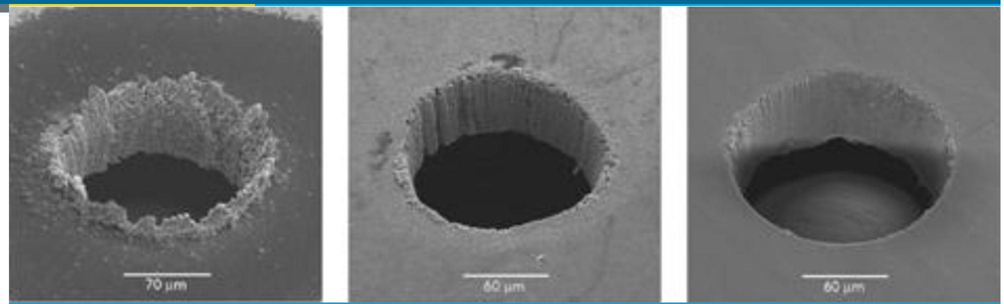
High Metal Removal Rate Process for Machining Difficult Materials

A Novel Machining Platform Using Ultrafast Lasers to Produce High-Precision Components.



150 µm diameter holes cut in a 50 µm thick silicon wafer via nano (left), pico (center), and femtosecond (right) pulse lasers. *Photo credit Raydiance.*

Machining is used in a variety of manufacturing applications in order to remove some material to create a finished product. Typical examples of machining include turning operations where a workpiece is rotated against a cutting tool, milling operations where the cutting tool rotates against the workpiece, and drilling operations where holes are produced or refined. However, traditional machining platforms are poorly suited to produce small parts with high accuracy requirements. The current machining methods are often too large, too inflexible, and lack the necessary precision to manufacture parts with complex shapes or micron-sized features.

The use of ultrafast (femtosecond) lasers can overcome these limitations and machine advanced materials into high-precision components. Short laser pulses can use athermal ablation, which produces the final part without requiring post-processing to eliminate machining defects. Combining a laser with high-precision manipulators would automate and therefore expedite the machining process. This machining platform could remove material with micron precision, without modification or damage to the remaining material, and in a single-step manufacturing process. The project focus is to prove this new method in the production of gasoline direct injection (GDI) fuel injectors and difficult to machine materials.

Benefits for Our Industry and Our Nation

Developing the ultrafast laser platform is a gateway to numerous advances in manufacturing. Combining lasers and motion control devices into a simple interface that can mesh with computer-aided design (CAD) renderings will expedite manufacturing compared to electro-discharge machining, a typical method used today for machining difficult materials. Energy efficiency is expected to increase by 20-25% and cycle time could decrease substantially. No consumables are required, which reduces materials costs and energy associated with their production. In addition, this process will eliminate post-production and its associated chemicals use. This technology could have broad impacts in diverse manufacturing sectors.

Applications in Our Nation’s Industry

Ultrafast laser technologies would represent a leap forward for machining processes, reducing both time and energy versus standard micro-machining platforms. Applications that could utilize the technology are diverse. For example, GDI fuel injectors play an important role in efforts to develop cars with better fuel economy. Engines that use GDI injectors are more energy efficient due to their higher compression ratios and better compatibility with turbocharging Turbocharged GDI engines could be downsized to improve fuel economy by 10% or more without affecting performance. This technology would also be available for use in other applications including electronics, defense, solar energy, wind energy, biosciences, and medical devices.

Project Description

The goal of the project is to develop an automated, ultrafast laser machining device that will then be used to first prototype GDI injectors. Combining the manipulators with the laser will result in a machine that is able to machine parts to high specifications. The platform will be able to turn CAD drawings into high-precision prototypes. Simultaneous to the creation of this platform, specifications needed for GDI component manufacturing will be established. Once the laser drilling system is completed, the platform will be used on a sample production line. The resulting prototypes will be tested to ensure that they meet known customer and performance requirements.

Barriers

- Ensuring that the laser can be tuned to work with necessary precision at an acceptable rate.
- Designing the mechanical manipulator to the necessary specifications.
- Ensuring that the laser and the mechanical manipulator can communicate with each other and take commands from the design software.
- Producing a prototyped part that is able to meet mechanical and performance metrics at cost.

Pathways

This project will proceed through two separate tracks that will be combined in order to reach the final objective. Researchers will simultaneously develop the enhanced ultrafast laser and the microscale manipulator, then integrate and test these two devices to specifications set by Delphi. Delphi will then test the automated laser drilling device by making GDI injectors. Spray and flow performance for these GDI injectors will be determined via bench testing before the injectors are evaluated in engines. The resulting advanced components will offer improved manufacturing efficiency and lower energy inputs compared to products made with currently available machining techniques.

Milestones

This project began in 2012.

- Develop an integrated laser and scan head that meets target rotational speed that exceeds 200Hz at an attack angle above 80% (Completed).
- Demonstrate drilling of fuel injector spray holes in less than 8 seconds and an overall 50% cycle time reduction in machine time with no degradation in quality compared to existing micro-machining processes (Completed).
- Increase laser machining efficiency by 20-25% compared to standard micro-machining processes (Completed).
- Produce fuel injectors that pass cold start engine tests and move technology towards production setting (Completed 2014 and adopted by Delphi).

Commercialization

Delphi has successfully adopted the technology to make GDI injectors. In the remaining project work, Microlution will focus on platform development applications relevant to the electronics and biomedical industries. These applications include ceramic hole drilling (electronics industry), precious metal drilling (biomedical industry), and precious metal tube cutting (biomedical industry). Consequently, completion of the project will ultimately result in a manufacturing method offering reduced process steps and energy consumption for hard-to-machine materials across multiple markets. Project completion is scheduled for end of 2015. The test bed is to be completed by end of June 2015 and process validation tests for the various applications are scheduled to be completed by December 2015.

Project Partners

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