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Abrasive waterjet lightweighting of ULE

Phase II SBIR contract NNX13CM22C

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Ormond, LLC

- Located in Auburn, WA
- Performs engineering and R&D services, custom tooling, software and manufacturing processes.
- Ultra-high pressure technology R&D, hyperbaric vessels and testing.
- Specialized **abrasive waterjet** (**AWJ**) machining of metal, glass, and ceramics.
- SBIR contracts with commercial success.

Channel wall rockets

2015 phase II SBIR: Low Cost Manufacture of nozzles and combustors for channel wall liquid rocket engines.

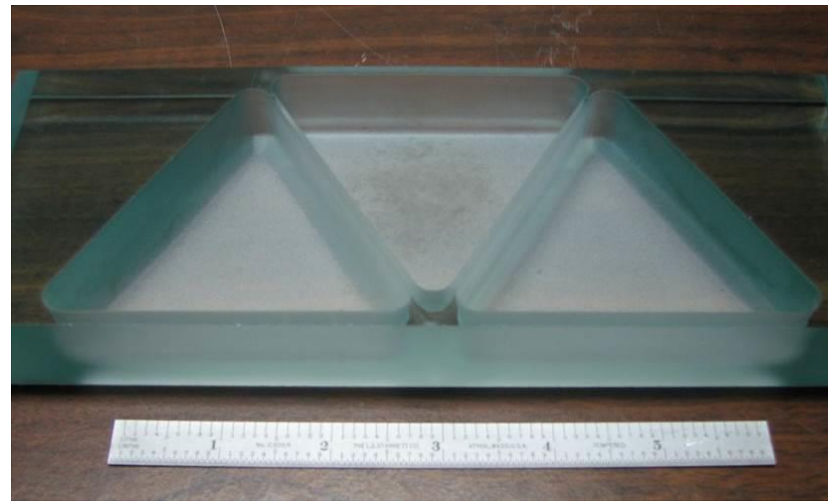
Motivation

- Identify fabrication **risks** and **cost** involved with large optics fabrication.
- Mirror lightweighting methods: **pocket milling** and **core cutting**.
- Can machine up to 2.4 x 1.8 x 0.6 m parts.
- 1.52m ø (⅓ scale of 4m AMTD-II).
- Scalable for larger mirrors.
- Serves as alternate vendor for mirror lightweighting.

AMTD-II mirror lightweighting

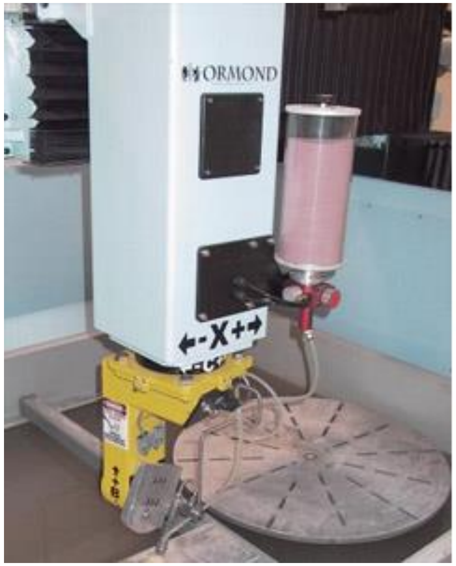
Core cutting

Pocket milling



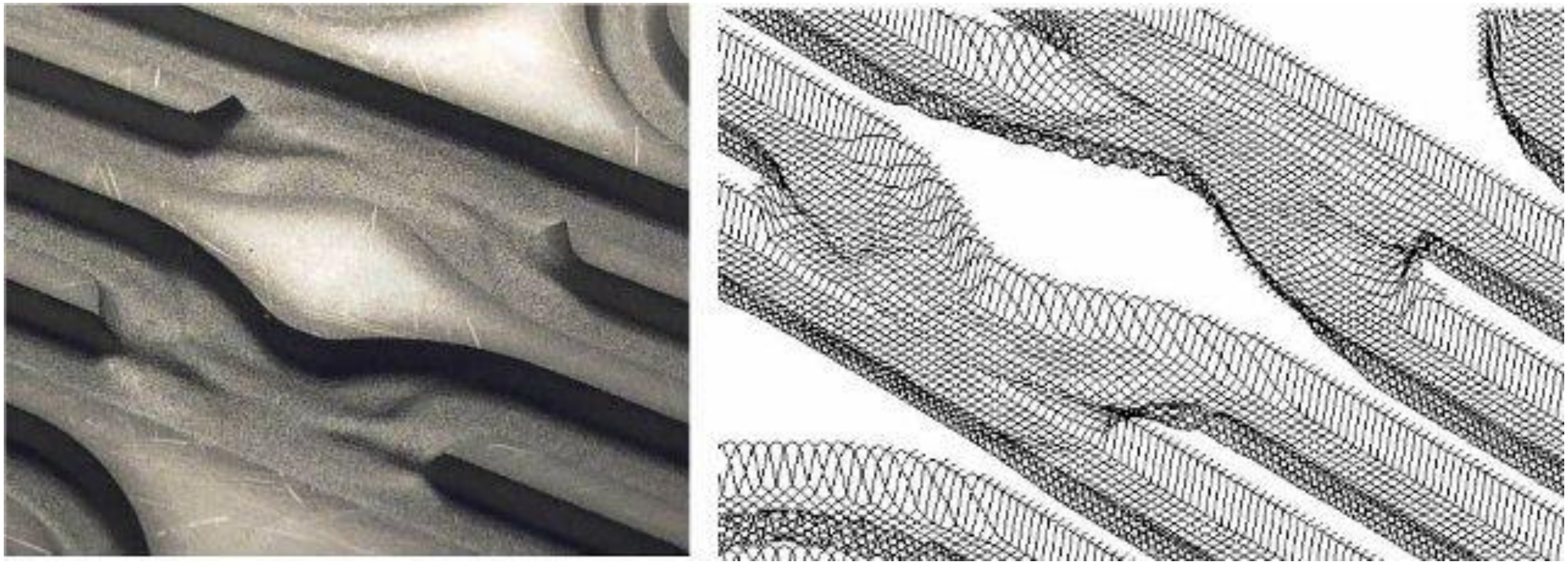
- Higher removal rate than milling.
- Lower damage to parts than grinding.
- Reduce areal mass, cost and schedule risks.
- Stacked and low temp fusion.

5-axis AWJ machine



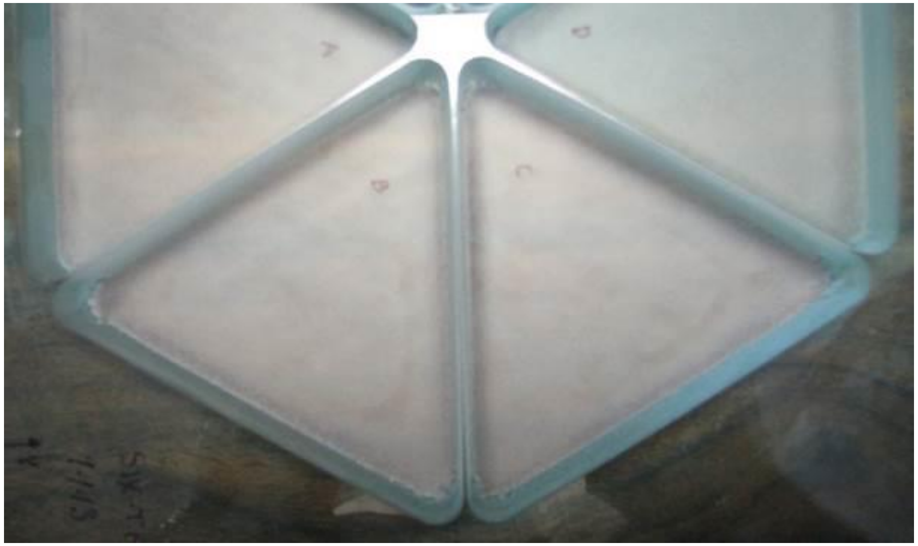
- Water at 600 MPa (~90 ksi) thru a sapphire orifice at 1.2 km/sec.
- Typical AWJ diameter from 0.1 to 0.5mm.
- Garnet abrasives serve as cutting medium.
- Process monitoring and control improved capability.

Deterministic AWJ machining



- Developed software to create complex CNC code.
- Predict resulting machined part geometry.
- Predict machine time based on material and size.
- Variables include cut speed, and jet nozzle parameters: attack angle, water pressure, flow rate, mixing tube diameter, abrasive material and size.

Pocket milled facesheets



- Demonstrated complex geometry on glass and SiC.
- Minimal subsurface damage and lower residual stress.
- Higher 4-point bending strength compared to milling.
- Material removal rate 2.4 cm^3/min with 8 cm^3/min goal.
- 1.5m scalable to larger mirror facesheet.

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Final focus: ULE core cutting

- Projected AMTD-2 core feature types demonstrated.
- Perform tests to show production readiness.
- **Trailback error**, **kerf taper**, striation reduction.
- Part-off cores safely.
- Improve process reliability.

Wall thickness: 1.3mm

Core thickness: 120mm

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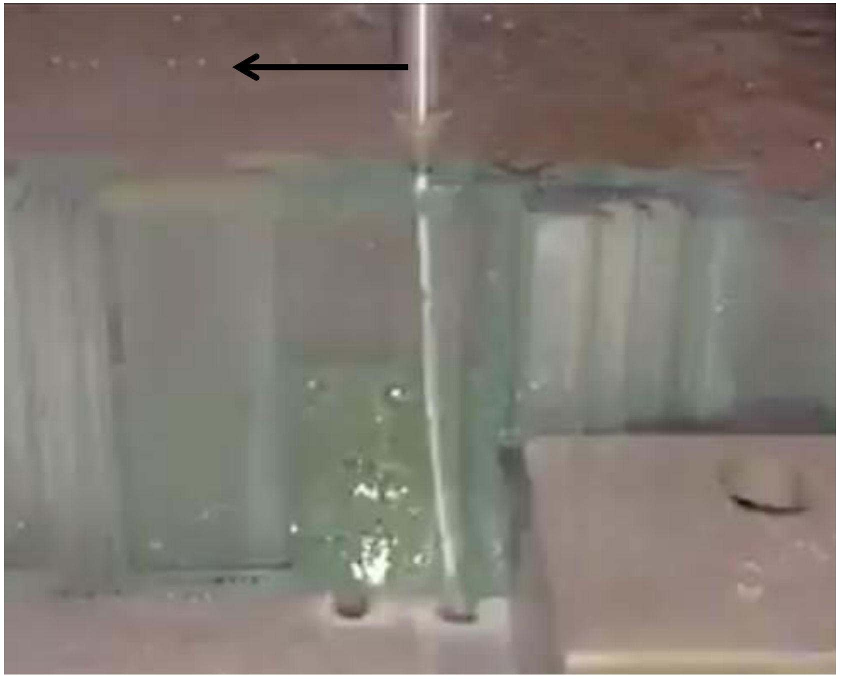
AWJ trailback

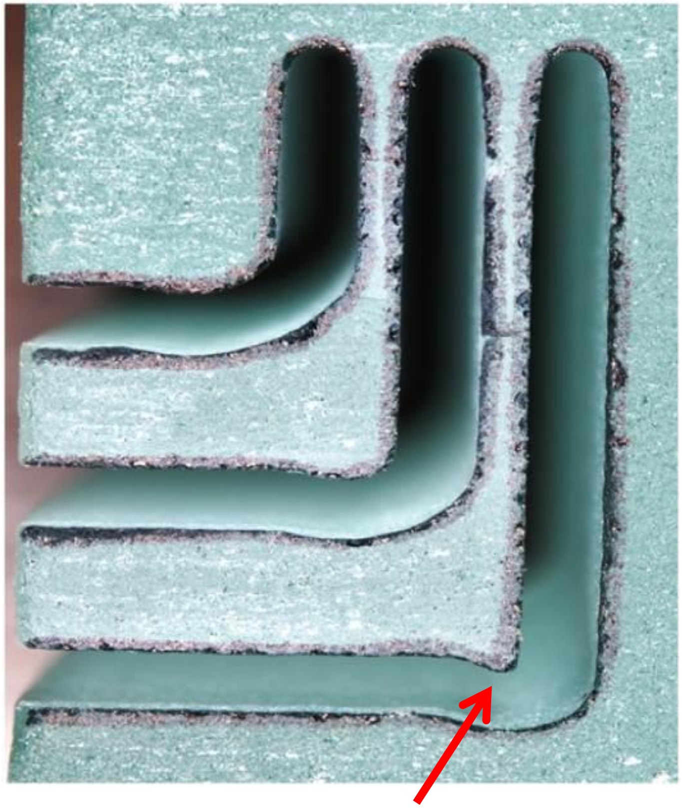


- As nozzle moves from right to left; the exit point at the bottom of the glass trails the entrance point.
- Can compensate with nozzle angle and cut speed.

Effect of trailback error

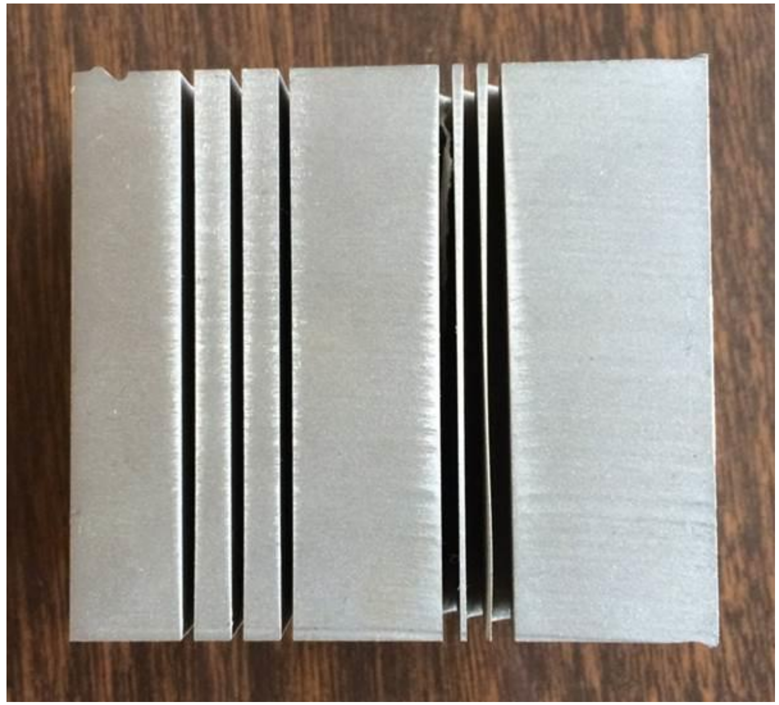
Top

Bottom



- Trailback error gets worse for smaller turn radius

Effects of kerf taper



- Left: ideal cut speed makes slight barrel shape kerf.
- Right: slower cut speed yields negative taper (wider at bottom).
- Faster cut speed yields positive taper (wider at top).
- Cut speed needs to be optimize for straighter cuts.

Core cutting progress

- Optimize cut speed to compensate trailback and kerf taper.
- Optimize cut speed with AWJ nozzle angle correction.
- Software development based on ULE test cuts.
- Challenge is that we can’t just slow down to eliminate trailback error because taper gets wider at bottom.
- Reduce chip size and crack by cut parameters.
- Built-in monitors to provide alarms and fail-safe shut down.
- Developed simple vacuum pickup tool to hold glass drops to prevent damage to part.

NASA SBIR/STTR Technologies

Phase II NNX13CM22C – Low Cost Method of Manufacturing Space Optics

PI: Daniel G. Alberts

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Identification and Significance of Innovation

A manufacturing technology is under development to increase large optics design options, significantly reduce manufacturing time, cost and risk involved in manufacturing large optics and to improve optical performance. Specifically addressed is lightweighting of glass and ceramic optical components. This gentle process is capable of milling with minimal subsurface damage or residual stress generation and has demonstrated increased glass strength compared to ground specimens.

Expected TRL Range at the end of Phase II (1-9): 6

Technical Objectives and Work Plan

The primary goal of this Phase II SBIR is to develop and demonstrate a working system that is capable of light-weighting a 1.5 m AMTD-2 mirror faceplate and core geometry.

The Phase II scope includes building and testing tooling that can support AMTD-2 and similar optics fabrication operations. Demonstration of scalability, risk reduction, and manufacturing cost data will be reported.

NASA and Non-NASA Applications

This SBIR is being conducted in support of NASA Advanced Mirror Technology Development (AMTD) program. Raytheon Space and Airborne Systems group stated that the developments made under this SBIR will directly support NASA programs including JDEM, IXO, LISA, ICESAT, ATLAST, CLARREO and ACE. Non-NASA applications include various ceramic and challenging metal milling applications, shaping armor, channel wall combustors, scramjet channel heat exchangers, etc.

Contacts

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NON-PROPRIETARY DATA