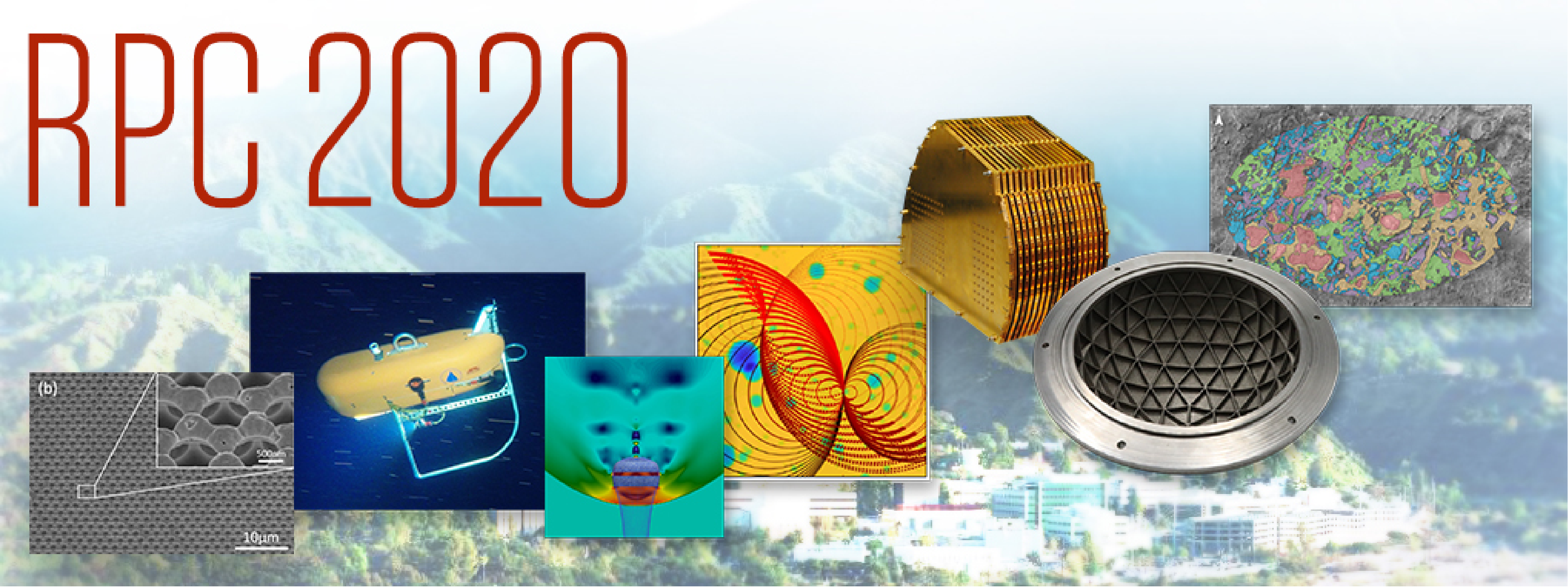

Virtual Research Presentation Conference

Adaptive Optics for Enhanced Laser Control in Powder Bed Additive Manufacturing

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Program: SURP

Assigned Presentation #RPC-167

Jet Propulsion Laboratory
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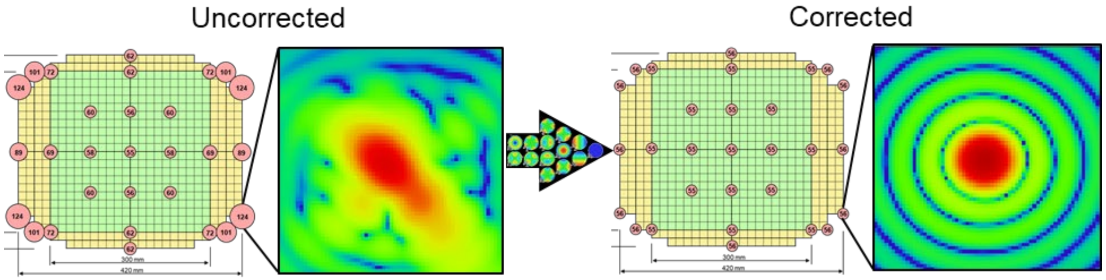
Tutorial Introduction

Abstract

Additive manufacturing optics chains consist of x/y positioning mirrors to raster the laser and an F-Theta lens to change the focal sphere onto build tray's plane. However, these systems do not correct for laser distortion when pointing off-axis. Previously, at JPL, we have shown adding an Adaptive Optics system eliminates this problem and provides diffraction-limited performance for >500% more area than existing systems. Professor Rollett's group at CMU are world leaders in modeling, in-situ measurements, and custom tuning of additive processes, and are an ideal partner to extend our simulations and transform them to a working system.



Problem Description

a) Context (Why this problem and why now)

- a) Additive manufacturing is becoming an integral part of manufacturing next-generation instruments and spacecraft
- b) Parts are often limited by printer size or resolution
- c) Large format printers sacrifice resolution for scale, small format printers get exceedingly high resolutions but very small volumes.
- d) Techniques have been developed to directly study the melt pool

b) SOA (Comparison or advancement over current state-of-the-art)

- a) F-theta lens currently creates a flat focal plane across the entire build tray
- b) F-theta lens does not correct for off-axis laser aberrations
- c) Adaptive optics solution can correct for both focal plane and off-axis errors, keeping laser power density constant across the entire build tray

c) Relevance to NASA and JPL (Impact on current or future programs)

- a) Increase the availability of large format powder bed metal additive machines
- b) Increase knowledge of laser/powder interactions to enhance predictive simulations of build processes
- c) Develop custom scanning parameters or scanning techniques with additional beam geometry freedom offered by adaptive optics systems

Methodology

a) Formulation, theory or experiment description
   a) All previous measurements of melt pool dynamics at beamlines were done on-axis to provide optimized interactions between powder bed, melt pool, and incident laser
   b) This project will:
      a) Create a highly off-axis beam set to the correct focal plane to simulate the corner of a powder AM build plate.
      b) Perform single line scans across a packed powder bed to mimic the printing process
      c) Use high intensity x-rays generated by the Advanced Photon Source to do high speed x-ray imaging of the melt pool
      d) Insert an adaptive optics system in-line with the laser to demonstrate its ability to correct aberrations

b) Innovation, advancement
   a) Demonstrate a source of known, but not well understood, issues when printing near the edge of a build plate
   b) Quantify the types of defects seen in the melt pool when printing off-axis
   c) Provide training data for melt pool simulations which incorporate laser/powder interactions
   d) Lead to methods of compensating for beam error with non-adaptive optics systems
   e) Underline the need for improved optics systems for high precision AM systems

Results

a) Accomplishments versus goals
   a) Took over six months to get on contract due to CMU and JPL confusion over ITAR/EAR concerns
   b) Student has begun work creating a test fixture for use
   c) Created a multi-center collaboration between JPL, Carnegie Mellon University, GE Research, and Argonne National Labs

b) Significance
   a) Should have beam time in early ‘21 to perform measurements at the Advanced Photon Source at Argonne National Labs

c) Next steps
   a) Pursue secondary SURP follow-on for additional years of funding to enable a student to build an actual AO system for integration into an AM testbed and integrate findings with models being developed by Prof Rollett’s group at CMU
   b) If results are promising Lawrence Livermore National Labs has a well funded group studying non-Gaussian beam geometries for use in AM. Multi-center collaboration could be expanded to include them, or possibly seek funding from DoE to develop an AO system for integration into an additive manufacturing testbed system available at CMU

Publications and References

None.