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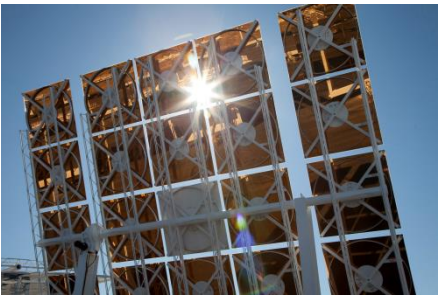

High-Flux Solar Simulator with Automated Sample Handling and Exposure System (ASHES)

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Overview

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- Introduction
- High-Flux Solar Simulator Design
- Automated Sample Handling & Exposure System
- Conclusions

Background

- Need for controlled, high-flux, high-T exposure tests

Solar Furnace

- Concentrates sunlight
- Operational up to ~6 hours/day
- Weather dependent

Solar Simulator

- Concentrates light from lamps
- Continuous operation
- Not weather dependent

High-Flux Solar Simulators Around the World

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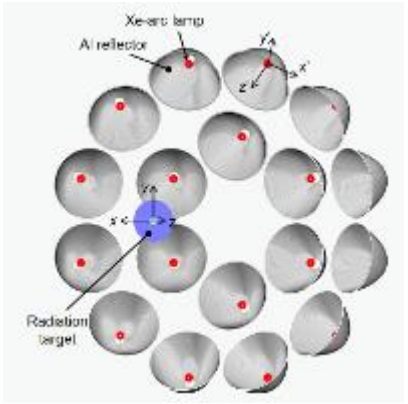
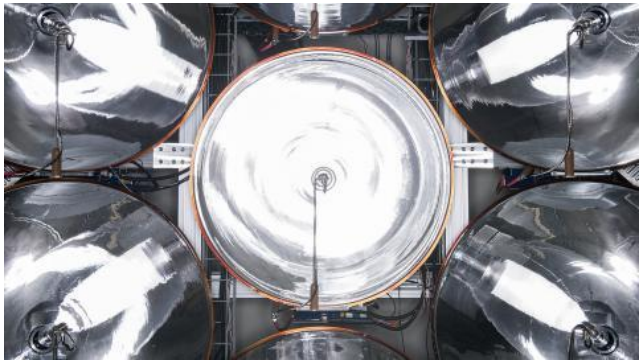
50 kW_e 8,500 suns, 7 Xenon-arc lamps, University of Minnesota

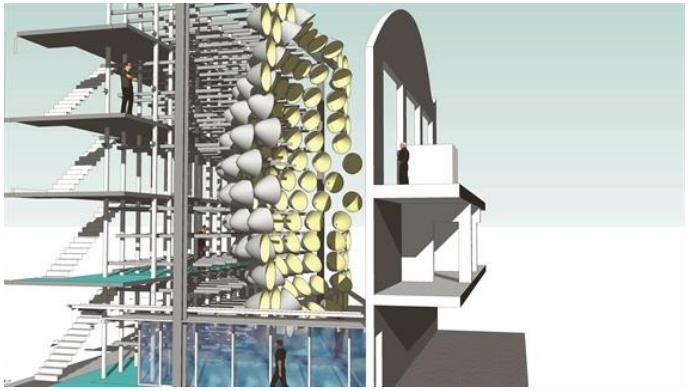
150 kW_e, 11,000 suns, 10 Xe-arc lamps, Paul Scherrer Institute, Switzerland



45 kW_e, 9,500 suns, 18 Xe-arc lamps, Australian National University



42 kW_e, 7 Xe-arc lamps
Georgia Tech University



SynLight, 1 MW_e, 149 Xe-arc lamps, DLR, Germany

Problem Statement & Objective

- All previous examples utilize horizontal aiming and have single, stationary sample exposure

Develop beam down system with Automated Sample Handling & Exposure System (ASHES)

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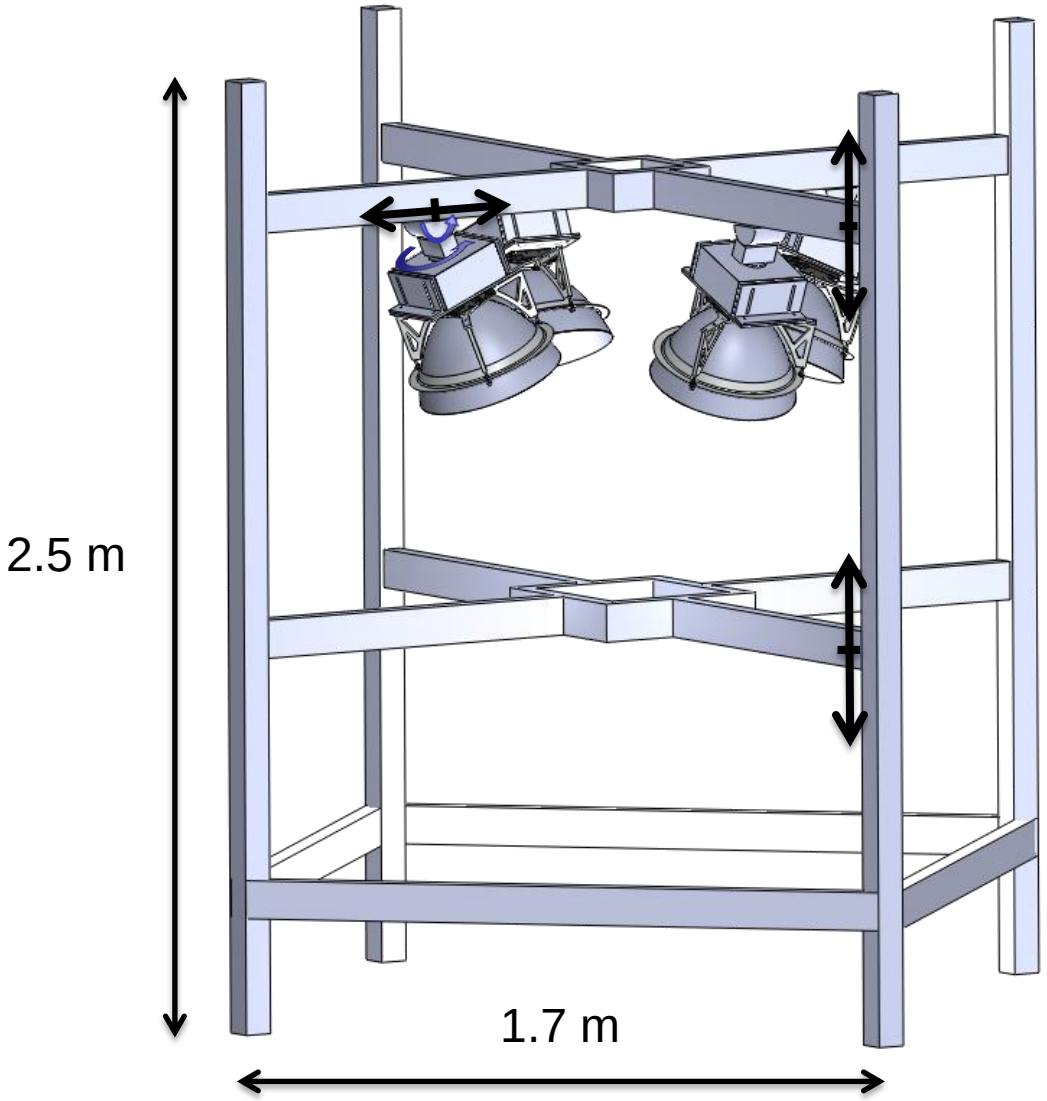
Base Construction

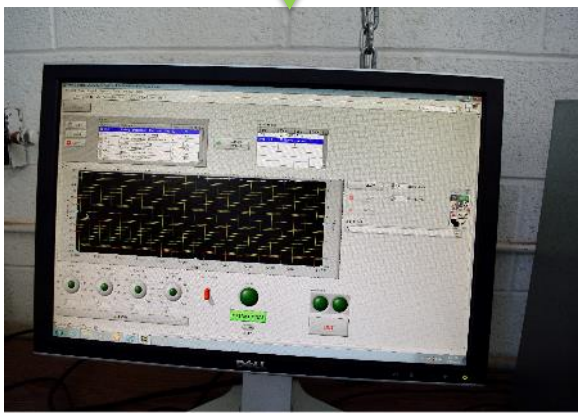
Boubault et al. (2015)

- Beam-down design
  - Easier positioning of samples
  - Mitigates risk of exposure
- Metal Halide lamps
  - Larger arc – less concentration
  - Cheaper than Xenon-arc
  - Matches solar spectrum



Construction

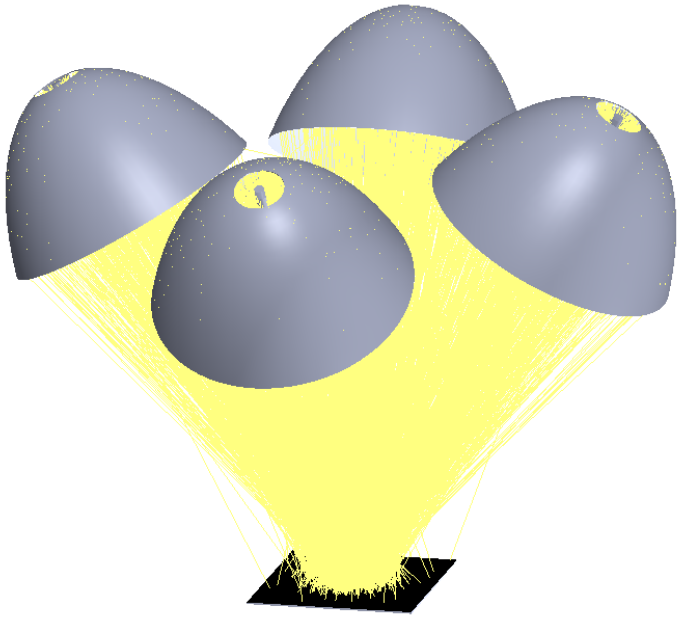
- Completion
  - Protective walls
  - UV proof windows
  - Instrumented with thermocouples
  - Control of operation and safety shutdown with a Labview application

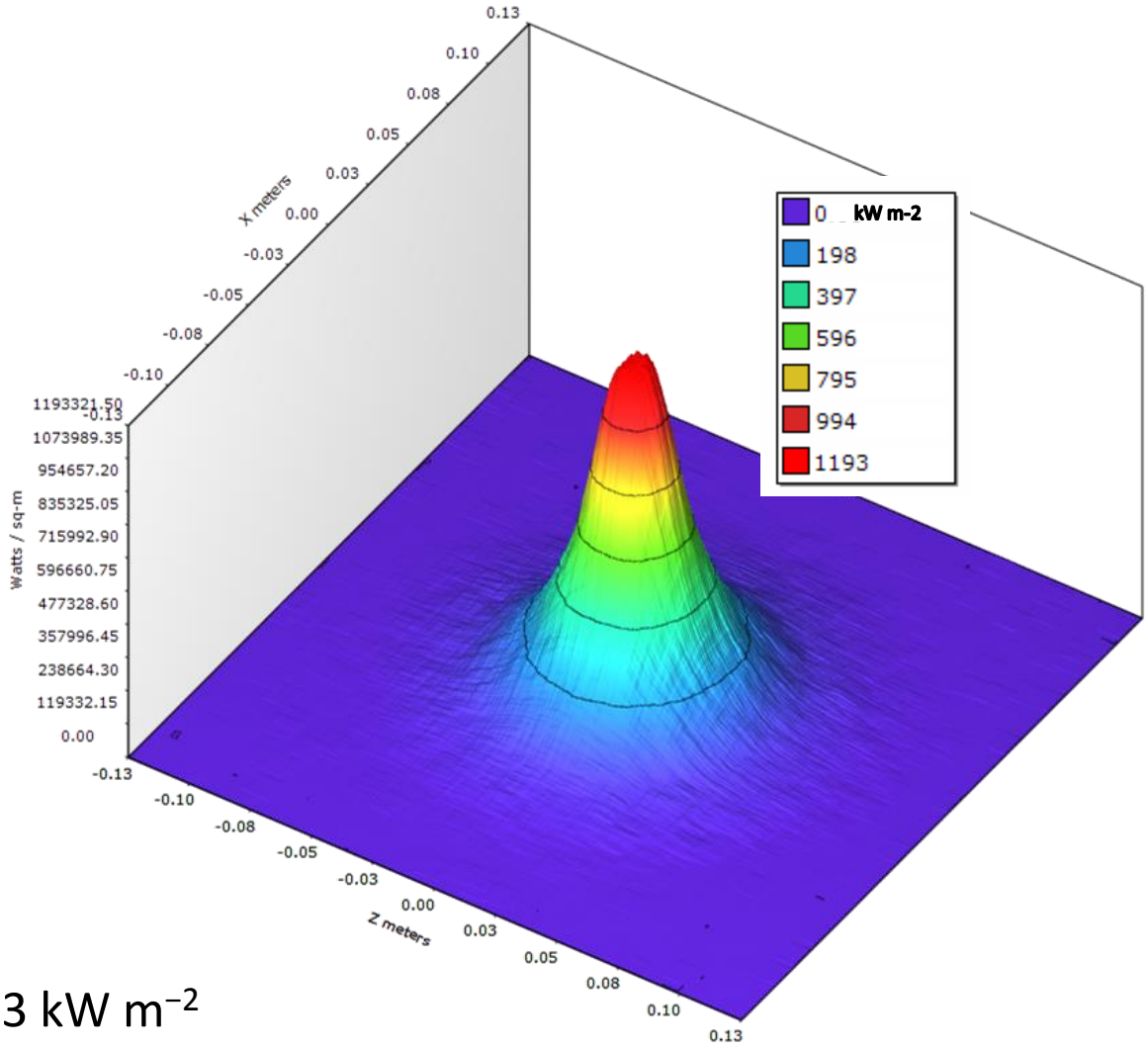


Characterization

Boubault et al. (2015)

- Irradiance





- Peak irradiance = 1193 kW m^{-2}
- Average irradiance (2.5 cm spot) = 1071 kW m^{-2}

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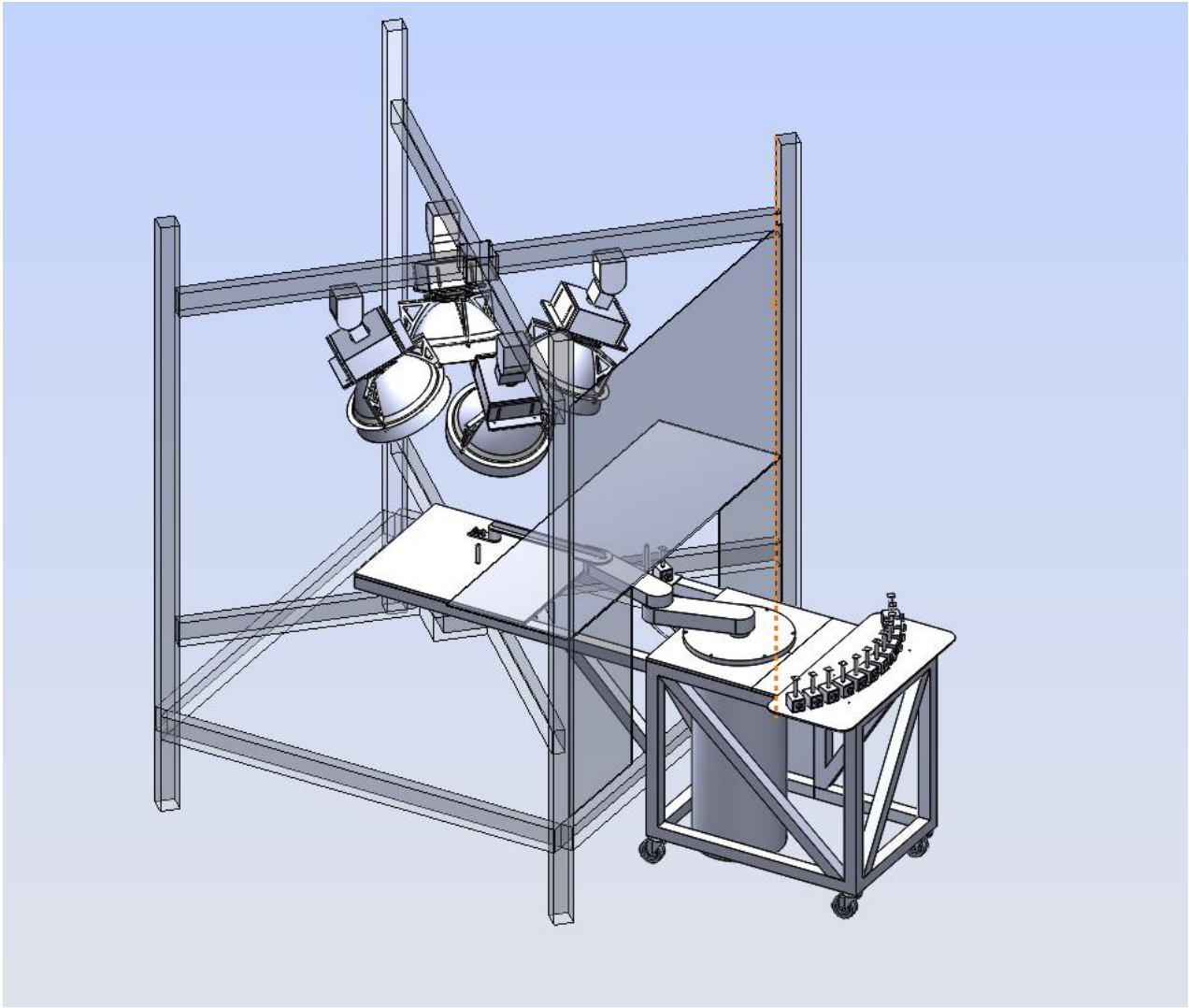
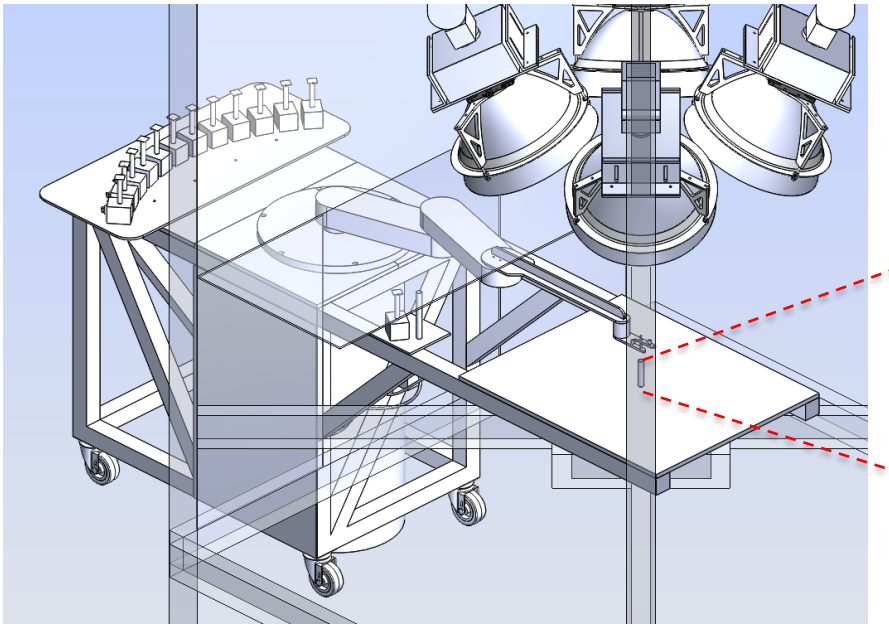
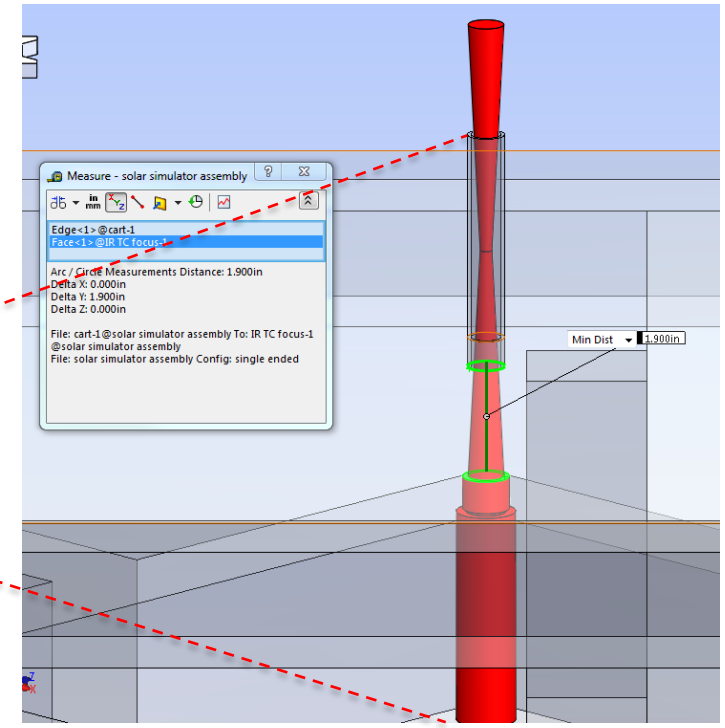
ASHES Design



ASHES Design

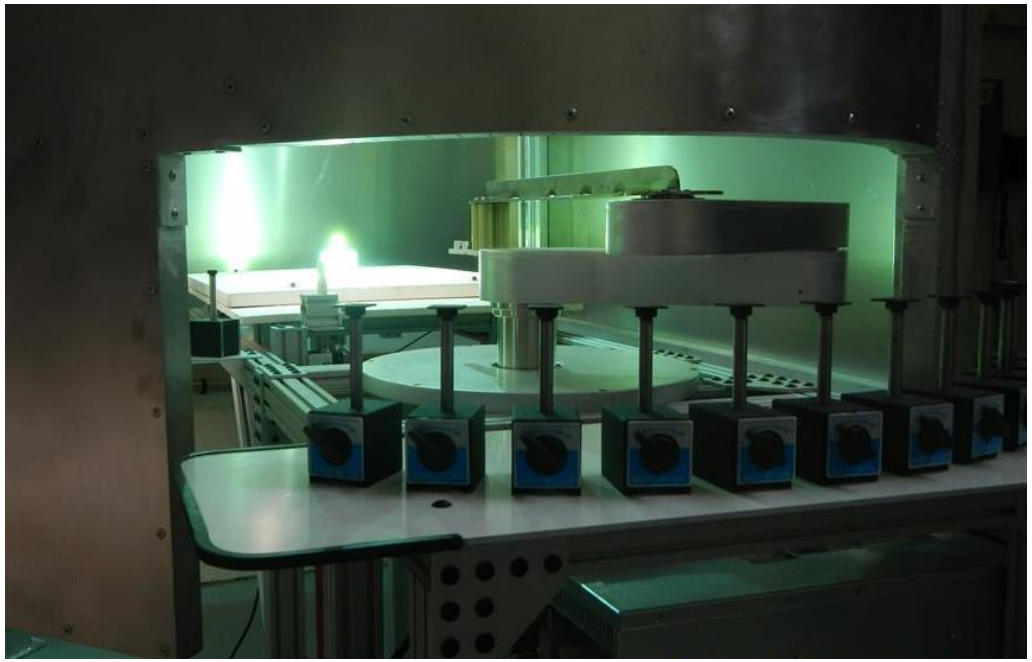




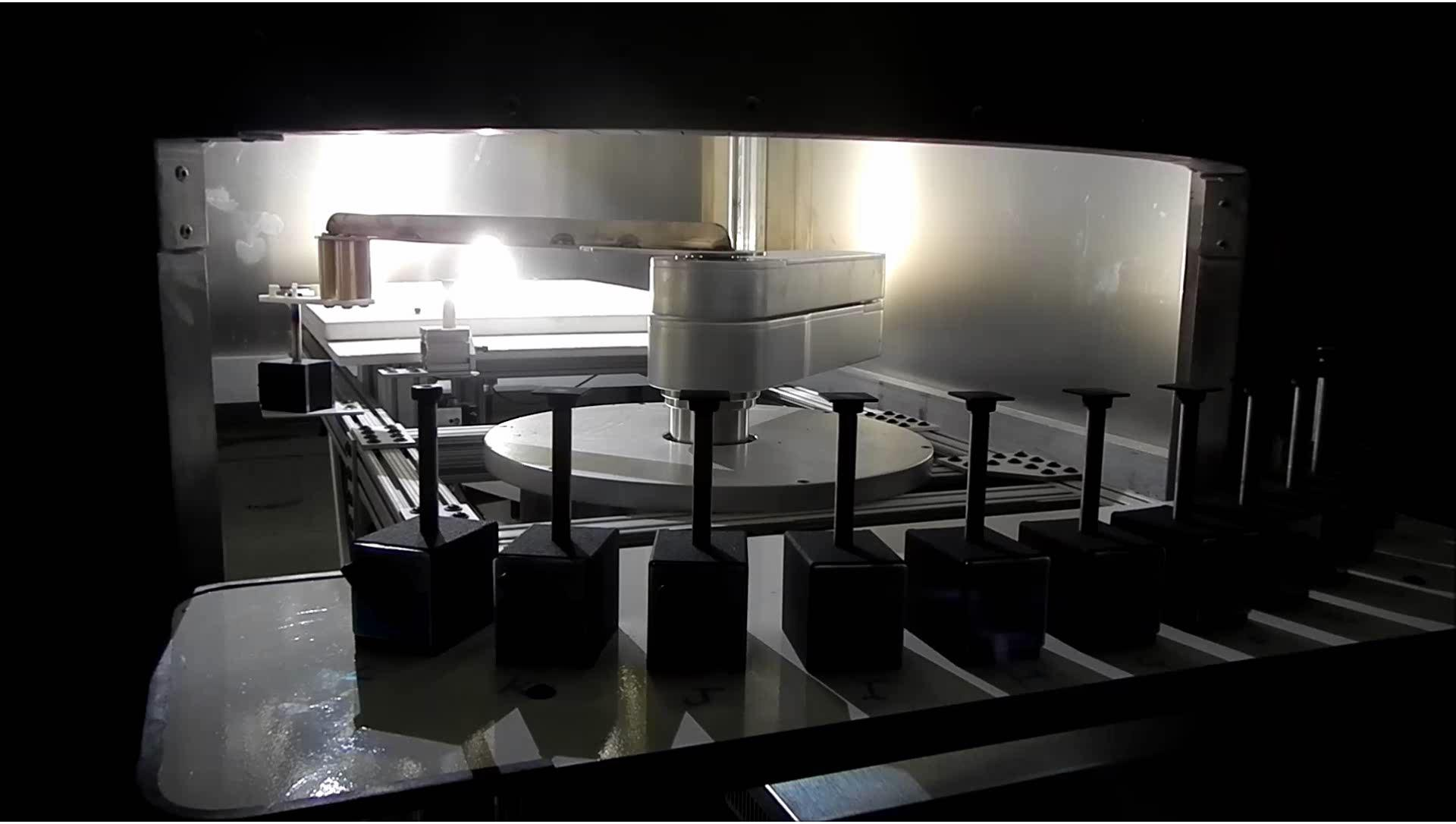
IR sensor measures sample temperature

ASHES - Photos

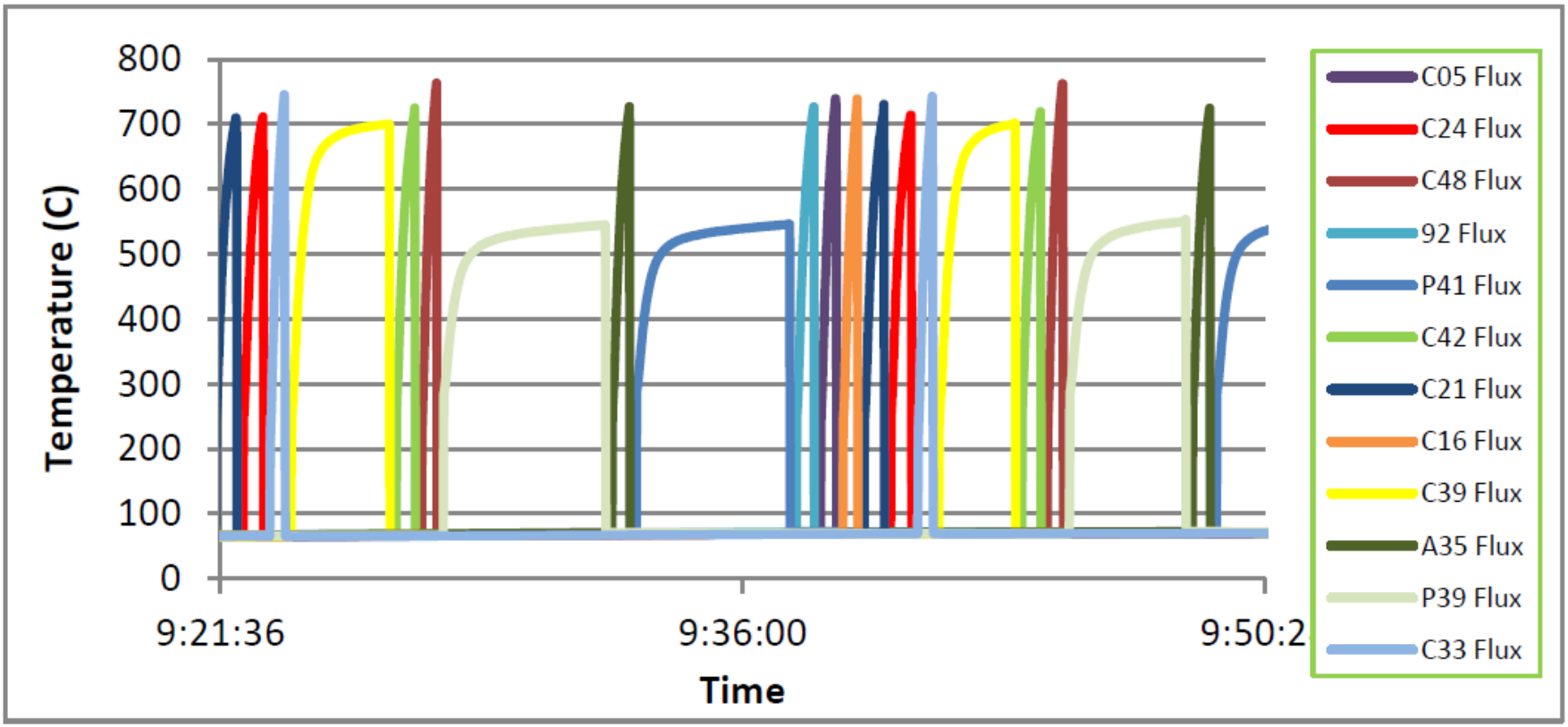
ASHES - Photos



ASHES Video

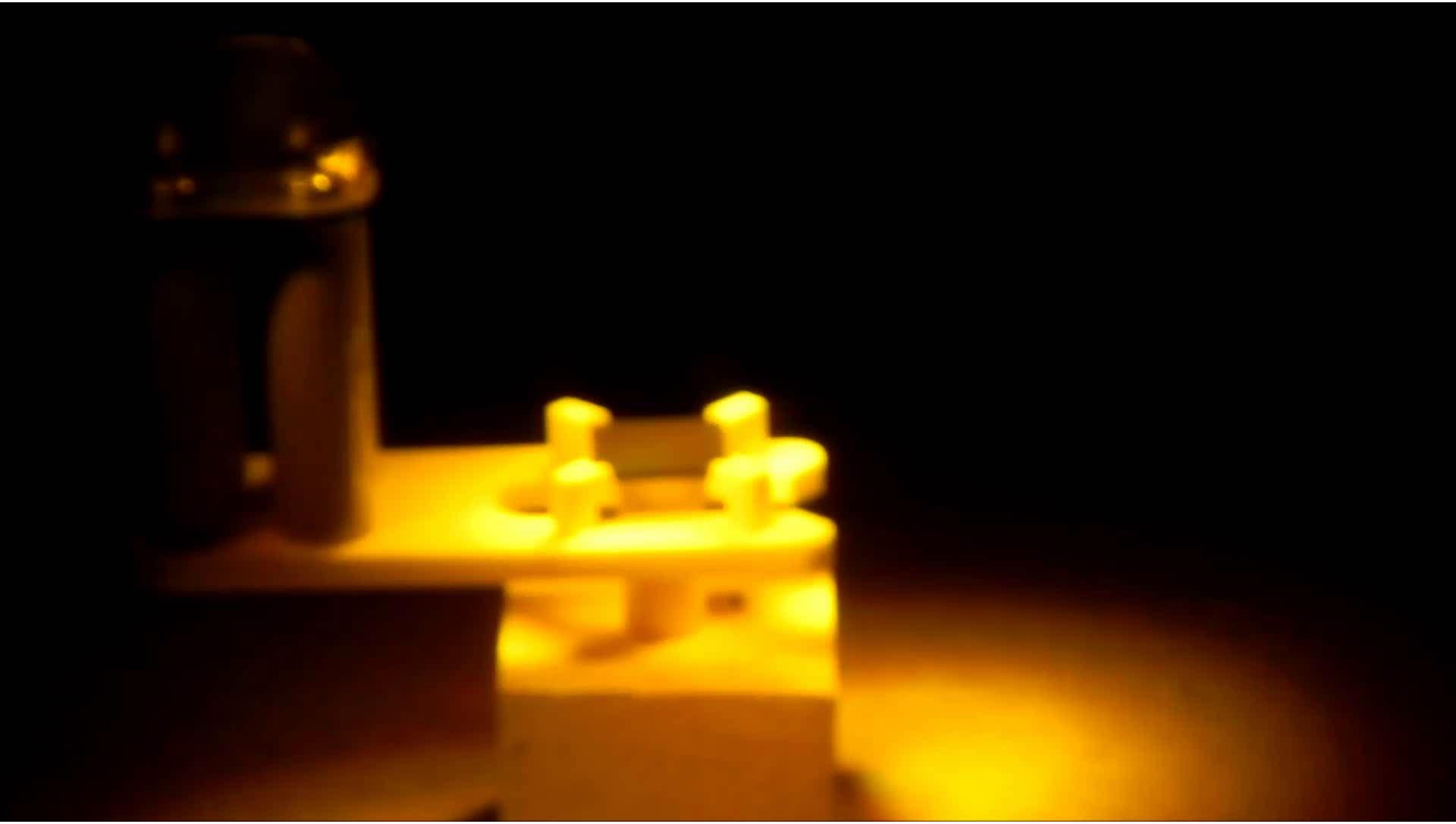


Sample Results



Ambrosini et al. (2016)

ASHES (sticking problem)



New End Effector

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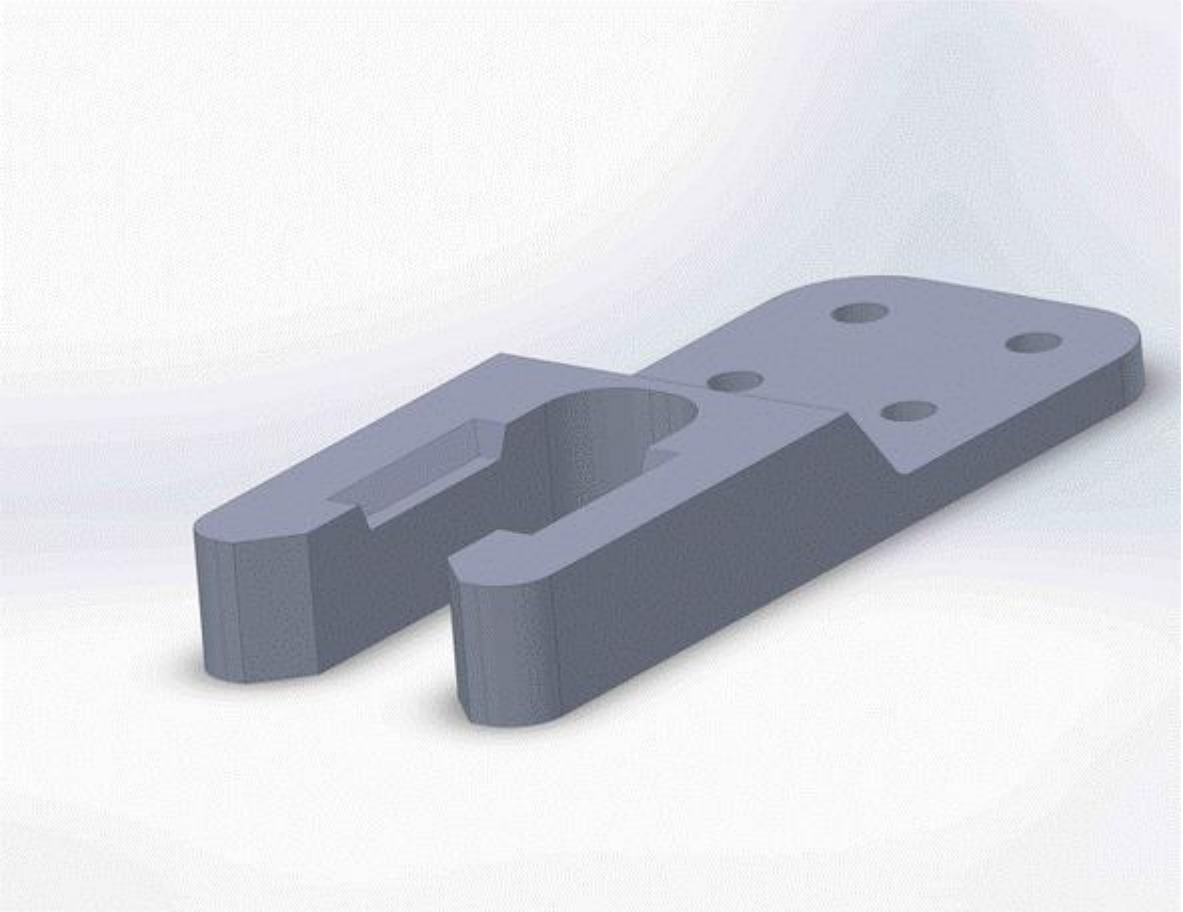

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Conclusions

- Designed and constructed high-flux solar simulator with Automated Sample Handling & Exposure System (ASHES)
- Performance specifications
  - 7.2 kW_e, ~6 $kW_{radiative}$
  - Peak irradiance of ~1,100 suns
  - Average irradiance 900 suns
  - Spot size ~25.4 mm
  - Multiple samples exposed sequentially using robotic arm
    - Prescribed exposure duration or max temperature at prescribed flux
    - Continuous operation

ASHES Available for Use

- ASHES @ National Solar Thermal Test Facility
  - Strategic Partnership Projects Agreement
  - Contact Cliff Ho (ckho@sandia.gov) or Bill Kolb (wjkolb@sandia.gov)

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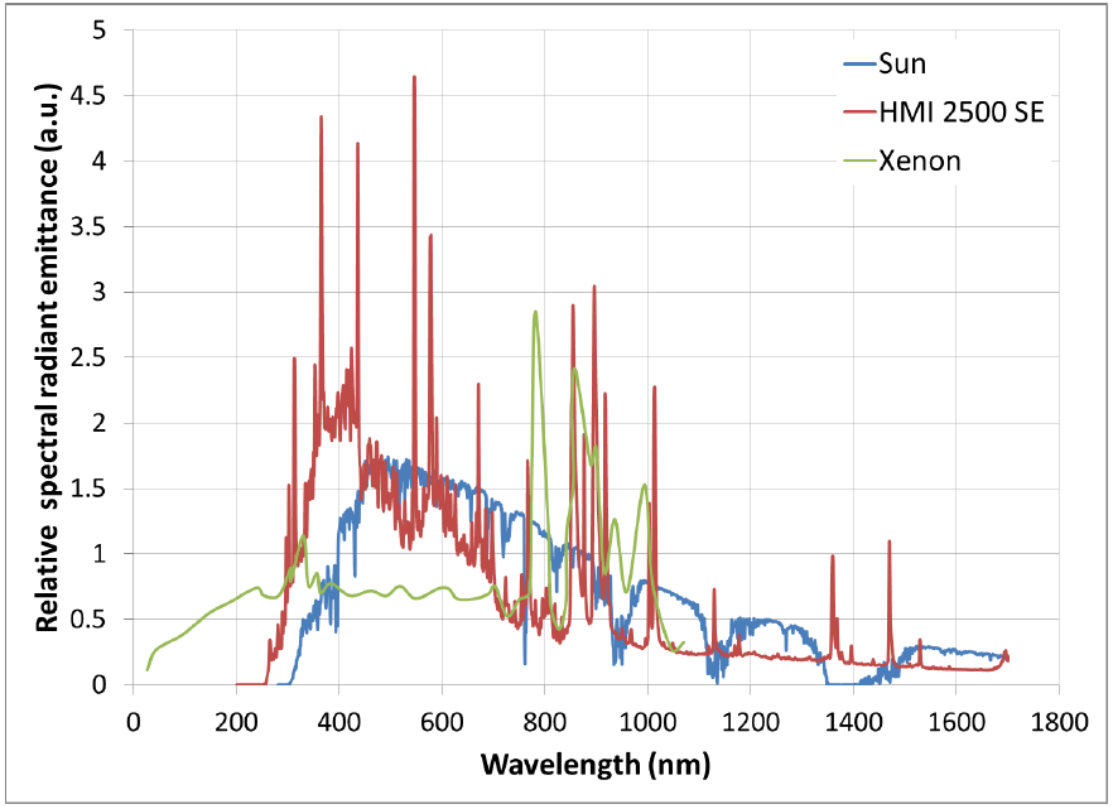
BACKUP SLIDES

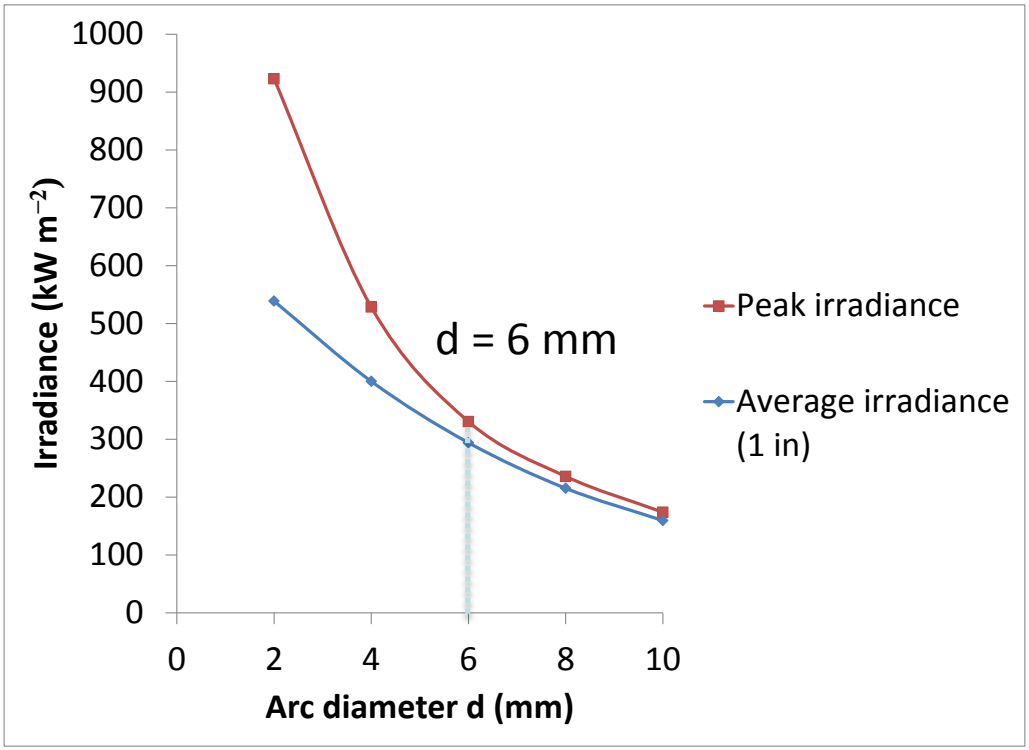
Xenon vs. Metal Halide Lamps

- Xenon lamps have smaller arc lengths
  - Higher concentration
- Longer lifetime
- 10X more expensive



Modeling and Design

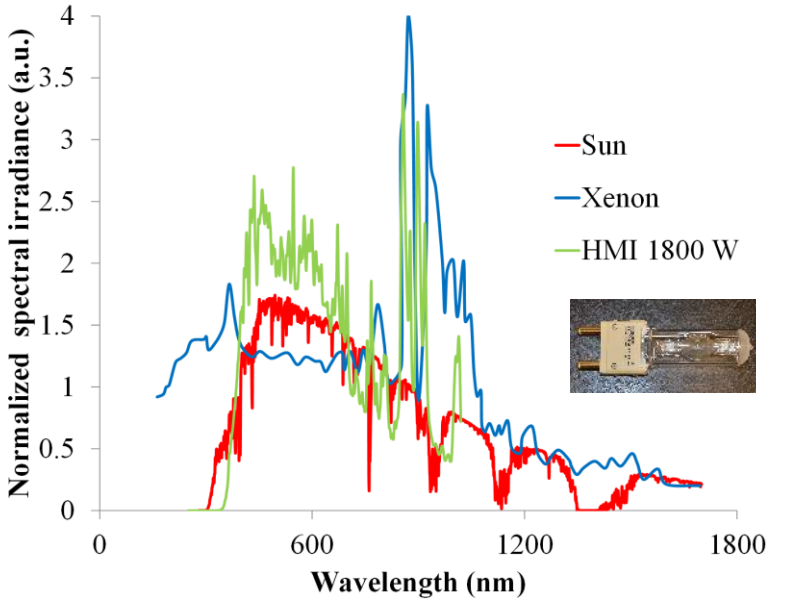
- Influence of arc geometry and size
  - Light source modeled by a cylinder



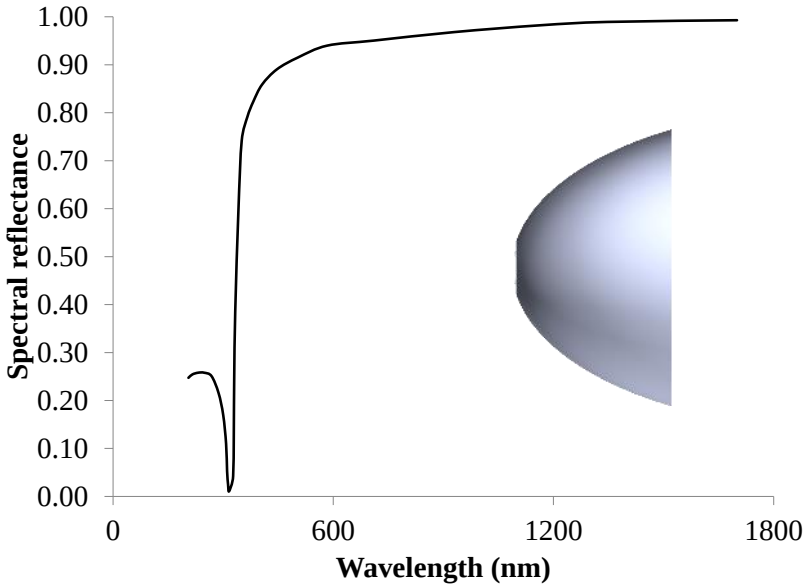
Modeling and Design

Boubault et al. (2015)

- Metal halide lamps match the solar spectrum better
- HMI 1800 W (efficiency = 0.86 or 1550 W emitted)



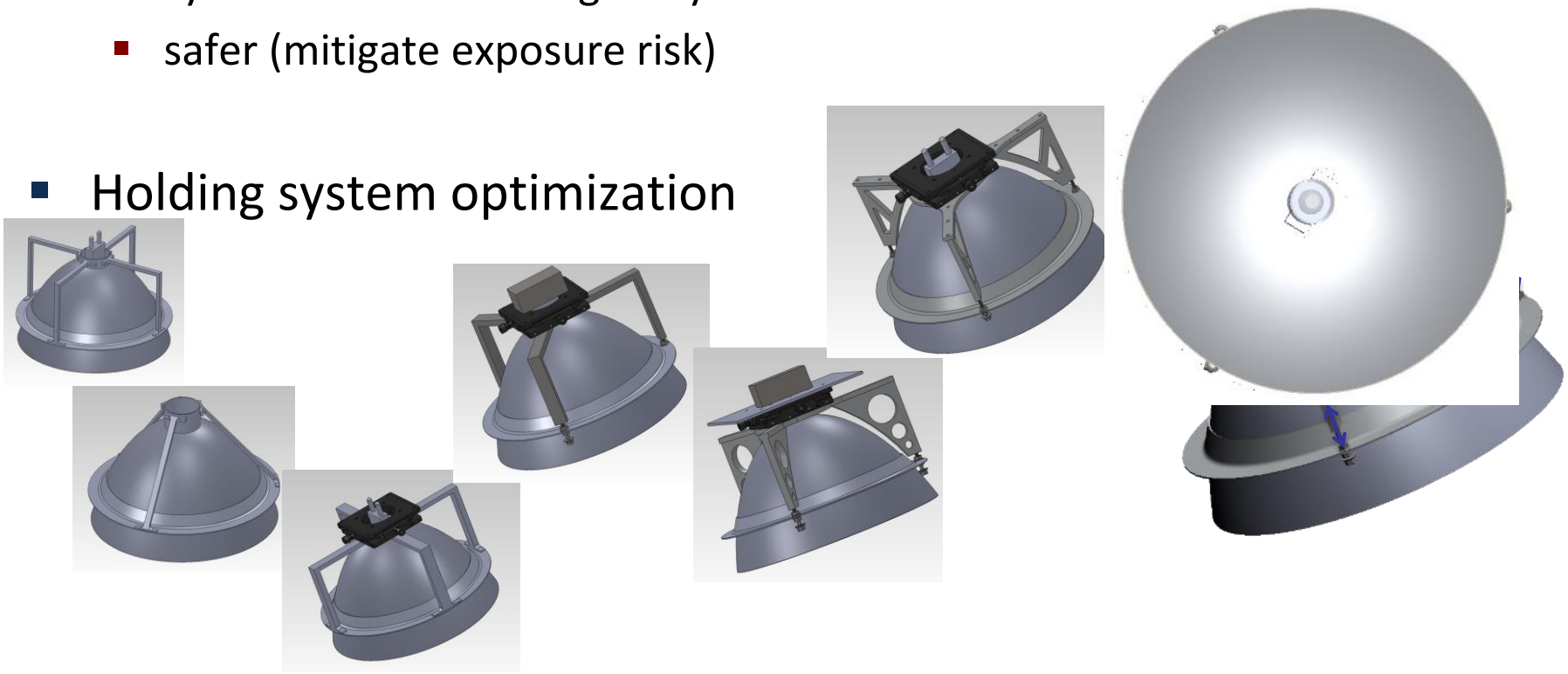
- Electroformed silver-coated nickel reflectors
- Total specular reflectance = 0.875



Construction

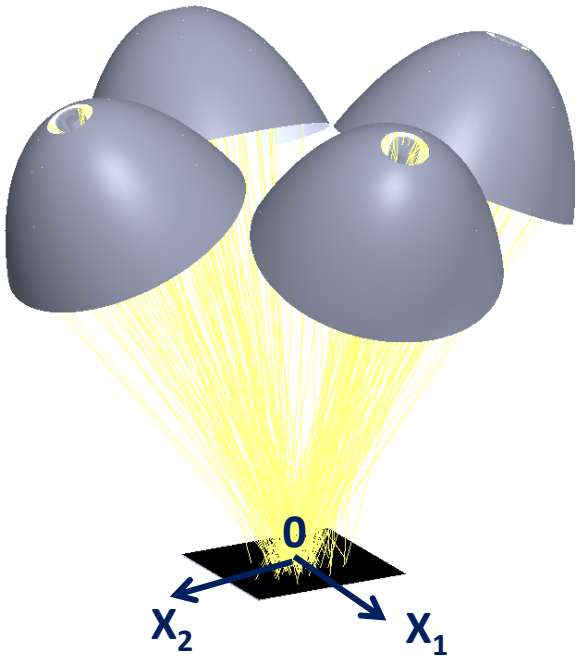
- Vertical design
  - easier positioning of samples
  - symmetric relative to gravity
  - safer (mitigate exposure risk)

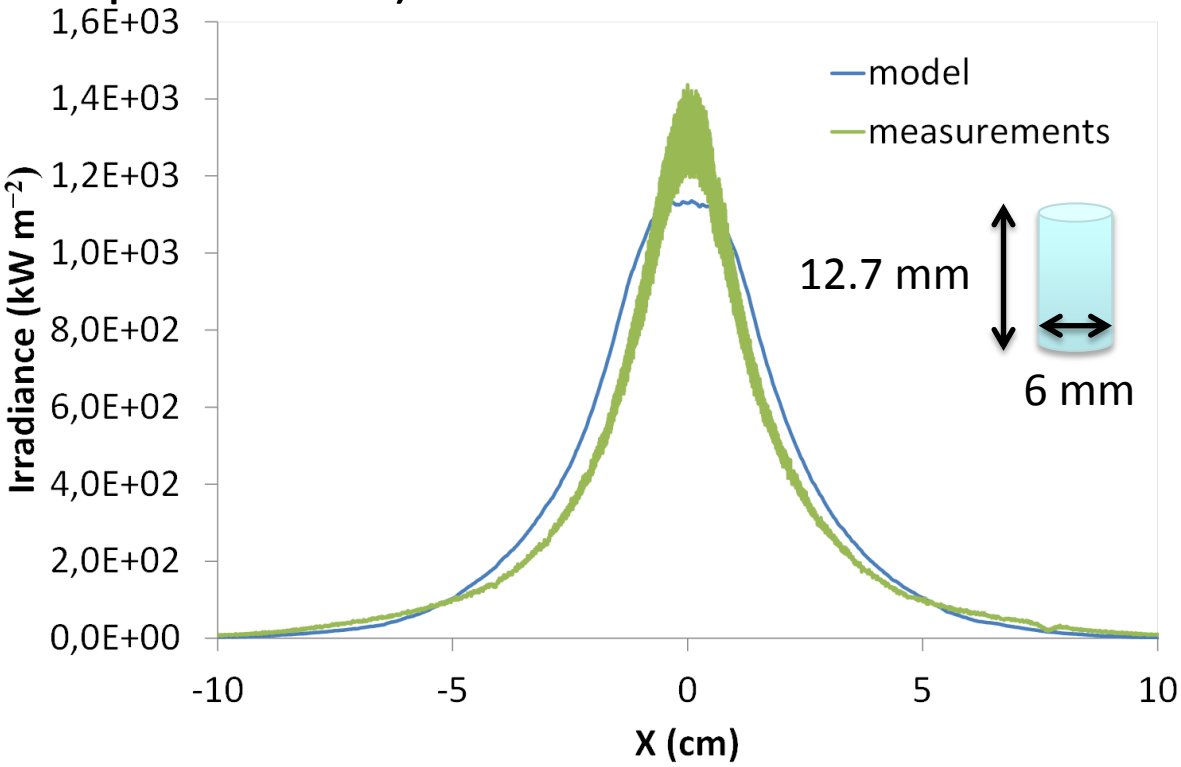
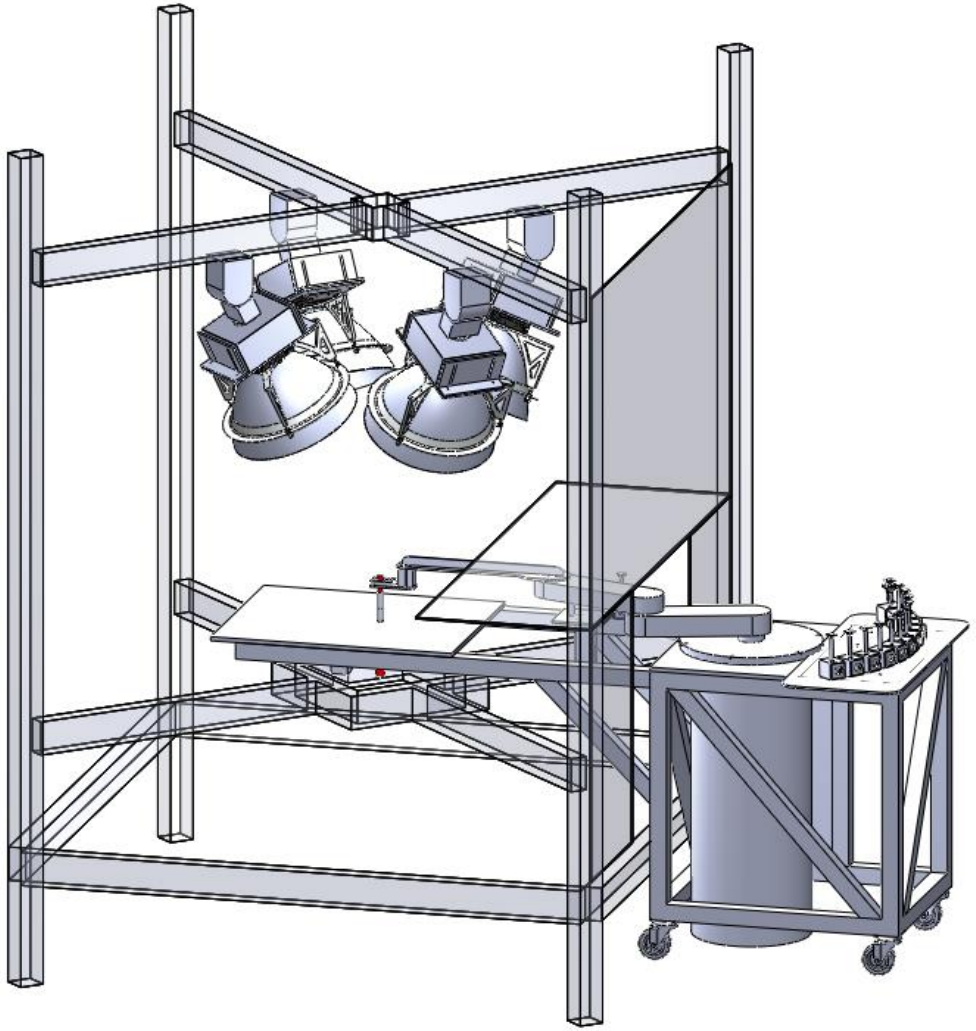
- Holding system optimization



Characterization

- 4 lamps (simulated + experimental)





ASHES Design