4PI Pre-Screen Process Improvements*

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4PI STATION - OVERVIEW

Spherical targets, a key component in Inertial Fusion research, have surface and sub-surface defects, as well as target wall thickness non-uniformity, that are amongst the major contribution to hydrodynamic instabilities during implosion. It is advantages if these multi-instrument measurements can be correlated relative to each other in one coordinate system.

Purpose:

- Multi-instrument coordinated and corelated metrology on a spherical capsule
- Targets' surface topography is measured via a holographic microscope
- total wall and layer thickness uniformities is measured using a computational Infrared technique
- Atomic force microscope (AFM), and Dark field spectroscopy capabilities.
- A 5-axis robot enables overnight measurements once setup by the operator
- Automatic processing, analysis, and defect classification provides fast results

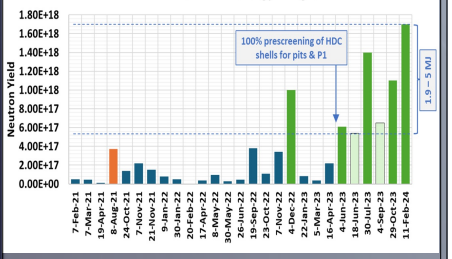
PRE-SCREENING

NIF capsule metrology process starts with Pre-screening. Targets are first measured and evaluated using 4PI system. Then, only If they meet the quality specifications, they would be designated into the metrology process.

Cleaning with Acid → Measurement Setup → Data Acquisition with Robot → Automatic Transfer and Data Analysis → Machine Learning Defect Classification → Final Check and summary

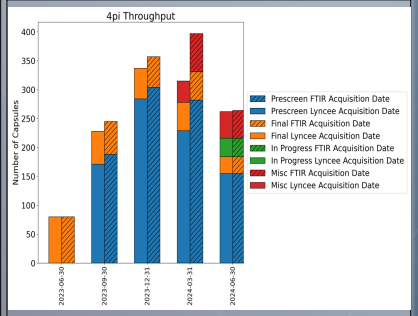
- The Process flow chart of target pre-screening: The steps requiring some operator involvement are marked as red

Effect of Pre-Screen Implementation on Yield



Delivery of higher quality targets reaching fusion has been possible by implementation of pre-screen process.

Pre-screen process pipeline

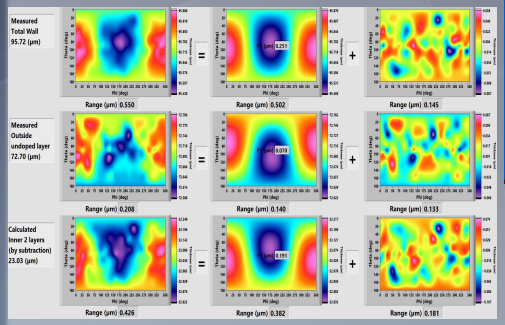


Number of measurements on the 4PI station. The first column from the left shows estimated measurements prior to automation.

Automatic measurement

FTIR Measurement

Total non-uniformity = First mode + higher modes



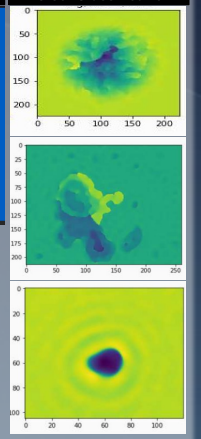
FTIR results of a HDC capsule showing layer thickness non-uniformity modes for total and outer undoped layers.

Topography Map

- High-Resolution 2D map: for good capsules defects don't show unless zoomed in
- A defect is highlighted and enlarged
- Intensity image of the highlighted defect

- A machine learning process implemented to classify defects into pits (intrusions), debris (extrusions), and engineered laser drilled hole.

Defect Classification

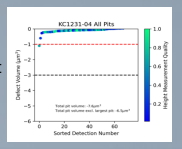


Spectral Transparency Challenges:

- Non-Homogenous crystal structure causes a calculated signal to signal to an anomaly usually corresponding to layer thickness.
- High dopant levels may cause the crystal structure to blockage the spectrum .

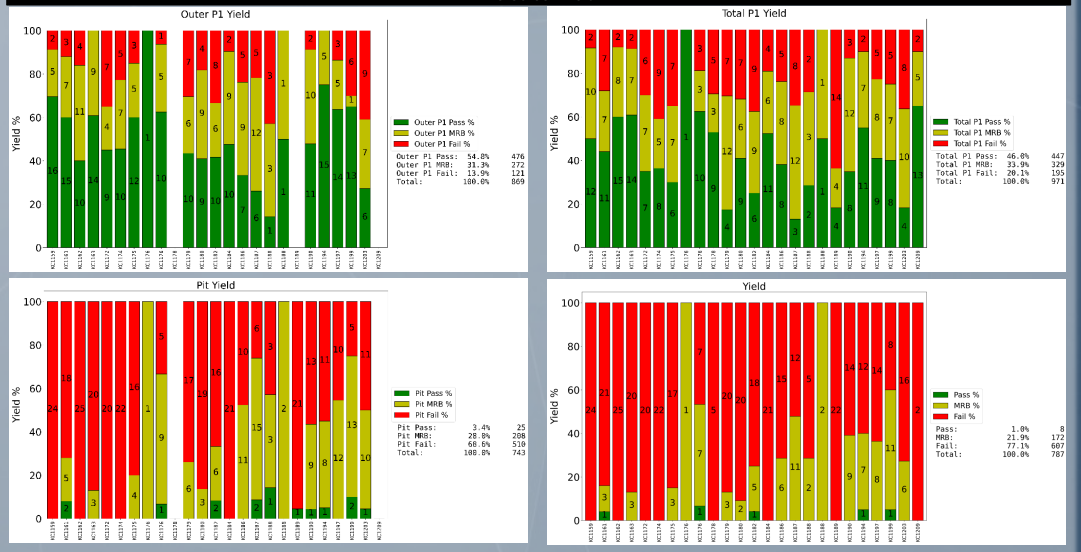
Summary:

Volumetric surface defects indicating height measurement quality factor (certainty)



Feature	Image Analysis accuracy	CNN accuracy
Drill Hole	67%	100%
Pits	89%	99.7%
Debris	27%	62%

Pre-Screen Yield



We now pre-screen and MRB all capsules and only process those that are approved

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