Capability Summary for the 200-kW Laser Enhanced Arc Jet Facility (LEAF)

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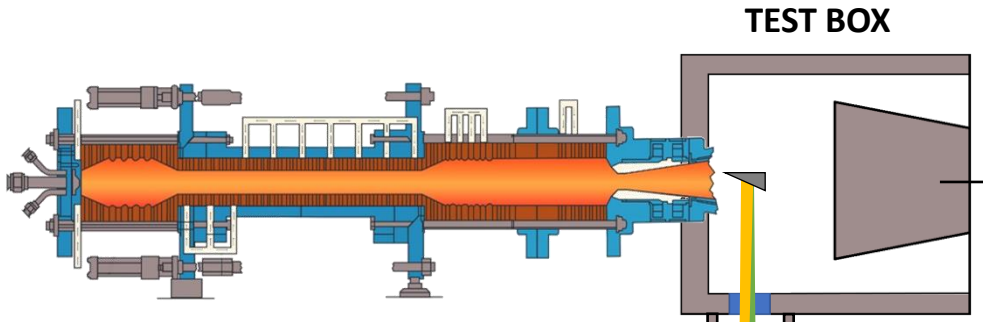
Motivation

- Radiant heating during atmospheric entry is relevant for large entry vehicles or high-speed atmospheric entries - Orion spacecraft is both
- Orion program added radiant heating capability to largest arc jet at Ames
- Combined heating at large scale has been critical to interpreting the results of the Artemis I flight and planning for Artemis II
- Have also accommodated customers wanting high power levels and small spot sizes

Arc Jet Convective Heating

- Interaction Heating Facility (IHF)
  - Simulates hypersonic boundary layer flow environments
  - 60 MW constricted arc heater
  - Enthalpy levels from 5 to 28 MJ/kg (2000 to 12,000 Btu/lbm)
  - Stagnation configuration max heating – 4.5 kW/cm^2 on 5-cm (2 in) models
  - Pressures from 0.1 to 1 MPa
- In LEAF configuration (free jet wedge or flat panel)
  - Max heating 0.16 kW/cm^2 over 15.2-cm square
  - Max heating 0.085 kW/cm^2 over 43.2-cm square

Laser Radiant Heating



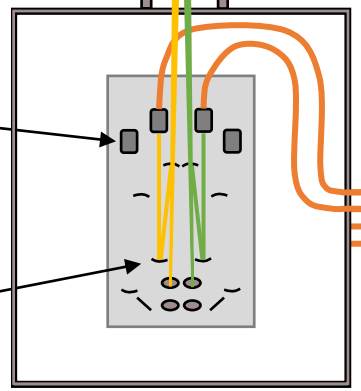
TEST BOX

To steam vacuum system

50 kW continuous wave fiber lasers (4)

LASER ENCLOSURES

Fiber optic cables (4)
(25–30 m)



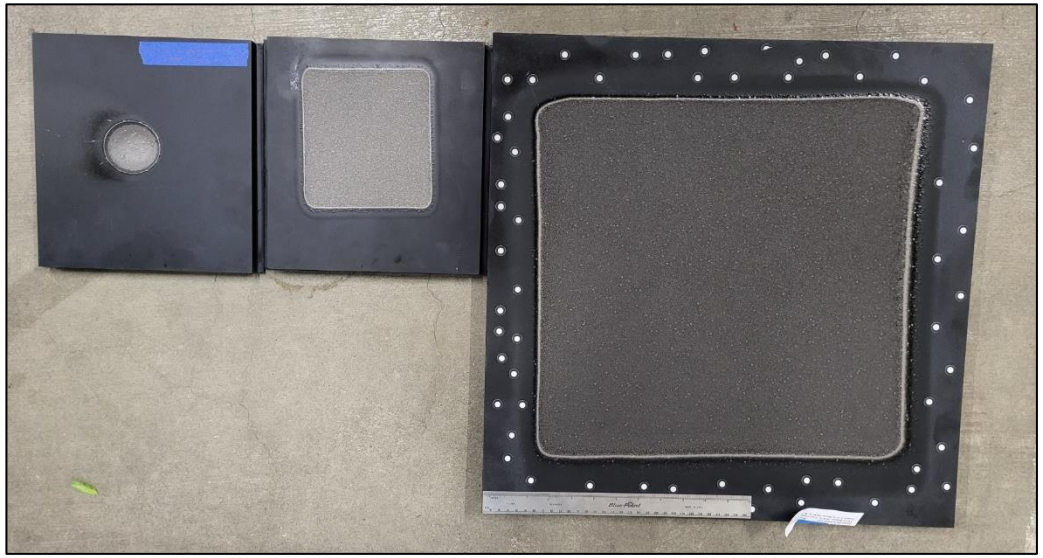
OPTICS ROOM

Beam collimators
Flat-top – collimator set for ideal collimation
Gaussian – distance between collimator lenses adjusted to control beam diameter

Integrating mirrors
Used for flat-top beams
Removed for Gaussian beams

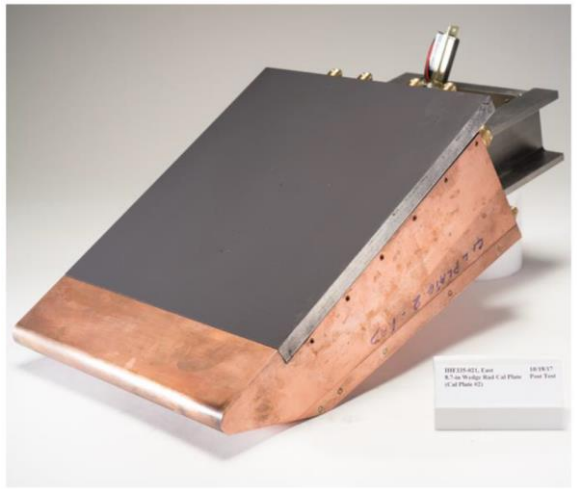
Beam Shapes

- Standard flat-top configurations
  - 15.2 cm flat-top square
  - 43.2 cm flat-top square
  - Run durations on the order of minutes
- Super-Gaussian configuration
  - $1/e^2$ radius of 1 to 4 cm
  - Have run up to 10s of seconds, this has been limited by material capability
- With 4 lasers, we can also run combinations of beam shapes
- Have added new beam shapes and sizes at customer request, ask if you need a different beam shape



Flat-Top Square Beam Irradiance

- 15.2 cm (6 in) square sample only requires two lasers to reach required heat flux
- 43.2 cm (17 in) square sample size was essential to interpreting Artemis I flight data
- Radiant heat flux plotted here was measured with a water-cooled calibration plate



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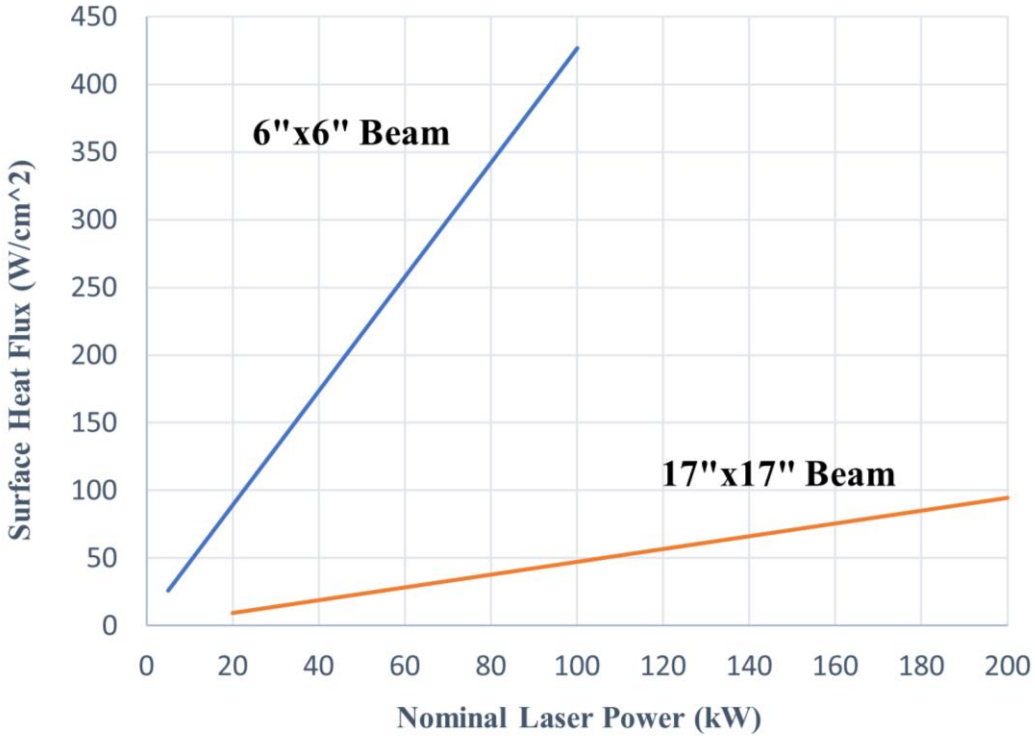
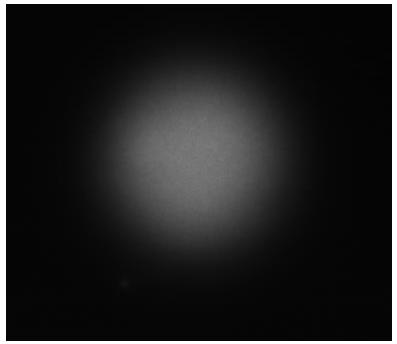
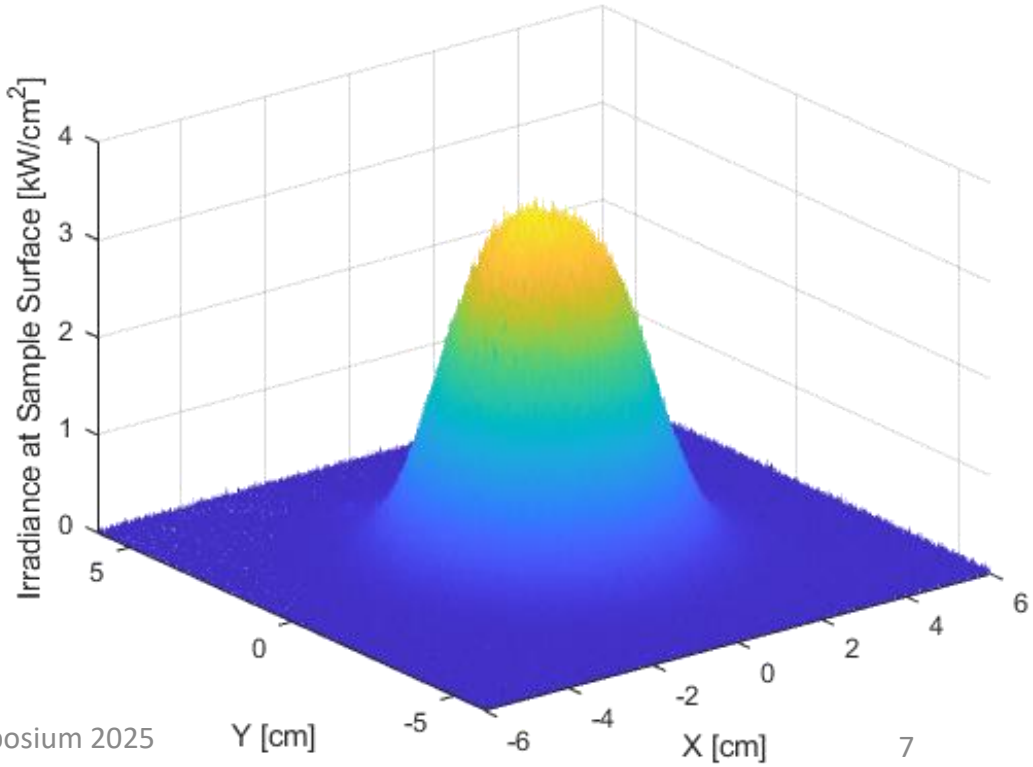


Super-Gaussian Beam Irradiance

- Super-Gaussian beam requires measurement method that can handle high irradiance levels
- Optical beam profiling
  - Use back reflection from test box window
  - Infrared camera image of each beam gives profile shape
  - Beam power via power meter
- Working through a beam characterization test now
  - Vary beam size and laser power for each laser independently
  - 4-beam configuration

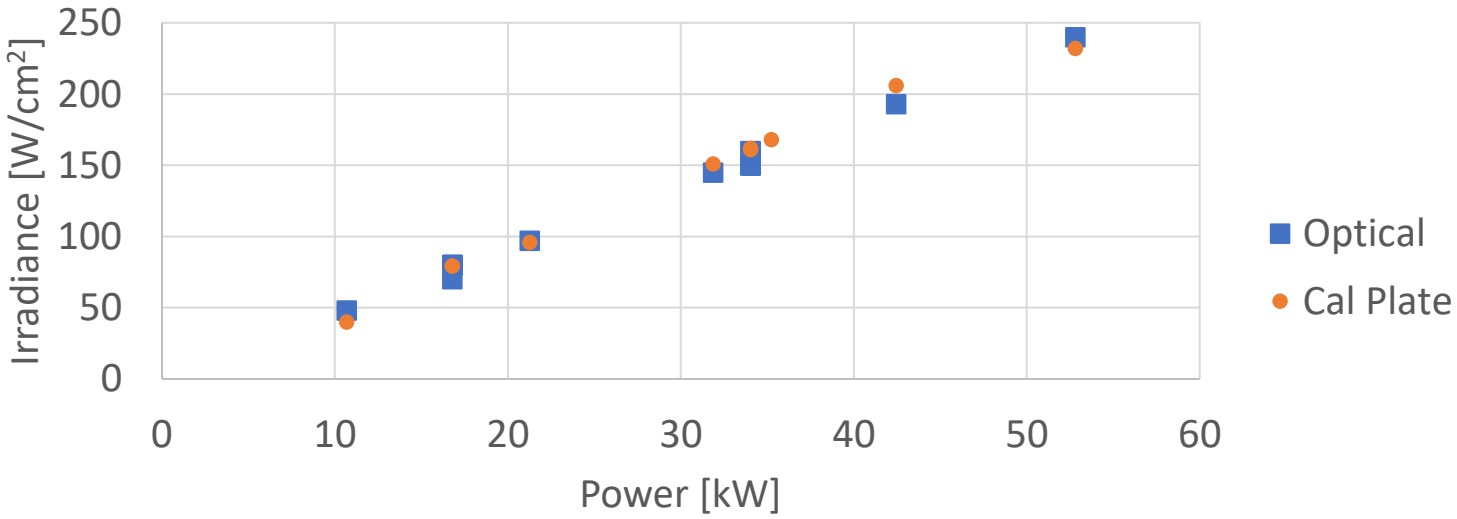


$$I(r) = I_0 e^{-2\left[\frac{r}{r_0}\right]^s}$$



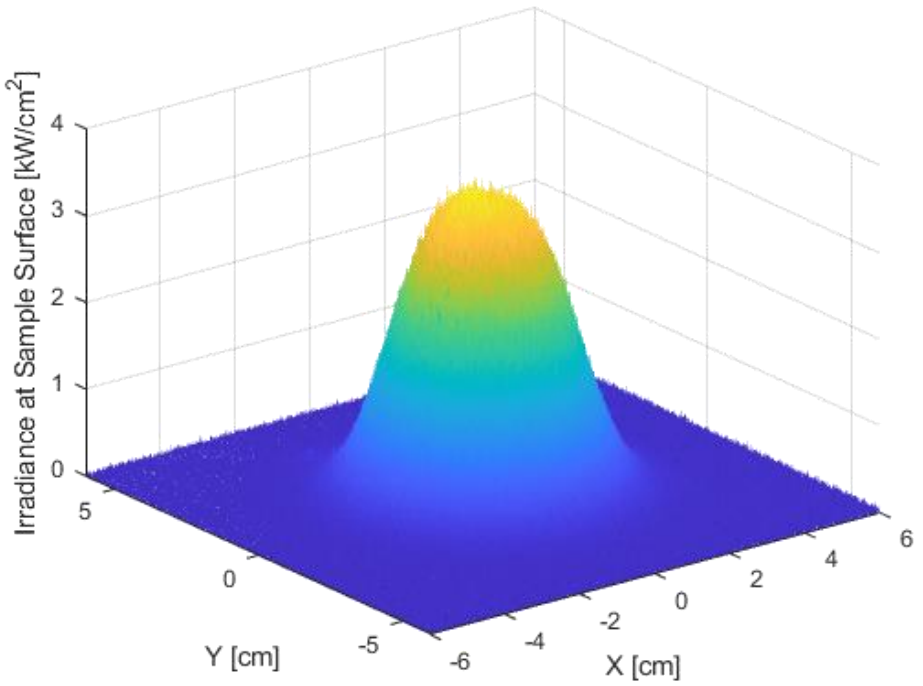
Comparison of Two Calibration Methods

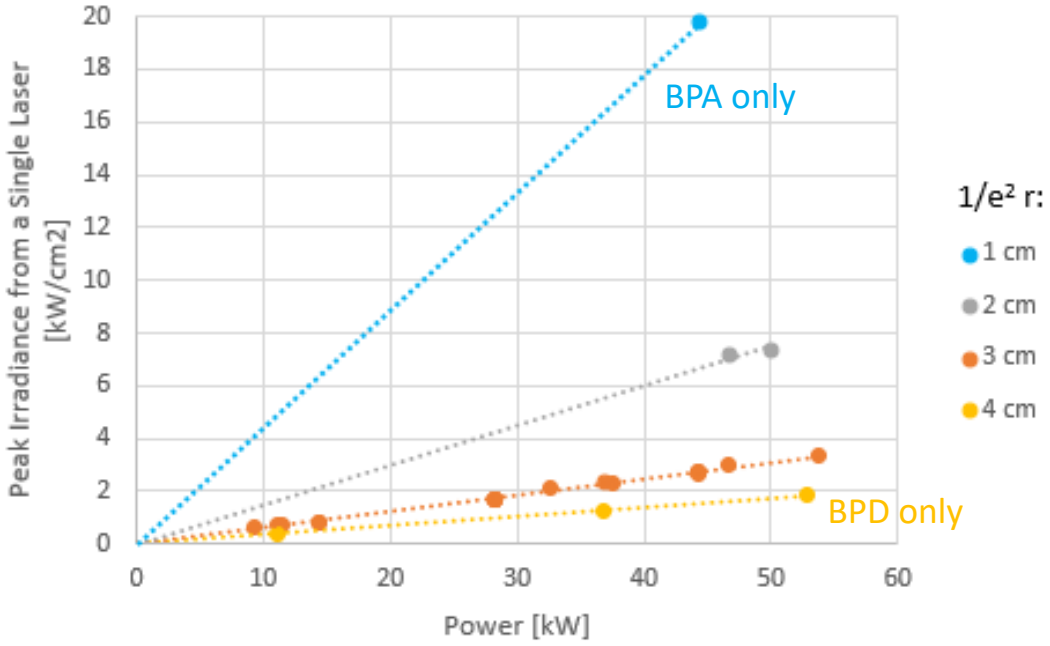
- Why two calibration methods?
  - Large square beam – cannot catch the entire window reflection, must use calibration plate with embedded heat flux gauges
  - Super-Gaussian beam – high irradiance would damage calibration plate, must use optical beam profiling method
  - Small square beam – both methods work
- Beam profiling and water-cooled calorimeter plate give same results to within 7%



Peak Irradiance Per Laser

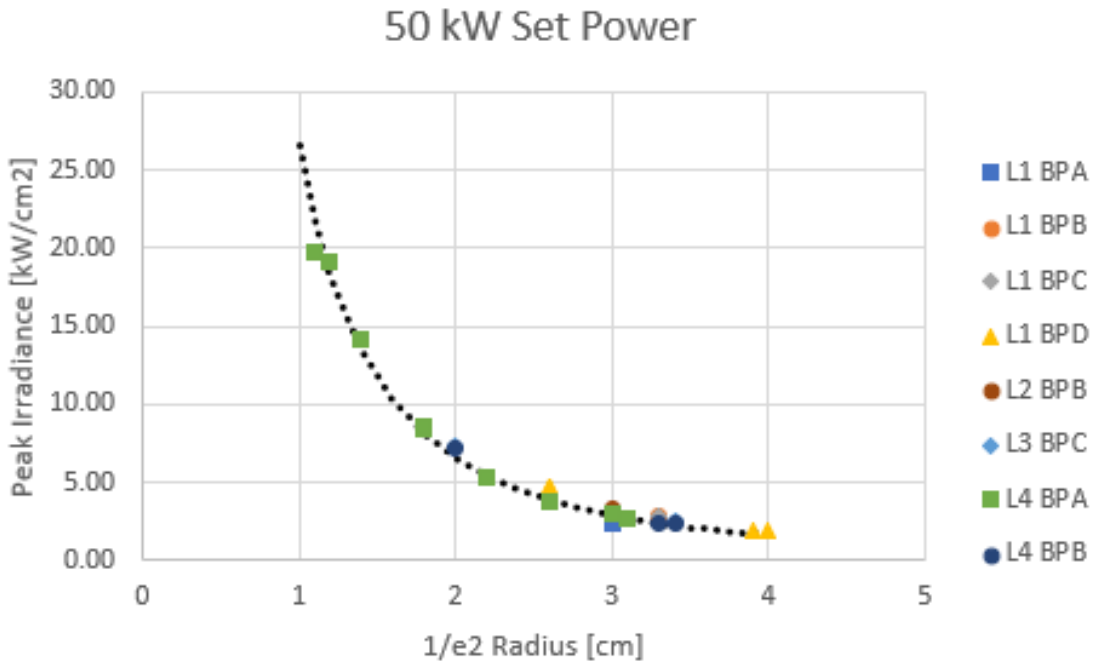
- Peak irradiance increases linearly with power
- Have characterized available radius and irradiance combinations
- Radius range for 1-beam operation: r_o = 1 – 4 cm





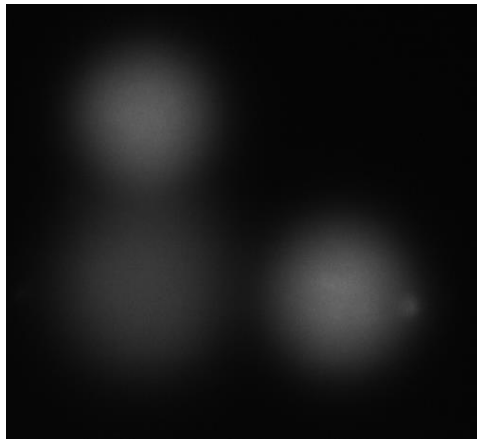
Super-Gaussian Beam Size

- At a given power, a smaller radius gives a larger irradiance, but relationship is not linear

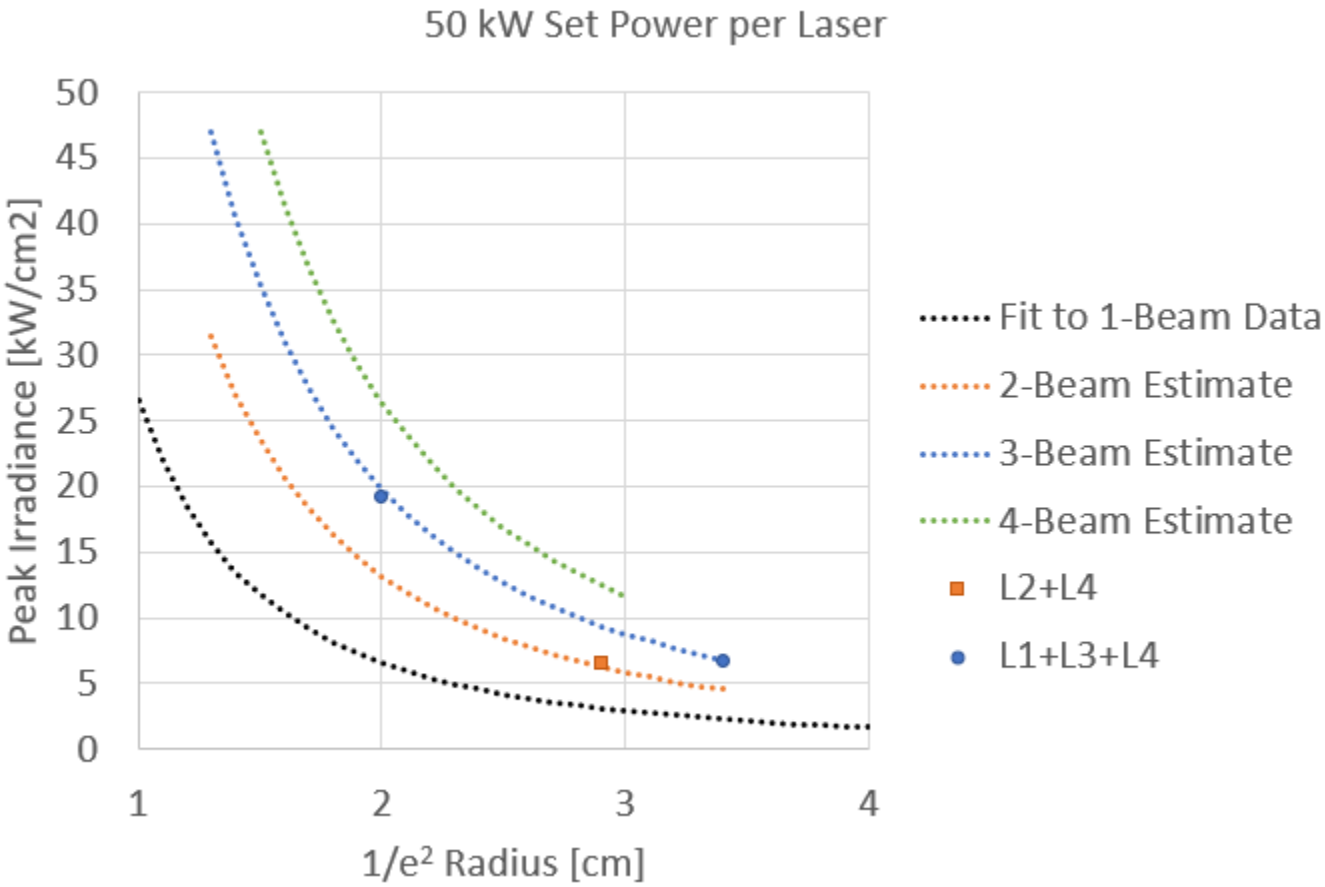


Multi-Beam Super-Gaussian

- Example shot with 3 simultaneous beams
  - Imaging plane location enables individual beam profiling even during multi-beam shot



- Because irradiance is linear with power, we get a reasonable estimate of multi-beam irradiance levels from the single-beam measurements



Conclusions

- Quantified irradiance for flat-top beams and super-gaussian beams
- Ready to go with the 4-beam super-Gaussian configuration
- Data here will be included in the latest iteration of the test planning guide – www.nasa.gov/thermophysics-facilities-test-planning-information/

Questions?

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Send questions to…

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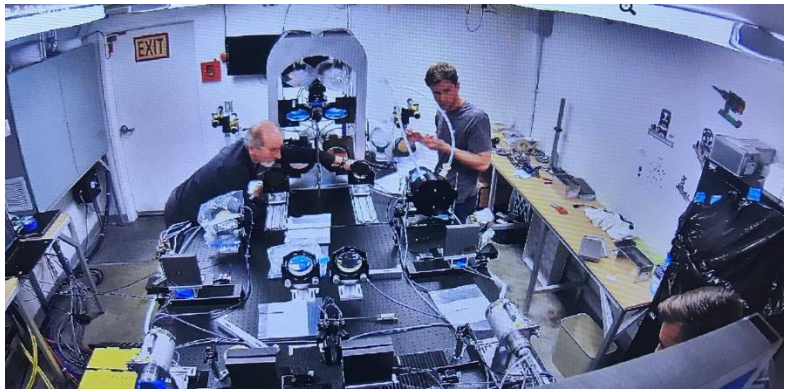

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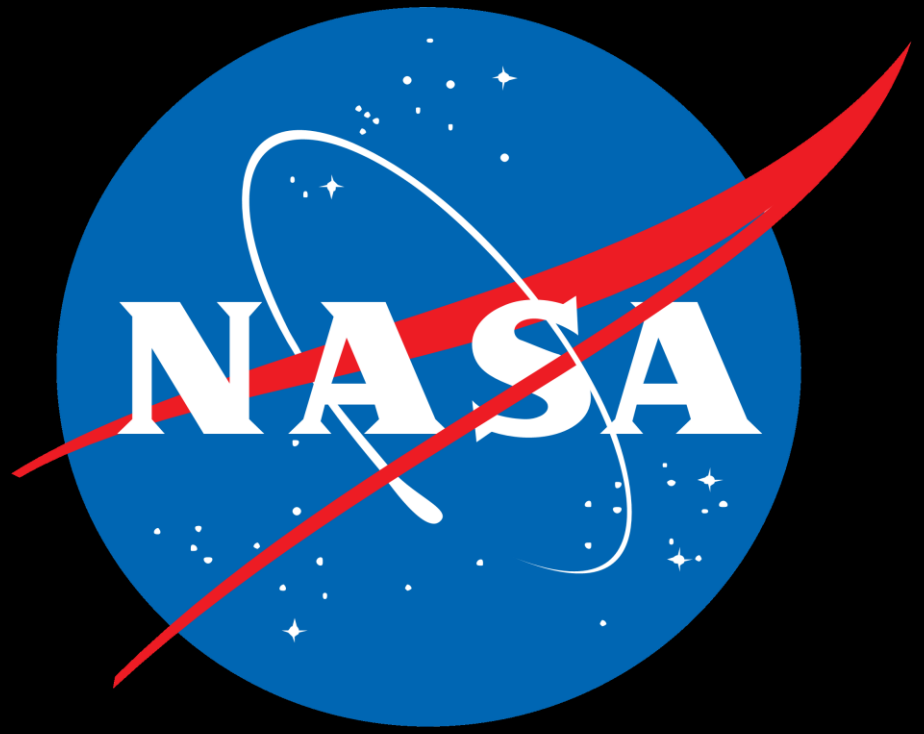

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