Printed Targets with Micron-scale Feature Patterns for the Study of Ablator Defects

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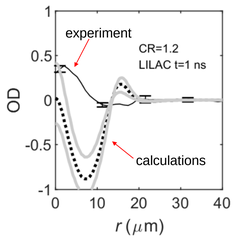
EXPERIMENTAL GOAL — STUDY ISOLATED DEFECTS AS A SOURCE OF IMPLOSION DEGREDATION

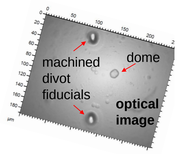
Motivation

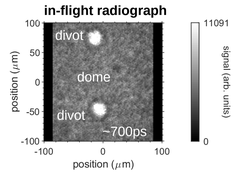
- Present models suggest laser imprint and implosion symmetry alone are insufficient to account for observed performance
- Need better data on ablator defects as a source of hydrodynamic instability and mix

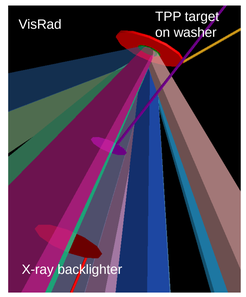
This Work (FY24)

- Defect growth comparison over laser intensities on OMEGA
- Need (1) repeatable targets and (2) a controlled variety of defects to glean more data from each shot
  - ➢ Requires "outside the box" target design and fabrication technique







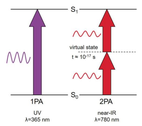


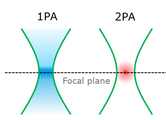
Previous Work (FY23)

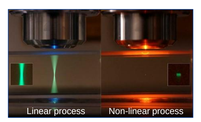
- Observed growth of intrinsic domes on GDP* shells
- Features varied substantially shot-to-shot

*GDP: glow discharge polymer (General Atomics)

FABRICATION METHOD — TWO-PHOTON POLYMERIZATION PRINTING WITH SUB-MICRON RESOLUTION





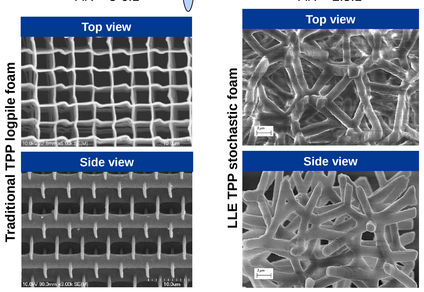


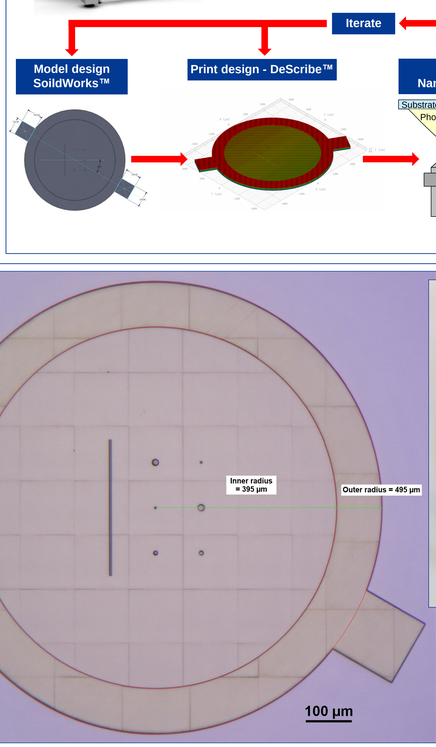
- 63x NA1.4 print optic
  - Pro – high resolution, low AR*
  - Con – small print field
  - ➢ Challenge: More stitching boundaries
- IP-Dip2 resin
  - Pro – high resolution, low Z
  - Con – shrinkage (5-10%)
  - ➢ Challenge: Stress deformation of high AR structures

25x NA0.8 Objective Print field Ø: 400 μm — Voxel: Axial resolution > 3 μm, AR ~ 5-6:1

VS.

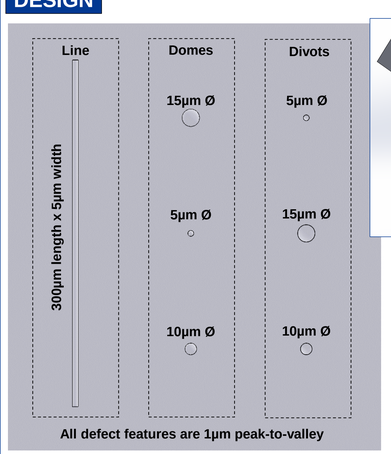
63x NA1.4 Objective Print field Ø: 200 μm — Voxel: Axial resolution < 1 μm, AR ~ 2.5:1



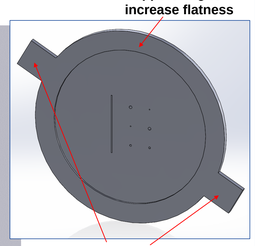


*AR: Aspect Ratio

DESIGN



All defect features are 1μm peak-to-valley



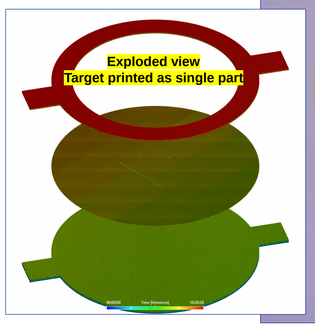
CAD model

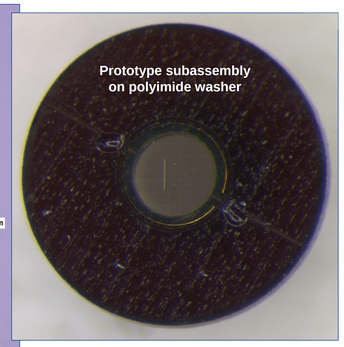
- Imported into printer software as STL
- Also imported into VisRad by PI for target fielding accuracy

PRINT

Print design

- 3 separately-processed sections to reduce print time
  - → Feature layer printed at highest resolution

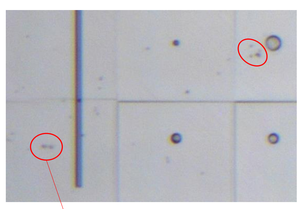




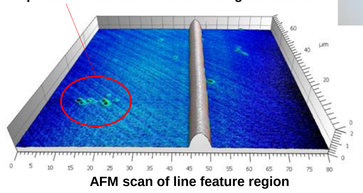
Stitching

- 120x120μm print blocks
- 1μm XY plane overlap
- Defects placed between seams

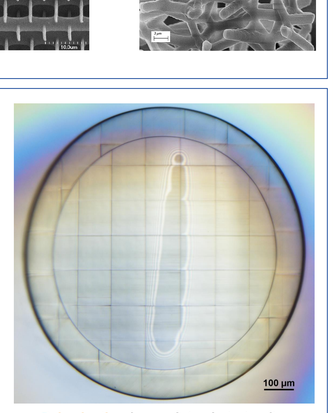
CHALLENGES



Overexposure microbubbles at surface, also present in the bulk → tune writing conditions



AFM scan of line feature region



Delamination from print substrate after post-processing → manage shrinkage-induced stress (optimize DoC*)

Print throughput → 8-10hr per target, expected to be 10-25x faster on next gen system

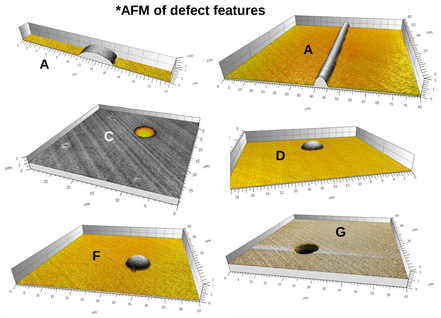
*DoC: Degree of Conversion (polymerization extent)

CHARACTERIZATION

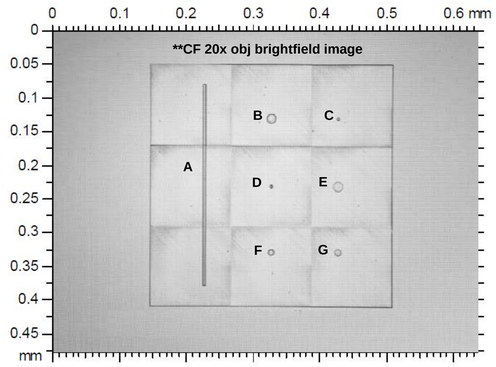
AFM scan conditions

- Probe velocity influences lateral measurements
- Scan direction influences p-v measurements
  - ➢ Tune both to reach agreement with Confocal

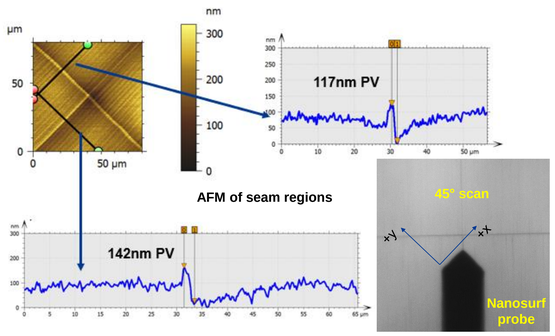
*AFM of defect features



360μm x 360μm sample for verification of feature layer print conditions



*AFM – Atomic Force Microscope, Nanosurf
**CF – Confocal Microscope, Leica



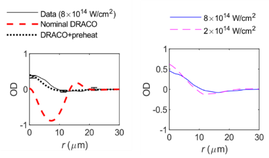
Results

- p-v < 150nm for representative vertical and horizontal seams
- Surface roughness < 50nm rms for non-seam regions
- Defect dimensions within 5-10% of design
  - ➢ Repeatability not quantified; qualified via optical images and shots

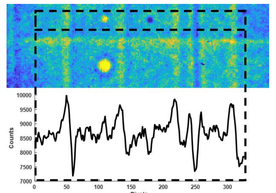
EXPERIMENTAL RESULTS & FUTURE WORK

Preliminary PI feedback

- Targets were highly repeatable
- Measurable, time-resolved x-ray signals for dome, divot and line features at high and low laser intensities
  - ➢ Many data points per shot!
- Placing features between stitching seams worked very well
- Stitching features also visible, primarily later in time



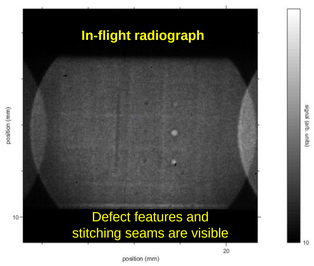
(a) Previous observation compared to nominal DRACO with and without preheat hypothesized to result from hot electrons. (b) Radiographs from recent experiment comparing low intensity and high intensity drive.



In radiographs, seams have a primary region of more x-rays next to a region with less, potentially indicating a region with lower mass adjacent to one with slightly higher mass, consistent with AFM scans

Next experiment

- Void features (2-4μm Ø) will replace line feature
  - ➢ TPP target design flexibility!
- Domes and divots will remain the same
- Void characterization via x-ray tomography
- Vary laser pulse shape on OMEGA



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