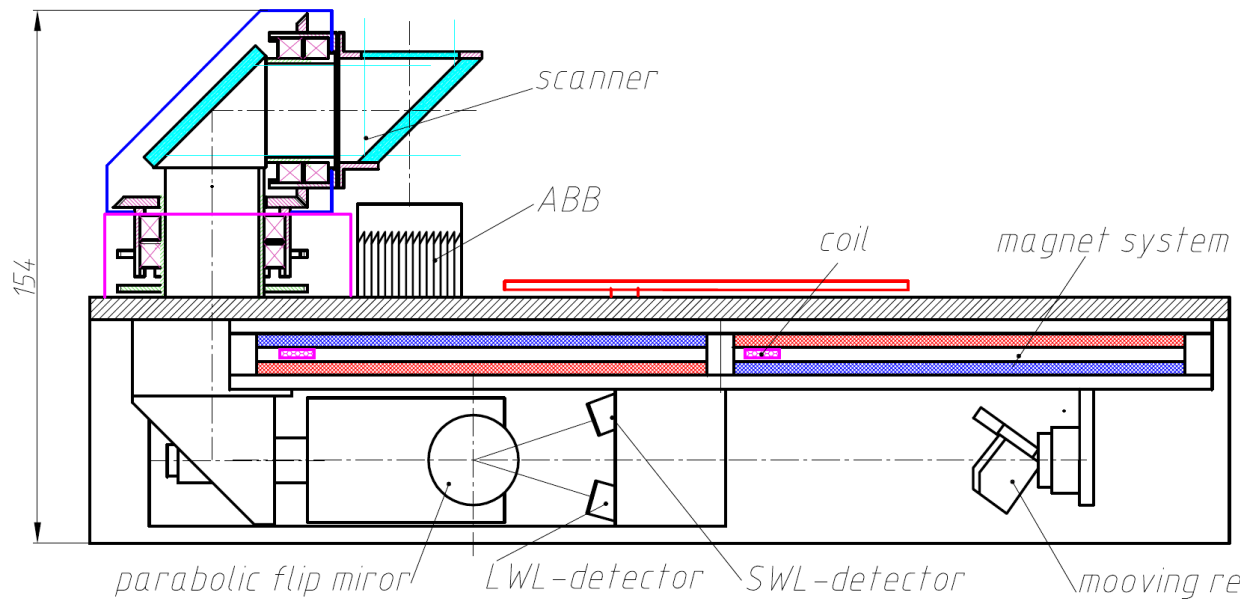
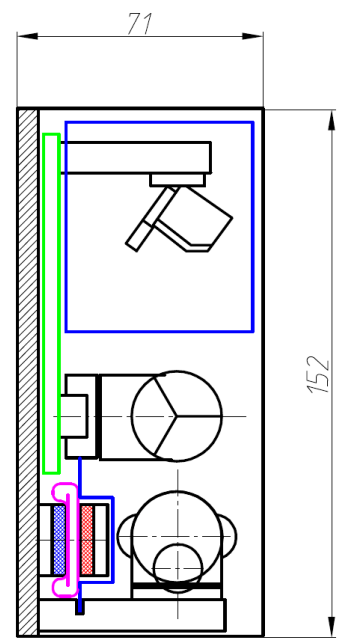
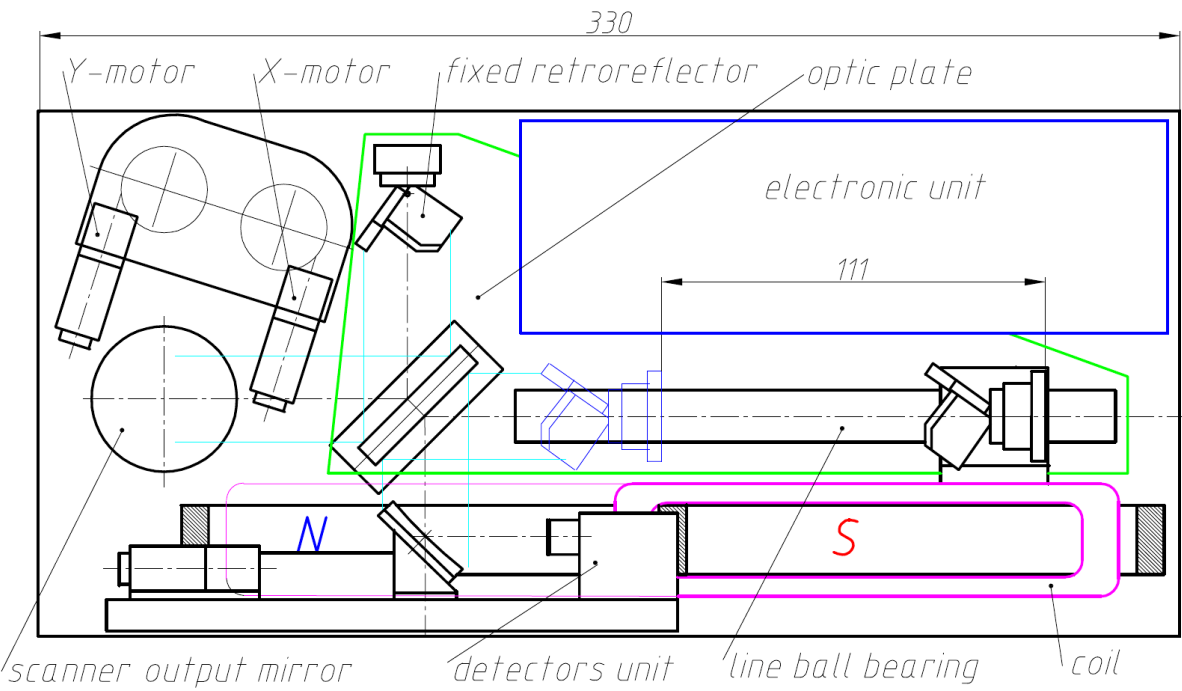


Size mockup

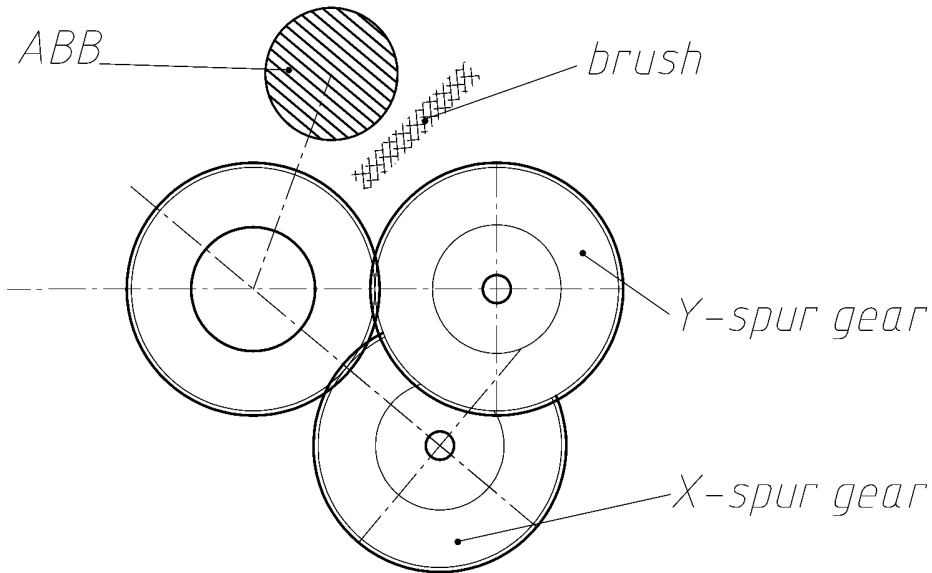
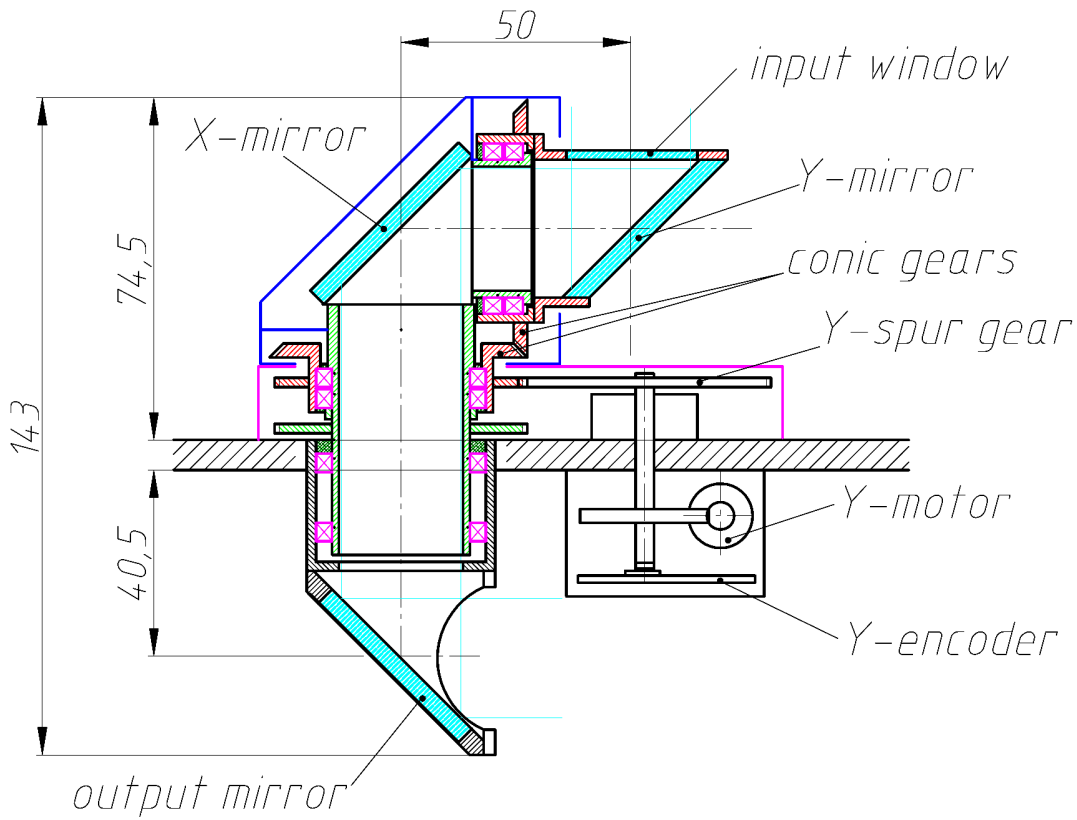


Layout

FAST (ExoMars-2018)



Scanner layout



Possible German inputs for FAST

<p>Moving mirror system</p>	<p>Rail with carriage, motor and electronics,incl. PID system, providing the stable 11-cm movement</p>
<p>Key optical subsystems: design (together with IKI), manufacturing (procurement), tests, measurements, certification,...</p>	<ul style="list-style-type: none"> • Beamsplitter-Compensator unit (ZnSe) • Laser for reference channel • Au-coated metallic mirrors for Scanner • ... • Retro-reflectors (1" cube corners) • ...
<p>Manufacturing of mechanical components</p>	<p>According to drawings issued by IKI and ASTROFEIN,...</p>
<p>On-board BlackBody</p>	<p>Design, manufacturing, tests, certification,...</p>
<p>...?</p>	