Argonne NATIONAL LABORATORY

Advanced Characterization of Emissive Materials: Photocathodes and MCPs

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What is common between the emissive materials we are studying at Argonne?

- Layers (or stacks of layers) of thin films
- We have to understand in depth the inter-relation between
  - Physical properties of the layers and layered structures
    - Thickness
    - Composition
    - Inter-diffusion
    - Surface morphology / roughness
  - Functional properties of the layers
    - What makes them emissive
    - How their emissive properties can be “tuned” / optimized
- A single experimental tool / probe enabling this understanding does NOT exist
  - A combination of characterization tools/approaches is needed.

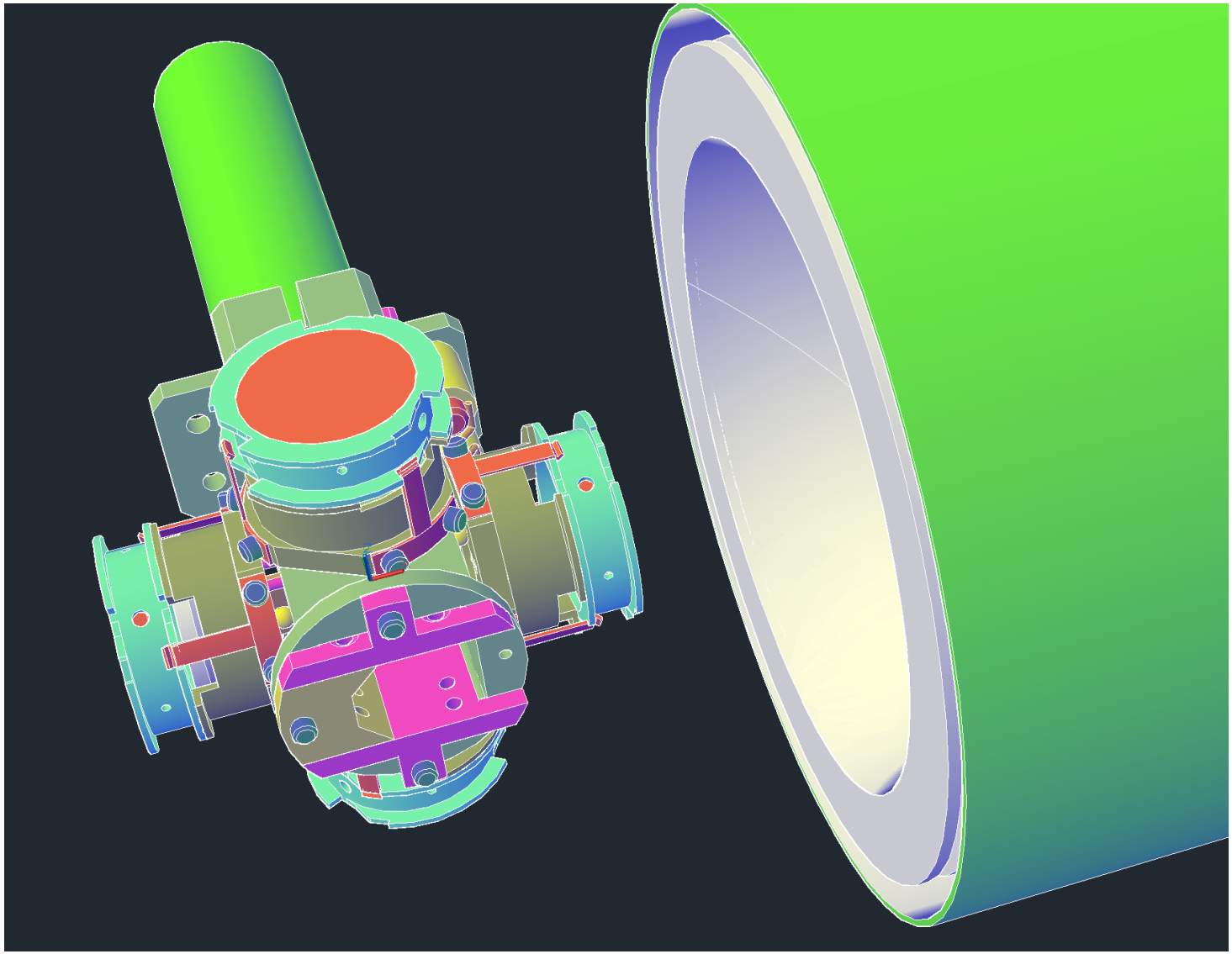
Ability to combine various characterization tools at Argonne is our strength

- The approach is the same for Photocathodes and MCPs
  - Characterization of emissive materials using a dedicated apparatus in MSD (XPS/UPS/LEED-SEY)
  - Characterization with other suitable tools available @ APS, EMC, CNM, MSD
- Photocathode-specific
  - Need sample transfer under (presumably) ultra-high vacuum
    - Need some sort of characterization protocol *prior to* and *after* sample transfer to enable functionality checks
      - assure that the transfer does not affect the functionality/performance
  - The range of available characterization tools is limited to those compatible with vacuum transfer
    - Means some (or a lot of) extra work to enable this compatibility for an instrument of interest

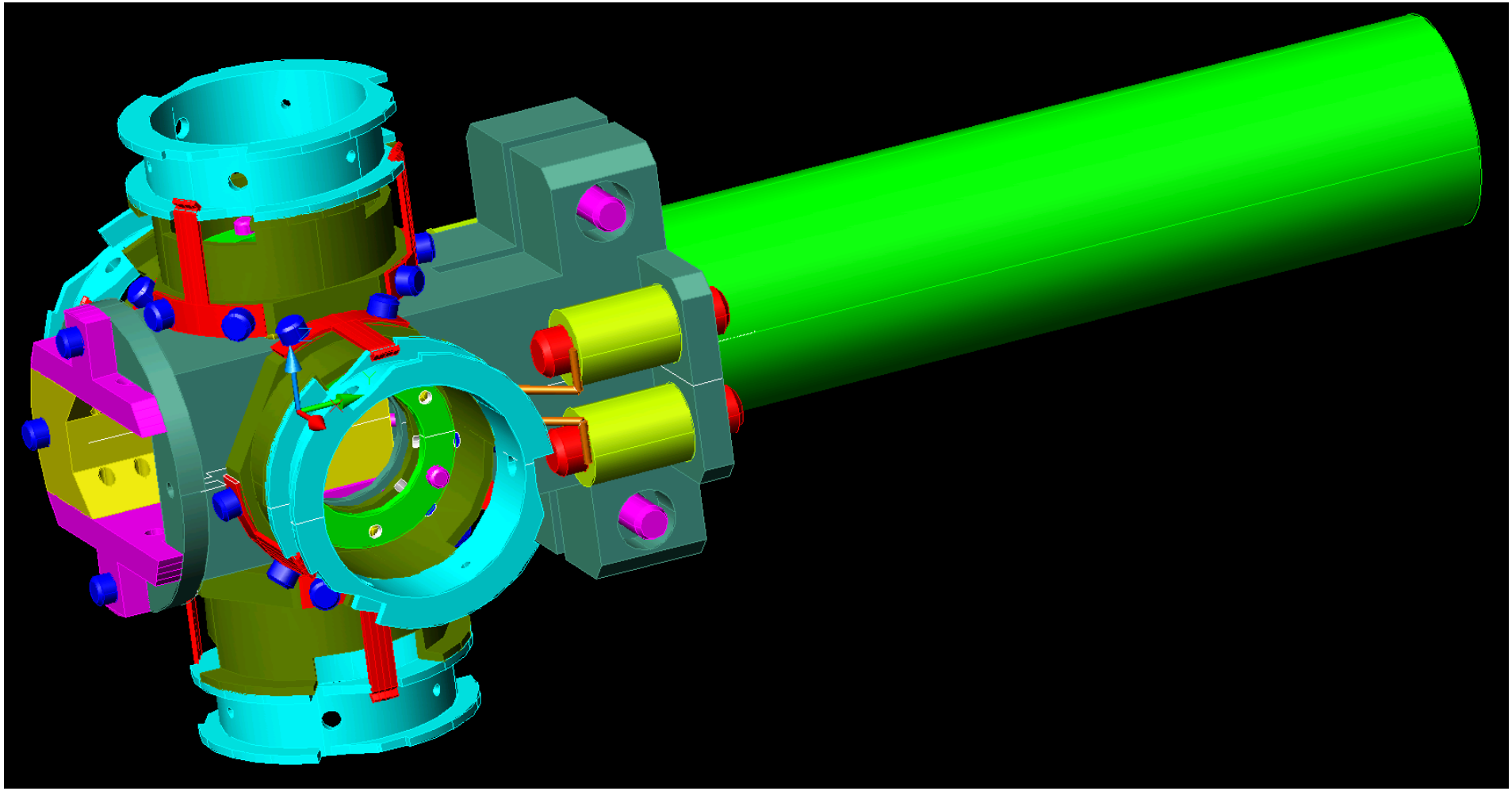
Our progress in photocathode characterization business since last review

- We worked on the design of upgrades enabling characterization of the photocathodes in our MSD instrumentation
  - Design of the new sample carousel almost complete (99%)
    - Must be fabricated and implemented ASAP
  - Conceptual design of the MS addition to the characterization apparatus
    - 80% completed
    - **The whole idea needs to earn support from the project management…**
  - Concluded that SEM/EDX characterization in the SARISA instrument will be needed
- We examined UHV transfer options for photocathodes
  - Our design developed for NASA Genesis Solar Wind analysis project can be adopted
    - Designed for SARISA, SPIRIT and CHARISMA instruments in MSD
    - Directly fits on the XPS/UPS/LEED-SEY apparatus after upgrading it with the new sample carousel and addition of a simple loadlock system (based on Kimball Physics spherical cross)
    - Will fit on the new photocathode growth chamber
    - A modified version fits on Zikri Yusof's Cs_2Te growth chamber
  - Sample transfer containers must be fabricated and implemented
    - **Zikri intends to fund the construction of the "test bed" container from his LDRD…**

New sample carousel



New sample carousel



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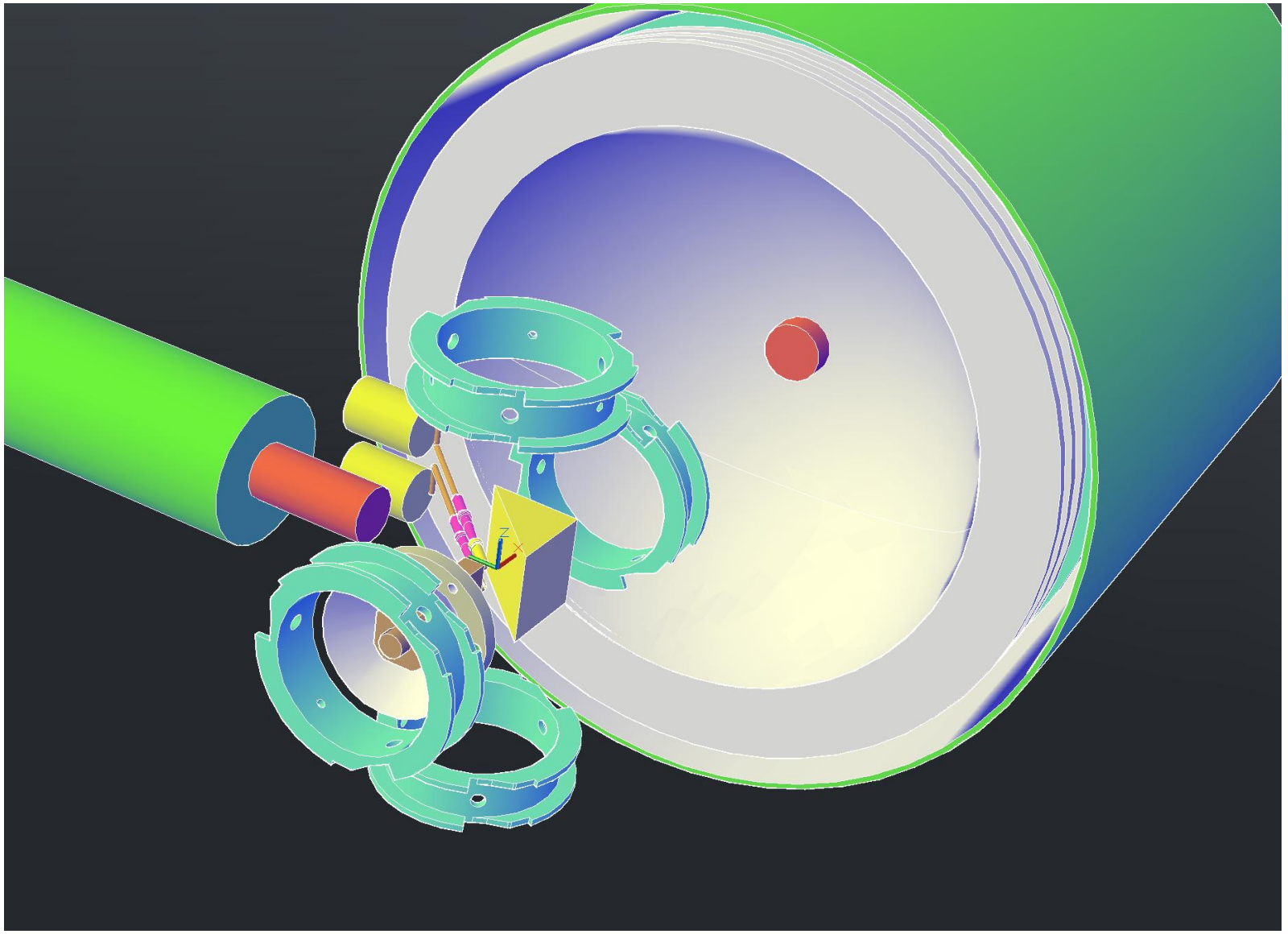

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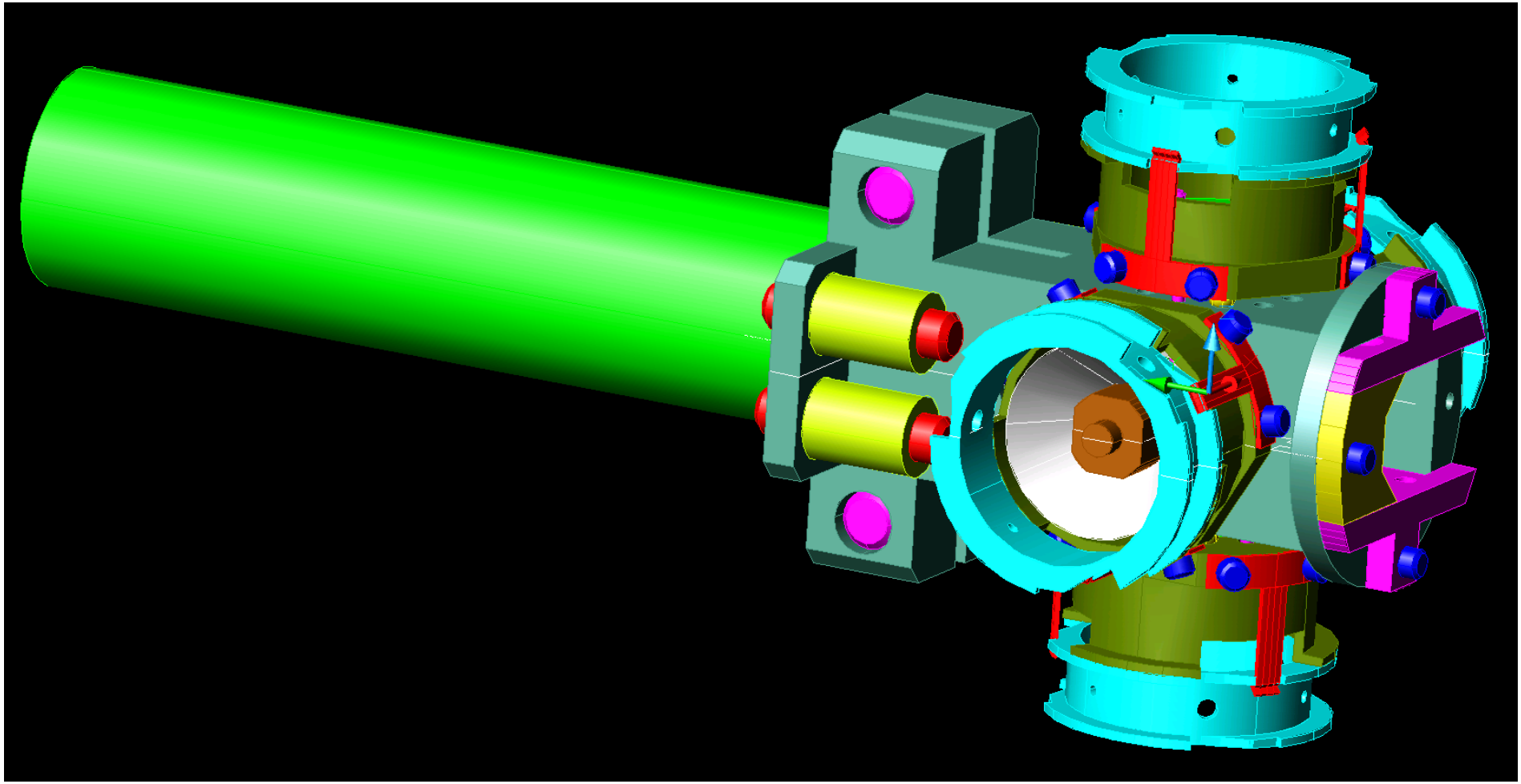
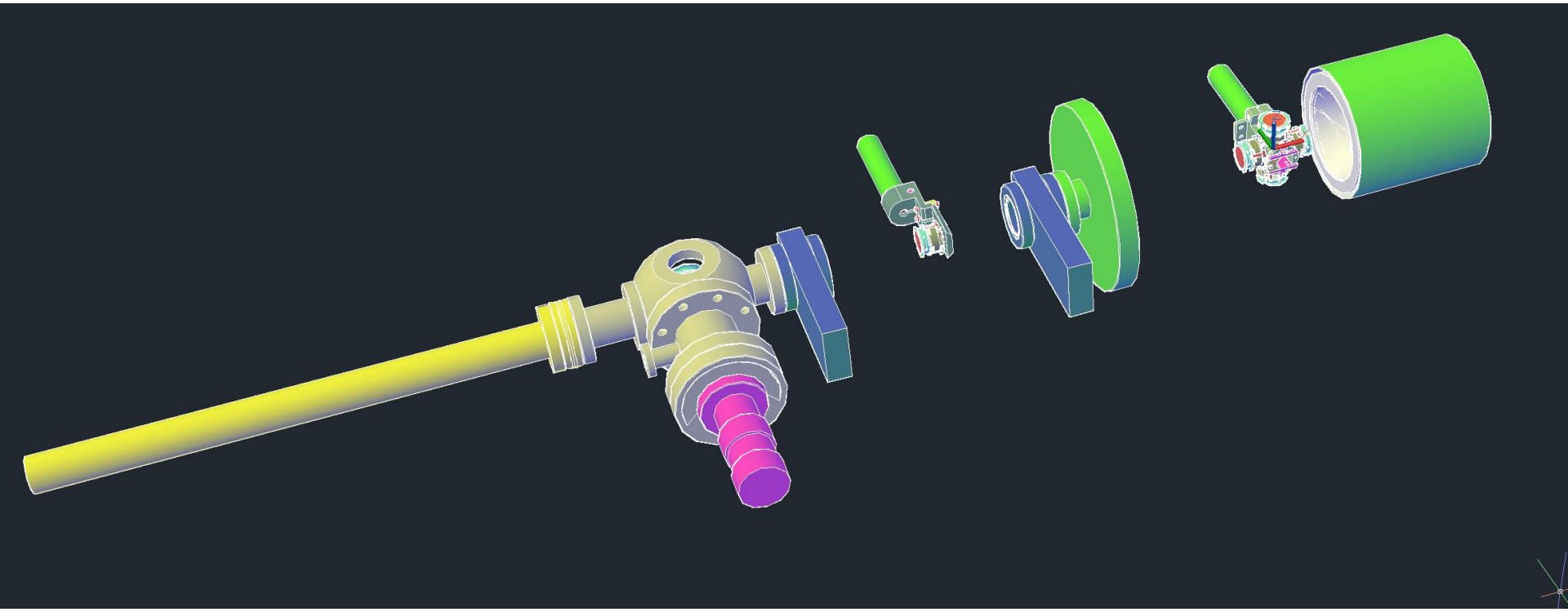


New sample carousel
- in relation to the rest of apparatus



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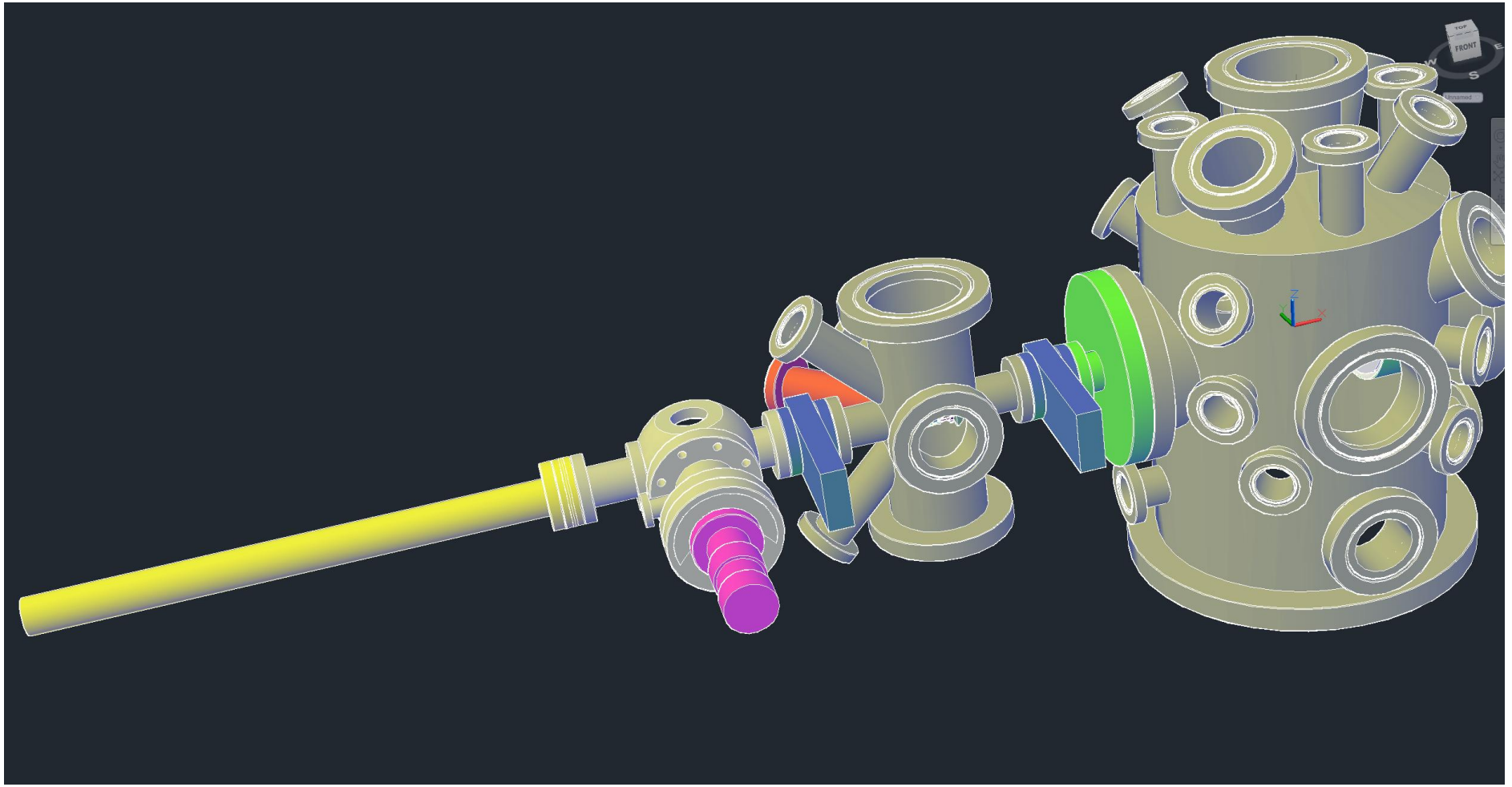
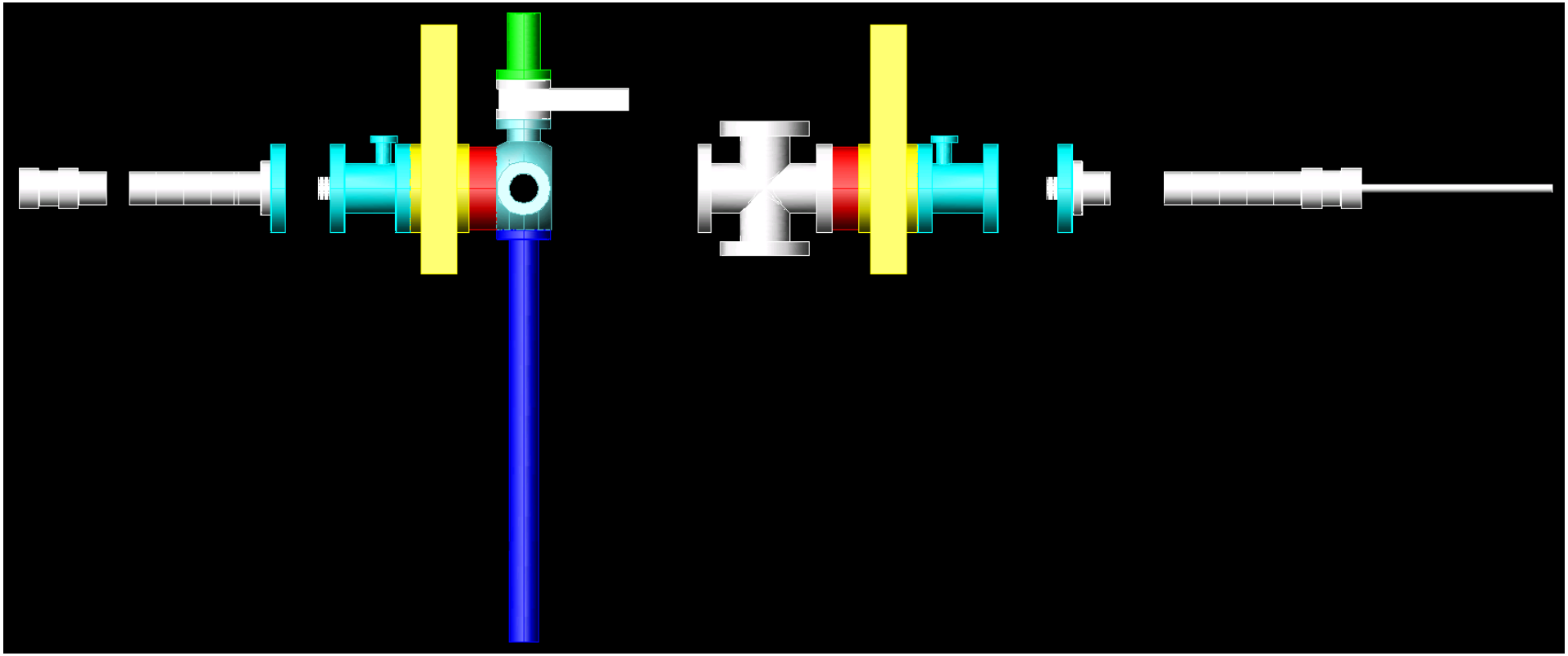
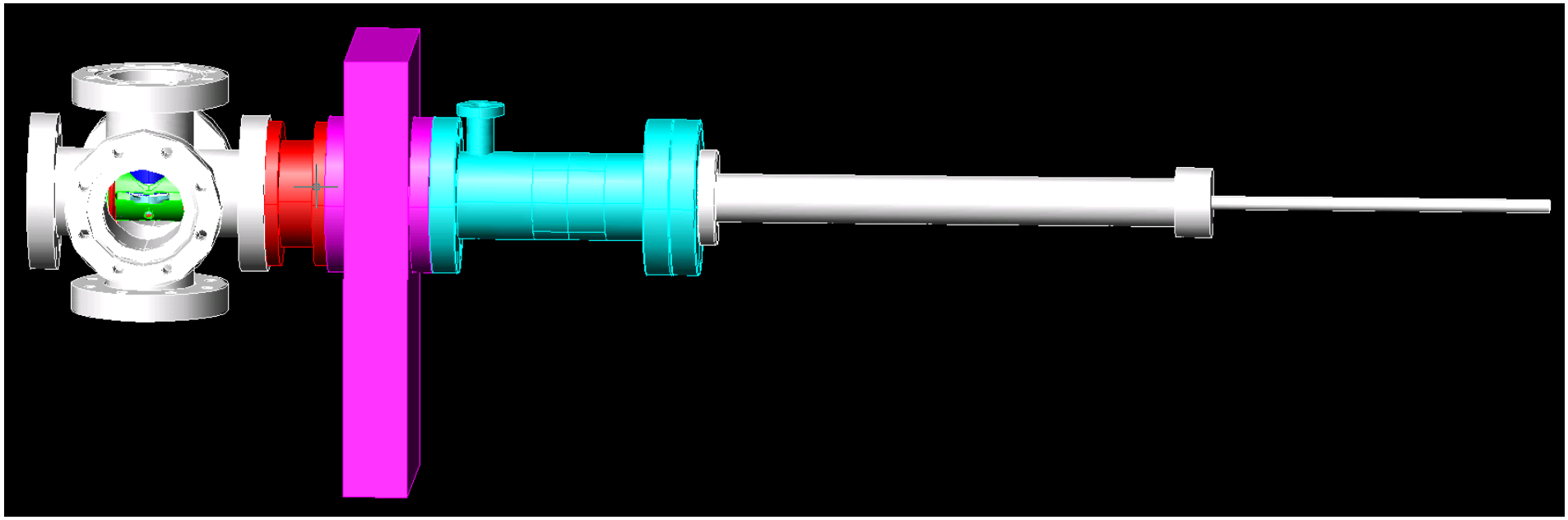


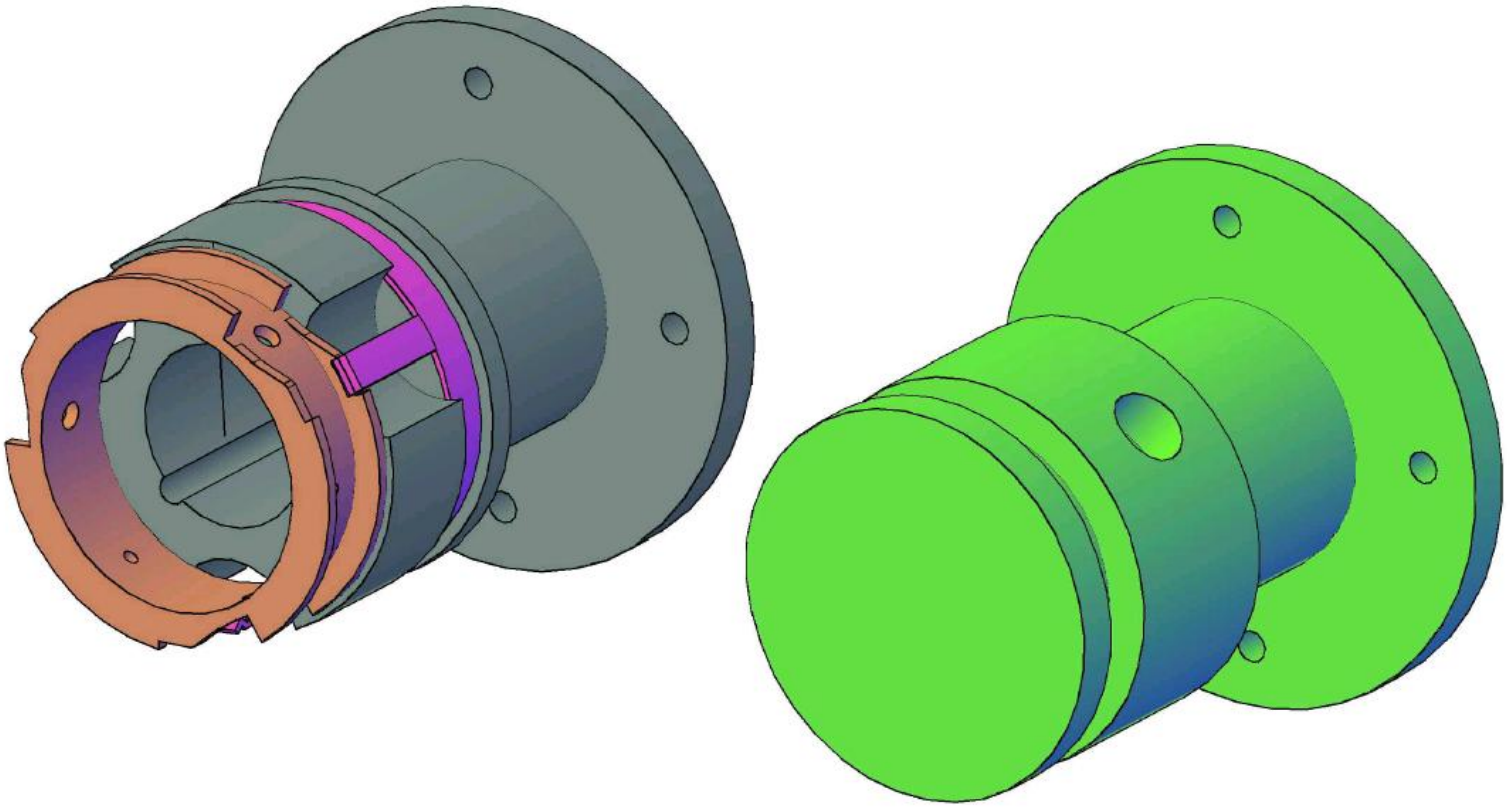
Transfer container options



Transfer container for Cs_2Te photocathodes



Enabling transfer of Cs_2Te photocathodes (Zikri-style plug)



Resources needed

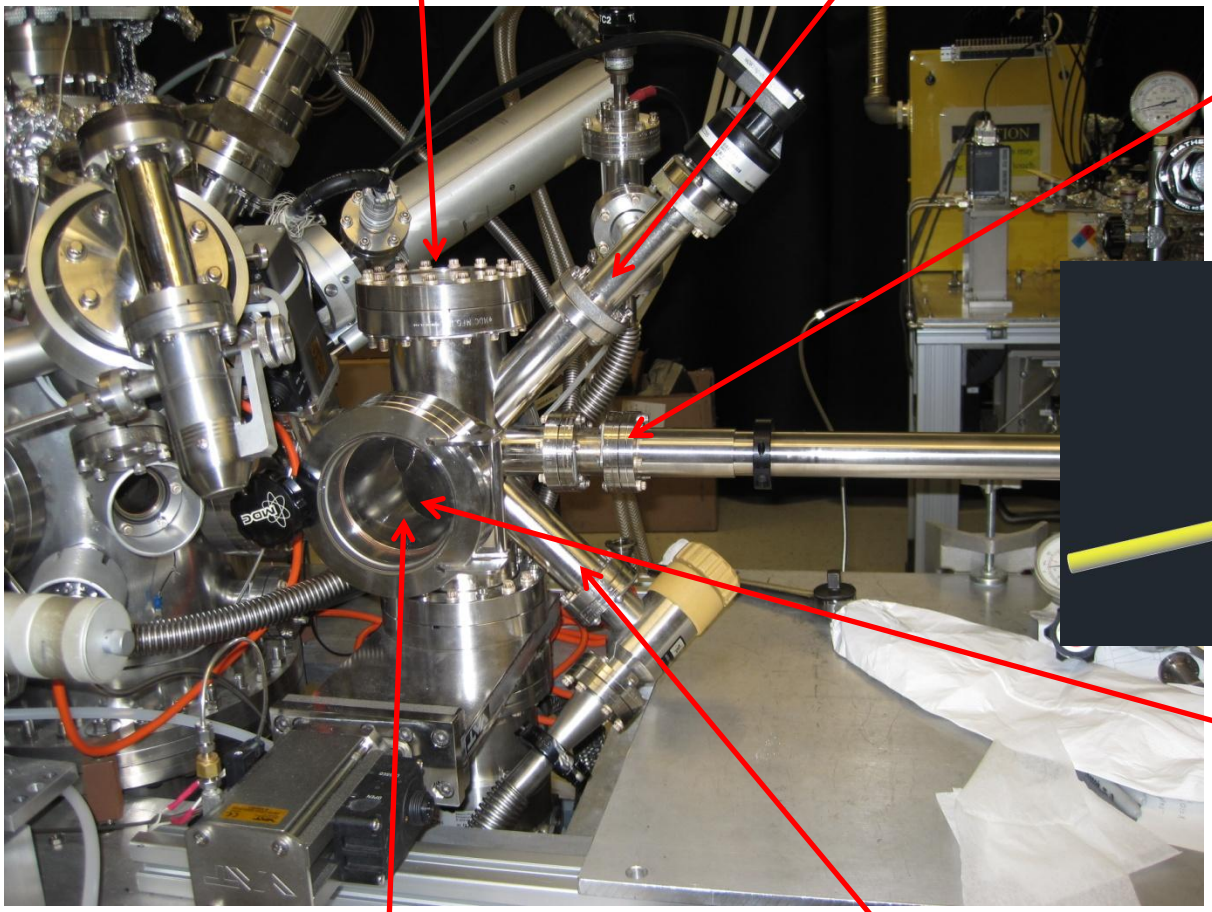
- **Urgent:** Machining costs - ???
  - Carousel – estimated $2-5K
  - Transfer containers – much more, with all the hardware and portable ion pumps.
- Instrument upgrades (described on following slides)
  - MS analyzer(s)
  - EDX detector
- **Some compensation for Igor's and Alex's time would be welcome**
  - A day per week, (20%-25% all together for both)?

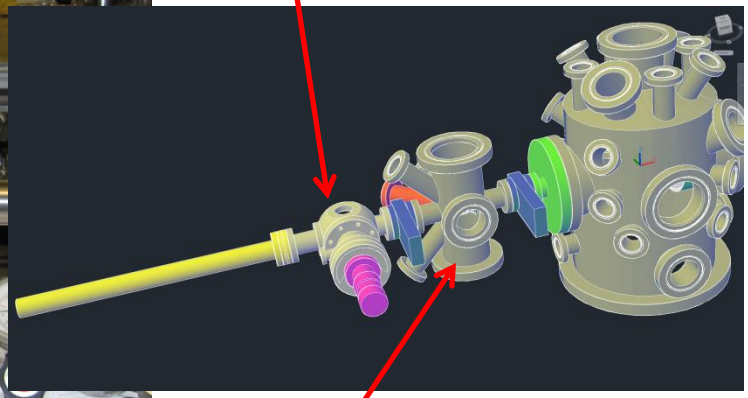
Key Upgrade: Adding SIMS/SNMS/RGA analysis tool

Quadrupole mass analyzer will go here

Ion gun will go here

New smaller **load lock chamber** (Kimball Physics spherical cross) will go here and will be compatible with sample transport container



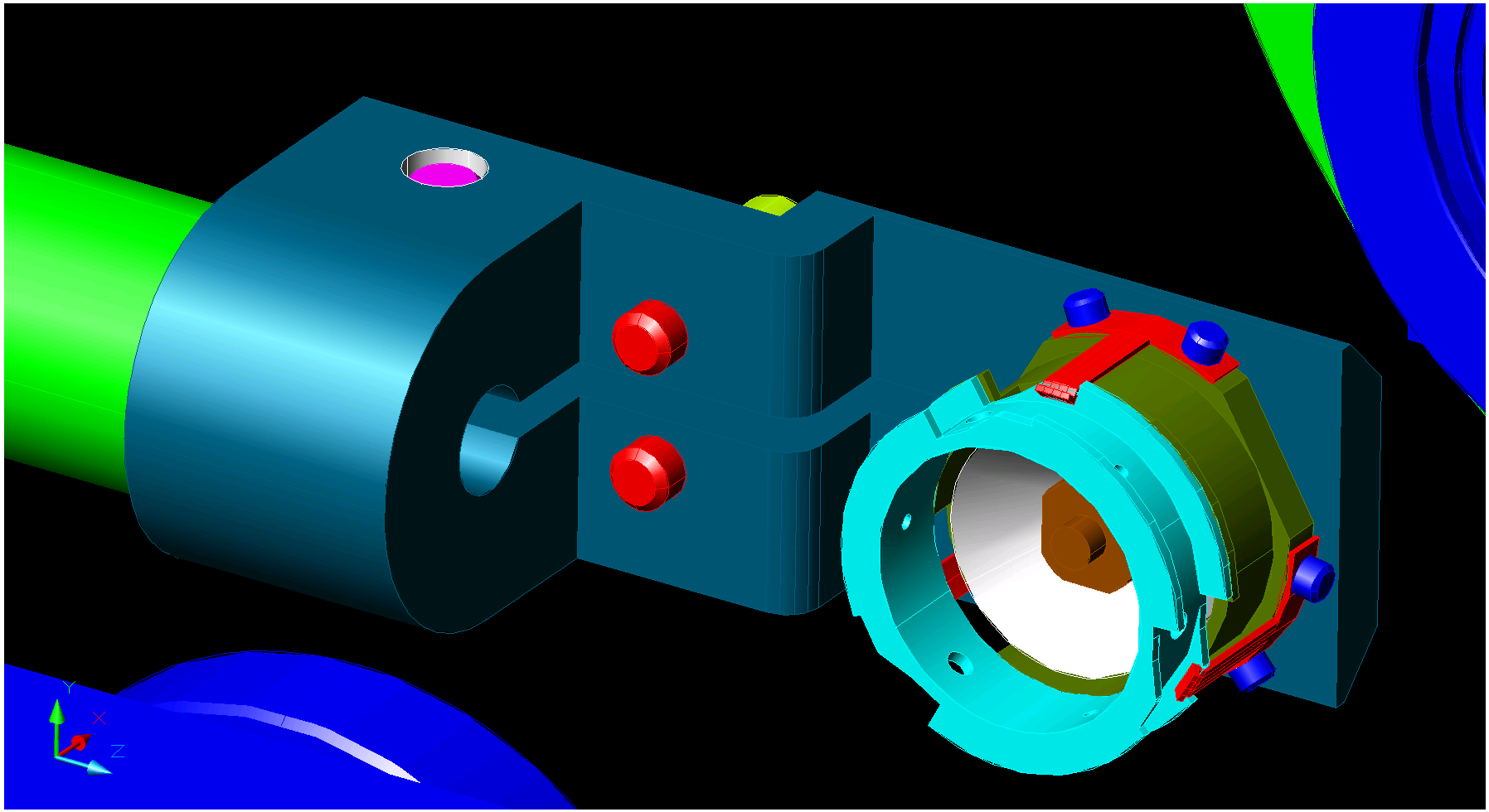


This larger **load lock chamber** will serve for SIMS-SNMS characterization of all detector materials, and also for scrubbing studies for MCPs

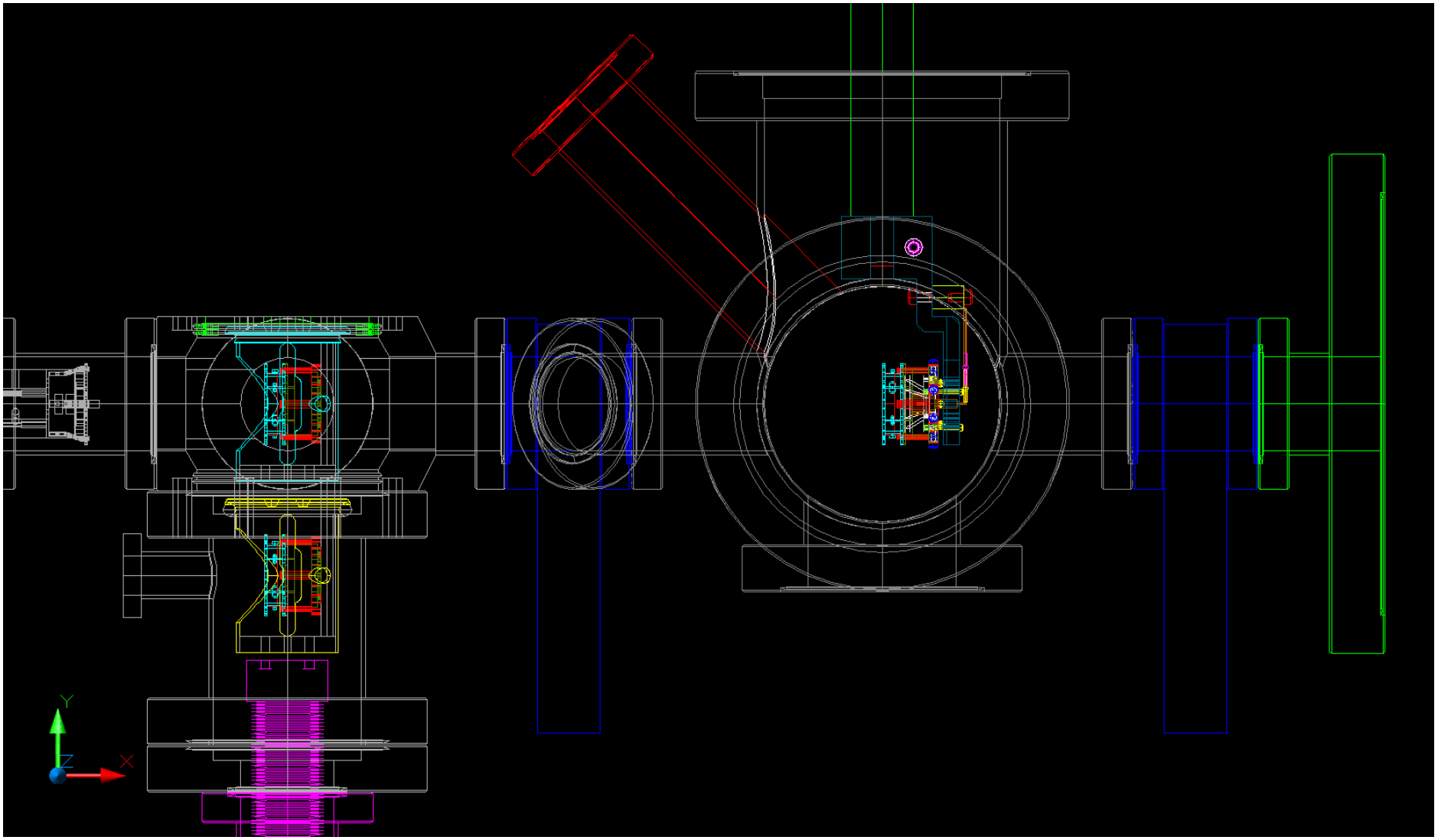
XYZΘ sample manipulator will go here

Electron gun will go here

MS sample holder



MS sample holder



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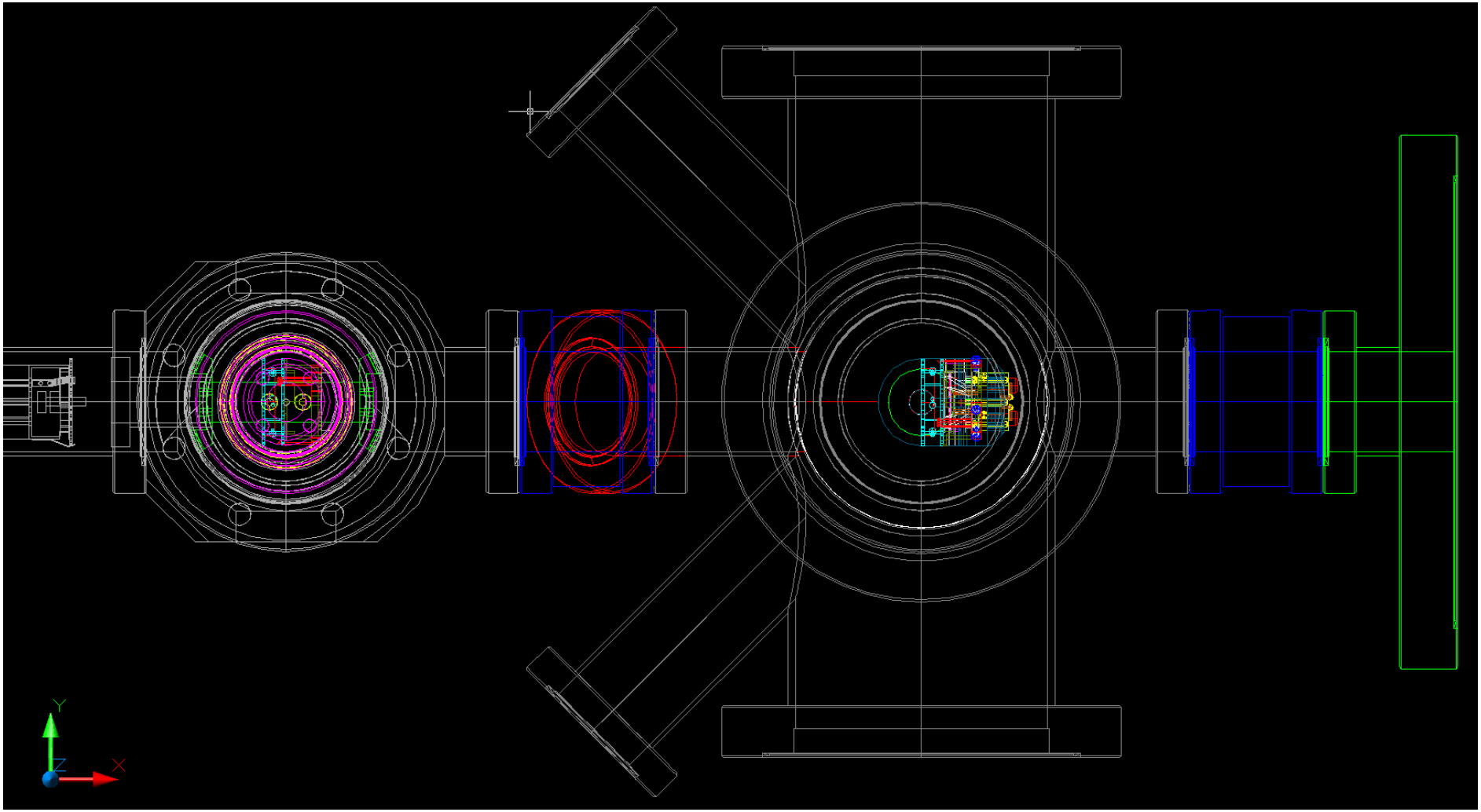
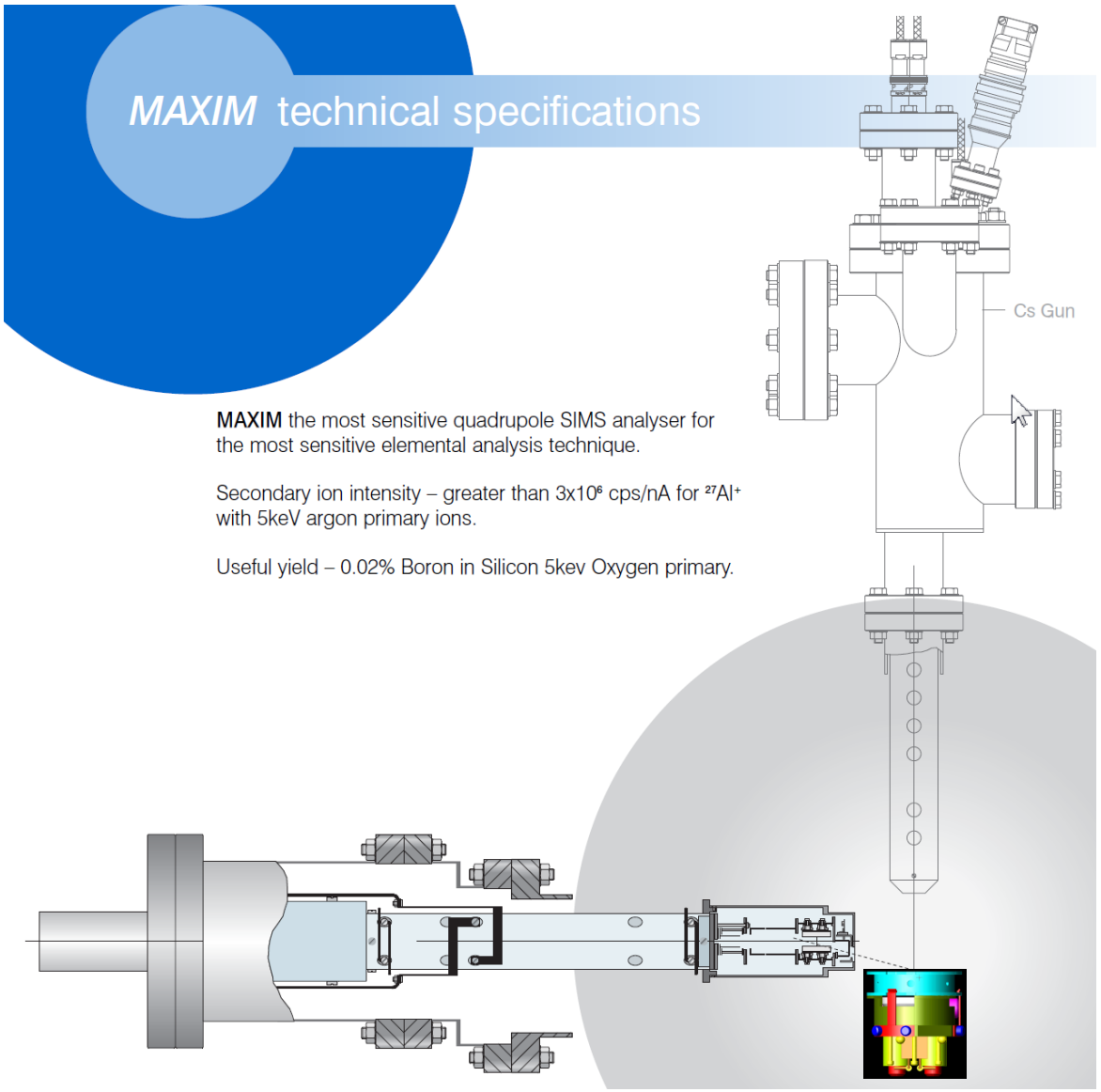
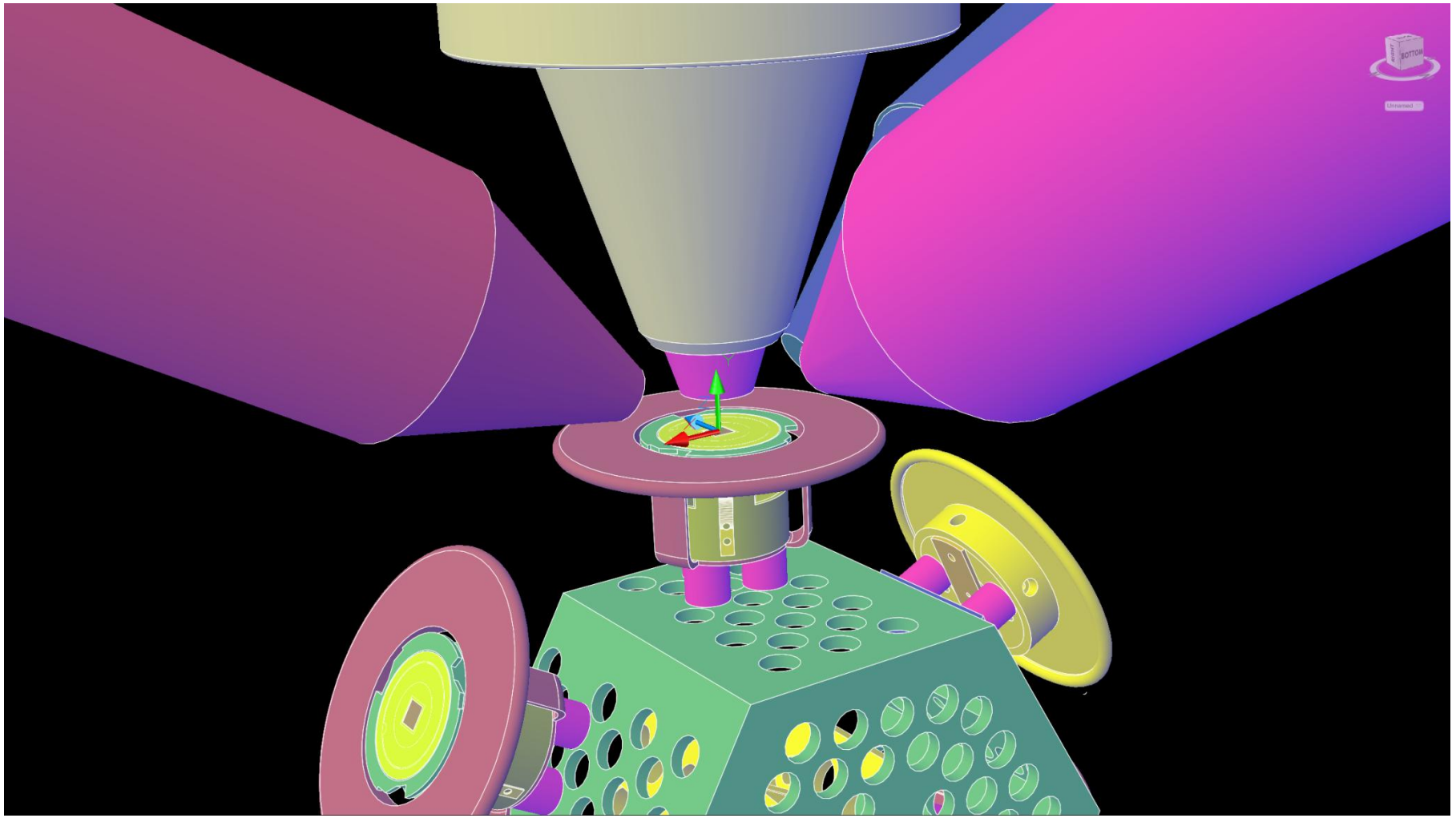


Key Upgrade: Adding SIMS/SNMS/RGA analysis tool

SIMS – Secondary Ion Mass Spectrometry
SNMS – Secondary Neutral Mass Spectrometry
SIMS/SNMS will enable
• routine measurements of dopant profiles in photocathode materials
• depth profiling to characterize layered MCP / photocathode structures including diffusion between layers
• sensitive surface analysis of all detector materials.
RGA – Residual Gas Analyser
RGA will enable studies of electron stimulated and temperature programmed desorption (***ESD*** and ***TPD***) from all detector materials.
We propose to purchase this Hiden Analytical quadrupole mass analyzer with built-in electron impact ionization, which enables SNMS and RGA regimes, besides SIMS. **Cost - $118K**



SARISA LPI-SNMS apparatus in MSD



Many fancy probes are looking at the sample in SARISA: ion, electron, photon and others

SARISA SEM probe can be upgraded with EDX detector option

RevolutionSEM™
Active-scan Digital Imaging System

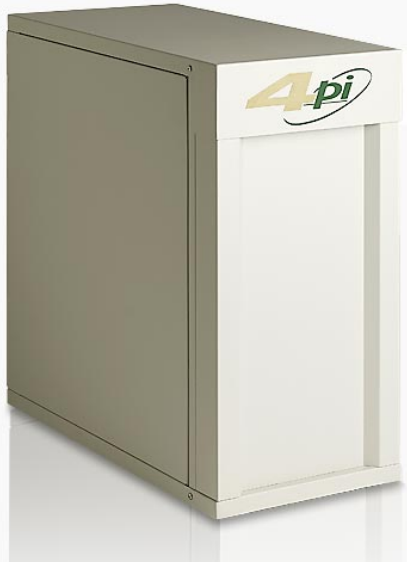
High resolution imaging for all SEMs and STEMs

RevolutionSEM incorporates the Universal Spectral Engine's highly accurate beam control and image acquisition electronics to obtain sharp high-resolution digital images. It is the most flexible digital imaging system on the market for SEMs and STEMs. The system interfaces to any computer running either Windows or Mac OS. The only requirement is an Ethernet port.

Image gallery >
Images have been resized for viewing on the web

General Specifications

Developed and manufactured by 4pi, the Universal Spectral Engine™ is a stand-alone unit with a small footprint (8.5" x 16.5" x 19"). The unit contains scan-control hardware and a 1GB Ethernet interface. The Universal Spectral Engine interfaces to any Windows or Macintosh computer that has an Ethernet port.



RevolutionEDX™
X-ray Microanalysis Systems

EDX Systems & Upgrades for TEMs, SEMs, ESEMs & Microprobes

Si(Li) and Silicon Drift Nitrogen-free X-ray detectors are built to fit the chamber of the specified microscope or microprobe. Full-color x-ray map collection is a standard feature on 4pi's EDX Systems configured for SEMs, STEMs, ESEMs, FESEMs, and EPMAs.

Detector Specifications >

X-ray spectrum image gallery >
Images have been resized for viewing on the web

General Specifications

Universal Spectral Engine® Developed and manufactured by 4pi, the "back-end" electronics of all systems is a stand-alone unit with a small footprint (8.5" x 16.5" x 19"). The unit contains a digital pulse processor, digital image acquisition and scan-control hardware, and Ethernet interface. The Universal Spectral Engine interfaces to any Windows or Macintosh computer that has an Ethernet port.

- Gain (spectrum range): 10keV, 20keV, 40keV, 80keV range
- Gain stability with temperature: 120 ppm/°C or better
- Peaking time: 0.25 - 80 microseconds (Triangular/Trapezoidal shaping)
- Integral Non-linearity: 0.1% or better of full scale output
- Pileup Inspection: pulse-pair resolution typically better than 250 ns
- HV supply: 0-1000V DC negative
- Operation Temperature Range: +5°C to +40°C; LN_2-protect circuitry
- **Seamlessly Interfaces to all modern x-ray detectors** including resistive feedback
- Simultaneously collect digital, x-ray and WDS images for installations that include WDS

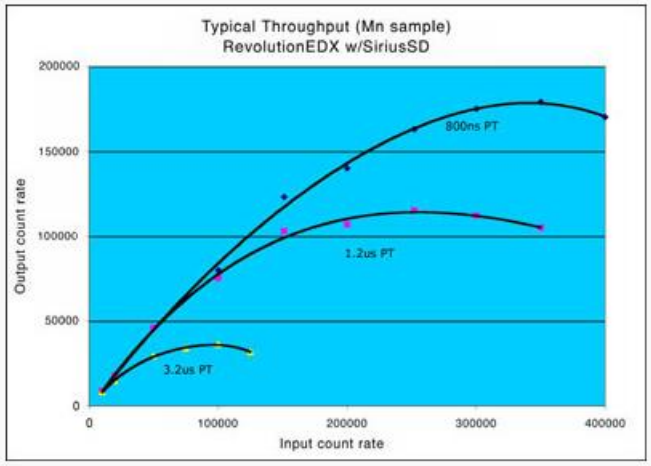
SARISA SEM probe can be upgraded with EDX detector option

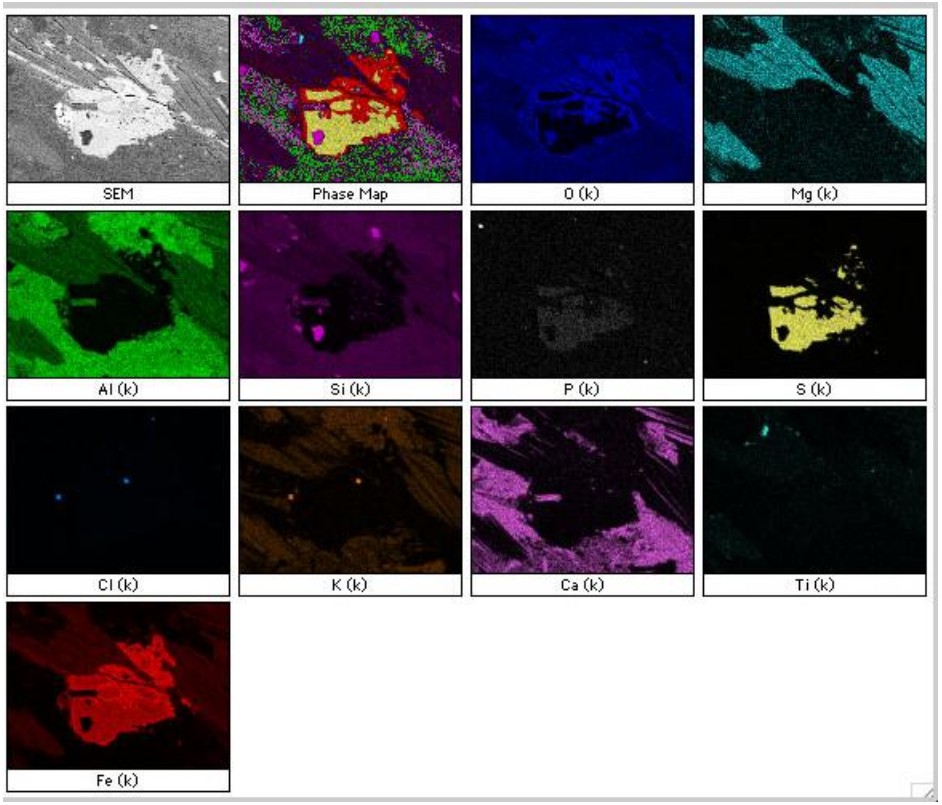
This will enable Scanning Electron Microscopy (10-15 nm resolution) with Energy Dispersive X-Ray Analysis – in SARISA instrument, with standartized UHV transfer of photocathode materials

Cost – $60K

Silicon Drift Detectors

- State-of-the-art drift technology
- LN_2-free operation- Peltier cooled; no liquid coolant required
- Cool-down time of less than 5 minutes
- Resolution: better than 133eV; stable over a wide range of input count rates
- Available with resolution better than 129eV
- Throughput: capable of output rates exceeding 100,000 counts per second
- Light element detection down to Boron with quantification of Carbon
- Sensor: 10 or 30 mm^2 active area
- Low-noise, high-rate preamplifier for high-count rate performance
- Tube diameter of less than 18 mm fits most EDS ports





Conclusion

- After fabricating the new sample carousel and sample transfer containers, we should be able to perform basic characterization of photocathodes, in the same fashion as MCPs (XPS/UPS in conjunction with quantum efficiency and, maybe, SEYs)
  - Feasible by the end of Year 2010
- We are trying to explain the need for instrumental upgrades since April 2010
  - It is almost half a year by now
- To build these instruments, manufacturers will require, at least, three months
- If we want to get some breakthroughs in understanding by Spring 2011, we have to get these tools by the end of Year 2010
  - The time we are wasting is precious
  - The time to make decisions is now