



GENERAL ATOMICS

Laser Micromachining Process for Pinholes and Collimators Used for X-Ray Imaging

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Pinholes used on the National Ignition Facility

Pinholes are utilized to image x-rays for diagnostics

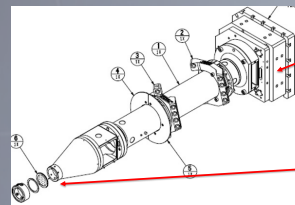
- Used on every shot done at the National Ignition Facility (NIF)

One type of imaging system on the NIF

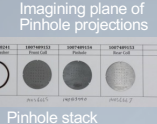
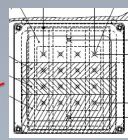
- Easy to install and setup
- Imaging is sufficient for most of the needs

A standard pinhole stack consists of:

- One pinhole array 75 μm thick for the imaging aperture
- Two collimator arrays, 500 μm thick, to provide shielding and protection to the cameras from debris & hard X-Rays



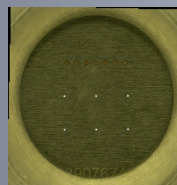
Pinhole stack location (6) when installed in NIF snout



Pinhole stack

General Atomics (GA) fabricates & characterizes pinhole & collimator components needed for all NIF experiments

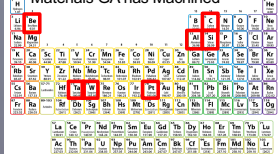
- Pinhole fabrication started in 2010
- Continual process improvement
- Equipment upgrades as the processes progress



Pinhole stack with associated x-ray image

Feature Overview

Materials GA has Machined



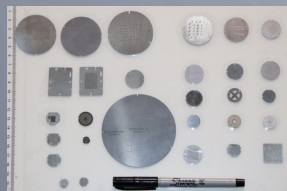
Materials GA has machined

Features

- Holes down to 10 μm diameter
- Slots as narrow as 20 μm
- Notches for alignment
- Contours

Part Dimensions

- Material Thickness < 1.00 mm
- Outer Diameter < 40. mm



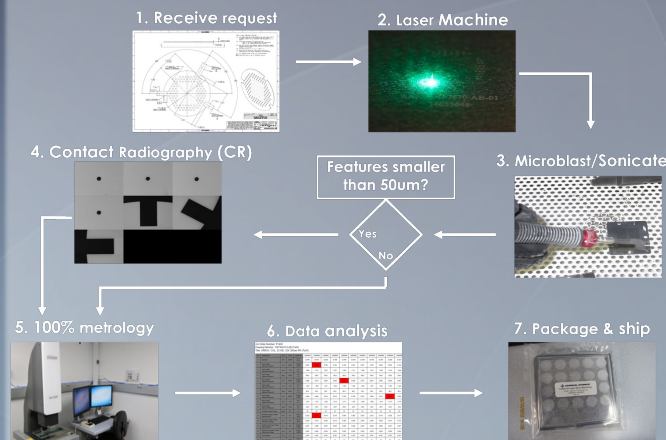
2023 Numbers

- ❖ Number of Orders shipped: 80
- ❖ Number of parts shipped: 788
- ❖ Number of designs made: 65
- ❖ Number of new drawings: 24
- ❖ Number of features: over 253,000

Overall Numbers

- ❖ More than 12,000 parts delivered
- ❖ More than 400 different designs have been fabricated
- ❖ More than 2,000,000 holes drilled

GA Pinhole & Collimator Fabrication Process



Laser Machine and Cleaning

Laser Machining

- Machine using a combination of a 5-axis stage, a femtosecond laser, and galvo scanner
- Attain positional accuracy to within 10 μm of specifications
- Machine 10 μm diameter holes with $\pm 1 \mu\text{m}$ specifications
- 150 μm hole diameter hole circularity to within 3 μm

Microblast/Sonication

- Cleaning after fabrication removes oils and debris from fabrication



100% Metrology

Contact Radiography (CR)

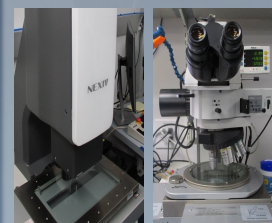
- For parts with features smaller than 50 μm , an image is captured using contact radiography (CR)
- Two different emulsions are being used on the CR plates
- X-ray images are captured on a glass slide
- The images are used for metrology



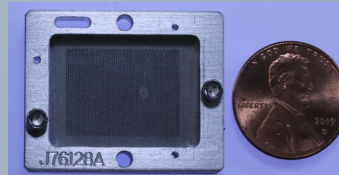
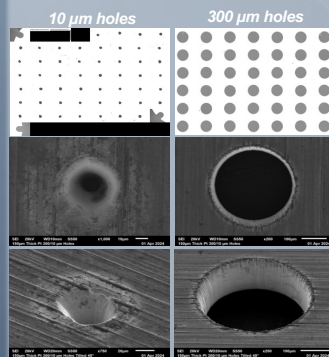
Developed CR Plate

100% Metrology

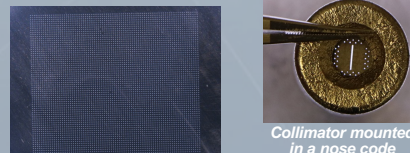
- 100% of all features are measured
- Record position, diameter, roundness
- For features smaller than 50 μm , the CR plates are measured
- If no features are smaller than 50 μm , the parts are measured directly
- Data report created and sent to customer



Pinhole Examples

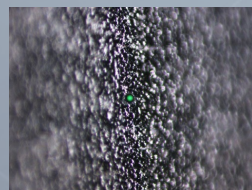


Assembly with 1 pinhole and 2 collimators Array with 2500 holes

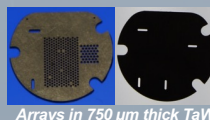


Collimator mounted in a nose code

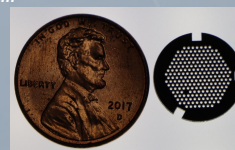
6,400 holes in 50 μm thick TaW



50 μm hole drilled at 20° angle

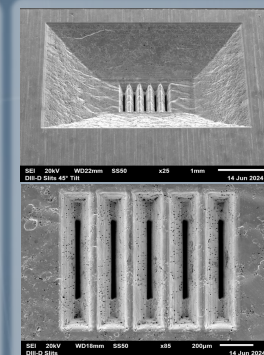


Arrays in 750 μm thick TaW

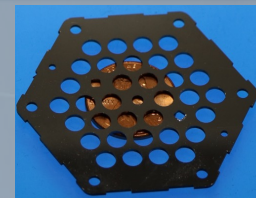


150 μm holes in AlN

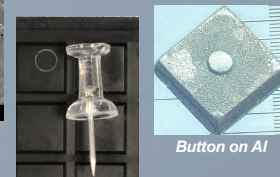
Other Capabilities



20 μm wide slots in 90T10Re

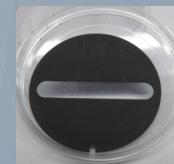


Holes in Si

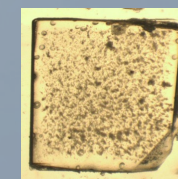


Button on Al

Ta washer with 500 μm wall



5 mm wide slot in 40 mm diameter in C



Machined SiO2 aerogel