DESIGN OF THE HGVPU UNDULATOR VACUUM CHAMBER FOR LCLS-II

Solutions to Accelerator Vacuum System Design Challenges

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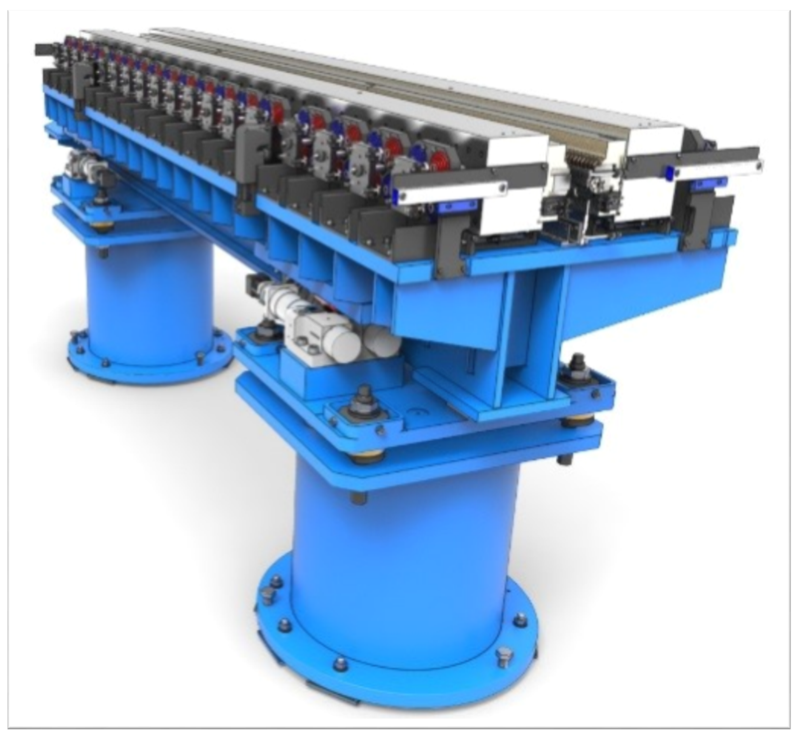
INTRODUCTION

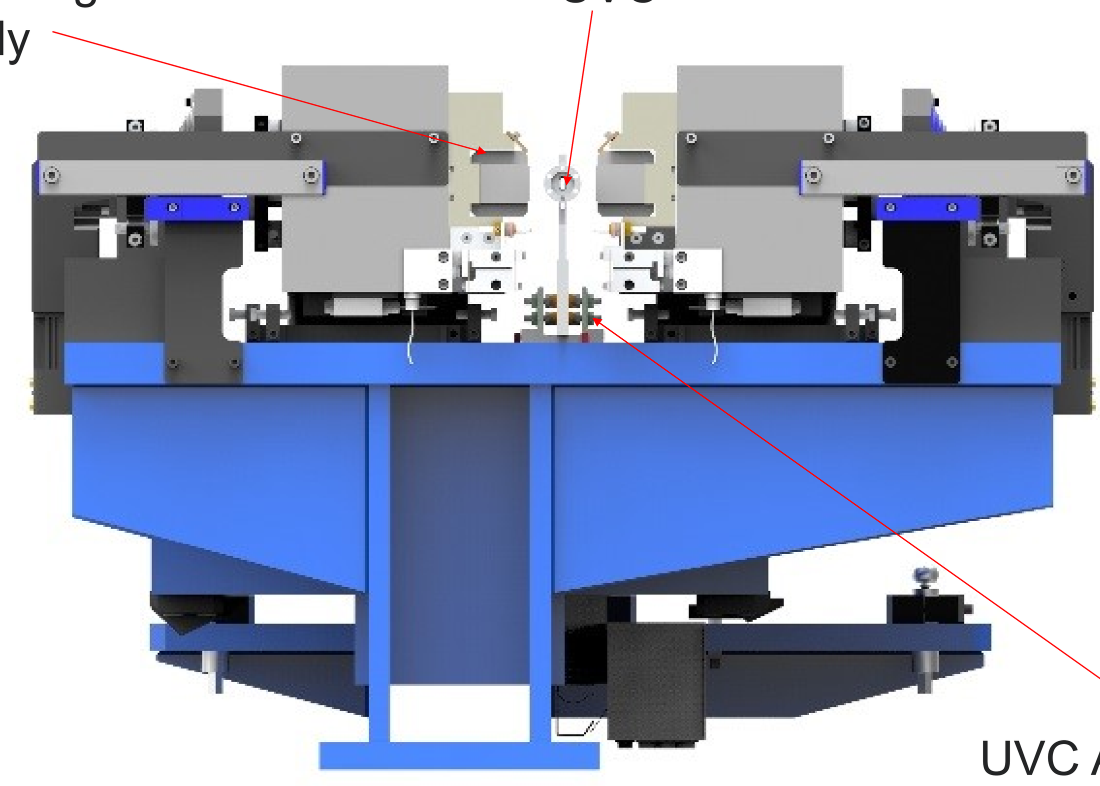
SLAC contracted the APS to design and manufacture a 3.5-meter undulator vacuum chamber (UVC) for use in an HGVPU as part of the LCLS-II upgrade project. The design process involved solving complex challenges that are becoming commonplace in next generation accelerator projects. The following is an overview of the UVC design process with an emphasis on the structural and thermal design challenges encountered.

STRUCTURAL DESIGN

- **Challenges**:
  - Vertical orientation within undulator
  - Alignment fixture: Non-magnetic, more rigid than the vacuum chamber
  - Narrow alignment and straightness tolerances across length of chamber
    - Straightness: $\pm 100\ \mu m$
    - Vertical position alignment precision: $< 50\ \mu m$
  - Thin wall: 0.5 mm aperture thickness
    - Due to beam aperture and closed gap magnet width requirements

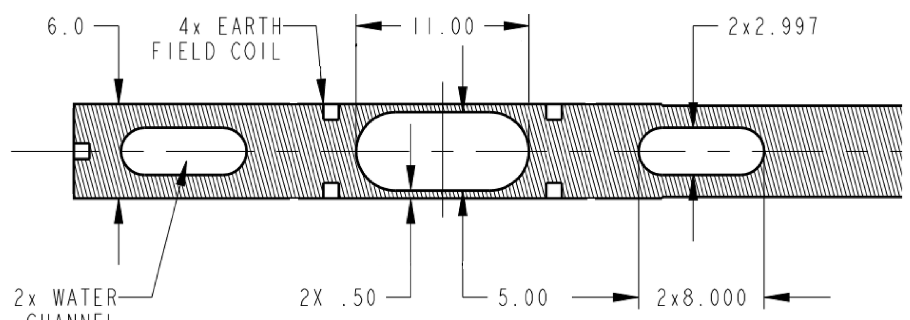


HGVPU Undulator Assembly

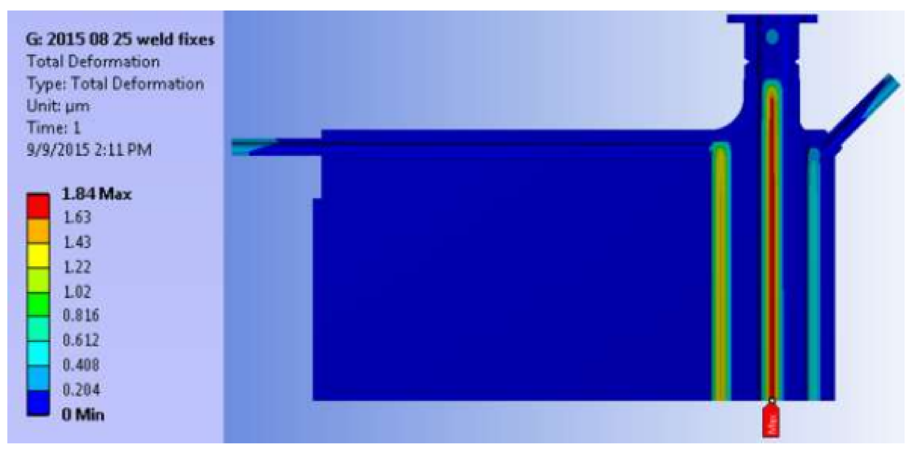


HGVPU Undulator Assembly

- **Solutions**:
  - Aluminum alignment fixture controls straightness and vertical position
  - Extrusion reduces manufacturing cost
    - 65 points of adjustment along fixture length for H and V alignment of beam aperture
  - Aperture geometry validated using FEA (Bottom Right)
    - Minimal wall deflection



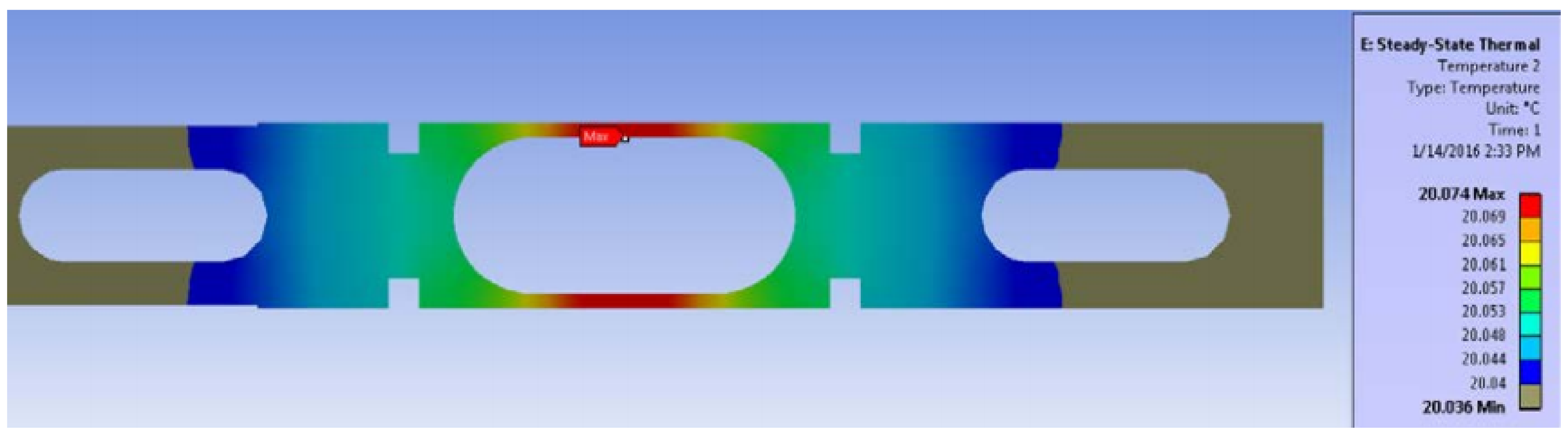
Chamber nose dimensions



ANSYS structural analysis

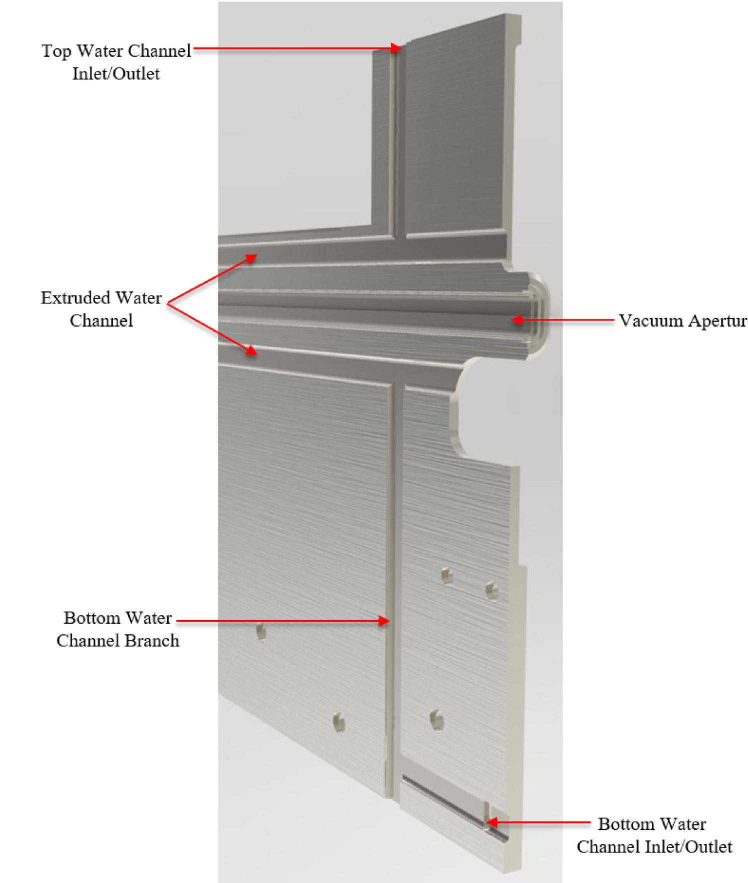
THERMAL DESIGN

- **Challenges**:
  - Mitigate $3.3\ {}^{W}/_{m}$ heat load
  - Temperature stability of $\pm 0.1\ ℃$ across 3.5 meter length
- **Solutions**:
  - Flow rate range of $2.2 - 3\ {}^{m}/_{s}$ determined to be acceptable
    - Lower limit provides sufficient cooling and upper limit avoids erosion
      - Verified by FEA thermal analysis

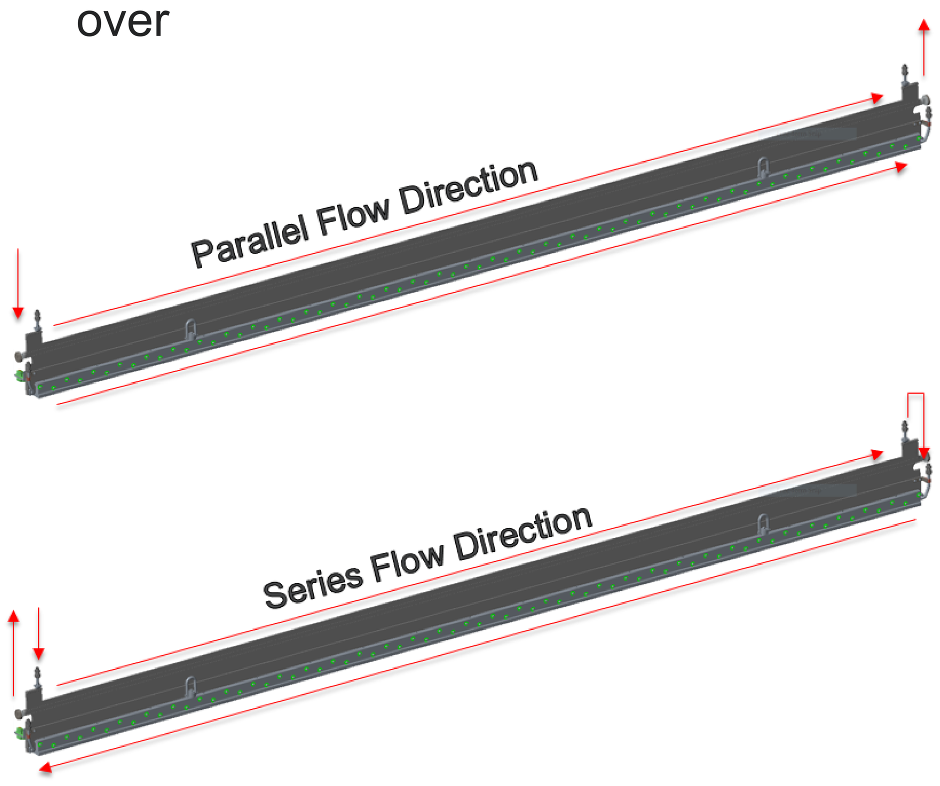


FEA thermal analysis

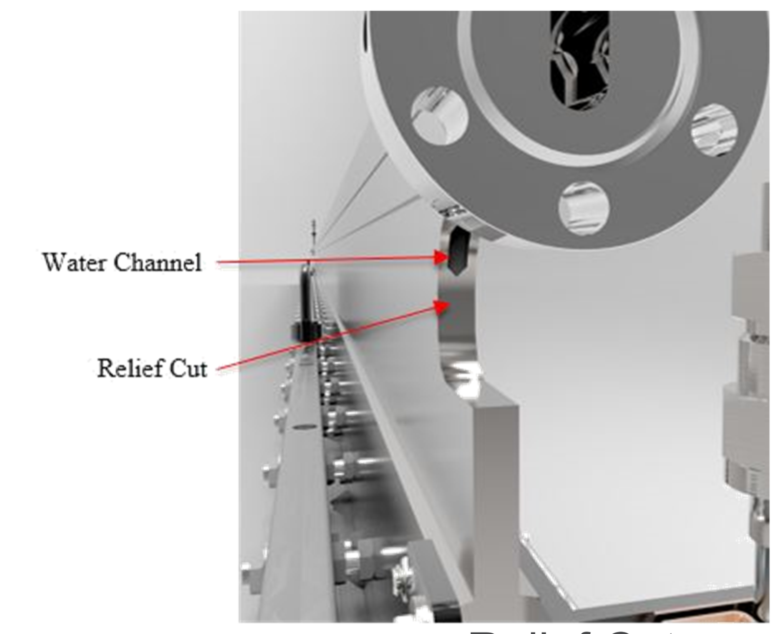
  - Water channels located and sized within larger system constraints
    - 2x 3 mm V x 8 mm H channels provide turbulent flow cooling as close as possible to heat source
    - Location of the channel a function of the relief cut needed to allow flange adjustment during alignment
    - Pressure drop minimized by limiting turns and eliminating cross sectional area changes
    - RAM EDM for straight channels
  - Parallel flow cooling water routing
    - Unclear thermal losses for a series cross-over



Water Channel Cross section



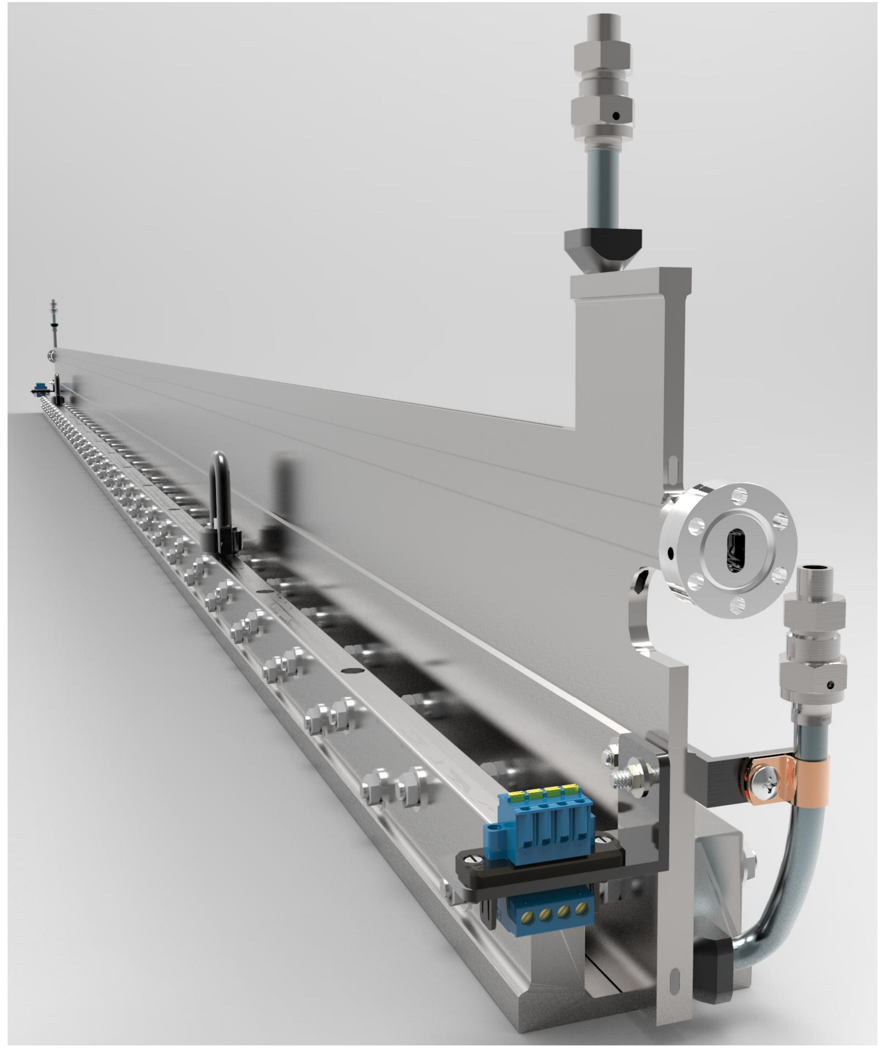
Flow routing – Parallel (chosen) vs Series



Relief Cut

CONCLUSIONS

A 3.5-meter length, thin walled, extruded aluminium chamber with interior water cooling was developed for the LCLS-II upgrade project. Numerous challenges were encountered during the design of the UVC. The chamber aperture thin wall needed to deform minimally to allow clear beam passage. The chamber was also required to have a small temperature change across its 3.5-meter length. FEA stress analysis was performed to ensure the chamber will not fail under vacuum and water pressure. A cooling scheme was optimized to ensure water flow is sufficient to maintain temperature without the risk of erosion and to minimize pressure drop across the chamber.



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