DESIGN OF THE JEFFERSON LAB IR UPGRADE FEL OPTICAL CAVITY

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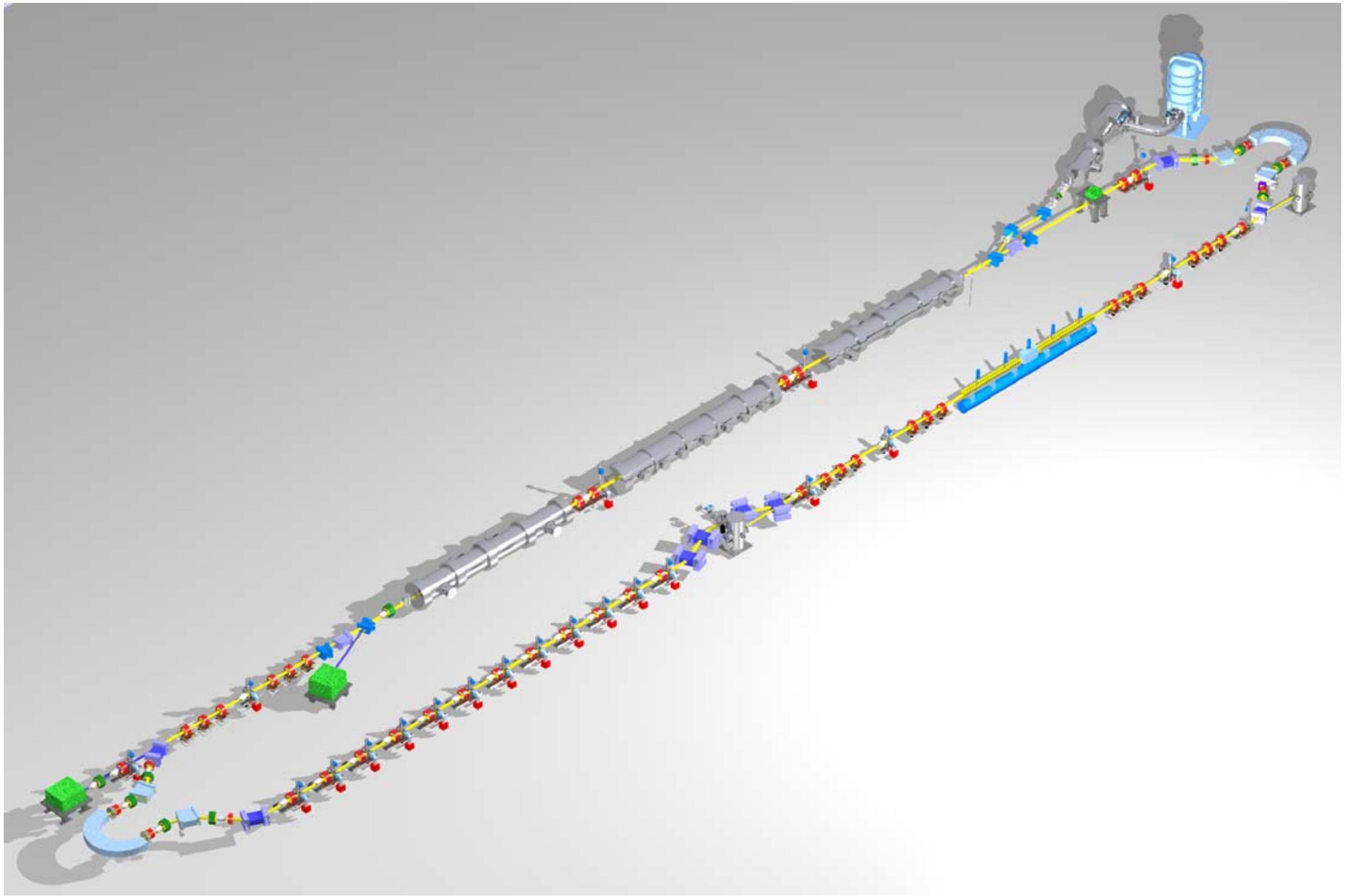
Work supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE Contract DE-AC05-84ER40150

OUTLINE

- Introduction to the JLab IR Upgrade FEL
- Design challenges
- Hardware
- Conclusions

IR Upgrade FEL



DESIGN CHALLENGES

- Design must provide cooling to offset power loading in a high vacuum environment
  - Estimated absorbed power is 10 - 50W
- Must develop method for deforming HR that are amenable to high vacuum environment.
- Must provide mirror actuation (coarse and fine) amenable to high vacuum environment.
- Design must not expose optics to irradiances that damage them.

Optical Cavity for 10 kW is based on IR Demo

- **Transmissive outcoupler on near-concentric cavity**
- **Add ROC control on total reflector**

Parameter	IR Demo	IR Upgrade
Cavity length (m)	8.0105	32.042
Rayleigh range (m)	0.4	2.0
Cavity magnification	101	65
Angular tolerance at 3 μm (μrad)	4.5	1.8
Mirror ROC (m)	4.0451	16.271

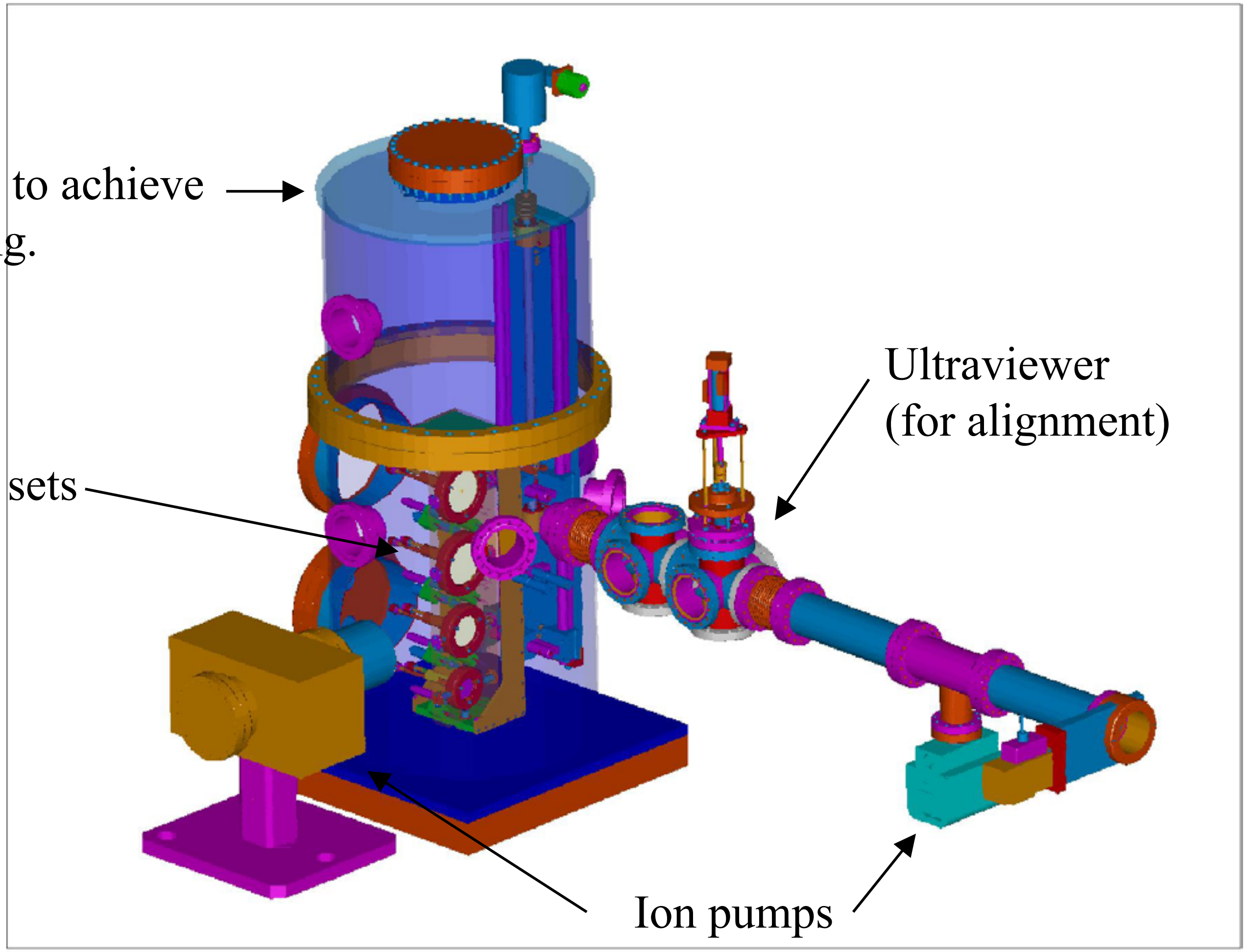
THE UPGRADE OPTICAL CAVITY

- Like the IR Demo optical cavity:
  - We will use a near-concentric resonator
  - The cavity mirrors will be in a high-vacuum environment
  - Require remote control and monitoring of mirror position and relative cavity length.

- Unlike the IR Demo optical cavity:
  - We will switch mirrors having different reflectivities *in vacuo*
  - We will deform the high reflector to compensate for thermally-induced changes in the radius of curvature.
  - We will incorporate active mirror orientation control and monitoring.
    - Designed for cryogenic cooling of the outcoupler mirror.

  - Our philosophy is to incorporate elements required for future upgrades now, so we save time and cost later.

HR VACUUM VESSEL REGION



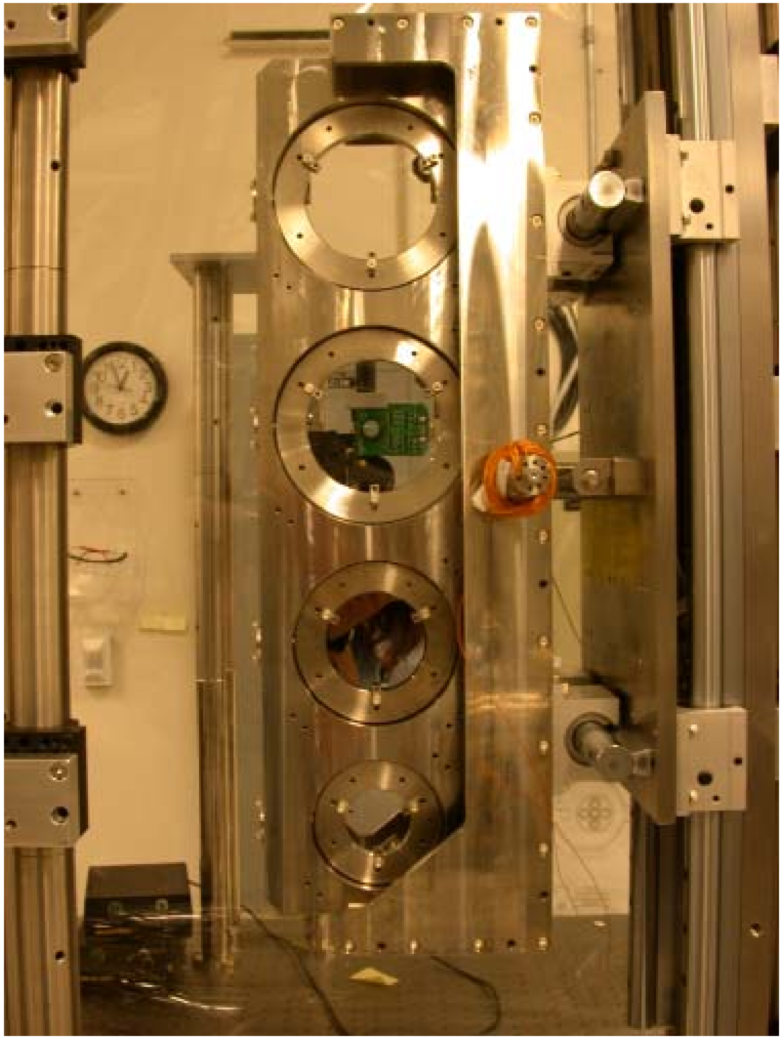
HR OPTICAL CAVITY UNDERGOING TESTS

Metal-coated mirror (3-14 μm)

Dielectric mirror λ > 9 μm

Dielectric mirror 4 > λ > 9 μm

Dielectric mirror λ < 4 μm



MIRROR FIGURE CONTROL

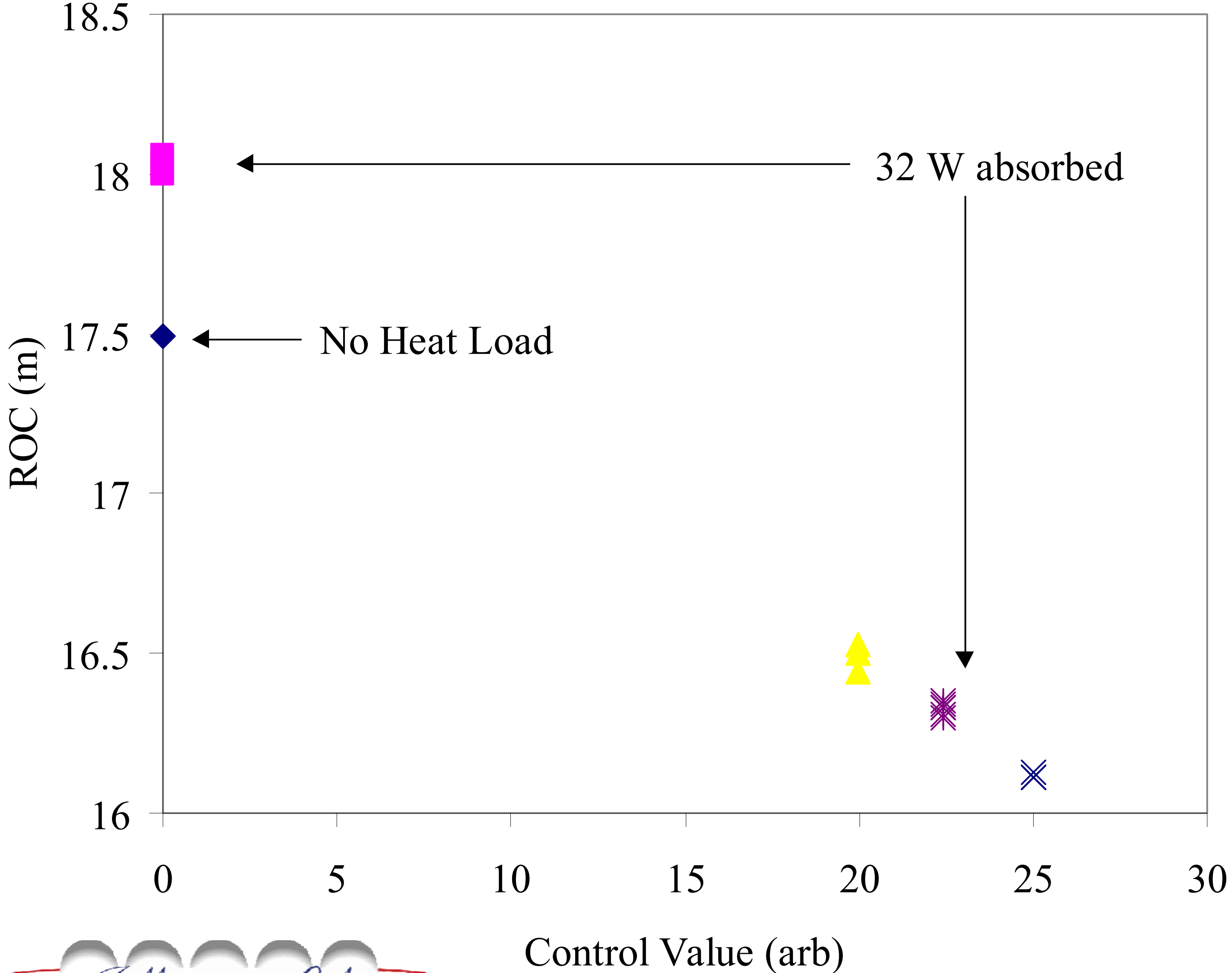
- To achieve the correct ROC of 16.271 m, we procure mirrors made from silicon substrates with ROC ~ 17 m, then bend them to the correct ROC.
  - This reduces the cost associated with producing an optic with a precise ROC.

- Review of designs amenable to high vacuum environment suffer from nonspherical errors.
- Our design:*
  - Simultaneously obtain backplane cooling.
  - Produces a spherical mirror figure, keeping the Rayleigh range constant as well as correcting a major component of the total aberration.

- Design was modeled and preliminary design produced under contract to Advanced Energy Systems.

  * Patent application filed

ROC CONTROL IS STRAIGHTFORWARD

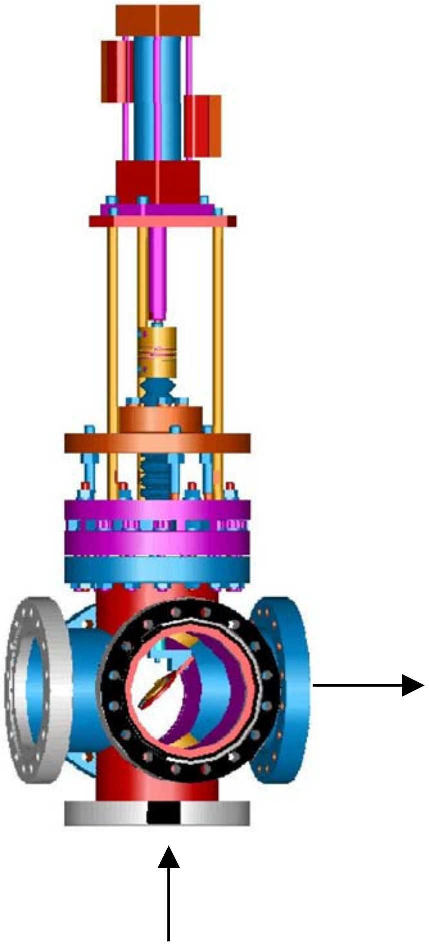


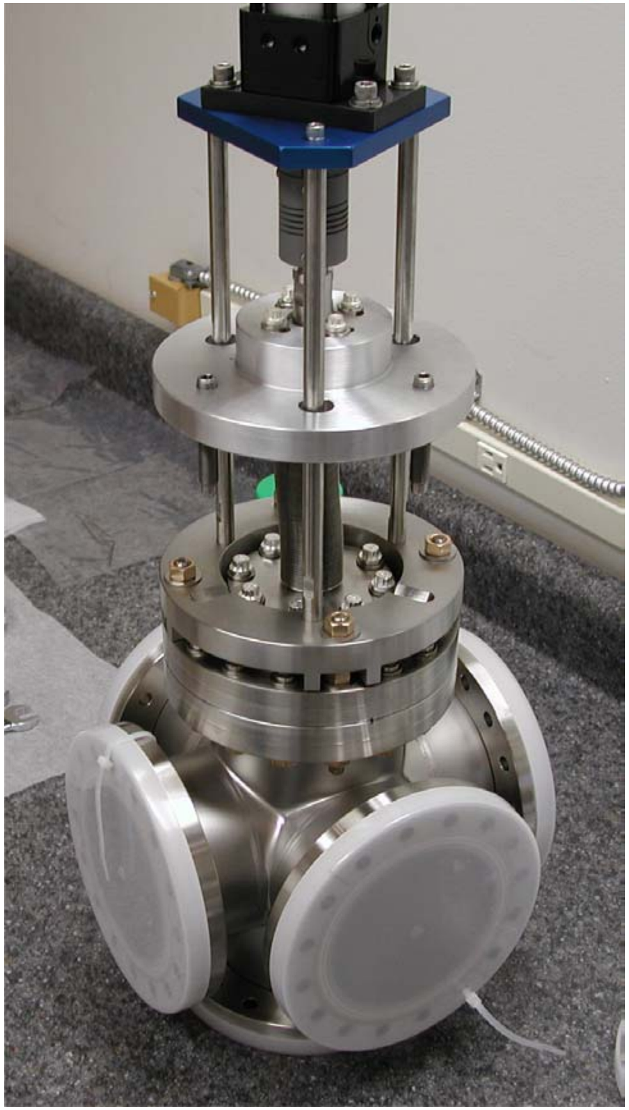
DISCUSSION

- For 10 kW output and ~ 15% outcoupling, the circulating power in the cavity is ~ 70 kW.
- If the mirror absorption is 100 ppm, the absorbed power is 7 W.
  - We anticipate obtaining lower loss coatings.
- We loaded our test mirror to 32 W absorbed power, and had ~ 0.1λ P-V distortion of the reflected wavefront.
  - Our spec is < 0.2λ, so we have a comfortable margin.
- Our ability to maintain the ROC by adding feedback should be quite straightforward.

ULTRAVIEWER

Exceeds angular repeatability spec of 50 μrad





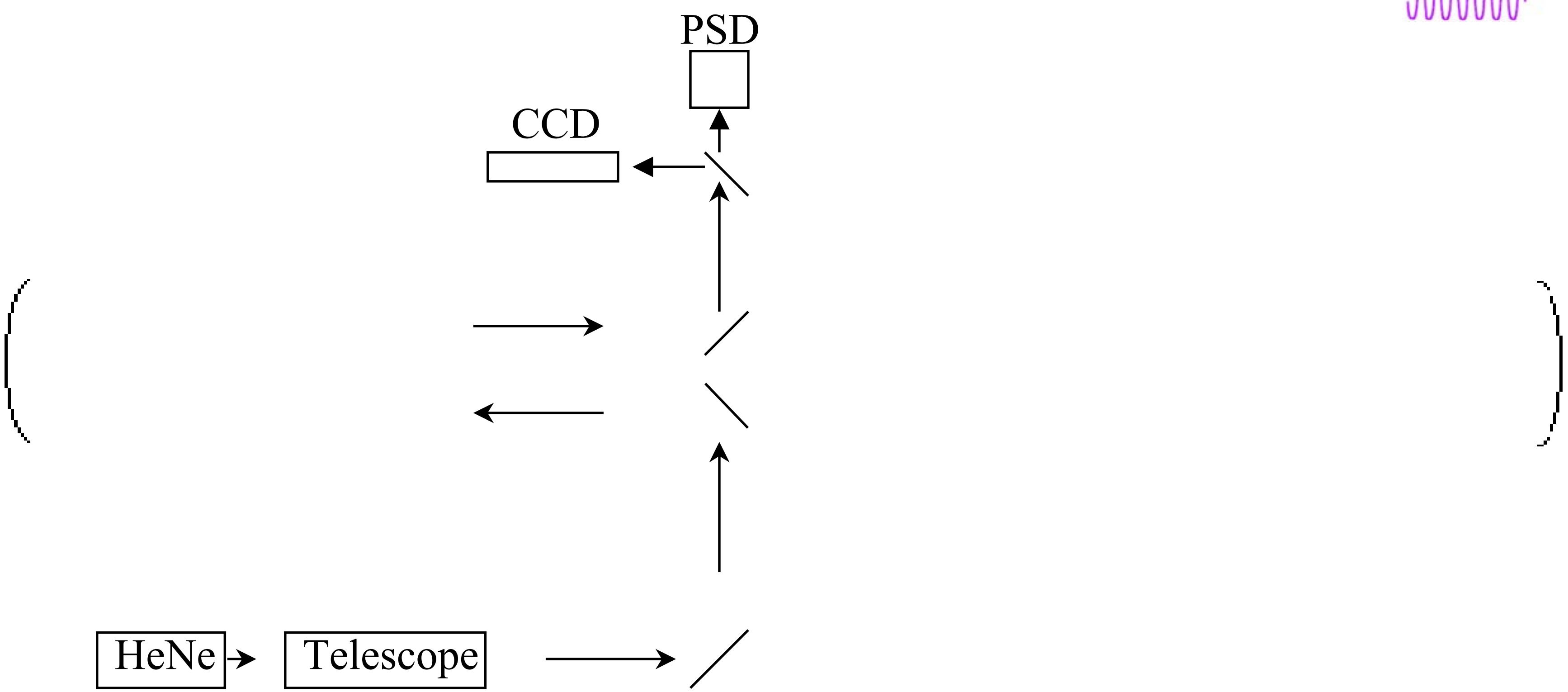
ALIGNMENT AND ROC CONTROL SUBSYSTEM

- Cold alignment (no lasing) will be done with external HeNe lasers, properly expanded and collimated, beam introduced with insertable mirrors (the ultraviewers), as was done on the IR Demo.
  - Beam size and position checked at wiggler.
    - This allows us to set the initial ROC as well.

- The **O**ptical **C**avity **M**irror **M**etrology **S**ystem (OCMMS) monitors the relative change in ROC and actively controls the mirror orientation.
  - External HeNe lasers reflected from mirrors positioned on either end of wiggler, and in the vacuum system.
  - Beams reflect off cavity mirror, then back outside the vacuum chamber, where it falls on a CCD camera.
  - Piezos on the mirror mount are used to maintain alignment.

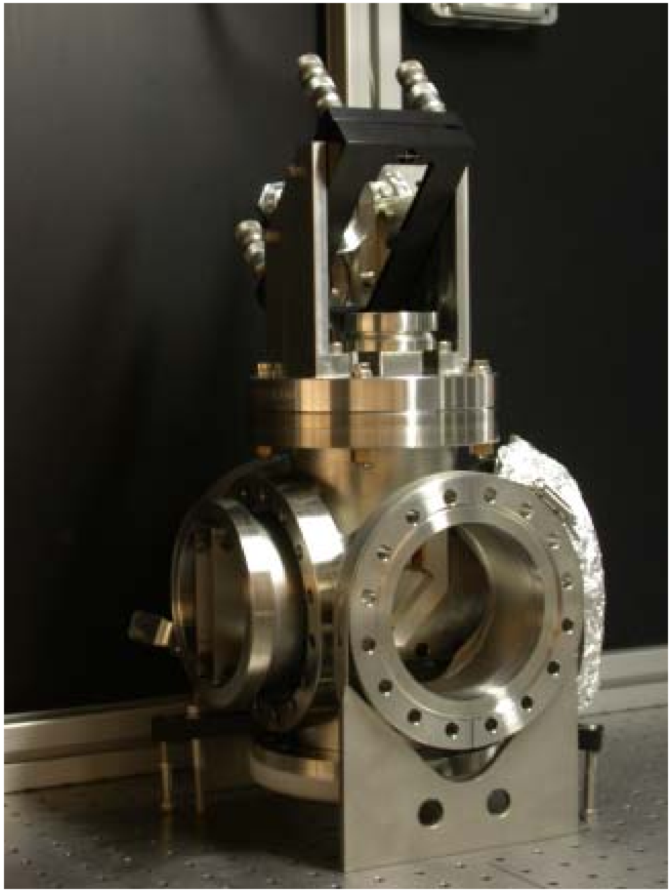
- Use Foucault technique to measure the ROC.

OCMMS SCHEMATIC



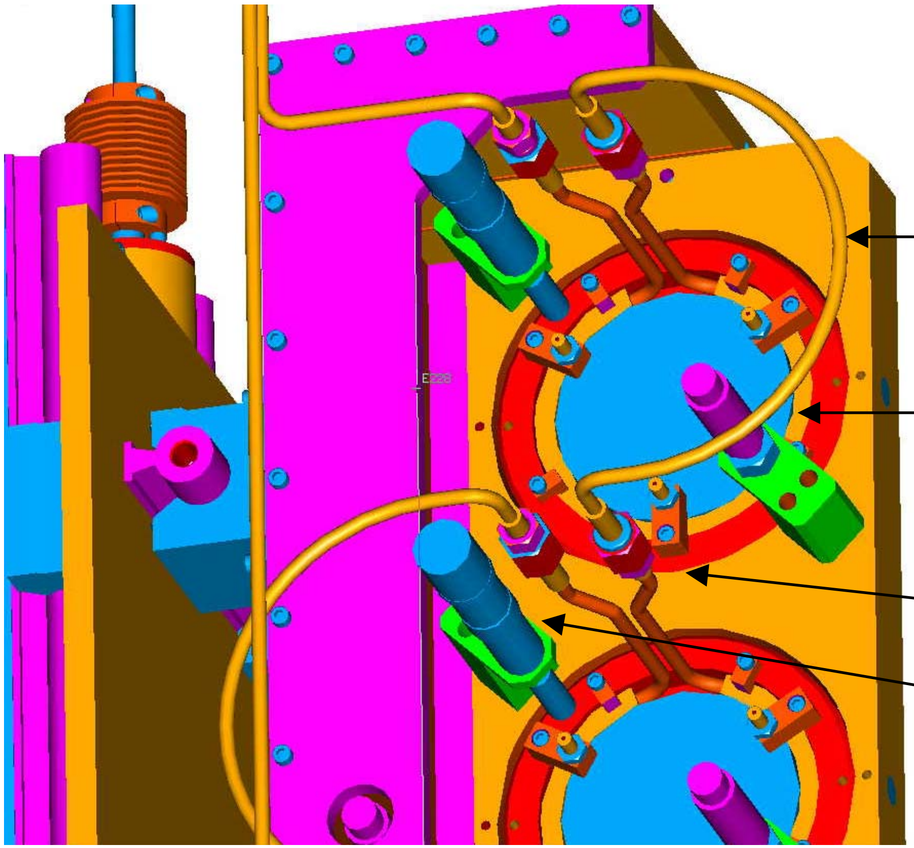
OCMMS HARDWARE

- Cross contains input/output viewports for sampling laser.
- In-vacuum mirror mount made of Invar and gold-plated to reduce thermally-induced distortion.



COOLING DETAILS

Outcoupler Assembly



- Similar cooling loop for HR Assembly

CONCLUSIONS

- Our design for the upgrade optical cavity is based on sound design principles:
  - From the synchrotron light source community
  - Other facilities with considerable optics expertise, *i.e.* LLNL
  - Other FEL facilities
  - Best-practice by optics companies
- Our design incorporates lessons learned from operating the IR Demo for 3.5 years.
- Our design provides flexibility for upgrades in power and wavelength range.