IPP INSTITUTE OF PLASMA PHYSICS OF THE CZECH ACADEMY OF SCIENCES

Introductory Call -- IR Diagnostics Discussion

Aiming to loosely cover the following topics over the next 30–45 minutes:

- Brief introduction to the project: What we're building, where the system fits in, and the main technical challenges
- Overview of the current design: What's been done so far (models, constraints, camera setup)
- Getting to know your team: Your expertise, past projects, and how you might contribute
- Next steps: Sharing files, clarifying technical details, and discussing how collaboration could move forward

INSTITUTE OF PLASMA PHYSICS
OF THE CZECH ACADEMY OF SCIENCES

Introductory Call – IR Diagnostics Discussion

Contact persons
Milan Berta bertam@ipp.cas.cz
Petr Vondráček vondracek@ipp.cas.cz

EUROfusion

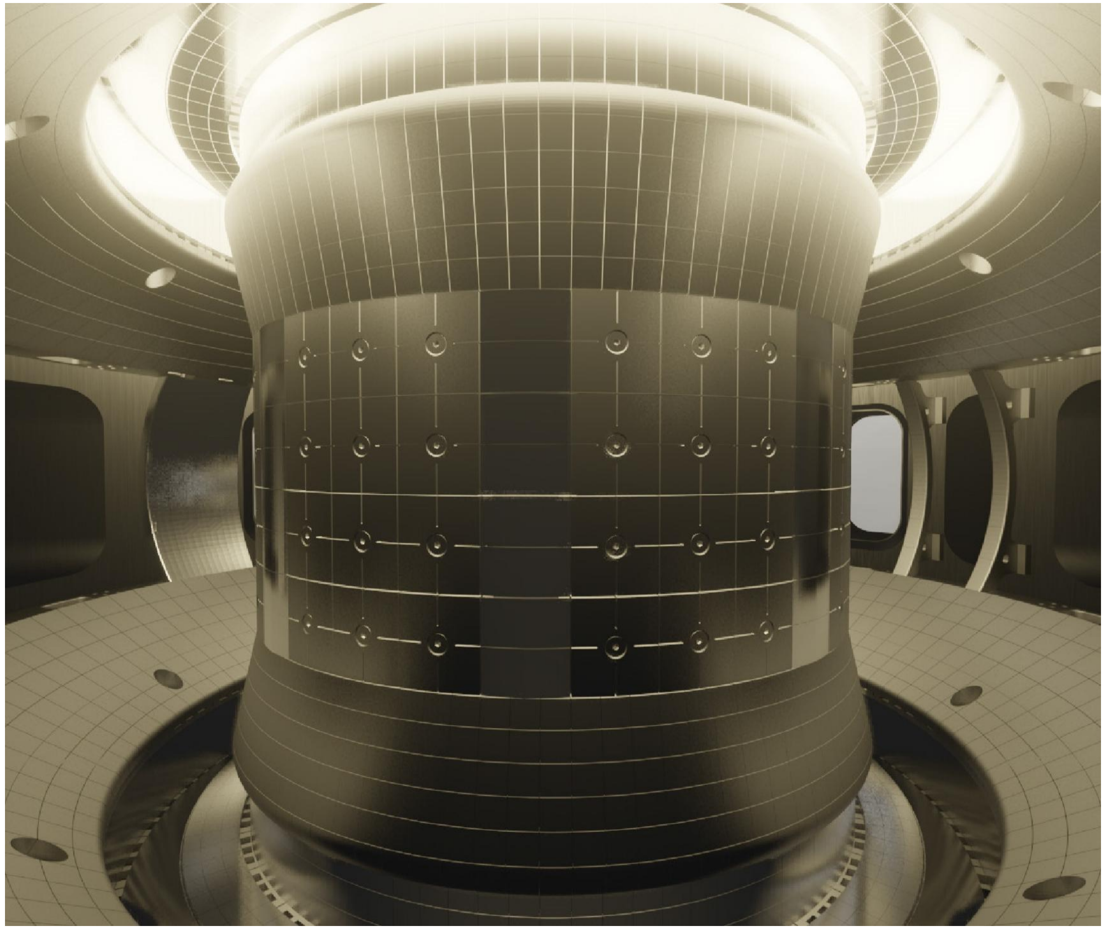
IPP

Diagnostics in the Tokamak

As part of the COMPASS Tokamak Upgrade project in Prague, we are preparing the development of a next-generation infrared (IR) diagnostic system. The system should include a mid-wave infrared (MWIR) camera (TELOPS FAST-IR 2K) with a fast indium antimonide (InSb) detector, sensitive to 3–5.5 µm spectral range, capable of reaching up to 1.9 kHz in full-frame mode and up to 90 kHz in subwindowed mode.

The new design will introduce updated optics and a rotatable input mirror system to allow wider field-of-view. The system will be integrated into a broader diagnostic framework, operating in a **high magnetic field environment and temperatures up to 750 K**.

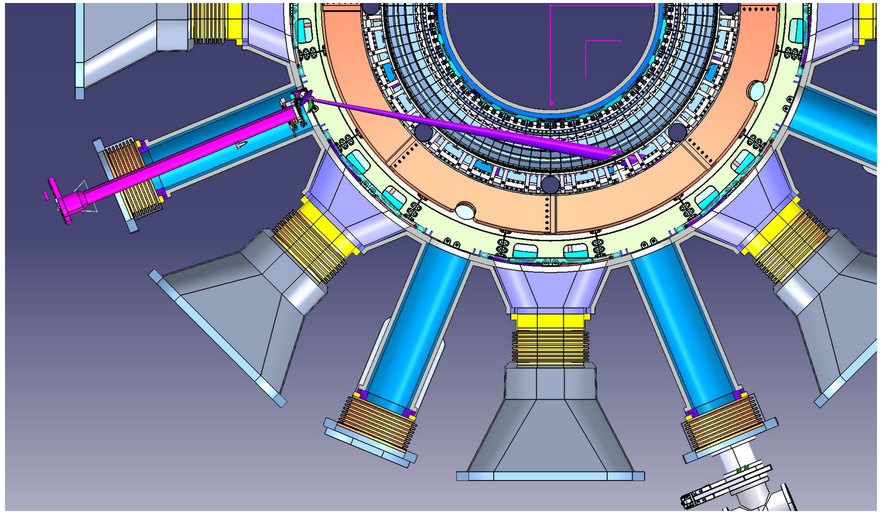
The system will be used to measure surface temperatures of internal machine components—such as tungsten or Inconel tiles—with target temperatures reaching up to 2000 K and with expected resolution (0.5 mm/pixel at 160 mm FOV).



Fast IR thermography for COMPASS-U

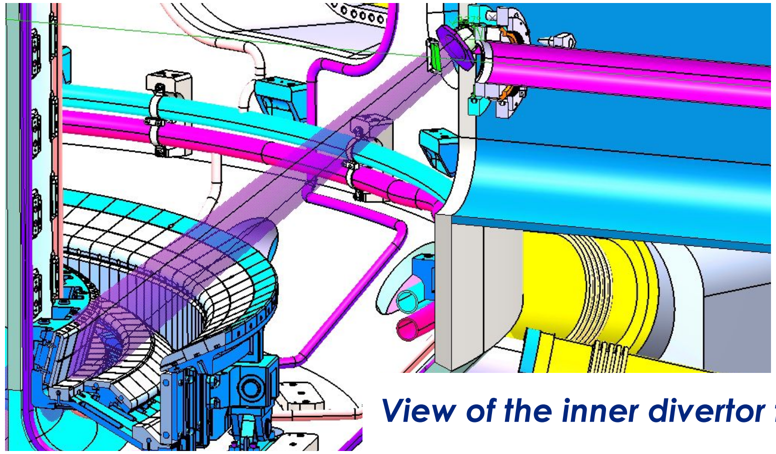
Fast MWIR camera TELOPS FAST-IR 2K

- 3-5 um InSb detector
- **2 kHz @ 320 x 256 px**
- up to 90 kHz in subframe mode

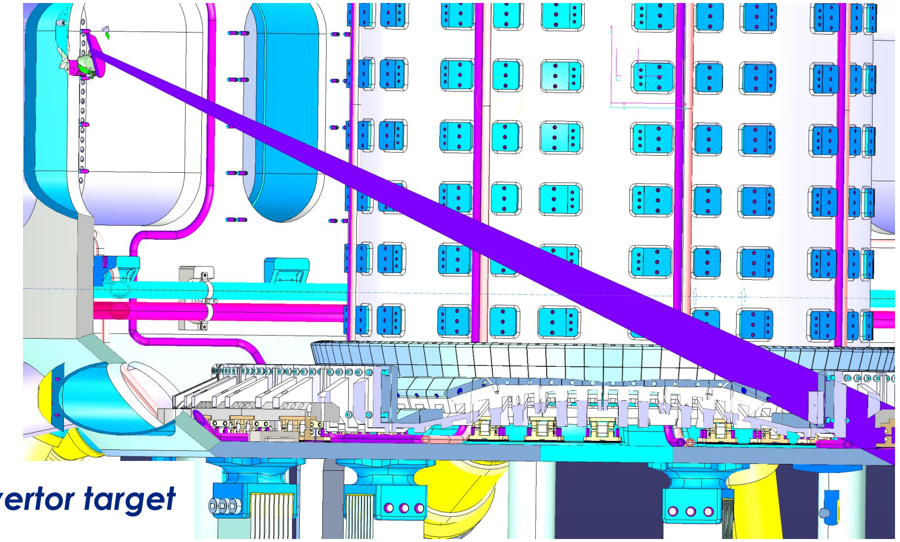


Steerable periscope based on AUG design planned to be designed

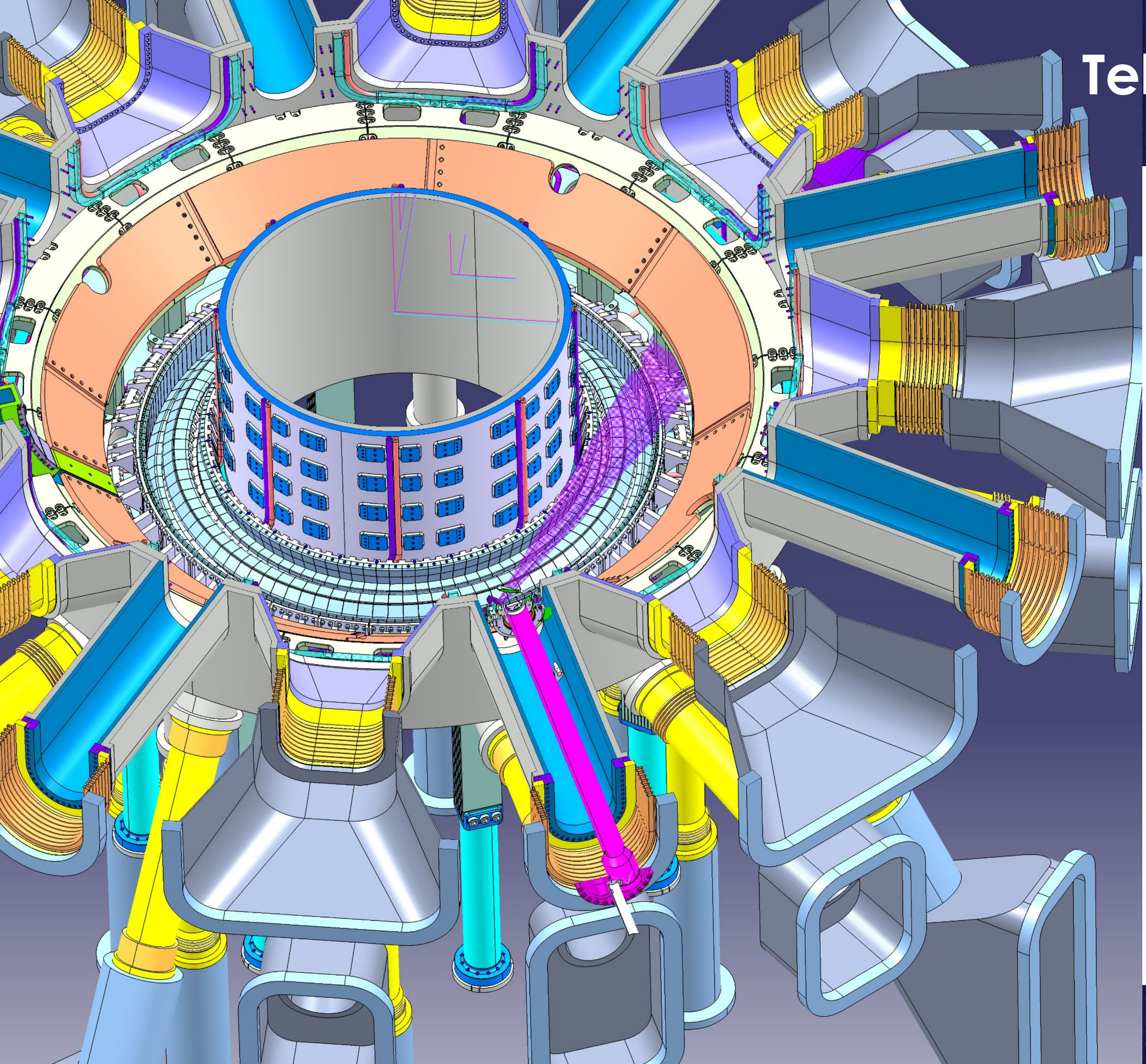
- 2 rotatable flat front mirrors
- pixel resolution at divertor targets **~0.5 mm/px**
- placed inside of narrow midplane port
- camera placed outside of cryostat



View of the inner divertor target



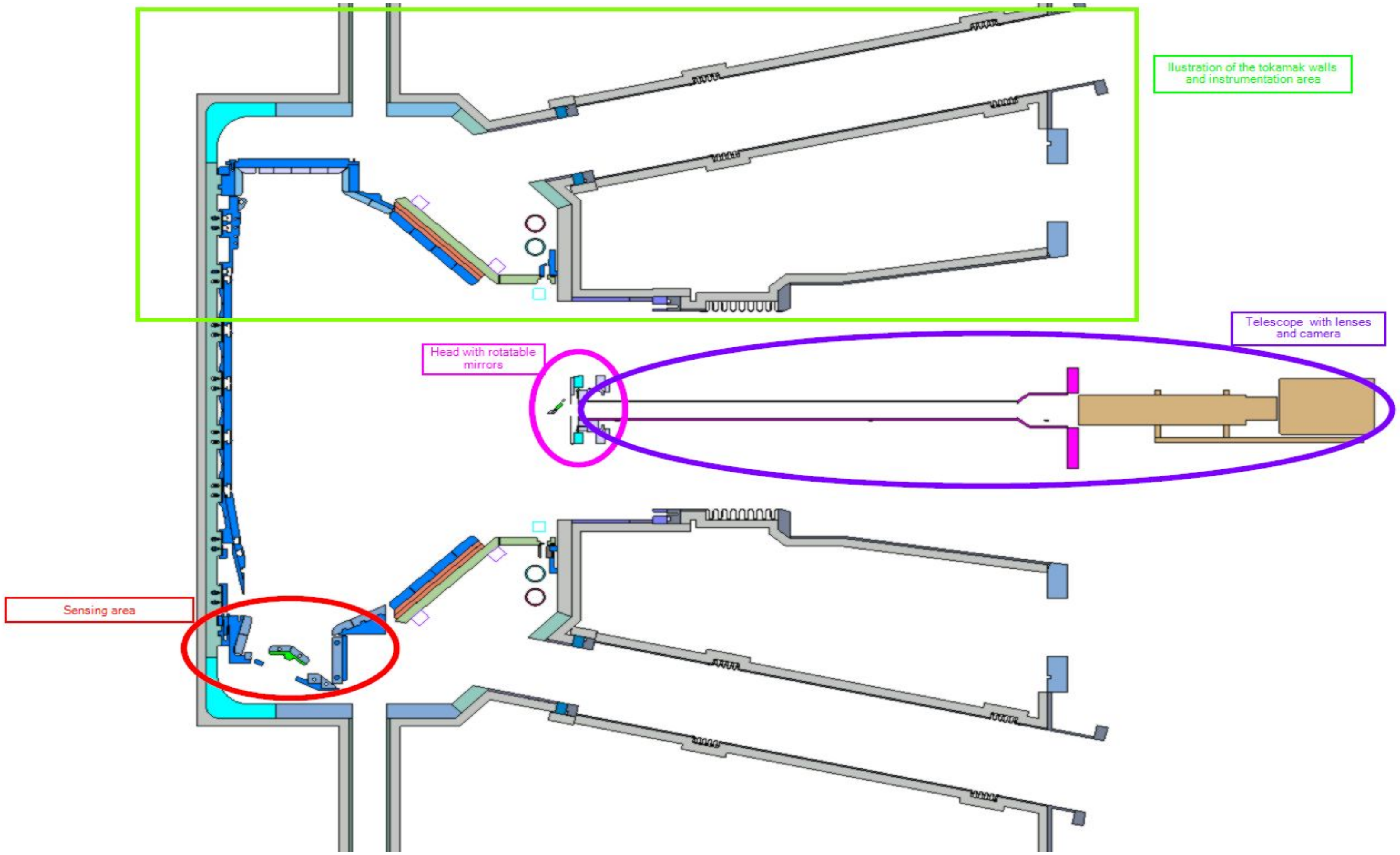
View of the outer divertor target



Telescope in the Tokamak I

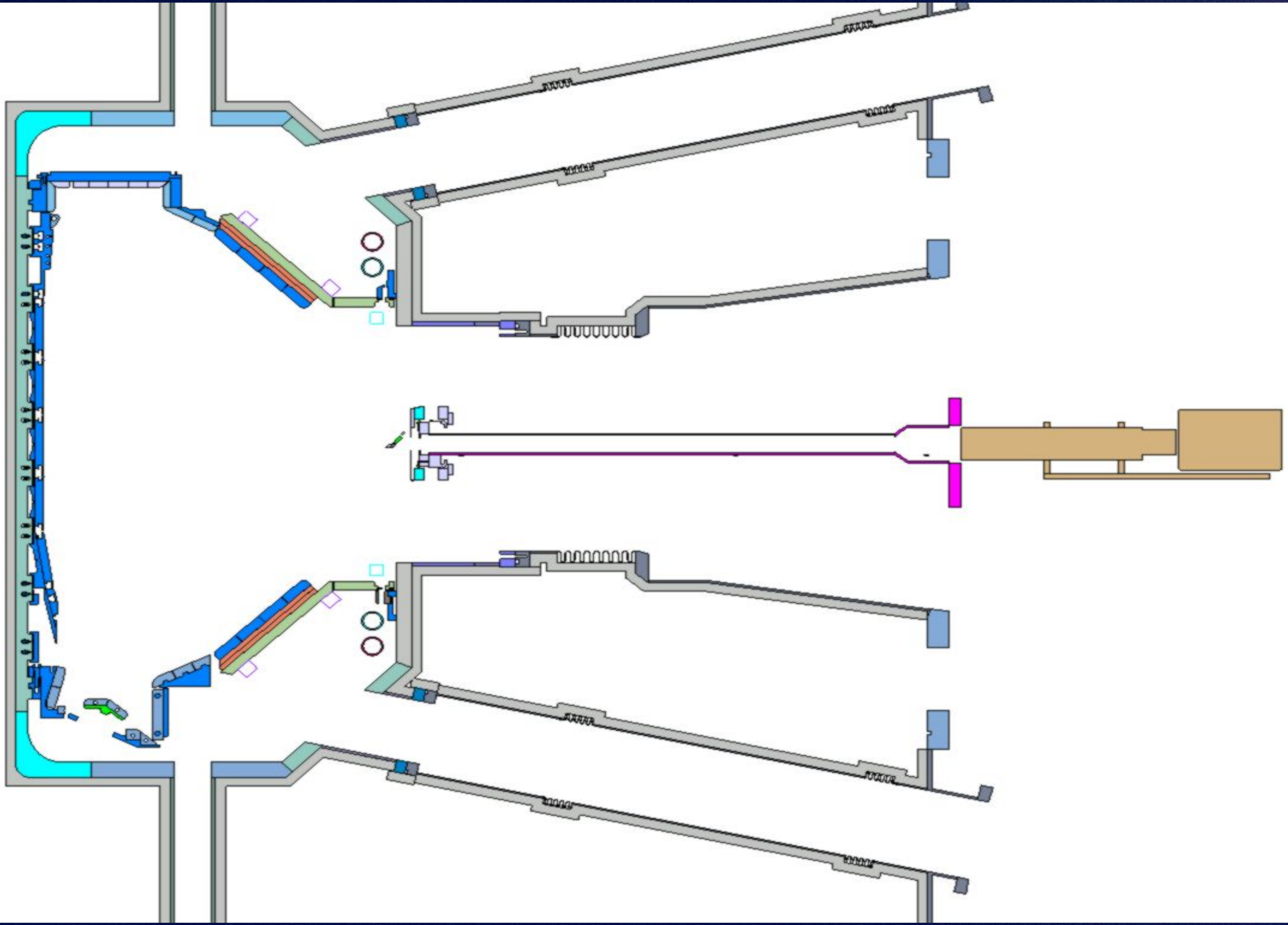
- The **horizontal cross section** shows the bottom half of the chamber with the cryostat
- The **telescope** enters the chamber at its pseudo-symmetry **horizontal plane under 0 degrees azimuth**
- The **2 rotatable mirrors** allow for **sensing** the radiation at its **top and bottom areas** as well
- **Radiation** from the so-called plasma facing components (PFCs, tungsten or inconel tiles) is **collected** and guided **to the infrared camera (not in image)**

Telescope in the Tokamak II



- The **vertical cross section** shows **one half of the chamber** with the cryostat
- The **telescope** enters the chamber at its pseudo-symmetry **horizontal plane under 0 degrees azimuth**
- The **2 rotatable mirrors** allow for **sensing** the radiation at its **top and bottom areas** as well
- **Radiation** from the so-called plasma facing components is **collected** and guided **to the infrared camera**
- **the mirror head** operating in **ultra-high vacuum at 10E-6 Pa.**

Telescope in the Tokamak (no annotation)

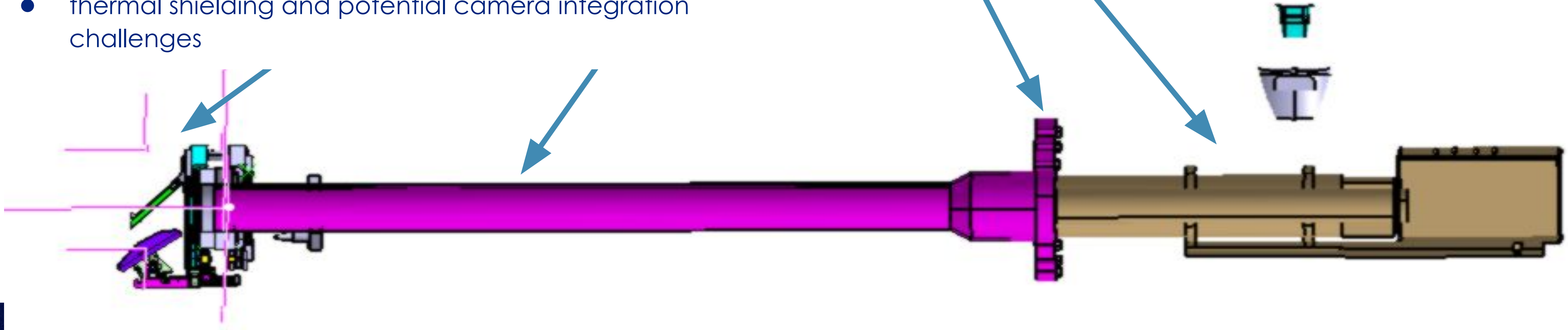


- The original telescope is designed for room temperature operation and optics is removed during occasional baking procedures.
- Revised design should be capable of operation in tokamak vacuum vessel heated up to 780 K (the optical telescope can be thermally shielded/cooled, the mirrors need to withstand the elevated temperature)
- To be solved: turning the camera to align with the view.

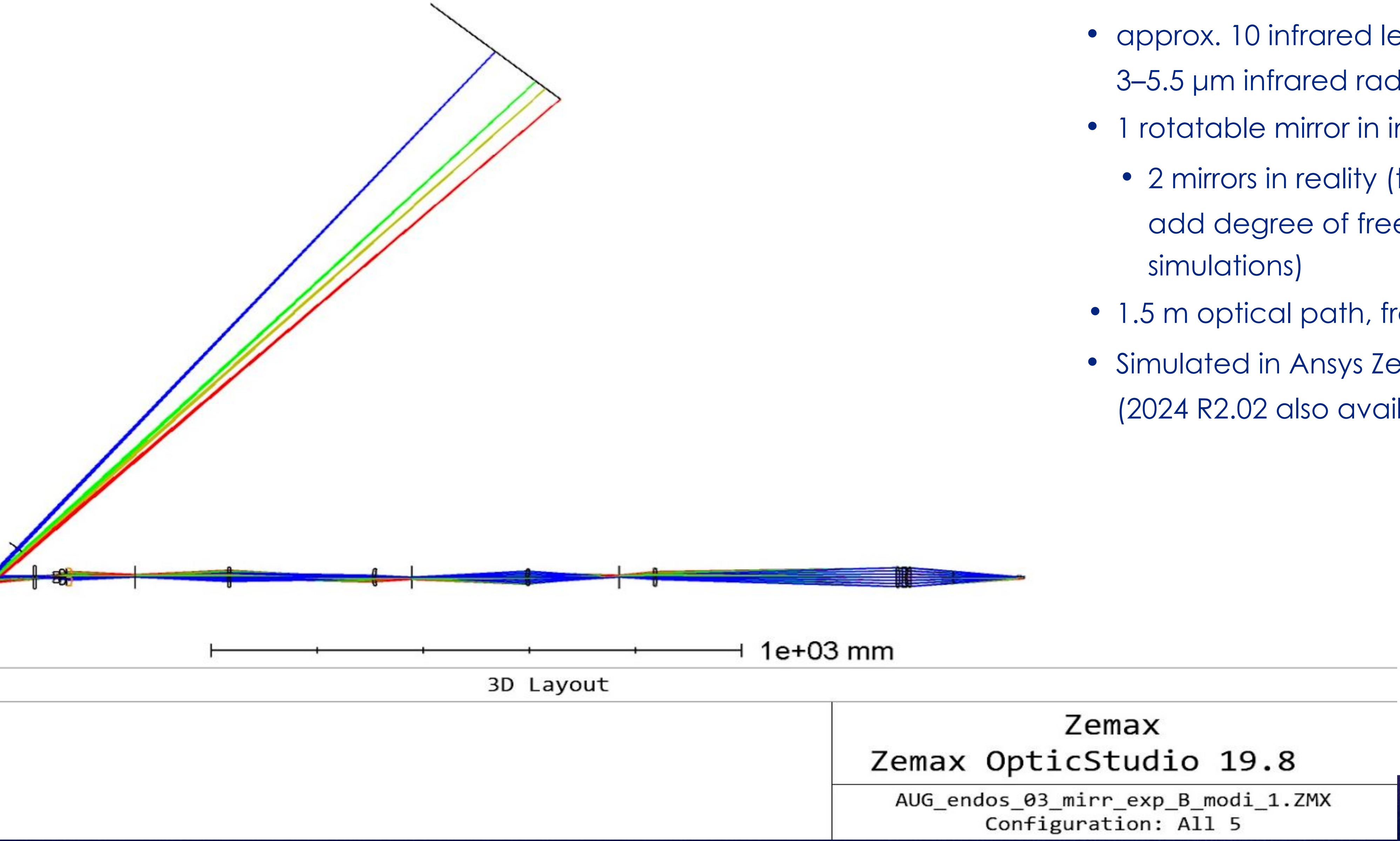
Telescope Design

- The current model is developed in Dassault Systèmes CATIA® Version 5-6
    - Based on heritage from ASDEX Upgrade system
- Full-inclusion and collision check is possible within the technology model
- The system must be suitable for integration into a high magnetic field environment, temperatures up to 750 K and meet demanding performance standards for fusion diagnostics.
- temperature zones: 500°C at head, cooled sections further along.
- thermal shielding and potential camera integration challenges

- rotatable mirrors
- telescope with the lenses
- high-speed infrared camera
- connection to the telescope by a flange

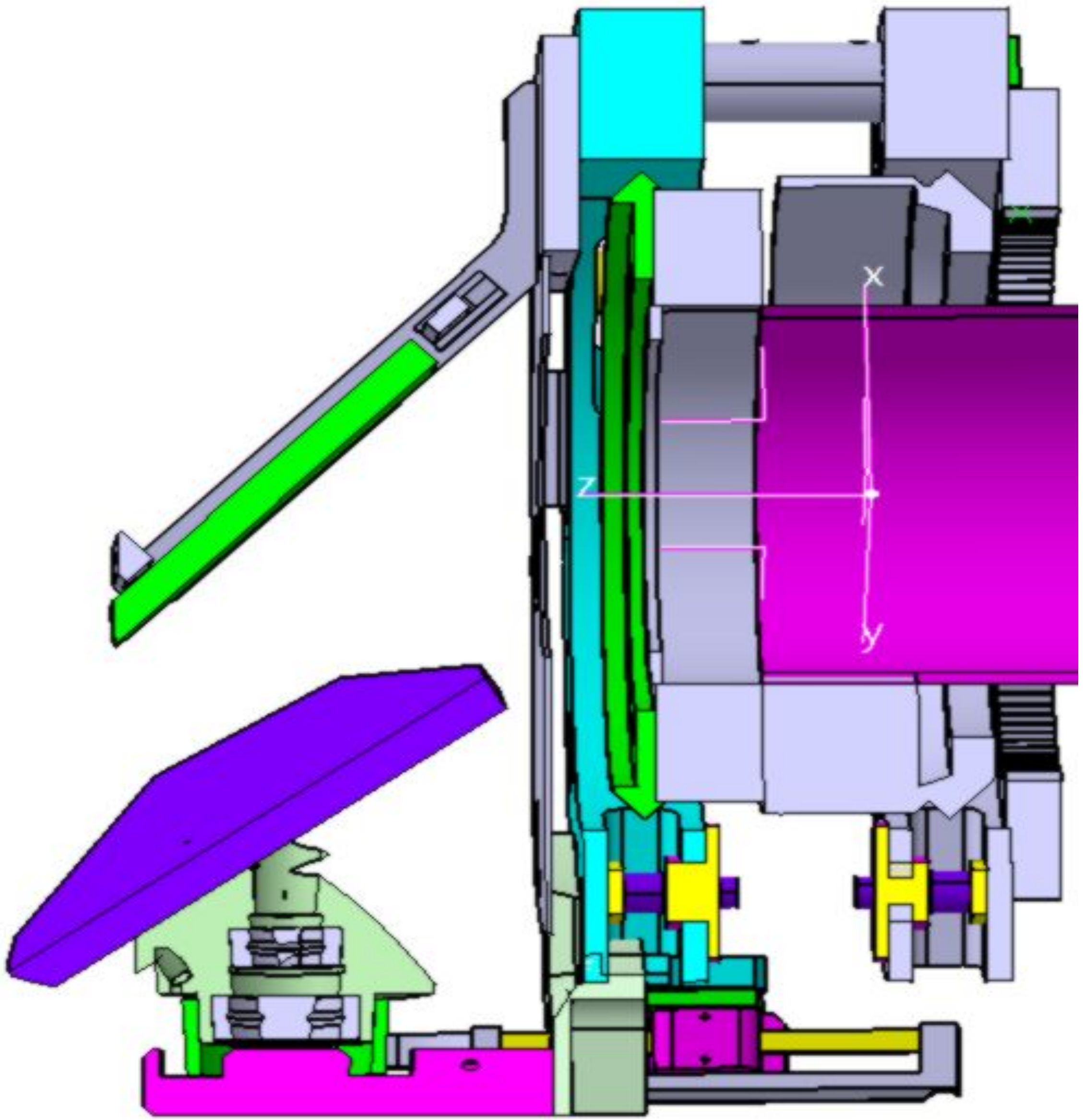


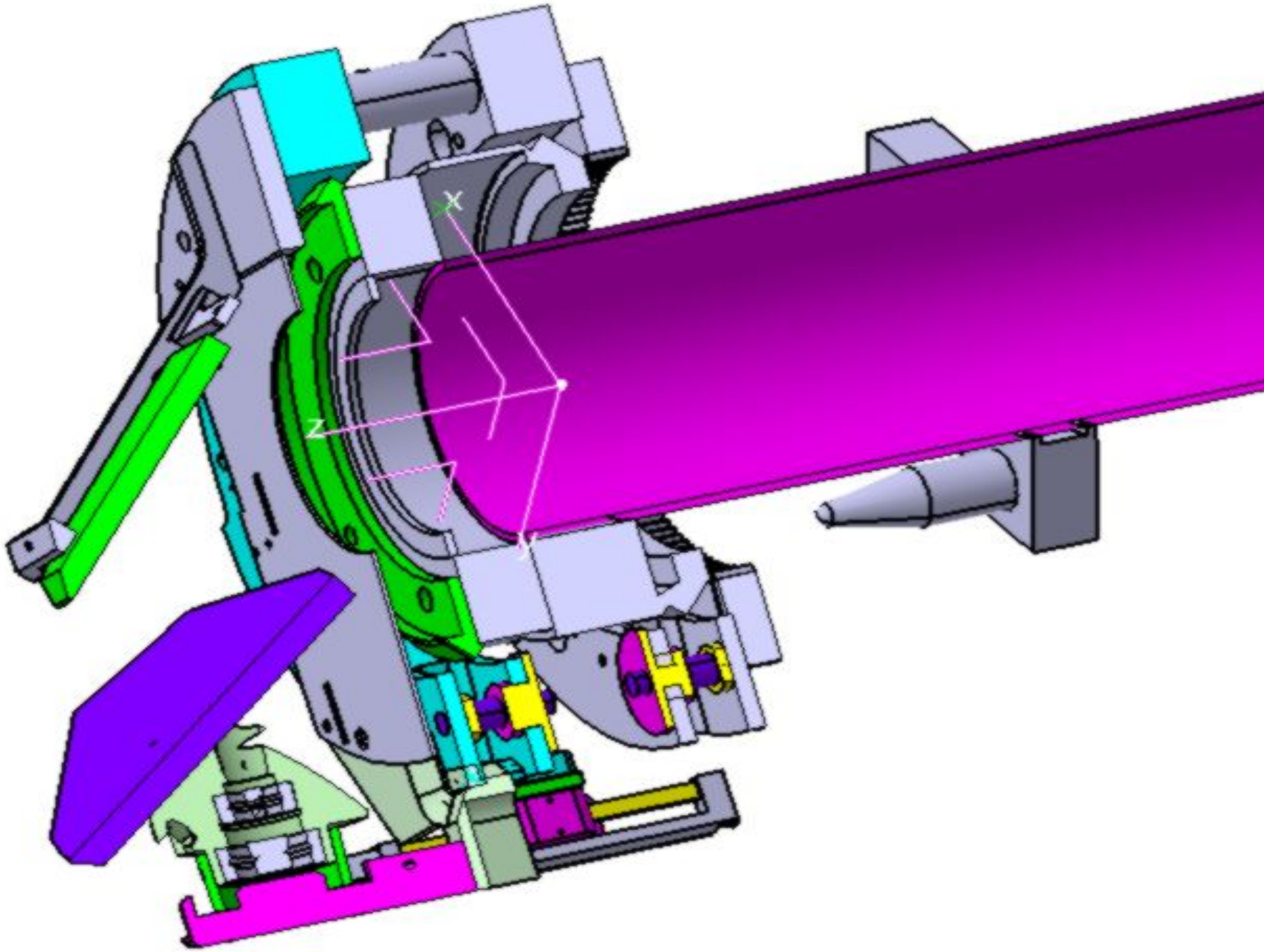
Zemax Simulation with one Rotatable Mirror



- approx. 10 infrared lenses transparent for 3–5.5 µm infrared radiation
- 1 rotatable mirror in image for simplicity
  - 2 mirrors in reality (the 2nd mirror does not add degree of freedom for this simulations)
- 1.5 m optical path, from head to camera
- Simulated in Ansys Zemax OpticsStudio® (2024 R2.02 also available)

Rotatable Head for Wider Sensing Field





System Requirements Overview

Operating environment:

- Max temp: 500°C at mirror head
- Vacuum: ~10^{-6} Pa
- Magnetic field: Tokamak-relevant shielding required for electronics

Imaging requirements:

- Resolution: 0.5 mm/pixel
- Field of view: 160 mm at ~1.4 m from the front mirror
- Depth of focus: ~0.7 to 1.5 m from the front mirror

Timeline: Delivery Q3 2026

IPP

Procurement Plan and Tender Strategy

Czech law requires public tendering

Phased tendering foreseen:

- Concept & Feasibility
- Detailed Optical & Mechanical Design
- Manufacture & Assembly

Technical partners encouraged to provide:

- Experience from similar phased projects
- Input on tender structure and risk mitigation

Collaboration goal: Minimize design-to-delivery risks

- **Technology shall be delivered by Q3 2026.**

Requested Partner Deliverables

Design:

- Redesigning the current optical setup
- Optics layout (Zemax or equivalent)
- Mechanical CAD integration (STP, CATIA)

Manufacturing:

- Telescope tube, lens holders, lens procurement
- Optional: rotatable mirror head (TBD)

Testing:

- Alignment verification (mechanical or optical)
- Temperature resilience assumptions

Documentation:

- Material specs, coatings, tolerances
- Assembly instructions and quality controls

Seeking support for...

We are seeking support for the optical and mechanical design of the telescope system. Specifically, the project includes:

- **Redesigning the current optical setup**
- Incorporating approximately **10 lenses** and **two rotatable mirrors** to allow a wider and flexible field-of-view for divertor observation
- Delivering both the **optical design** and **manufacture of optical and mechanical components** (e.g., lenses, mirrors, telescope housing)
- The head with the mirrors may be outsourced to our local workshops (in discussion).
- **Technology shall be delivered by Q3 2026.**

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Contact persons
Milan Berta bertam@ipp.cas.cz
Petr Vondráček vondracek@ipp.cas.cz