High Metal Removal Rate Process for Machining Difficult Materials

DE-EE0005752

Recipient: Delphi Automotive Systems, LLC

Partners: Microlution Inc. & Raydiance Inc.

September 1, 2012 to March 31, 2016

Presenter:
Andy Phillip
President
Microlution, Inc.

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 14-15, 2016

Project Objective

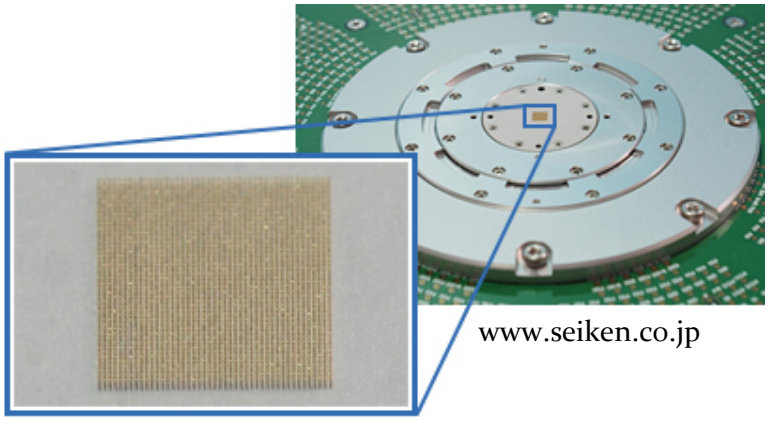
- Develop ultrafast laser and precise motion control technologies for micromachining difficult-to-machine materials

- Provide conceptual design of production line systems which will take maximum advantage of unique properties of ultrafast lasers as a machining tool and dramatically enhance factory throughput

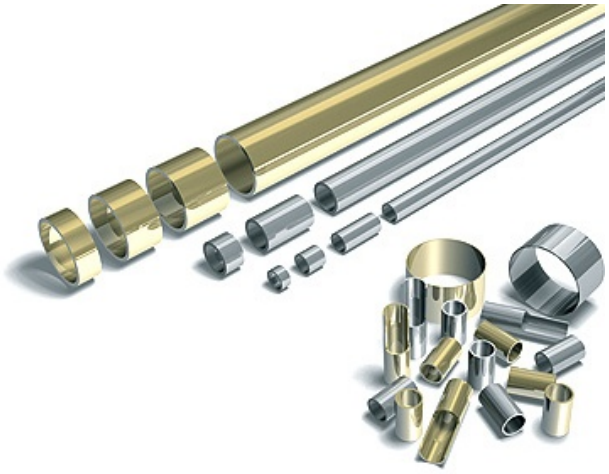
- Demonstrate new manufacturing processes enabling better quality and reduced cycle times and energy consumption in high precision manufacturing environments:
  - Fuel injector nozzle drilling (automotive industry)
  - Ceramic hole drilling (electronics industry)
  - Precious metal drilling (biomedical industry)
  - Precious metal tube cutting (biomedical industry)

Project Objective

- Probe Card (electronics device):
  - Holes are becoming too small for mechanical milling, well suited for laser
  - Devices have large features that must be accurately located relative to small holes
- Marker Band (biomedical device): Laser improves quality and allows in-process measurement, improving processing efficiency



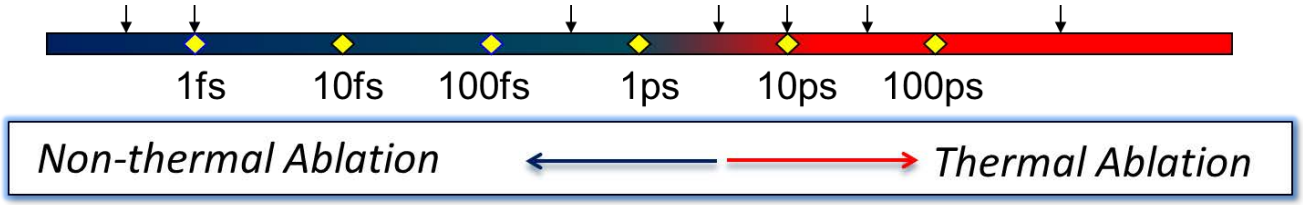
Probe Card:
Up to 40,000 holes, 0.075mm diameter

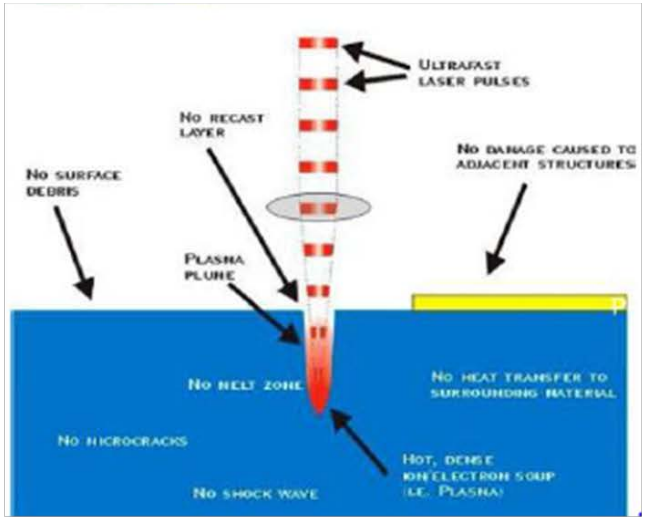


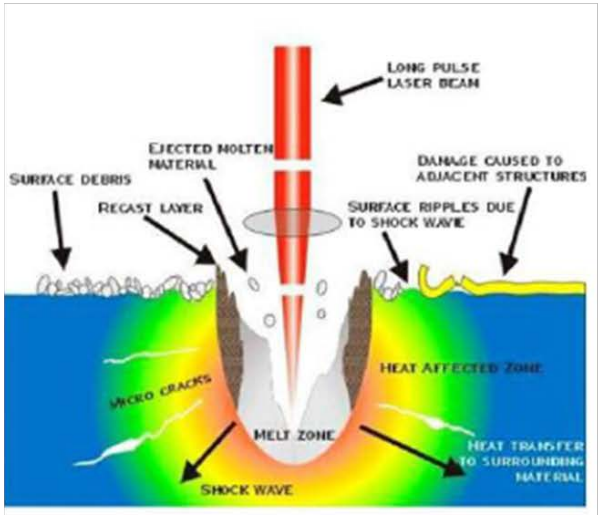
Marker Band:
0.250mm diameter, 0.025mm wall thickness, soft, fragile material

Technical Approach

- Traditional manufacturing methods (mechanical milling, mechanical drilling, and Electric-Discharge-Machining) have reached their limits in terms of feature size, surface finish, geometric tolerance, and positional tolerance
- Typical laser-based methods use relatively long pulses with poor performance due to the heat imparted to the work piece
- Ultrafast laser technique eliminates thermal effects for superior material removal capability







Technical Approach

- As demonstrated during BP1 for fuel injector nozzle "counterbore" machining, many applications require a hybrid processing approach combining ultrafast lasers with mechanical cutting and/or in-process measurement
  - Ultrafast laser best suited for ~0.5mm and smaller features, many devices include larger features too
  - Opportunities identified in other commercial applications

- Hybrid capability for pre-machining to remove bulk material, qualification of incoming workpiece and/or part measurement prior to being singulated into tiny pieces

Project Management & Budget

- Project duration: 9/1/12 to 3/31/16
- BP2 project task/milestone schedule and budget:

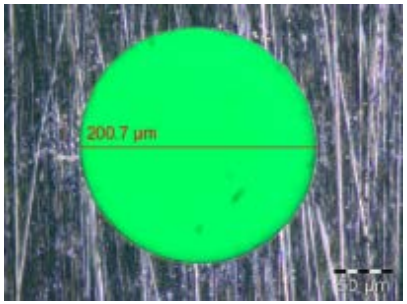
Task #	Subtask #	Milestone #	Task / Milestone Title or Brief Description
			DOE agrees to proceed into Budget Period 2 (Go/No-Go Decision Point)
5.0			**Multi-Application Testbed Development**
	5.1		Design Multi-Application Testbed
		5.1.1	Demonstrate testbed design meets or exceeds performance criteria
	5.2		Build and Test Multi-Application Testbed
		5.2.1	Demonstrate testbed system meets or exceeds performance criteria
6.0			**Advanced Control Development for Coordinated Motion and Laser Firing**
	6.1		Multi-Axis High/Low Frequency Coordination
		6.1.1	Demonstrate advanced control with multi-axis high/low frequency coordination
7.0			**Laser Processing Strategy Development**
	7.1		Precious Metal Drilling for Cardiac Catheter Devices
		7.1.1	Demonstrate precious metal drilling performance
	7.2		Ceramic Hole Drilling for Probe Cards
		7.2.1	Demonstrate ceramic hole drilling performance
8.0			**Hybrid Machining Strategy Development**
	8.1		In-Situ Measurement for Laser Tube Processing for Marker Bands
		8.1.1	Demonstrate tube cutting process
	8.2		Hybrid Machining for Test Sockets
		8.2.1	Demonstrate hybrid machining of test sockets

Total Project Budget	
DOE Investment	$3,700,000
Cost Share	$932,841
Project Total	$4,632,841

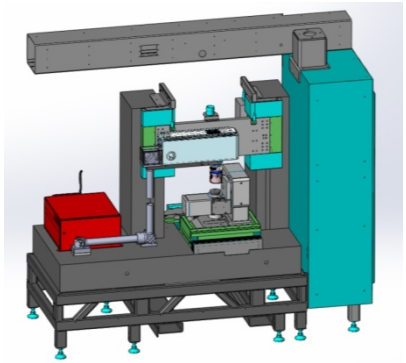
- Project was completed on schedule and within budget

Results and Accomplishments, BP1

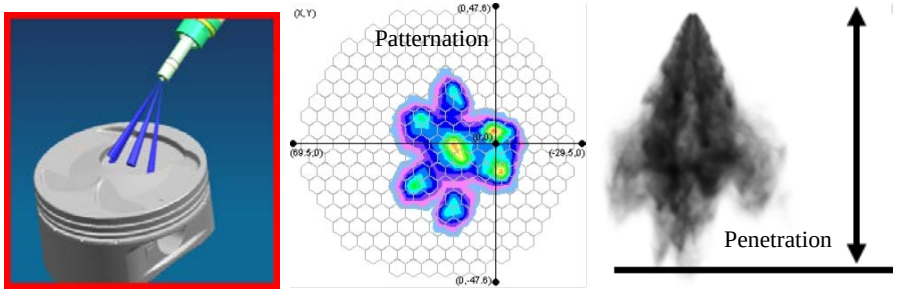
- Demonstrated improved laser scan head performance
- Demonstrated 50% faster through hole laser drilling
- Demonstrated enhanced machining platform performance (thermal stability, speed, synchronized laser cutting)
- Demonstrated prototype micromachining capabilities for a production-intent application with reduced energy consumption (67% estimated reduction compared to baseline EDM, 30% reduction compared to Delphi laser capability at start-of-project)



GDi - 0.5 second hole at 20W



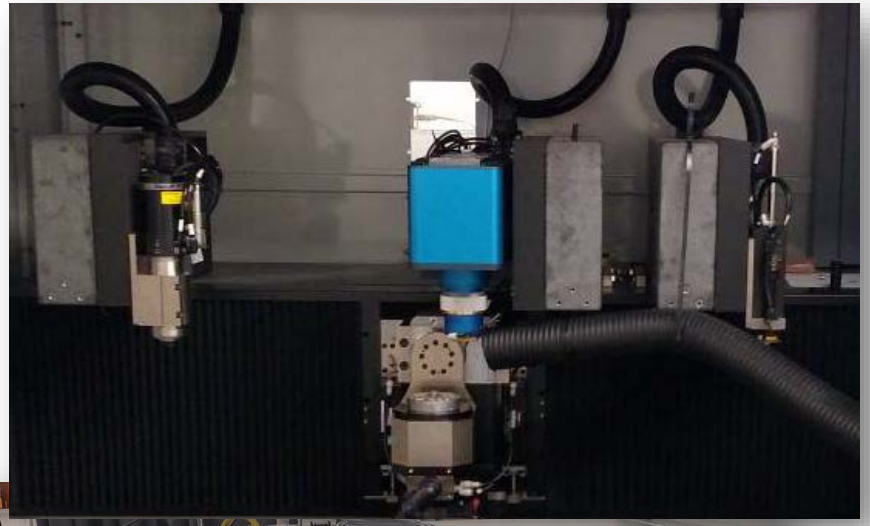
Enhanced Machine Platform

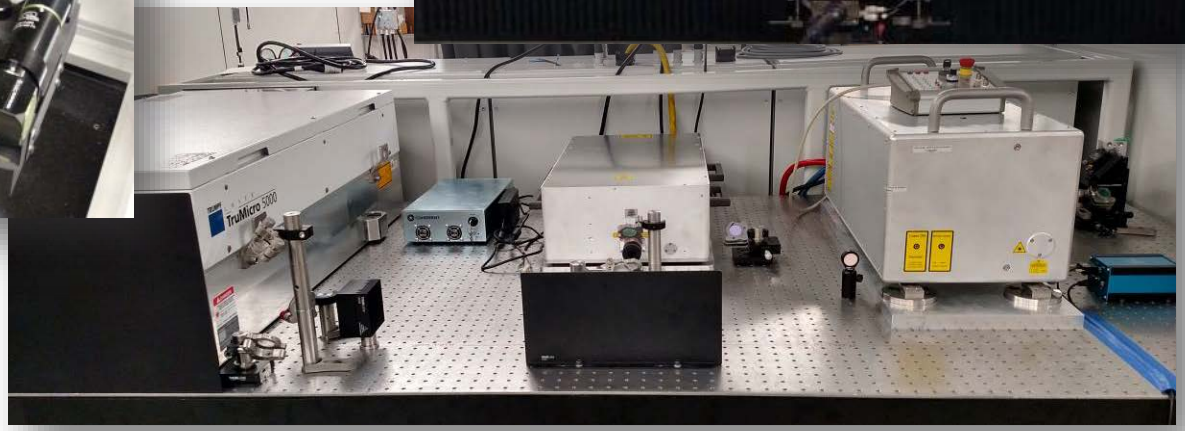


Examples of Spray Criteria Evaluated

Results and Accomplishments, BP2

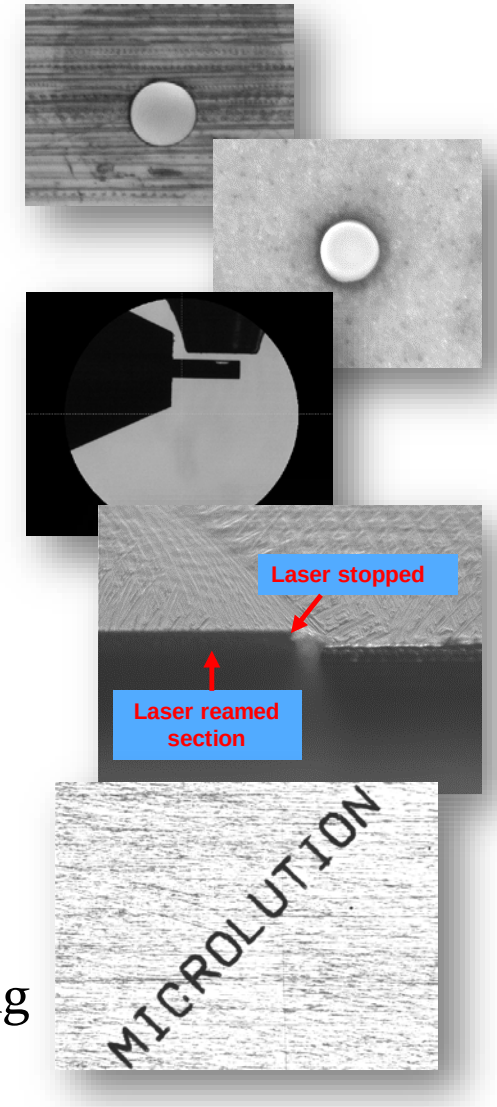
- Multi-axis hybrid processing Testbed system
- Provides ultrafast laser cutting, measurement, and mechanical milling for probe card and other applications as well as laser cutting with in-process metrology for marker band





Results and Accomplishments, BP2

- Demonstrated 40% faster drilling of precious metal cardiac catheter
  - Drill time 1.7s (benchmark was 3s)
  - Exceeded dimensional and geometric tolerance specs
- Demonstrated 70% faster drilling of ceramic holes
  - Drill time 3.1s (benchmark was 10s)
  - Exceeded dimensional and geometric tolerance specs
- Demonstrated In-Situ Measurement for marker bands
  - Capable measurement process w.r.t. tolerance band
  - Cut and measurement time 1.2s
- Demonstrated Hybrid Mechanical/Laser Machining
- Demonstrated Multi-Axis High/Low Frequency Cutting



Measure of Success

- Smaller, more accurate, higher fidelity features and better metrology data are key enablers of next generation probe cards, marker bands, test sockets, and other devices

- Demonstration of hybrid processing capability performed during BP2 enables commercialization of the technology

Transition and Deployment

- Microlution has a track record of developing new manufacturing capabilities and being at the forefront of high-tech manufacturing
- Microlution has deployed over 100 milling and laser micro-manufacturing systems into production applications in medical, consumer electronics, automotive, and other industries

Example of First-Generation Laser Cell Installed for Biomed Mfg