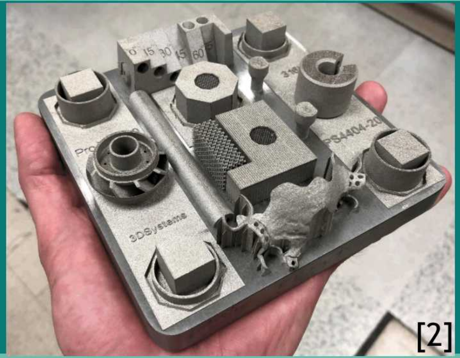
SAND2019-9526C

High Rate Monitoring of Laser Motion and Melt Pool Dynamics During Laser-Powder Bed Fusion



PRESENTED BY

Matthew Roach

B. Jared, D. Saiz, A. Nassar (Penn State), J. Blecher (3DS)

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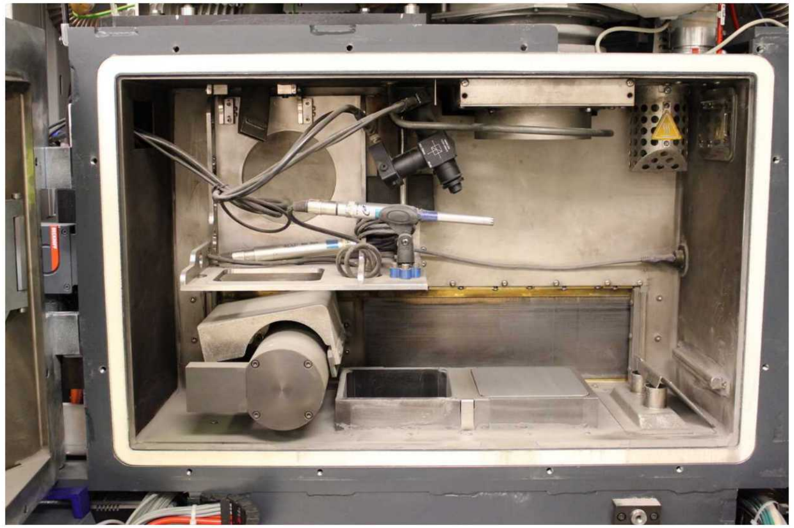
[1] Design by UT-Austin, [2] Design by 3D Systems

Overview

Goal: To identify normal and abnormal process conditions of laser powder bed fusion by monitoring machine signals and melt pool dynamics.

Process: Collect high rate signals from printer. Analyze signals for potential errors. Verify through physical analysis. Line scans to area scans to volumes.

Equipment: Modified 3D Systems ProX 200 3D printer, MATLAB, Keyence Metrology equipment (VK-X100)

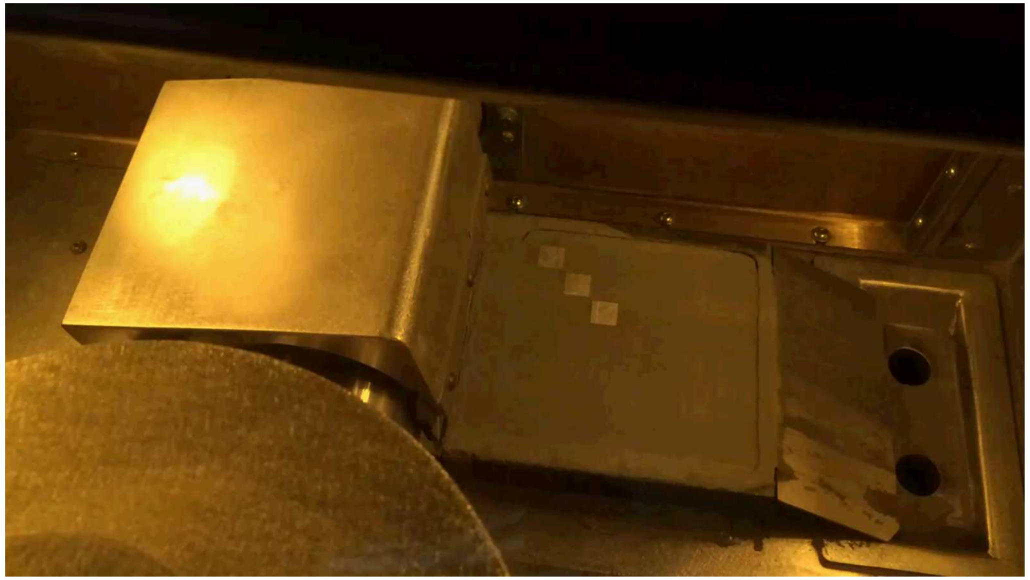


ProX 200 Build Chamber

MATLAB®

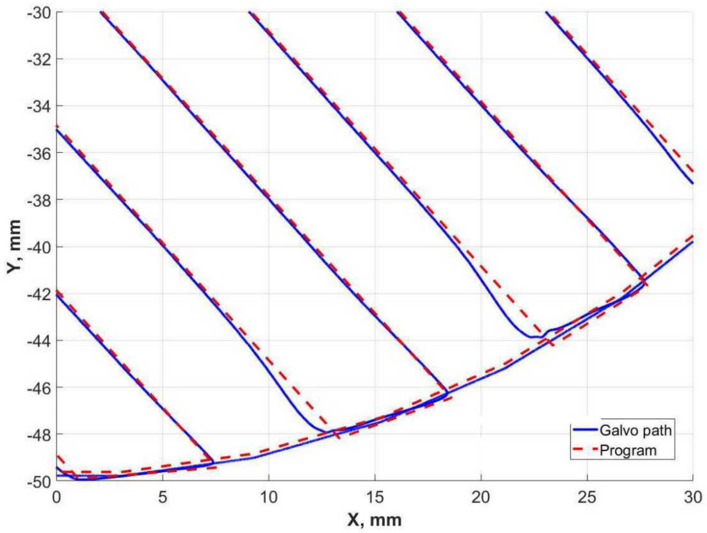
Keyence VK-X100

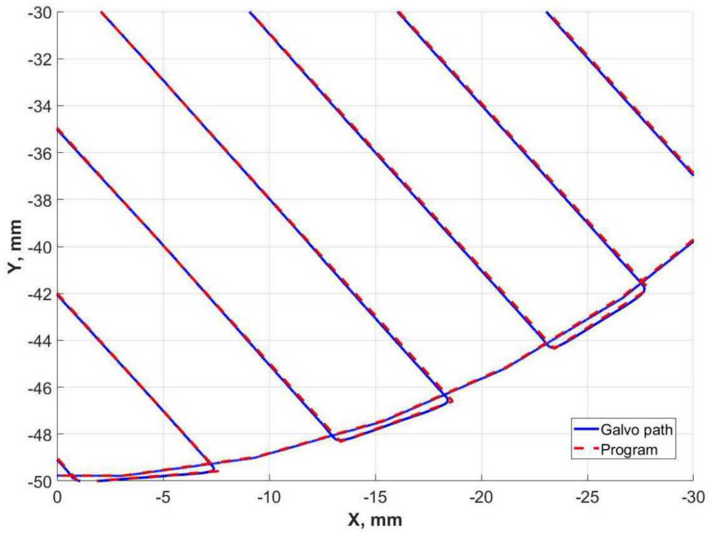
Introduction

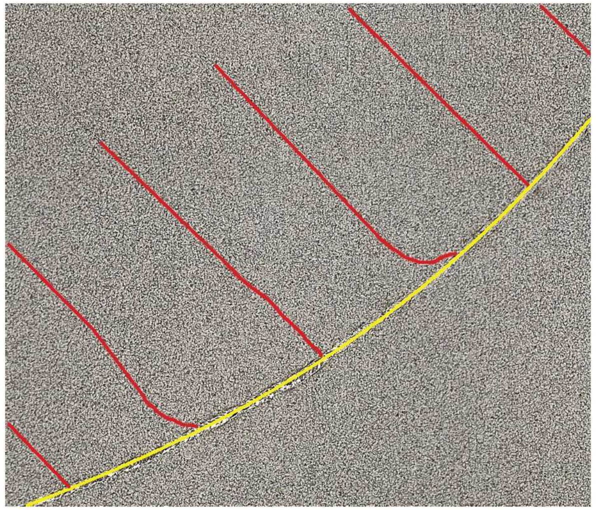


Possible failure modes
- Part deformation
- Short feeding
- Voids
- Laser galvo malfunction (investigating)

Initial Results:







ProX 200 Modifications

ARCS (Archive, Research, Control, Synchronization) System

- Laser motion

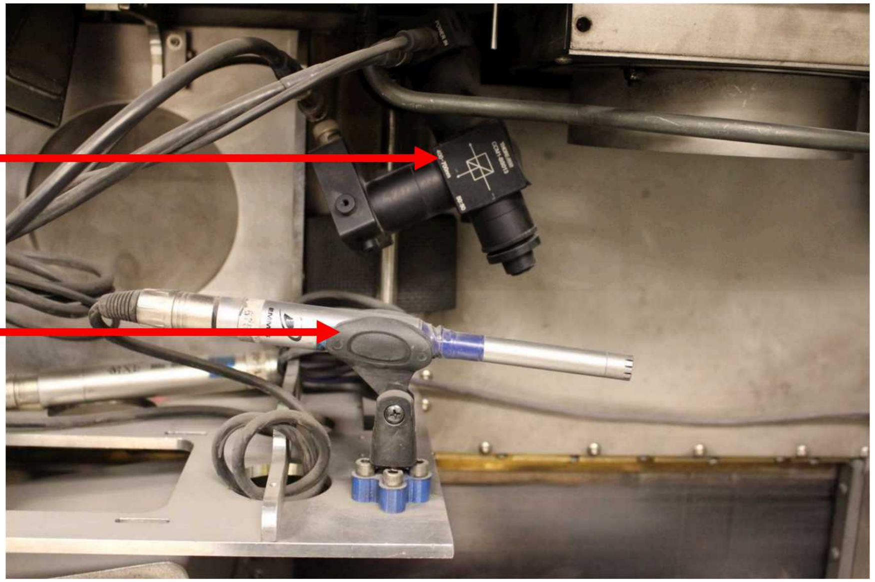
Two spectral sensors (520 nm & 530 nm)

- Melt pool

Microphone

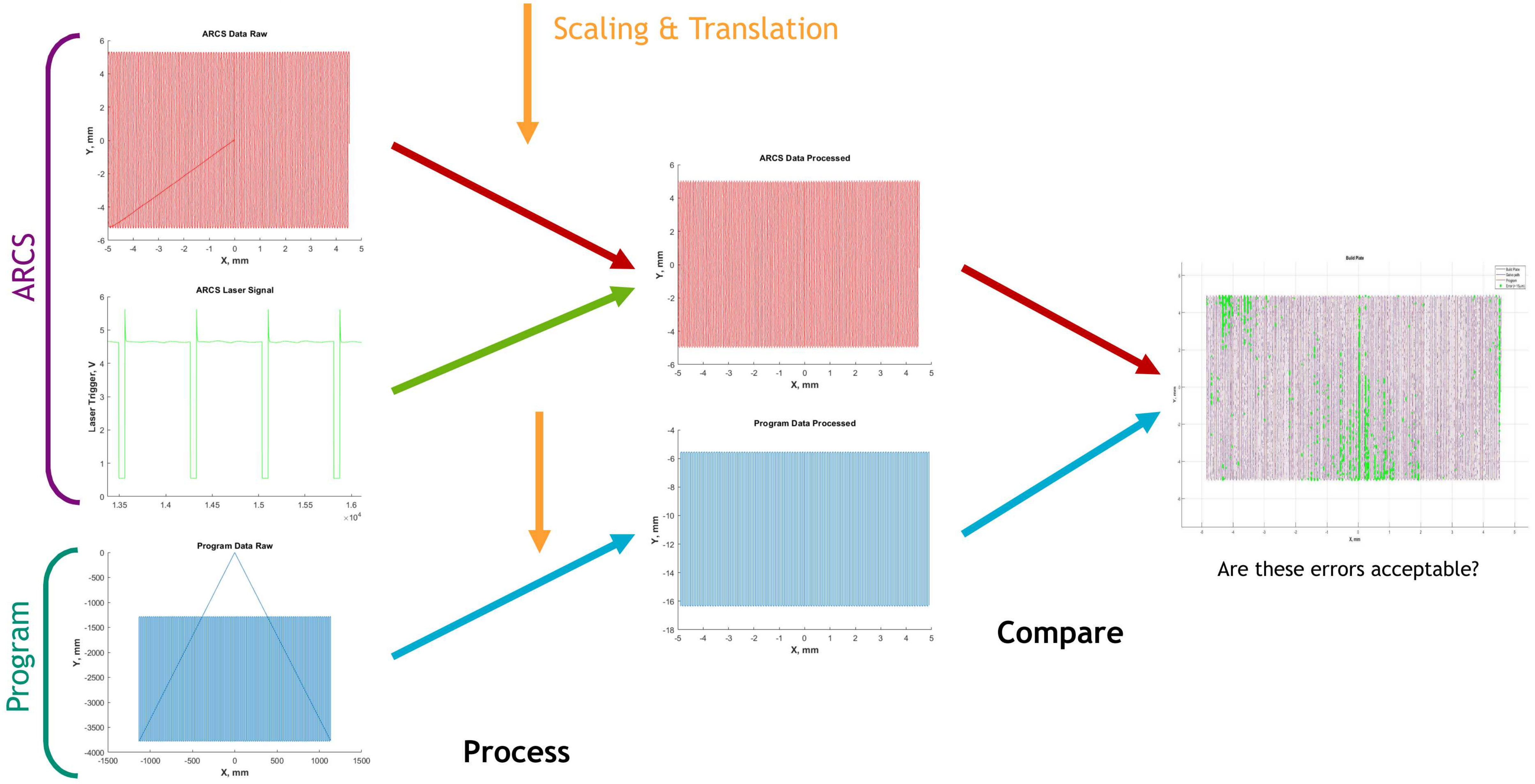
3D SYSTEMS

PennState Applied Research Laboratory



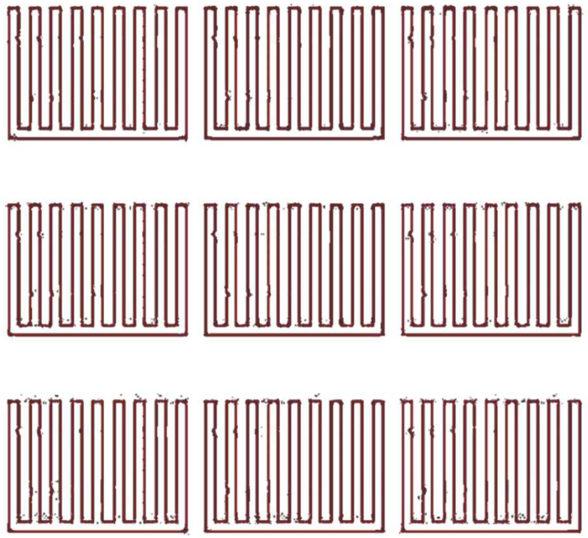
ProX 200 Modification, Spectral & Microphone

Data Analysis



Are these errors acceptable?

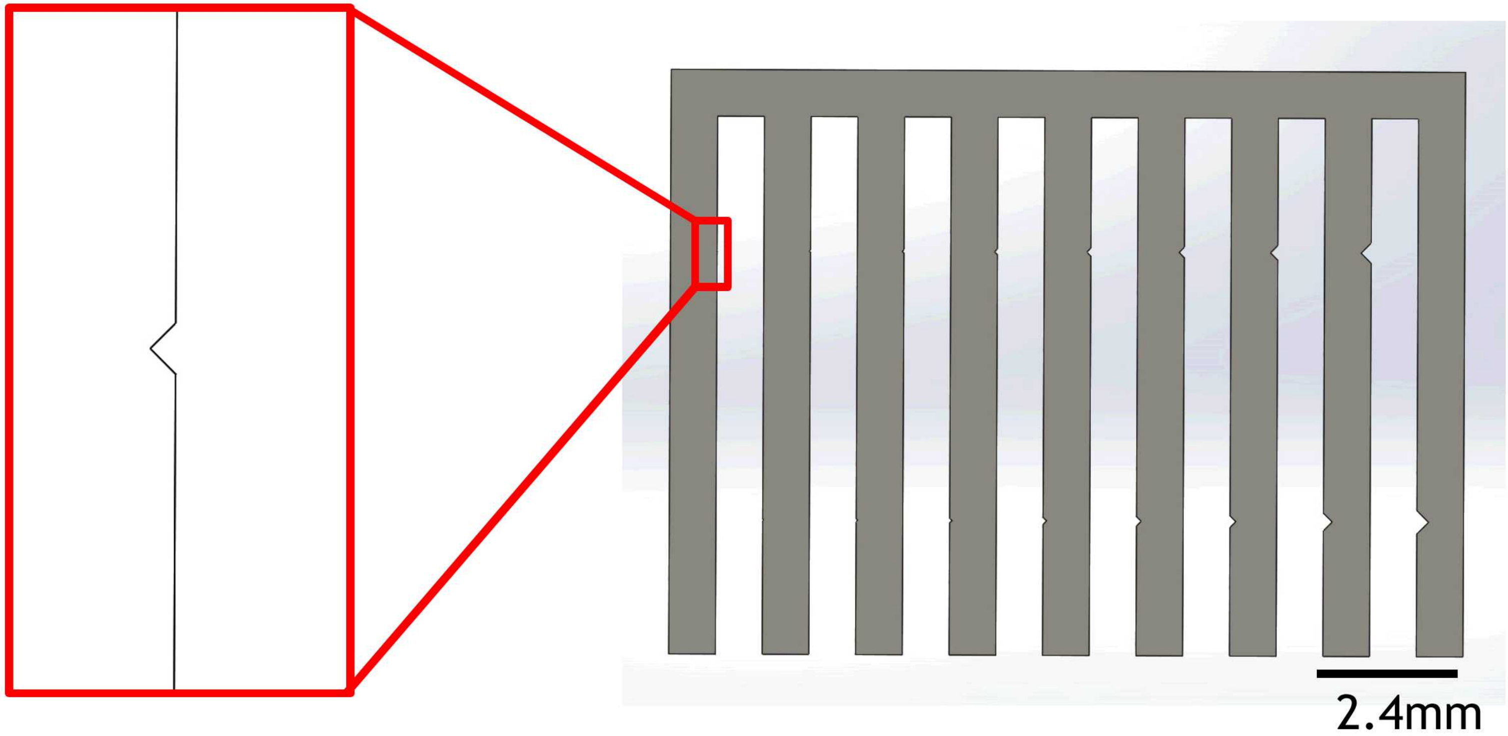
Experiment- Line Scans with Induced Defects

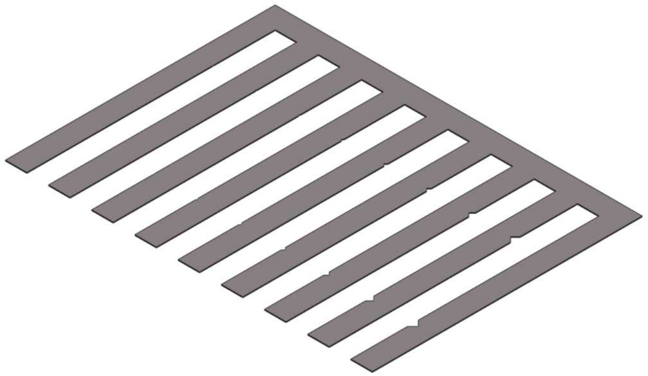


Why? ARCS resolution and validation

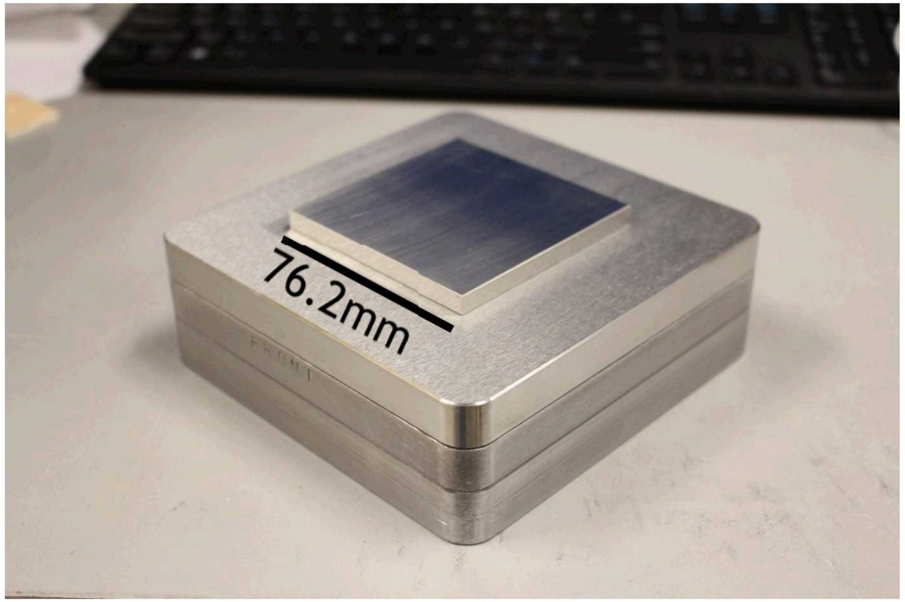
Define laser path through solid geometry outline

10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200 um





Experiment Setup

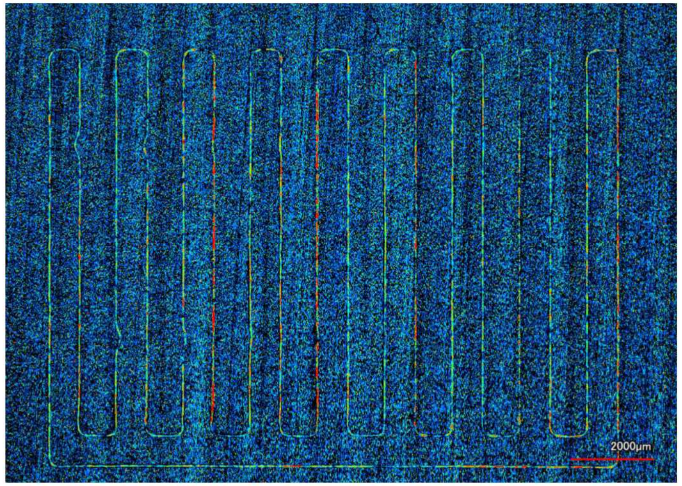


Build plate has ground pattern, hard to see single laser path

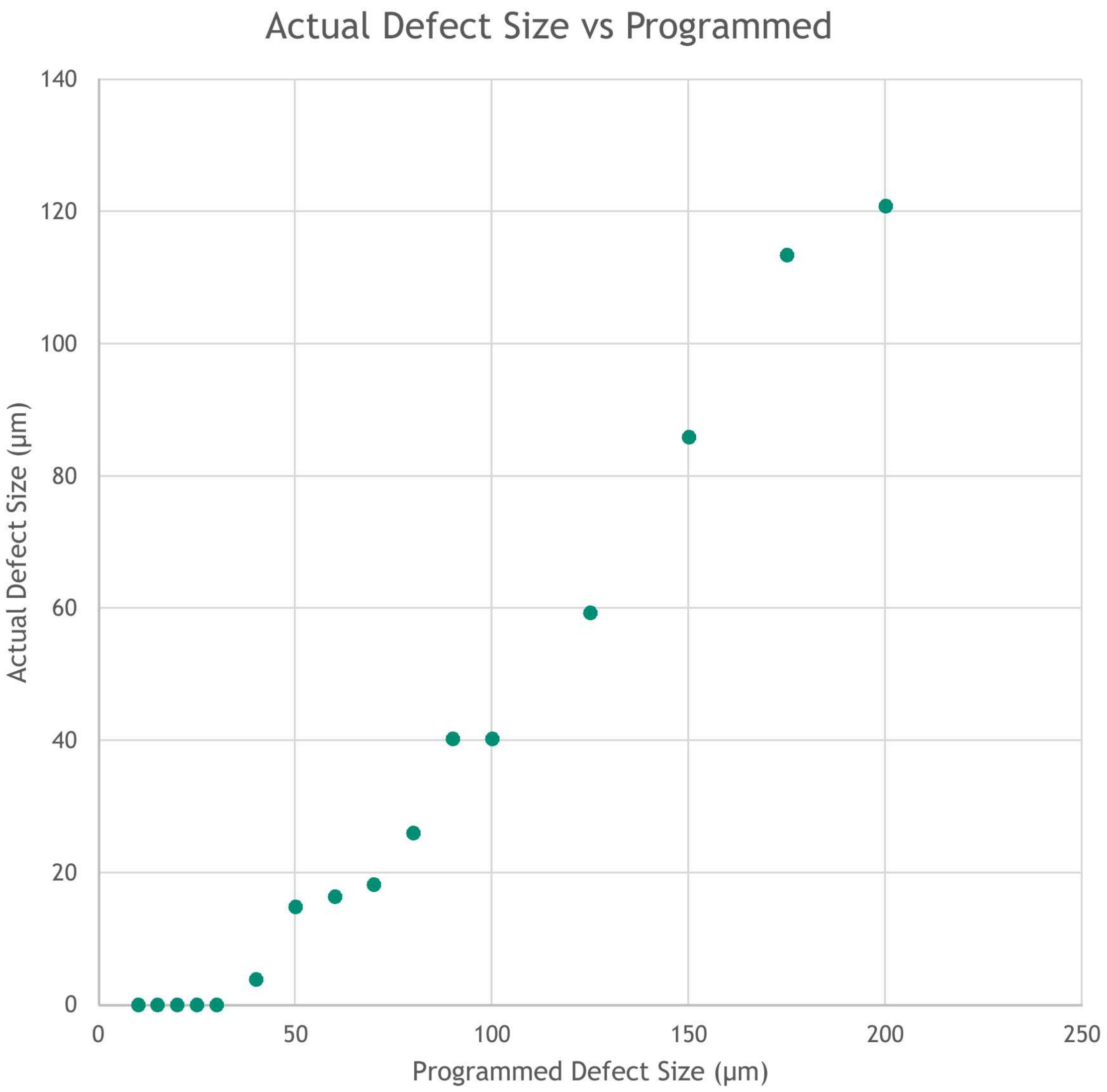
Flat 316L SS plate adhered to build plate, then laser fired

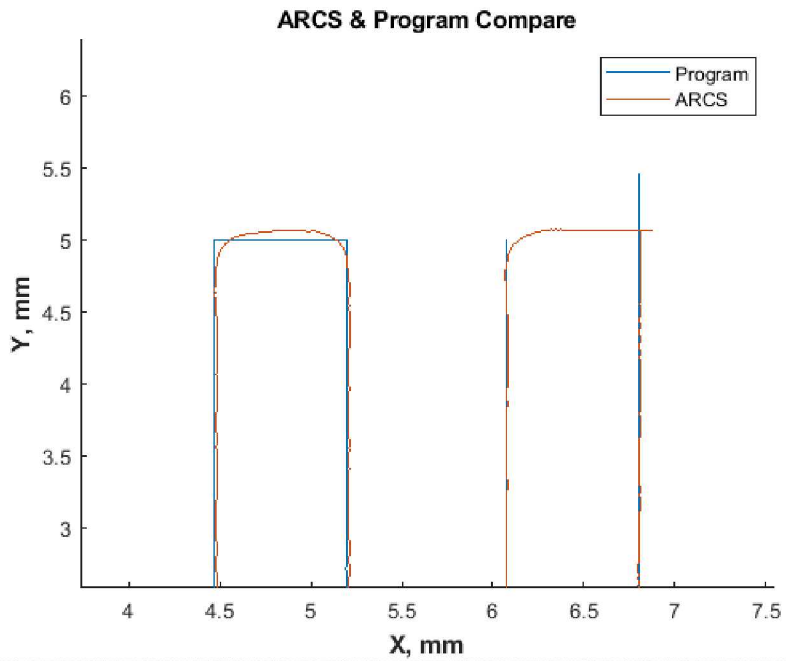
ARCS data collected

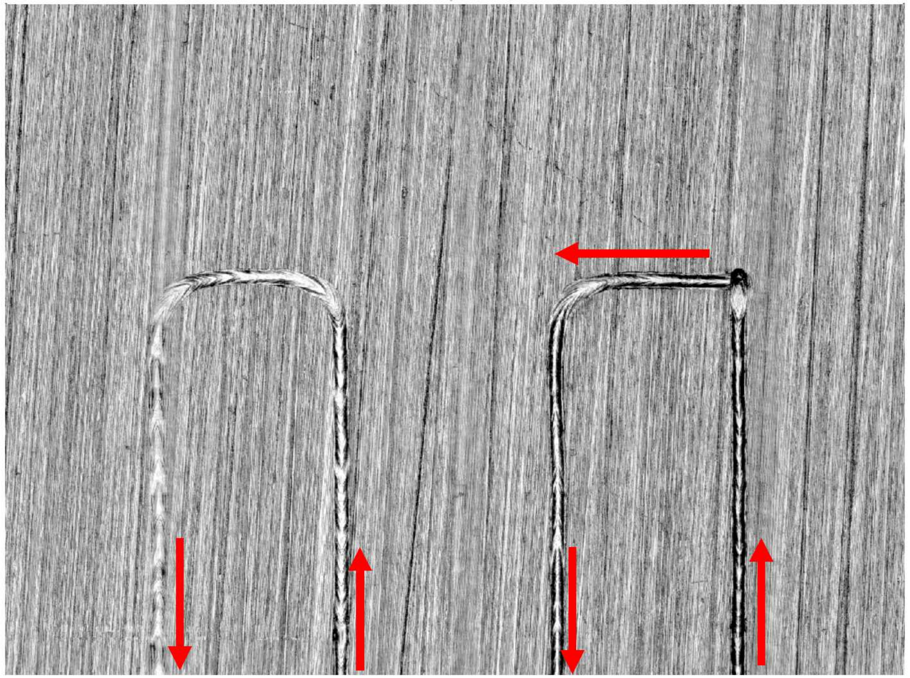
Plate imaged on Keyence VK-X100 3D Laser Scanning Microscope



Results- Line Scans

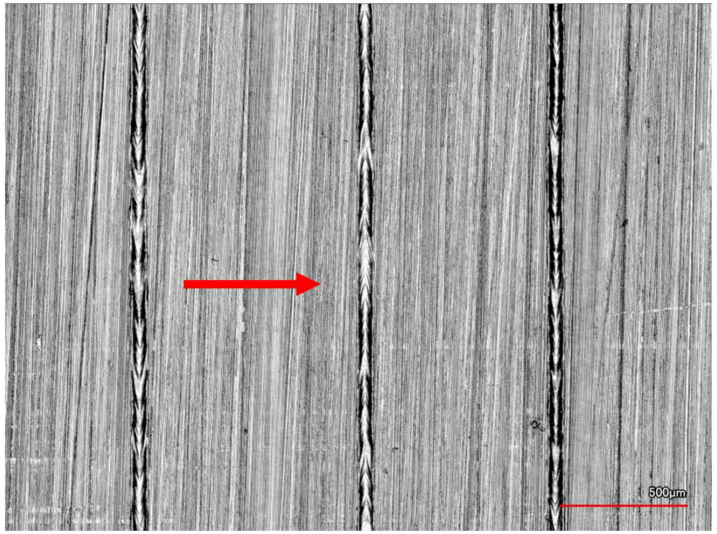


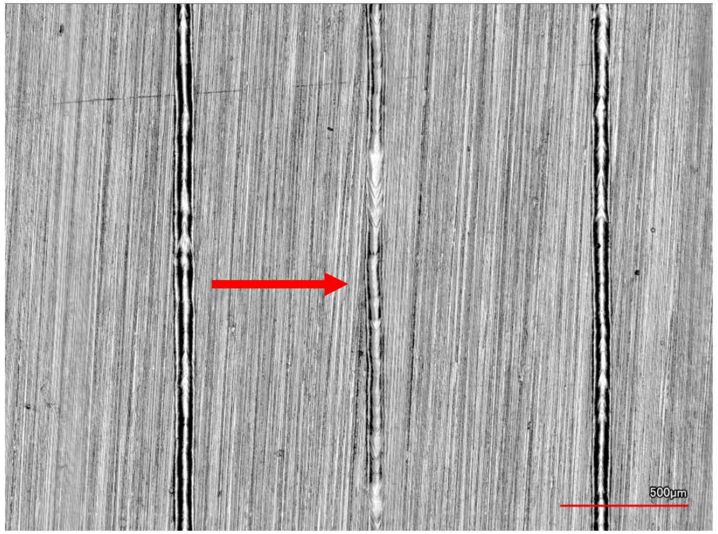


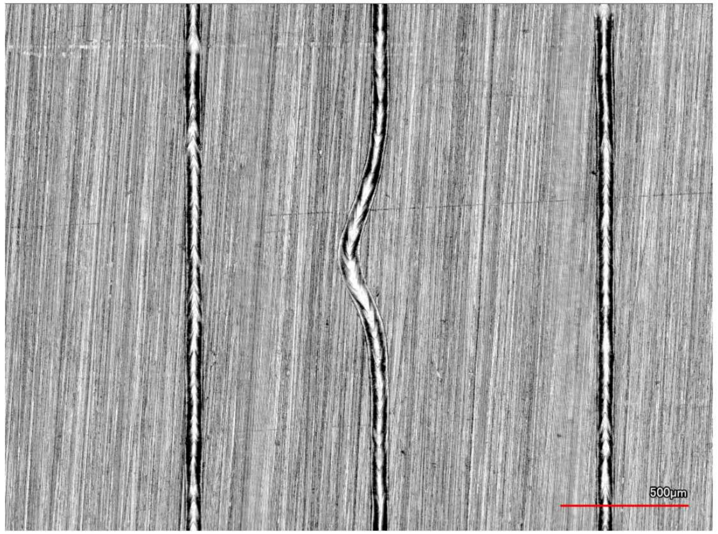


Results- Line Scans

Smallest Visible Defect



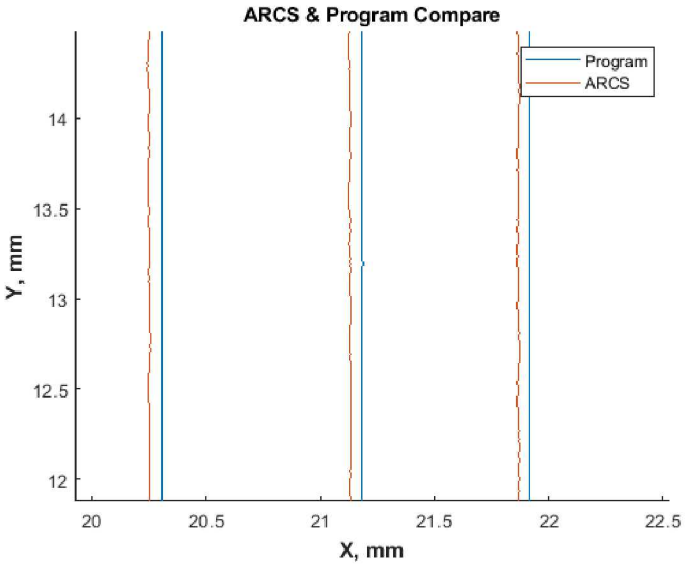


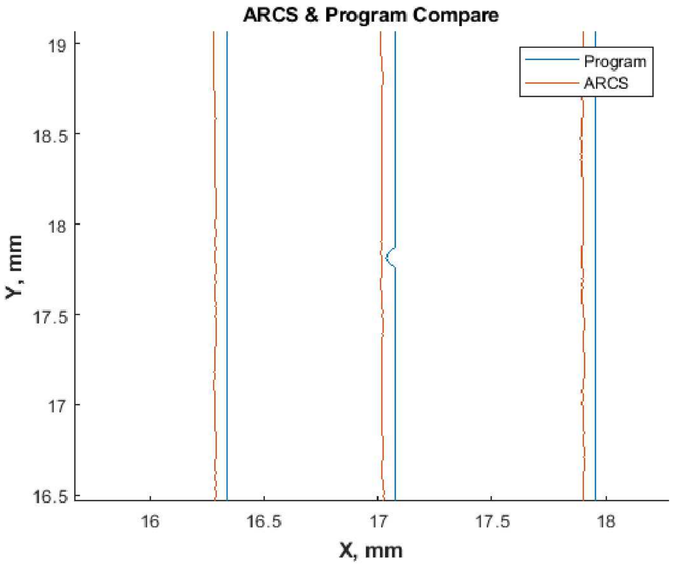


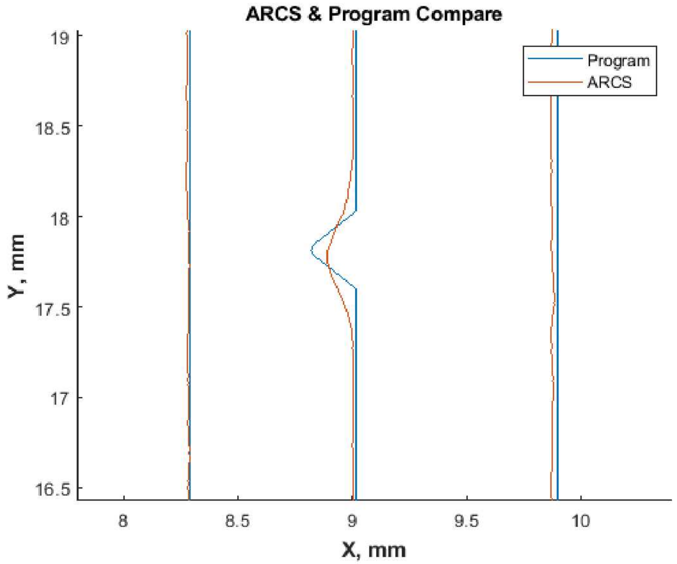
10µm

40µm

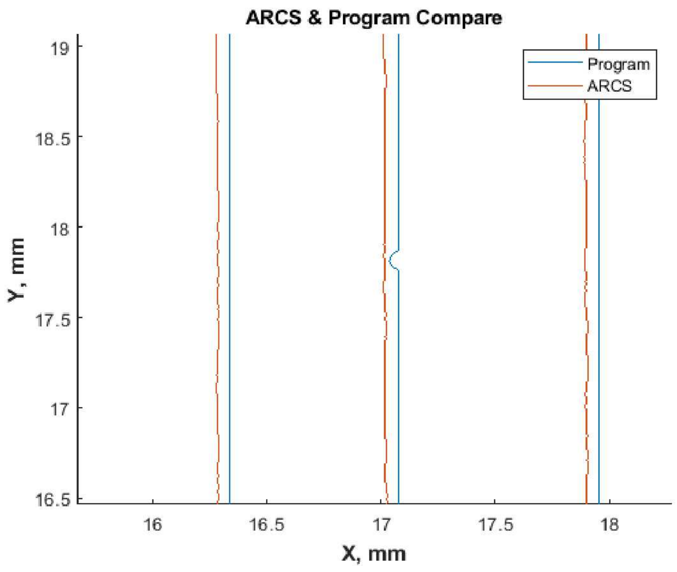
200µm

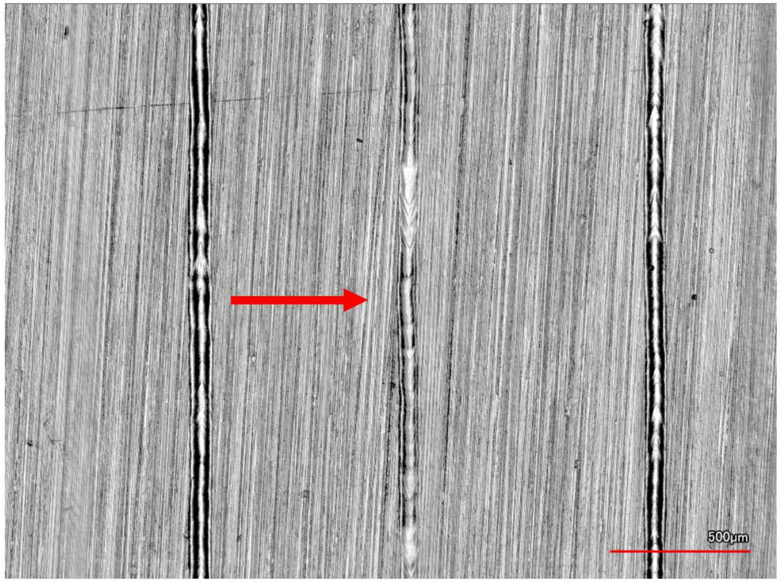




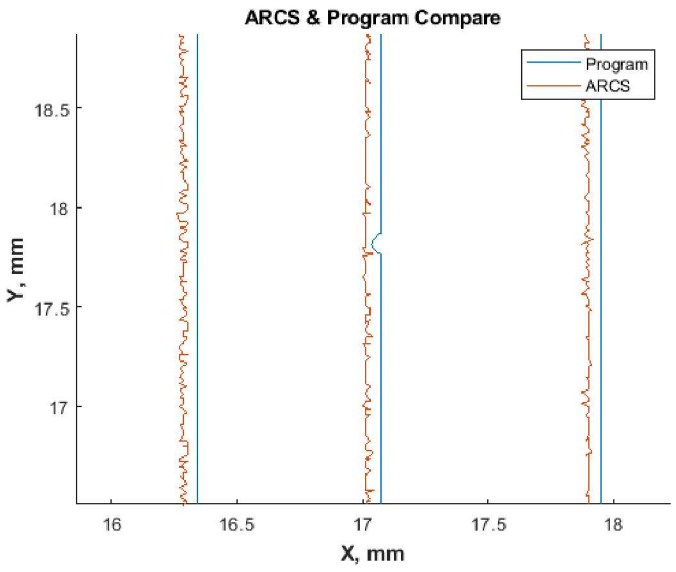


Results- Line Scans





40µm

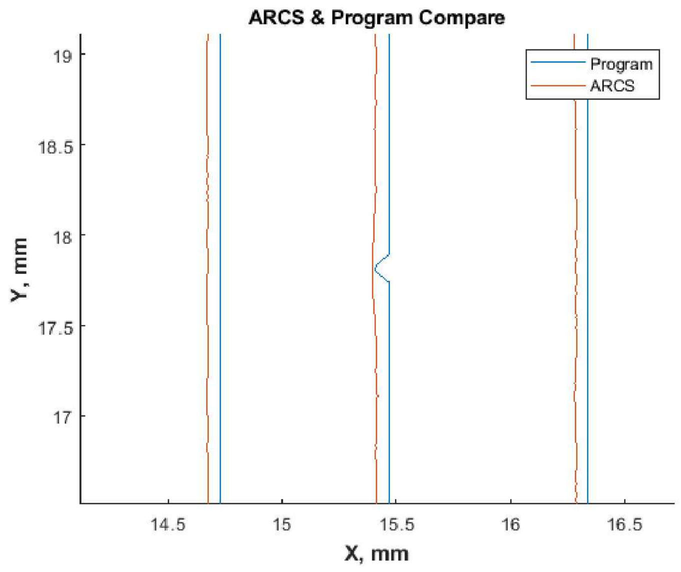


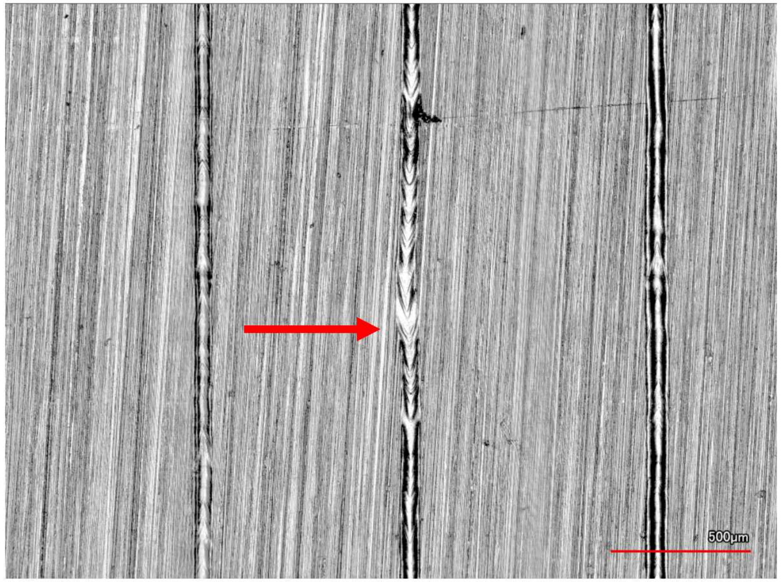
Smoothed Data

Raw Data

ARCS Resolution

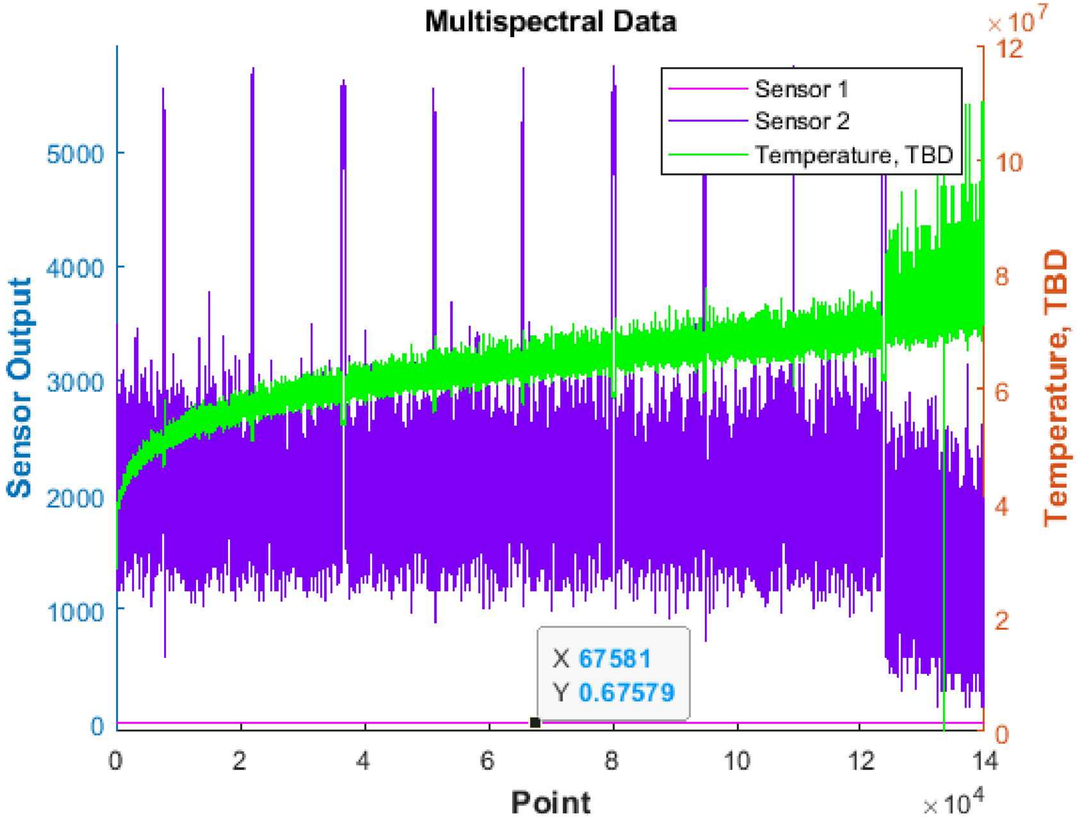
Smallest Detectable Laser Deviation

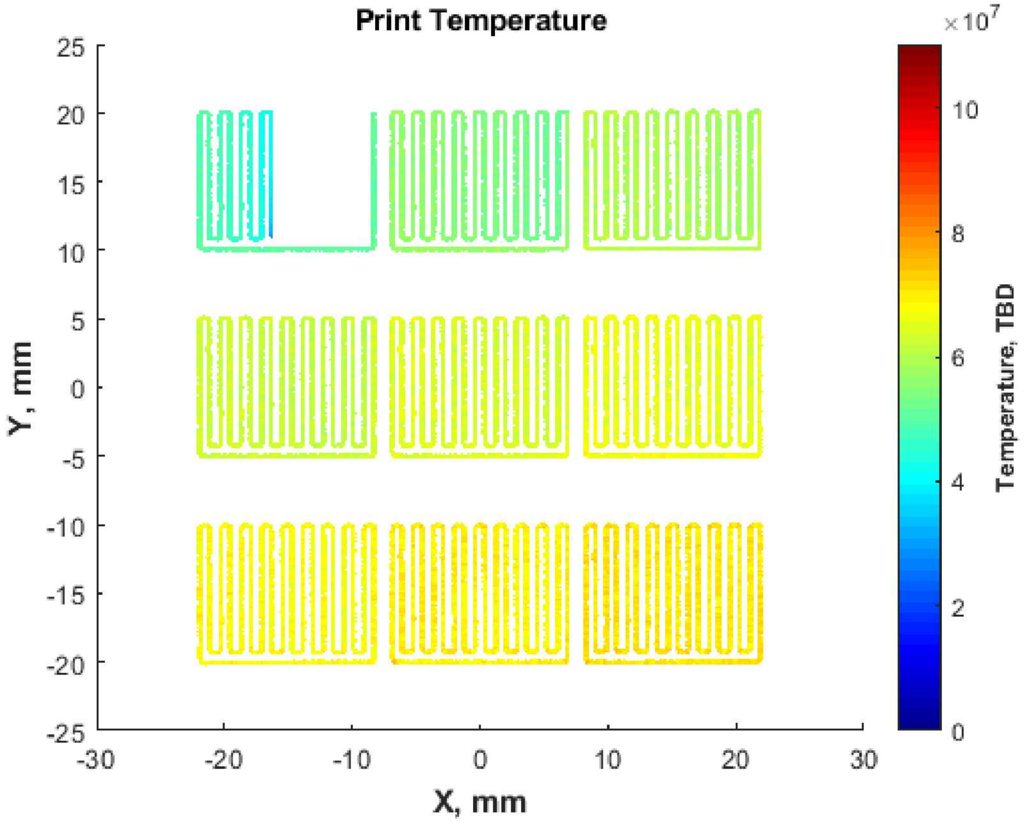




60μm (ARCS Resolution)

Results- Line Scans





$$T_s = \frac{c_2(\lambda_2 - \lambda_1)}{\lambda_1\lambda_2(\ln\frac{s_2 k_1}{s_1 k_2} + 5\ln\frac{\lambda_2}{\lambda_1})}$$

T_s- Surface temperature (melt pool temp)
$s_{1,2}$- Output signals
$k_{1,2}$- Proportionality constants (Requires calibration)
$\lambda_{1,2}$- Detector wavelengths (520 nm & 530 nm)
c_2- Radiation constant (1.4388 x 10^4 μm K)

[1] Araújo, A., Multi-spectral pyrometry—a review. Measurement Science and Technology, 2017. 28(8): p. 082002.

Conclusion / Future Work

ARCS implemented
- Laser galvo tracking demonstrated
- Perturbations observed

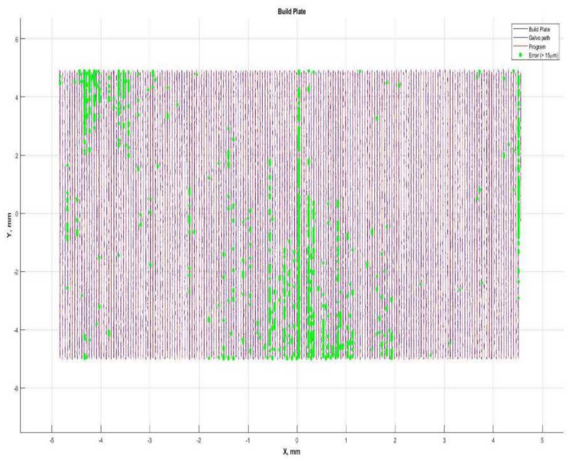
Exploring detection tolerances
- What can be seen?
- Mechanical response is critical

Useful to establish filter & data collection threshold
- when will galvo error motion impact part / material
- what data must we collect / archive / document

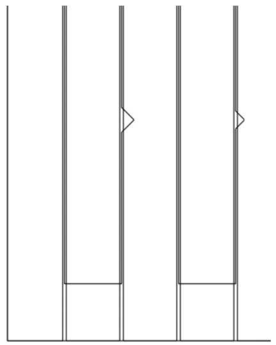
Validation of AM parts

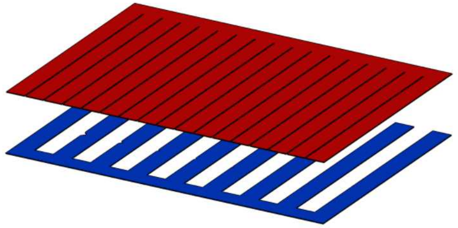
Potential for material structures

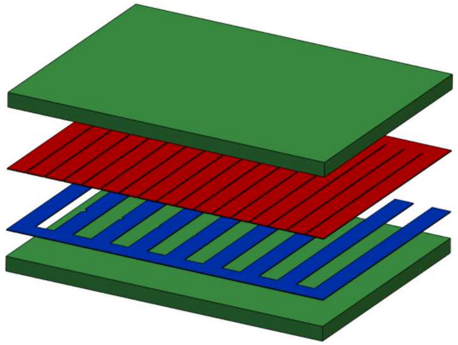
Area scans and volume verification



Are these errors acceptable?
- Most likely yes
- Errors do not exceed 60μm







Questions?

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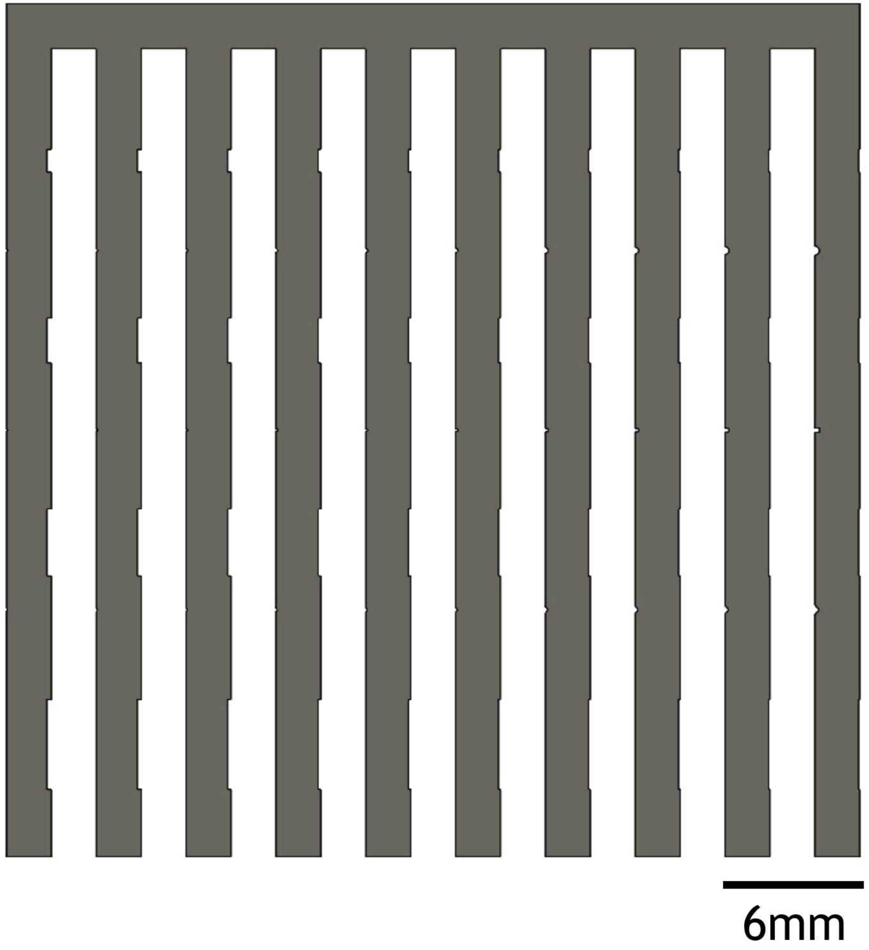
Experiment - Extended Notch and Shape Defects

Why? Investigate Mechanical Response of galvos

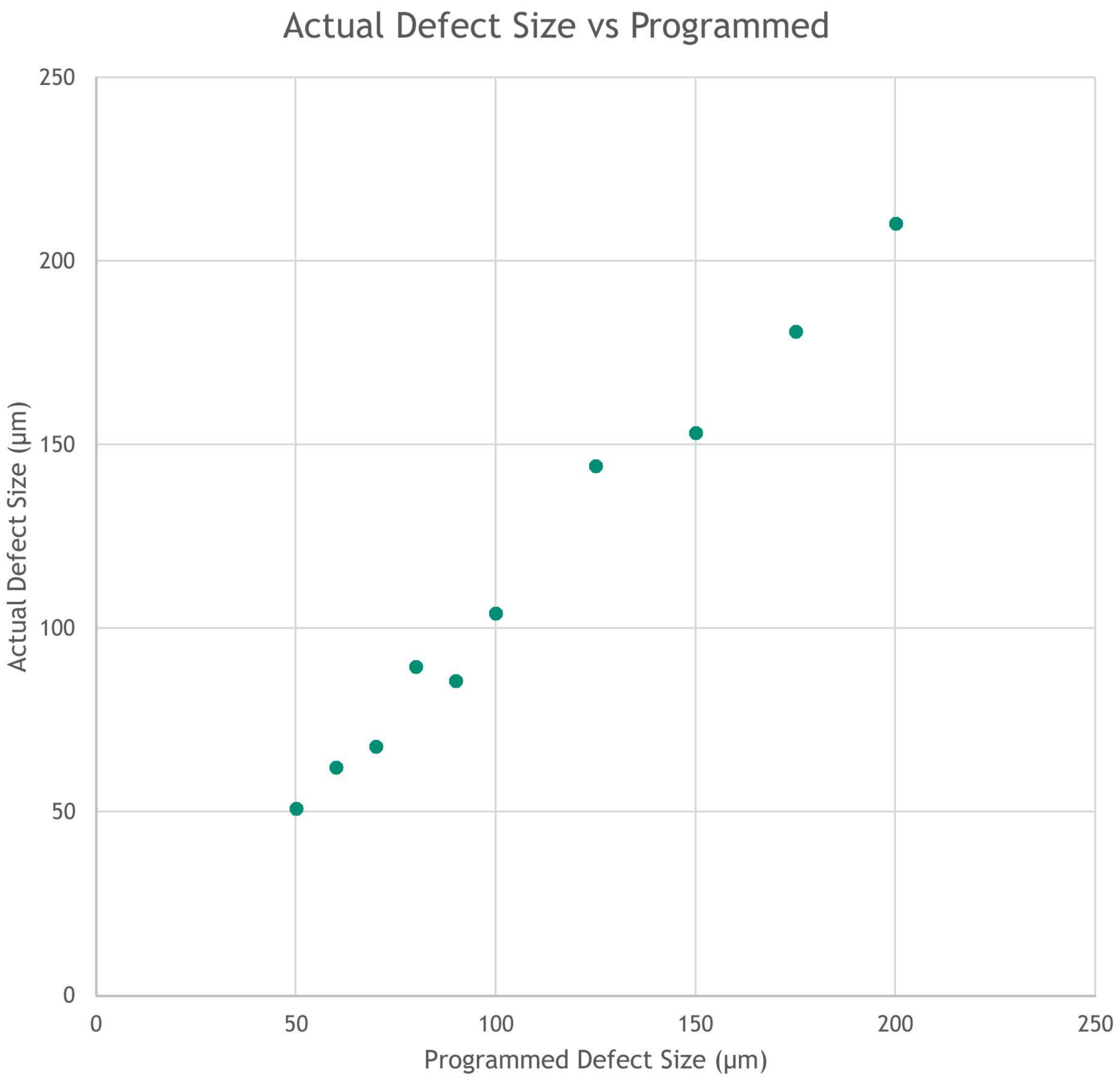
Define laser path through solid geometry outline. Both shapes and extended notches.

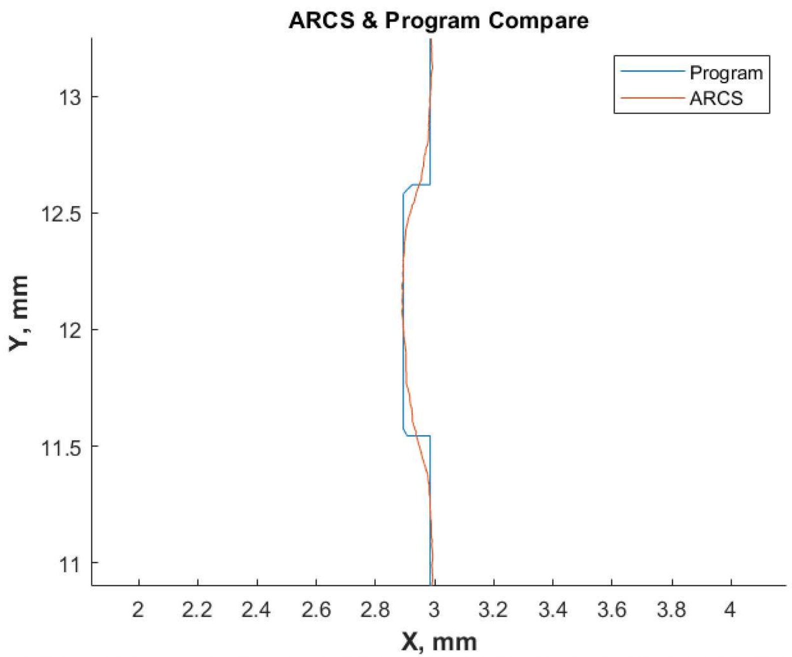
- 1, 2, 3, 4 mm extended notches
- Circle, square, and triangle defects

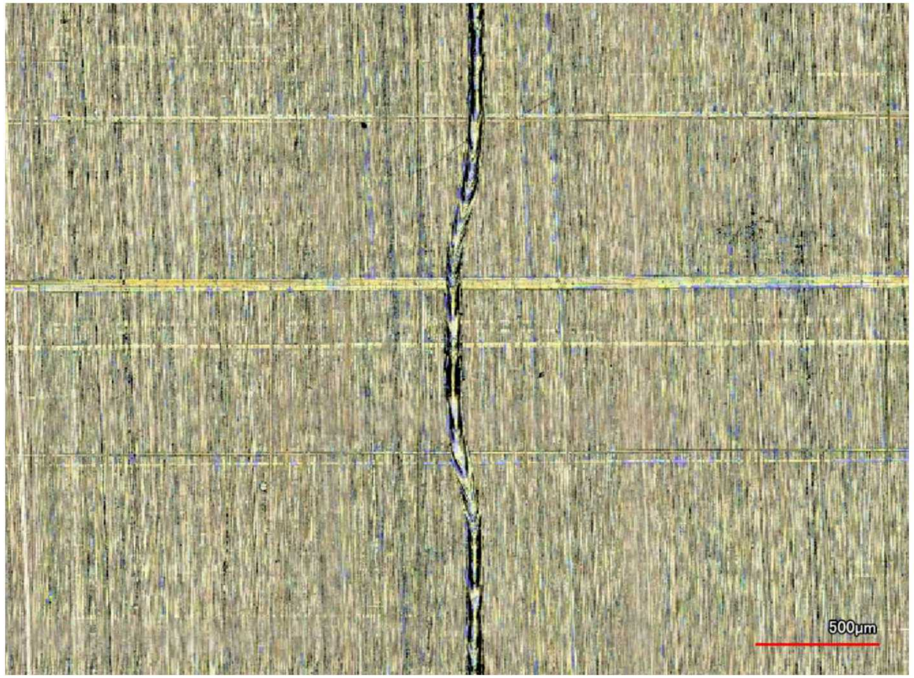
50, 60, 70, 80, 90, 100, 125, 150, 175, 200 um



Extended Notch Defect





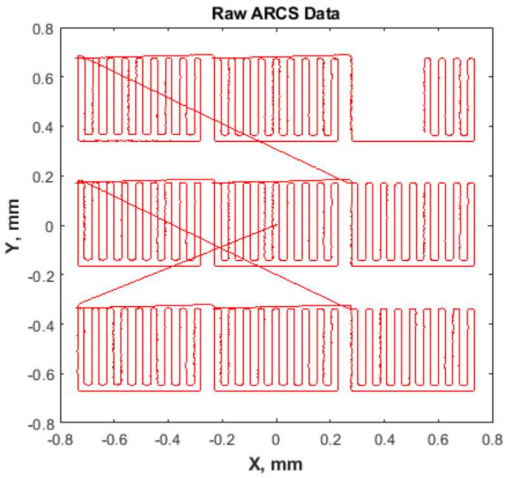


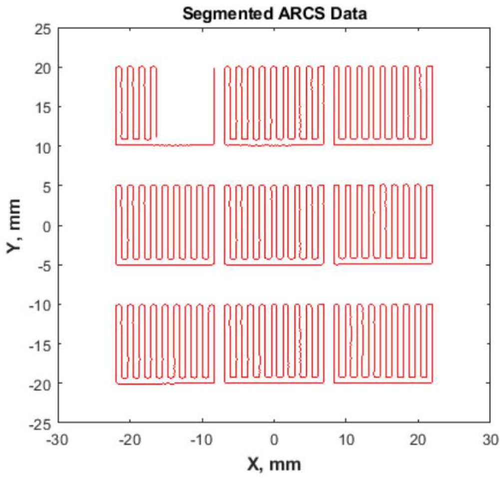
Data Analysis Setup

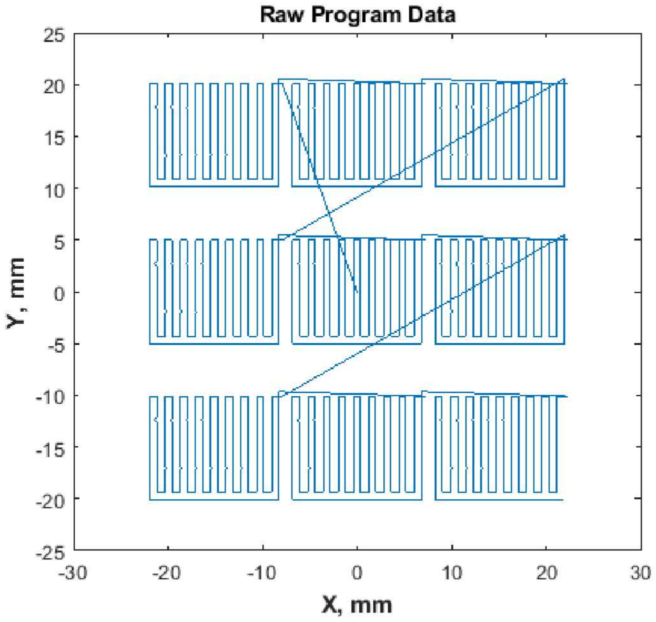
Program data used to determine lines of laser firing and interpolating scan path.

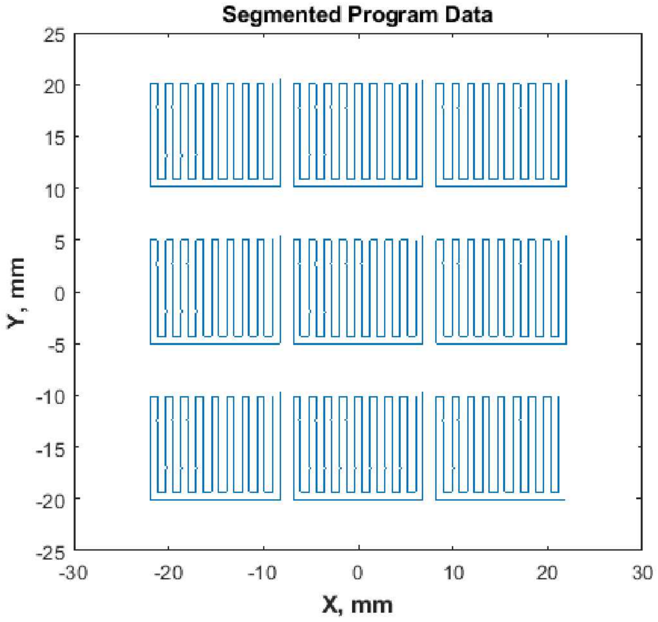
ARCS data segmented to laser firing events

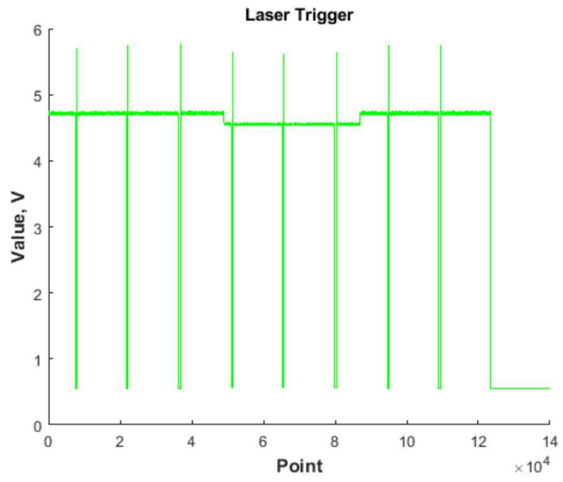
Grouping and correlating of ARCS data to program data









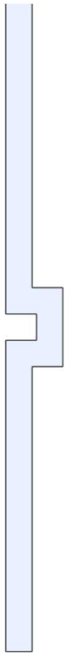


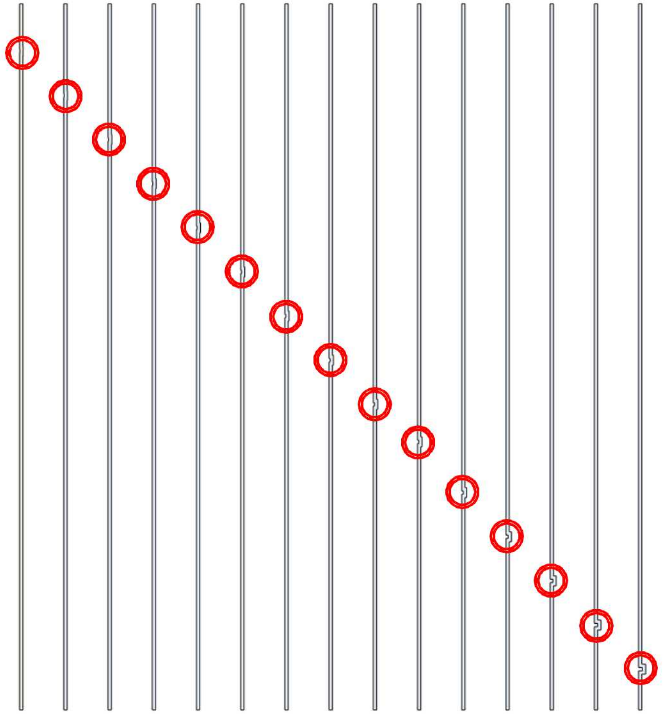
Experiment- Line Scans (Method 1)

Define laser path through solid geometry

Introduce defects of 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 75, 100, 125, 150, 175um

Why? ARCS resolution and validation



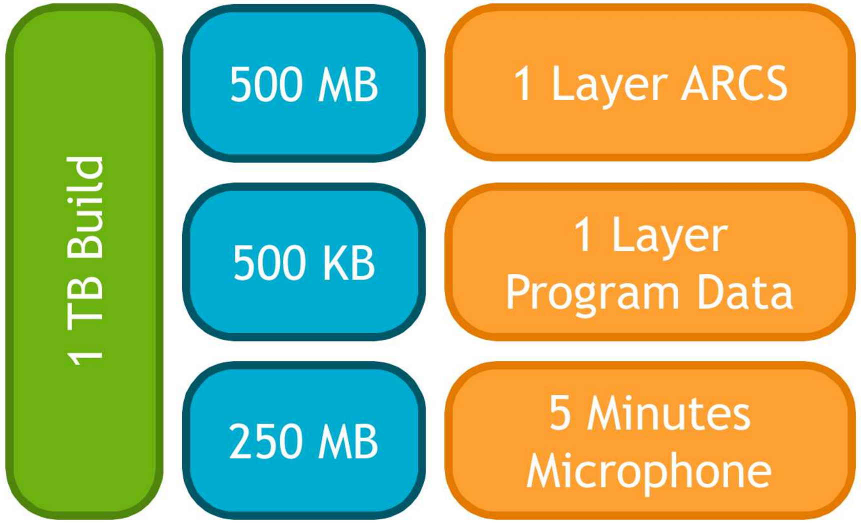


Data Management

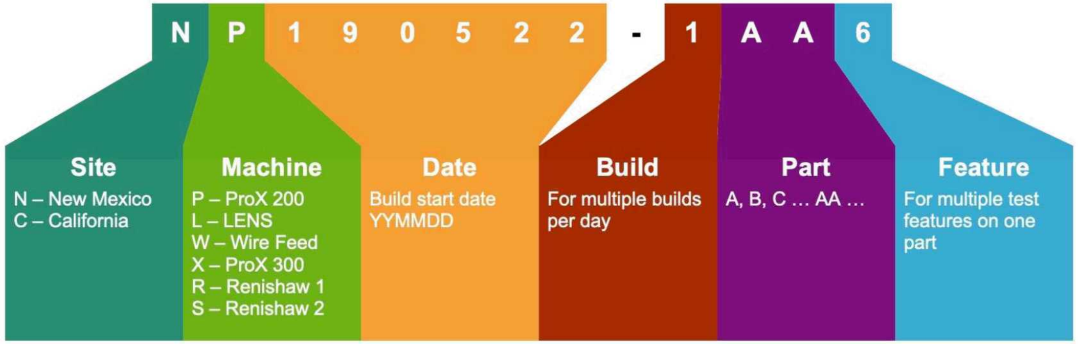
Large file sizes per build requiring transfer and storage.

Naming convention required for tracking and locating data.

Network drive



Sandia AM Naming Convention



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