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 December 31, 2014

Presenter:
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U.S. DOE Advanced Manufacturing Office Peer Review Meeting
Washington, D.C.
May 6-7, 2014

Project Objective

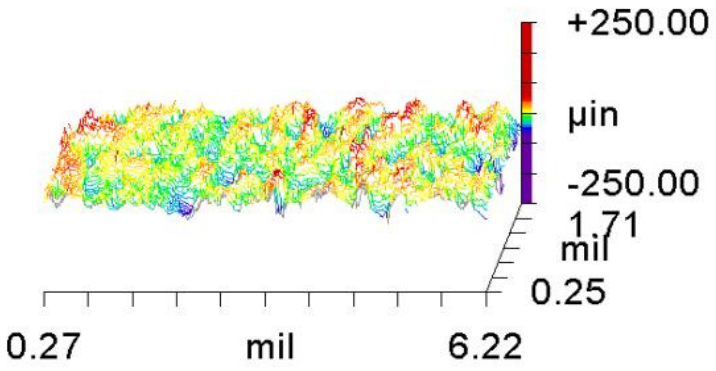
- Develop ultrafast laser and precise motion control technologies for micromachining difficult-to-machine materials
  - Provide conceptual design of production line systems which will take maximum advantage of unique properties of lasers as a machining tool and dramatically enhance factory throughput
  - Demonstrate reduced cycle times and energy consumption in a high precision manufacturing environment: machining fuel injector orifices for gasoline direct injection (GDi) fuel injectors

Technical Approach

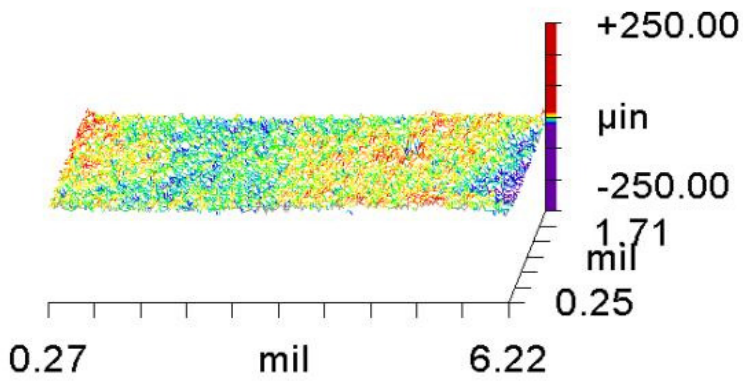
- Traditional material removal techniques comprise large platforms that are poorly suited to produce small parts efficiently with high precision

Reality of Scale:
Typical spray hole size for
GDi injectors (150 microns)

Surface Finish Profiles for GDi Injector Holes



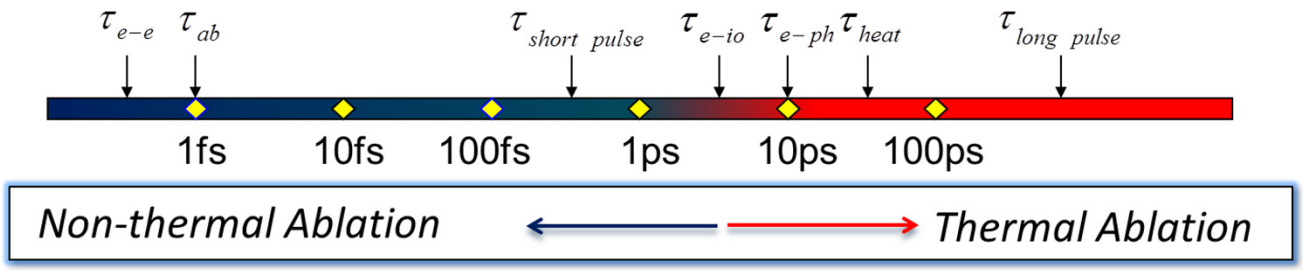
EDM

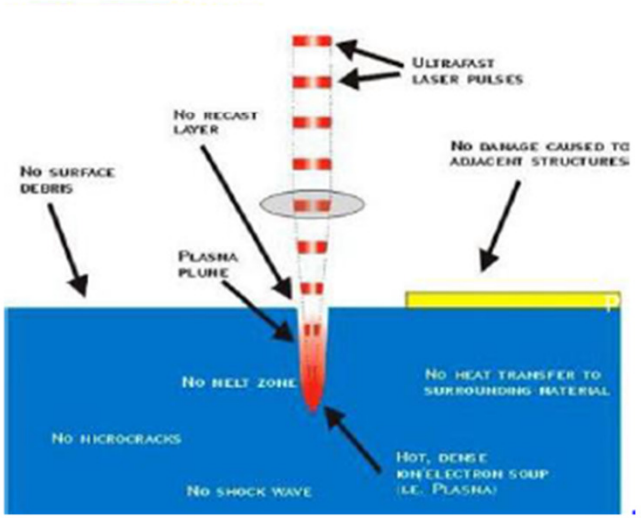


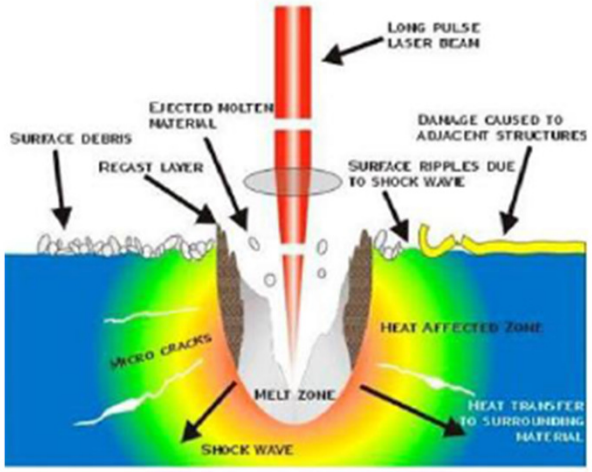
Laser

Technical Approach

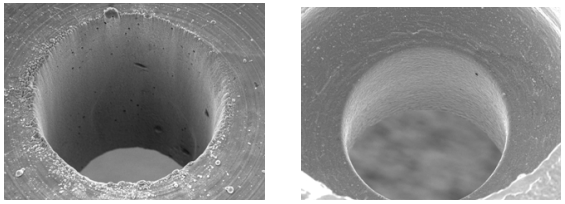
- Typical laser-based methods use relatively long pulses with poor performance due to the heat imparted to the work piece
- Ultrafast laser technique eliminates thermal effects for superior material removal capability







GDi Injector Holes



ps fs

ps – picosecond (10^{-12} sec)
fs – femtosecond (10^{-15} sec)

Project Management and Budget

- Project duration: 9/1/12 to 12/31/14
- Project task/milestone schedule and budget:

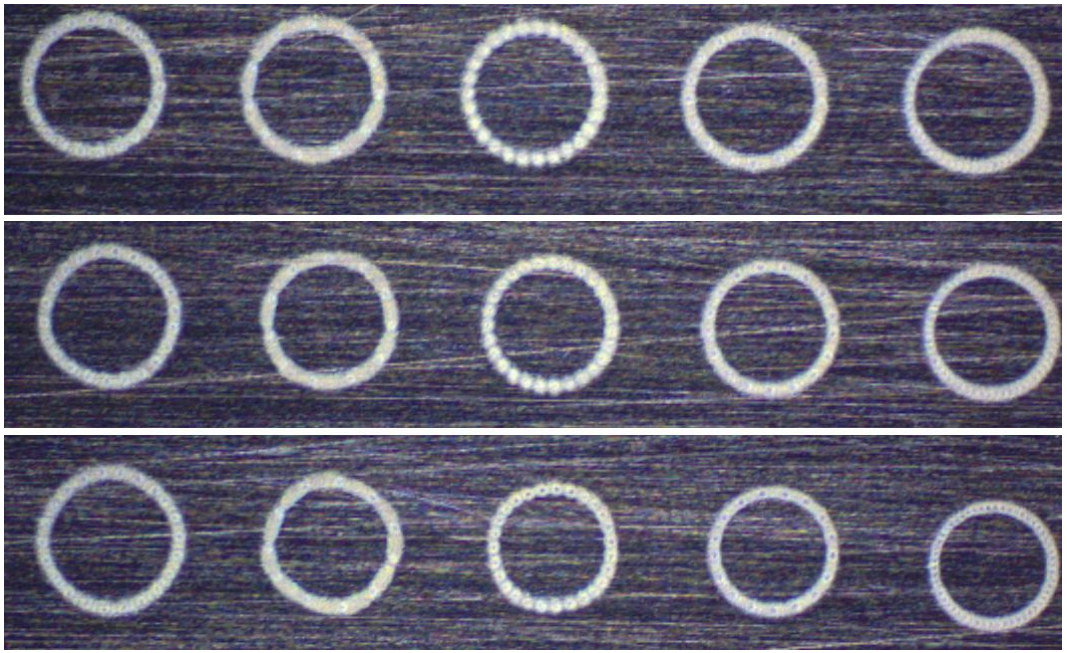
Task #	Subtask #	Milestone #	Task Title or Brief Description
1.0			**Laser and Scan Head Development**
	1.1		Develop Workstation Design and Build
		1.1.1	Demonstrate scanning head meets or exceeds performance targets
	1.2		Material Removal
		1.2.1	Demonstrate 50% CT reduction for laser drilling through holes
	1.3		Counterbore Process Development
		1.3.1	Laser drill c-bore and spray hole < 8 seconds and pass spray criteria
2.0			**Work Holding and Automation**
	2.1		Develop Work Holding Concept and Datum Structure
	2.2		Automated Work Holding Demonstration
		2.2.1	Present concept selection matrix, tool trial data, and results summary
3.0			**Laser and Scan Head Chassis Development**
	3.1		Laser Chassis Development
	3.2		Integration and Test
		3.2.1	Demonstrate enhanced laser chassis meets or exceeds performance targets
4.0			**Optimization and Valve Seat Build**
	4.1		Integrated Component Processing
	4.2		Develop Valve Seat
		4.2.1	Utilize enhanced laser chassis to develop a seat for a specific customer application
			DOE agrees to proceed into Budget Period 2 (Go/No-Go Decision Point)
5.0			**Performance Demonstration and Validation**
	5.1		System Optimization
		5.1.1	Demonstrate process capability and stability of enhanced laser chassis over an extended period of time
	5.2		Injector Assembly Validation
		5.2.1	Injectors produced using enhanced laser drilled seats pass cold start engine test

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

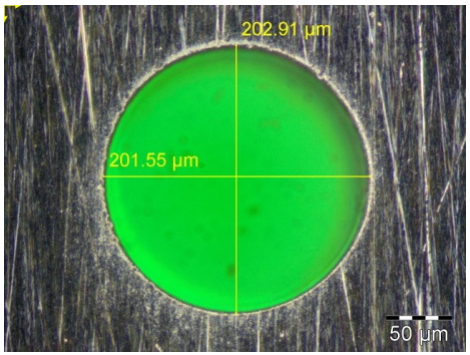
Results and Accomplishments

Raydiance, Inc.

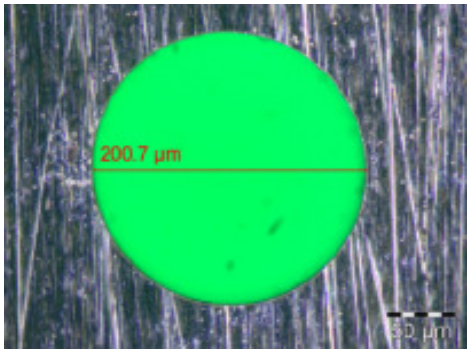
- Demonstrated a laser scan head performing with a rotational speed > 200Hz at an attack angle > 80%
- Demonstrated through hole laser drilling in seats in 50% less time than the current system with no degradation in quality



Left to Right: 300, 250, 200, 150, 100Hz
Top to Bottom: 60%, 80%, 100% attack angles



GDi - 1 second hole at 10W

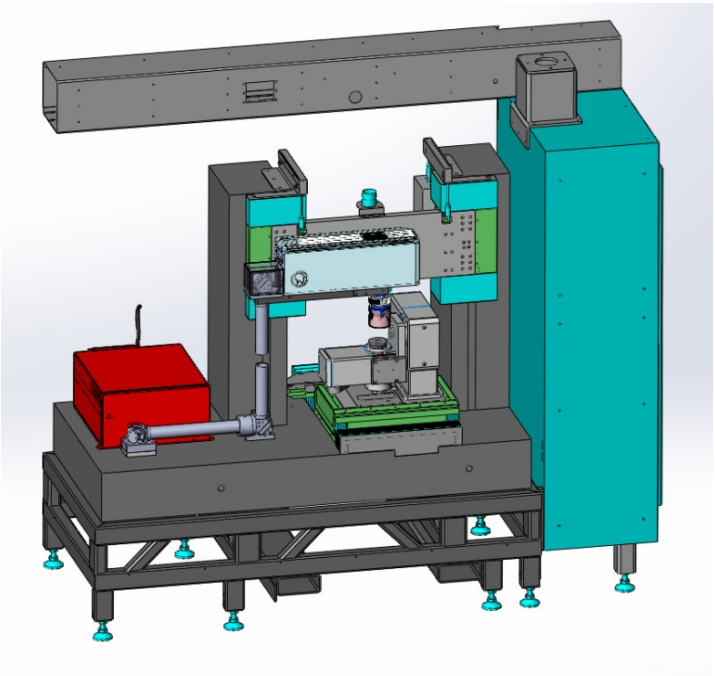


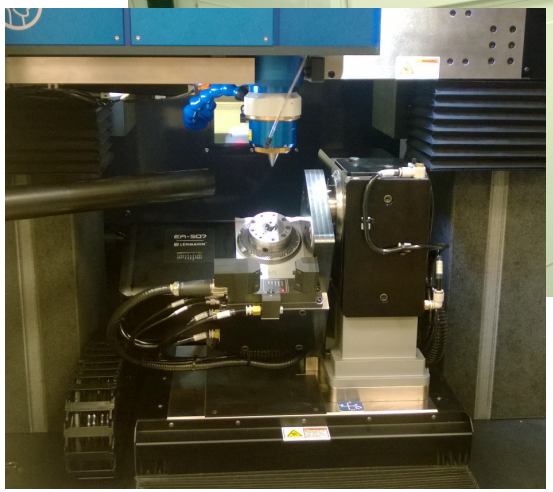
GDi - 0.5 second hole at 20W

Results and Accomplishments

Microlution, Inc.

- Demonstrated enhanced laser-based micromachining platform with automated motion control
  - Warm-up time < 15 min
  - Work piece positioning time < 3 sec (load + unload)
  - Synchronized movement during laser machining operation

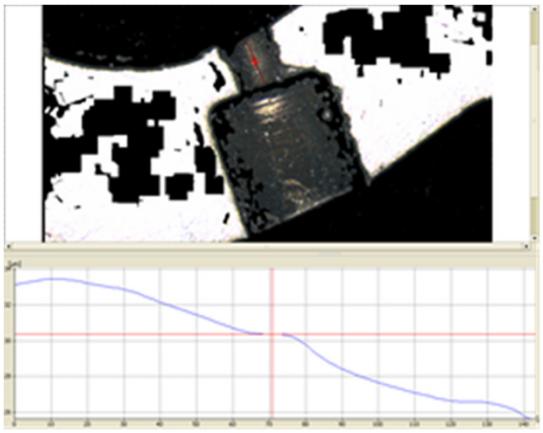


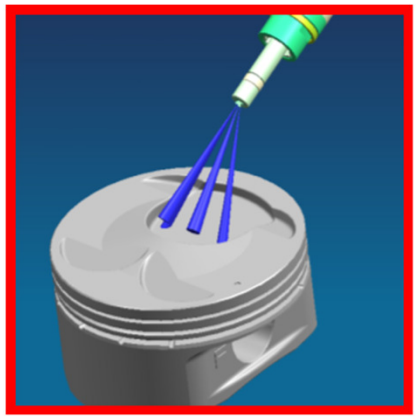


Results and Accomplishments Delphi

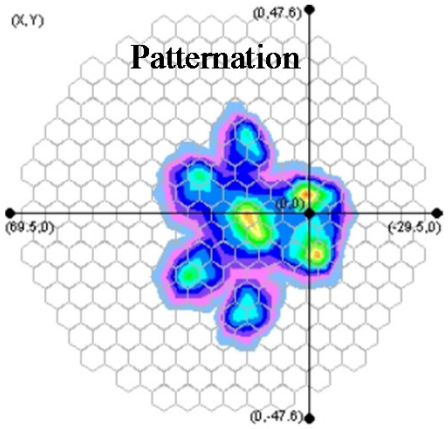
- Demonstrated prototype micromachining capabilities for a production-intent application
  - Generated spray holes meeting stringent, customer-specific GDi injector requirements
  - Reduced energy consumption substantially
    - 67% estimated reduction compared to baseline EDM
    - 30% reduction compared to Delphi laser capability at start-of-project
    - Further optimization during the current FY expected to yield an additional 30% reduction in energy consumption

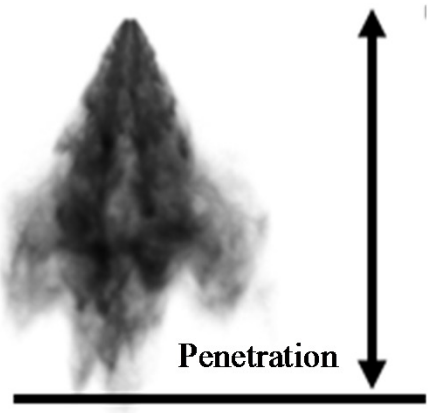
Customer X Seat





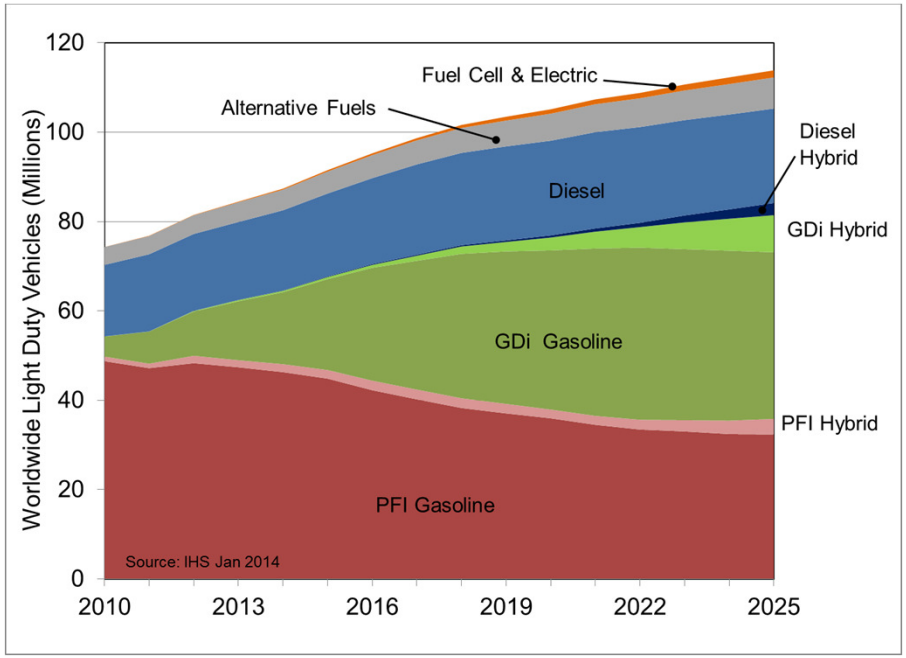
Examples of Spray Criteria Evaluated

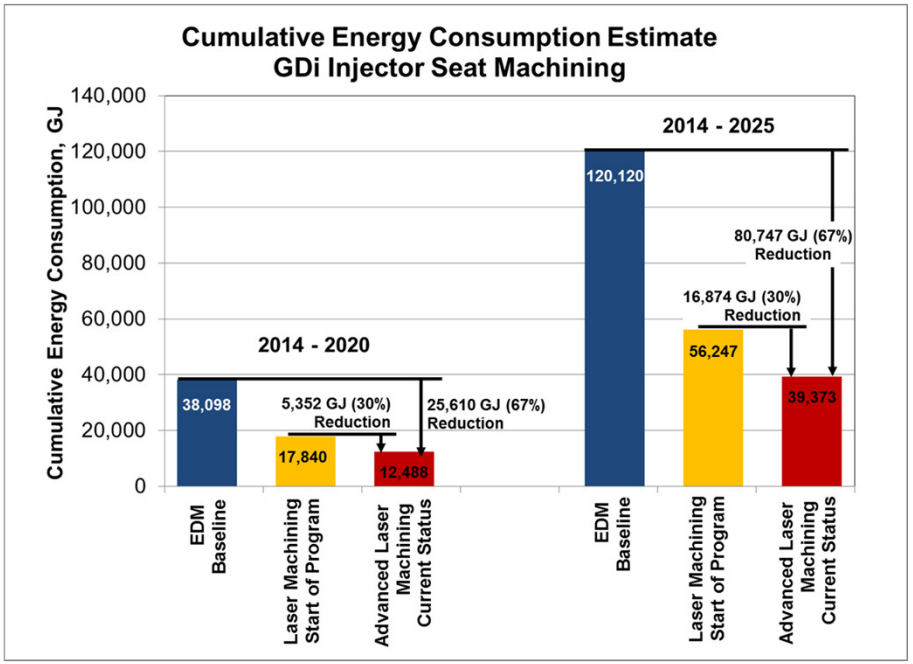




Measure of Success

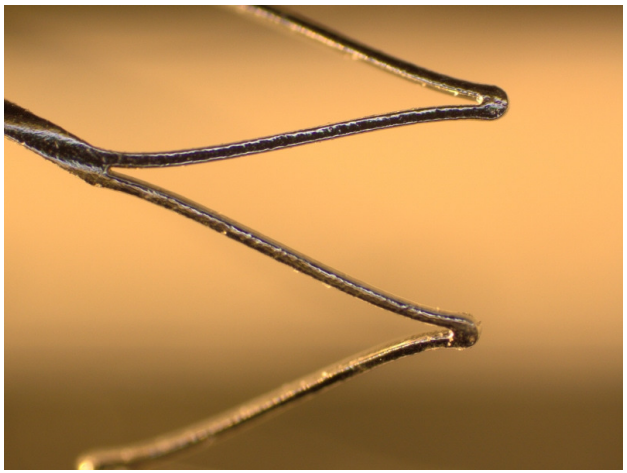
- GDi engines are a key enabler to meet fuel economy / CO_2 mandates worldwide
  - EPA estimates new US fuel economy standards will save 6B barrels of oil and reduce CO_2 emissions by 3.1B metric tons through 2025
- We estimate manufacturing capability developed during this project to reduce energy consumption through 2020 by 81,000 GJ (67%) compared to EDM





Transition and Deployment

- Our industrial-based project team is well-positioned for technology transition and deployment
  - Delphi has already deployed key laser and work holding technologies from this project into production
  - Raydiance and Microlution have a broad customer base for laser-based micromachining technology transfer to other industries
    - i.e. medical and aerospace



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Summary

- Our expert team has developed and demonstrated a proof-of-concept laser-based micromachining platform for a production application
- Current state-of-the art capability of our prototype platform delivers an estimated 67% energy reduction for machining GDi injector spray holes compared to EDM baseline
- Optimization efforts during the next FY are expected to provide an additional 33% reduction in energy consumption