High Metal Removal Rate Process for Machining Difficult Materials

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Recipient: Delphi Automotive Systems, LLC
Partners: Microlution Inc. & Raydiance Inc.
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This presentation does not contain any proprietary, confidential, or otherwise restricted information.
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:

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<td>Multi-Application Testbed Development</td>
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<td>Build and Test Multi-Application Testbed</td>
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<td>Demonstrate testbed design meets or exceeds performance criteria</td>
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<td>Advanced Control Development for Coordinated Motion and Laser Firing</td>
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<td>Demonstrate advanced control with multi-axis high/low frequency coordination</td>
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<td>Laser Processing Strategy Development</td>
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<td>Precious Metal Drilling for Cardiac Catheter Devices</td>
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<td>Demonstrate precious metal drilling performance</td>
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<td>Ceramic Hole Drilling for Probe Cards</td>
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<td>Demonstrate ceramic hole drilling performance</td>
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<td>Hybrid Machining Strategy Development</td>
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<td>In-Situ Measurement for Laser Tube Processing for Marker Bands</td>
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<td>Demonstrate tube cutting process</td>
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<td>Hybrid Machining for Test Sockets</td>
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<td>Demonstrate hybrid machining of test sockets</td>
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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)

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