**Reflective Field Stop** Provides melt-pool monitoring during TEMPS system operation, 3x magnification

**Removable Splitter/Reflector** 

Exchangeable optic to allow back-emitted melt pool light into Process Control Module or **TEMPS** module

50 mm dia. CA Laser scanner

100 kHz positioning control with well characterized geometric positioning accuracy mapped to build plane

100 mm x 100 mm Build Area Extendible area with coordinated motion of translating carriage gantry

# **Optics Tower** &TEMPS Module

**Process Control** 

Module

Variable Focus Lens

melt pool imaging

Provides laser spot control & optimized

Melt Pool Image (1x) Diffraction-limited imaging performance at Laser 850 nm. Re-imaging lens allows extension of optics path for varying camera size

Main Carriage

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Power: 500 W Type: CW Multimode Yb Fiber Wavelength: 1070 nm Spot Size: 100 µm FWHM Profile: Mixed Gaussian/Uniform Rise Time: 57 µs at 50% power

**AM Build Platform** Build Area: 100 mm x 100 mm Build Height: 180 mm Low Temp Build Plate: 80 °C Hi Temp Build Plate: 400 °C

**XY Scanner Mirrors** Max Scan Speed: 10 m/s Max Acceleration: 5 x 10<sup>5</sup> mm/s<sup>2</sup>

**Environment Control** Vacuum: 10<sup>-3</sup> Torr **Recirculated Ar Purge** 

Scan/Laser Control Power/speed control at 100 kHz

**500 Watt CW Yb Fiber Laser** Includes external power monitoring and capabilities

for in-situ spot profile measurement

### **Powder Recoating Platform**

Platform for exchangeable powder recoating types (flexible or stiff blade or roller). Available space for recoater-based instrumentation.

**Features and Capabilities** 

Laminar Flow Air Blanket Allows removal of the main carriage for servicing, cleaning, or reconfiguration

> **Granite Base** All metrology instruments are mechanically coupled to stable reference base.

Radiometric **Calibration Sources** 0.4  $\mu$ m to 10  $\mu$ m blackbody sources, reflectance standards, and reflectance sample heater which can be interrogated by the laser co-axial instrumentation

Air Blanket Return

Can be removed for easier user

access to build space

**External Port for Offline Observation** Allows imaging of build area Customizable port for externally mounted cameras/illumination.

Laser safe viewports

**Removable Panels** Customizable panels for cable/hose feedthroughs. Hinged doors/panels for quick access to main carriage and build area.

## **Front Panel Doors**

Hinged doors allow user access to build space, powder feed and build pistons, or cabling/instrumentation.

## **Process Chamber**

100 µm FWHM

Laser spot

Full vacuum and backfilling of inert gas, includes controlled & monitored recirculation and filtering.

#### **Build Area Platform**

Includes powder feed bed, build bed, and overflow bin. Includes optional removable contamination chamber to limit stray debris.

#### **Translating Carriage Gantry** Positions build area or radiometric calibration sources under the laser and co-axially aligned instrumentation

## **Transfer Dolly** Allows removal of the main

or reconfiguration

carriage for servicing, cleaning,

#### **Kinematic Posts** Main carriage is lowered onto kinematic mounts within chamber for repeatable positioning

## **Initial System Testing and Results PROTOTYPING SYSTEM**

#### LASER SCAN CONTROL with AM-G CODE

• Custom laser scan controller allows position, velocity, and power control at 100 kHz using xy2-100 protocol.

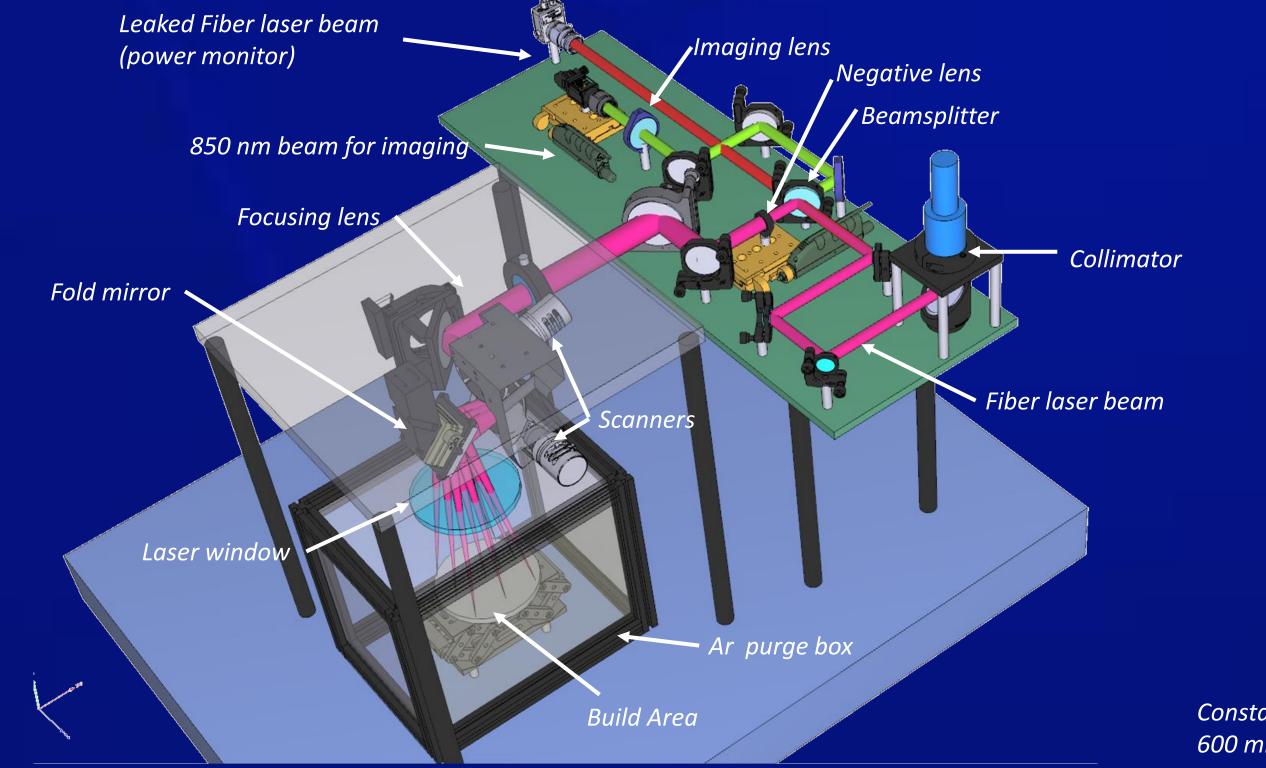
#### PART or POWDER SURFACE IMAGING

• In-situ layer-wise monitoring camera captures, measure, and quantifies Initial testing of the co-axial cameras . Ultimately, these surface geometry or irregularities. cameras will quantify melt pool size and intensity dynamics,

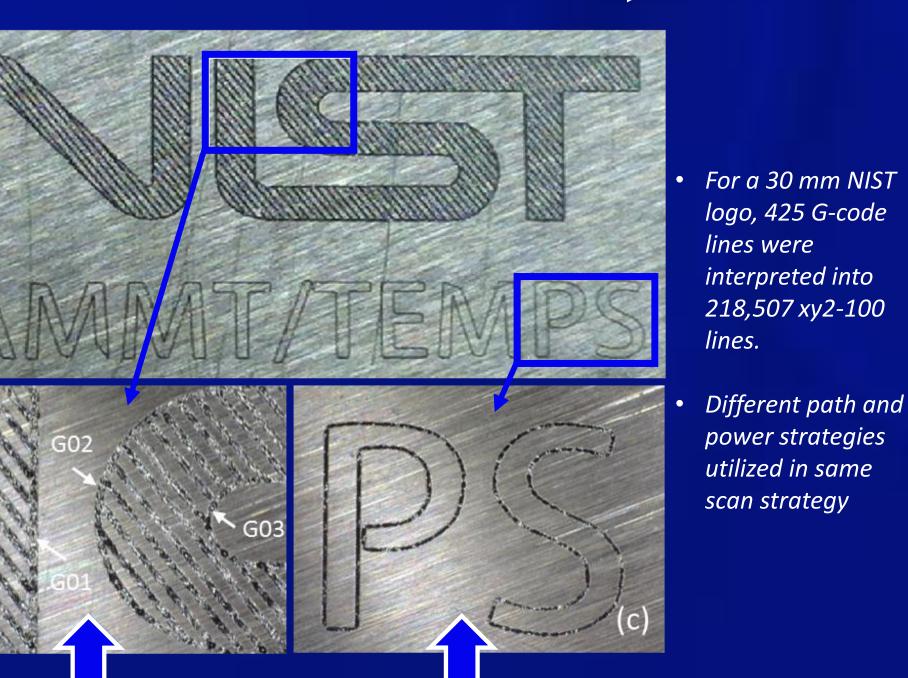
#### HIGH SPEED IMAGING of MELT POOL

Initial testing of the laser, optical components, and programming of controller and user interface.

Evaluate stability of optics, sensitivity of sensors, laser beam profile, etc.



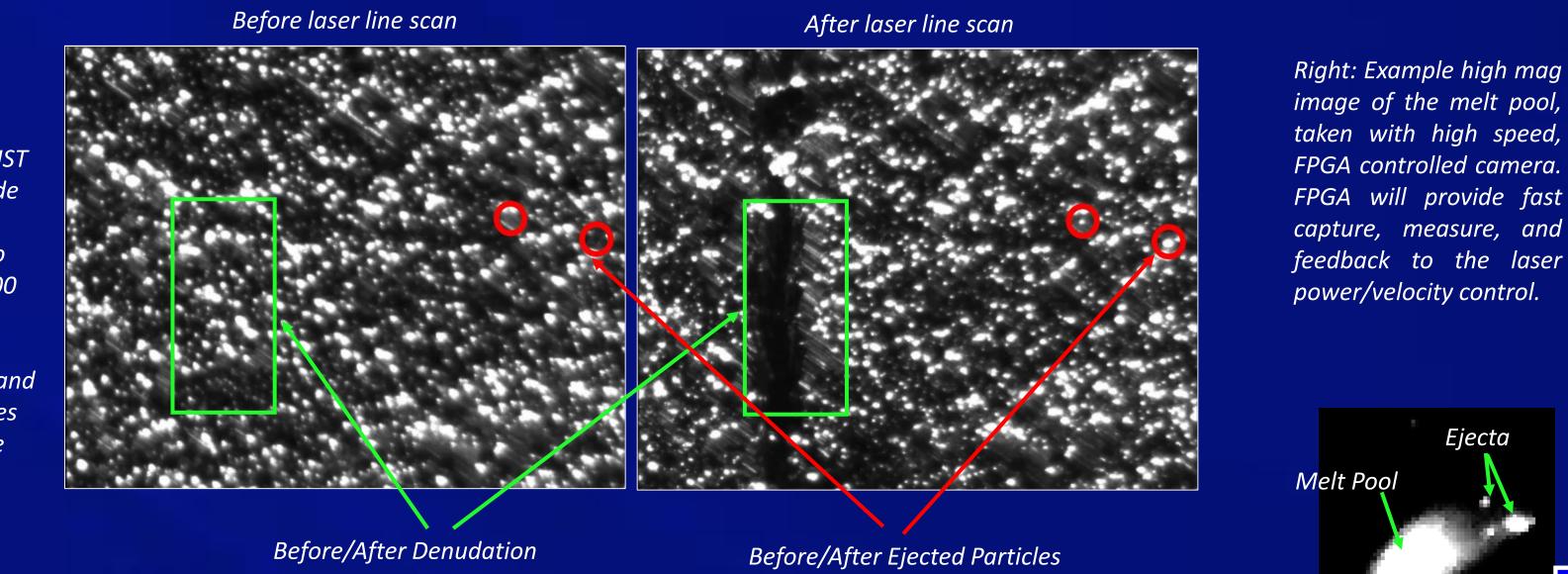
 Provides example of open-source control to promote LPBF controller standardization. 30 mm



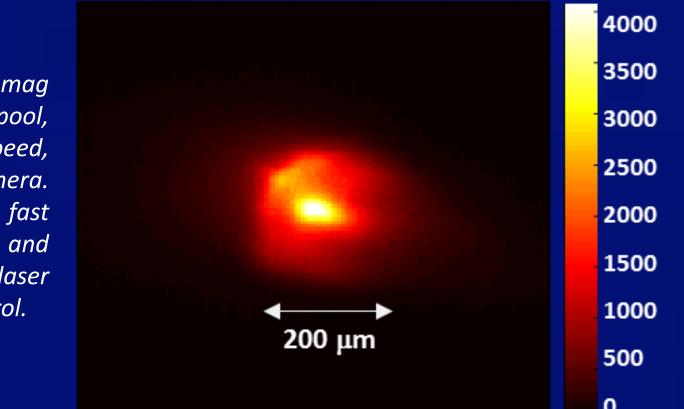
*Constant build speed - constant density mode,* Continuous path - constant power 600 mm/s, 225 W maximum laser power mode, 200 mm/s, at 75 W laser power High magnification of powder layer enables study of phenomena such as enable research in melt pool feedback control, and denudation or particle ejecta.

potentially provide melt pool temperature values.





Images taken before(left) and after (right) deposition of a scan line on a single 20 µm layer of stainless steel powder, which show material ejection and denuding of powder highlighted in green and red, respectively.





Example of particle ejecta phenomena captured at 50,000 frames/sec. These higher frequency phenomena may not be captured at lower frame rates or erroneously interpreted.