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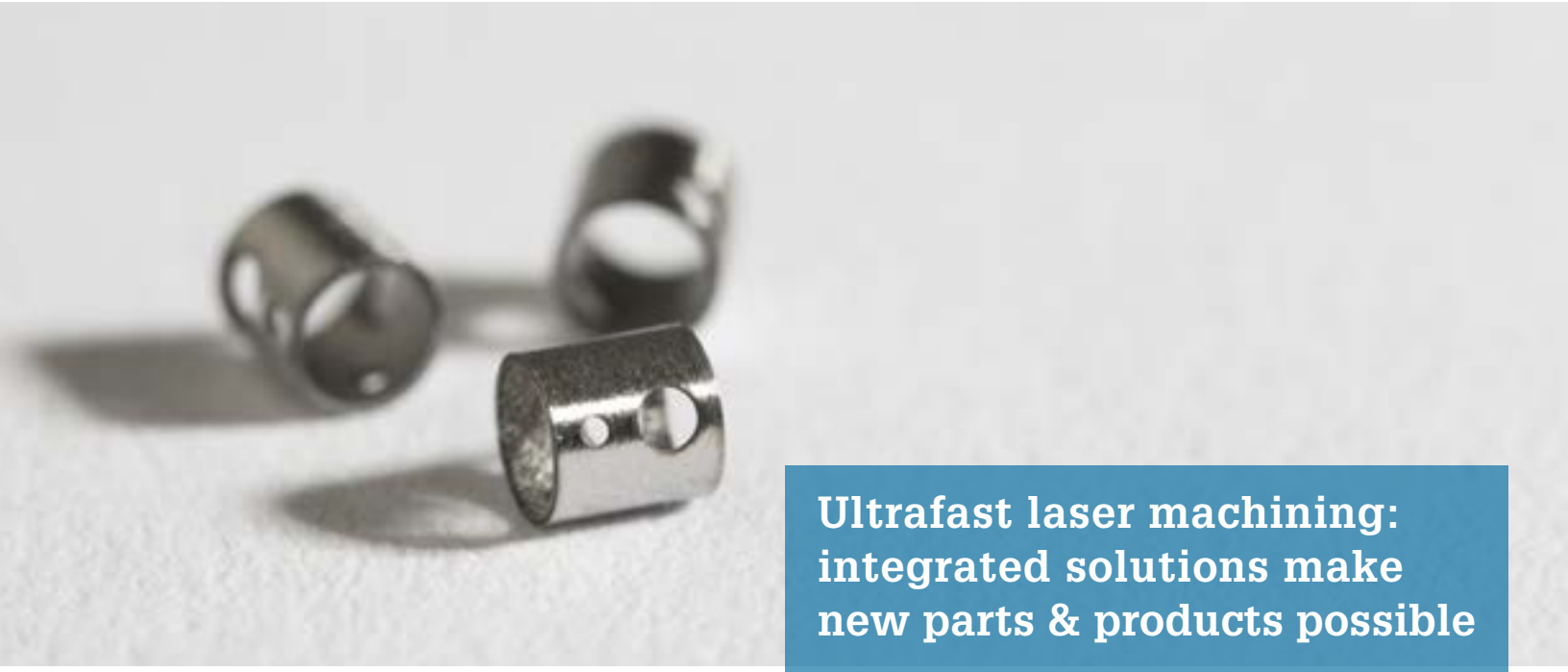
Laser Micromachining

Ultrafast laser machining: integrated solutions make new parts and products possible

Introduction

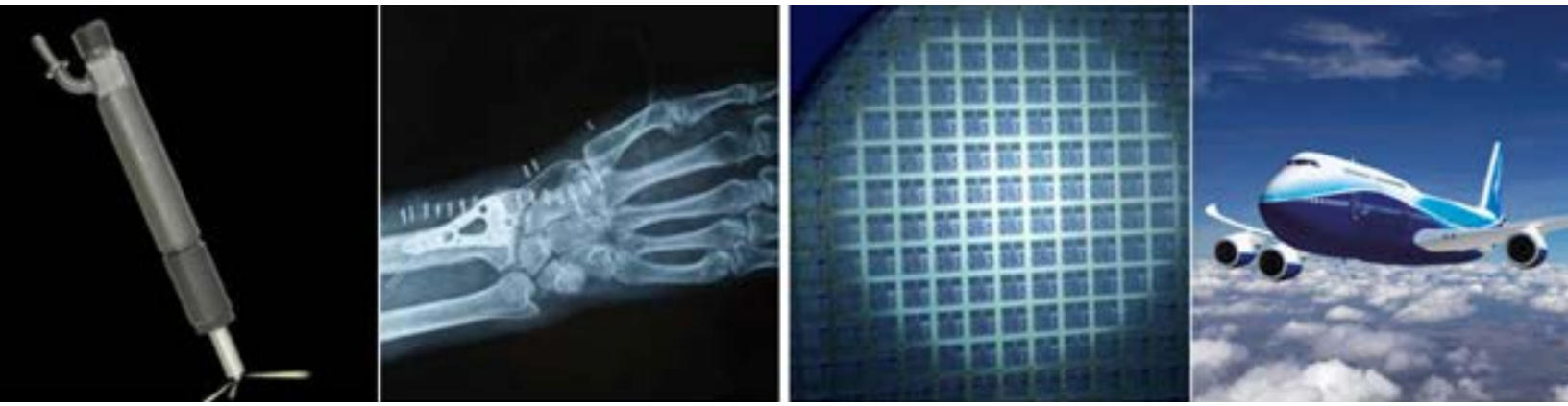
Ultrafast laser micromanufacturing, the fabrication of parts measured in microns, was once the stuff of laboratories and research facilities. Experiments were conducted with materials and machining processes to create concepts for new products with micro-scale features and futuristic designs. These experiments were interesting, but the equipment was extremely sensitive and manually controlled which meant that machining micron-scale geometries was not feasible in a real-world manufacturing environment.

Meanwhile, the products desired and required by people around the world are getting smaller and smaller – and the components that make these up must be even smaller. Existing products have also incorporated advanced and highly precise features that make them more effective. These range from fuel injectors that increase mileage and turbine blades that boost jet engine efficiency to implantable medical devices that save lives and integrated circuits with tens of thousands of connections.



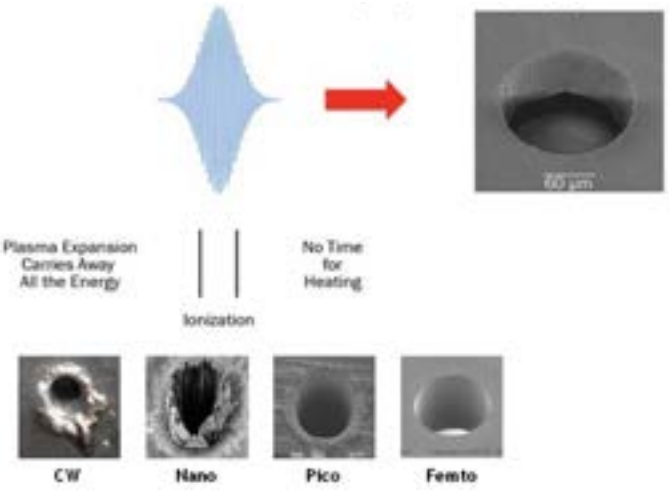
Ultrafast laser machining: integrated solutions make new parts & products possible

As the world demands smaller, smarter and more sophisticated products, the manufacturing processes to make them must do the same. But with ultrafast laser micromanufacturing solutions that can produce tiny features with extreme accuracy, manufacturers have access to key capabilities for enabling the next generations of precision parts.



Recent advances in laser micromachining technology, material processing, metrology, and motion control have resulted in ultrafast laser manufacturing solutions capable of fabricating precision micro-scale parts for these new products at production speeds in high-volume manufacturing environments. Foremost among these advancements is the commercialization of ultrafast lasers for industrial use. Now robust enough to leave the laboratory, lasers at femtosecond pulse rates that can perform in factory environments have arrived.

Ultrafast lasers are prized for their ability to machine without heat. Removing material without causing thermal damage makes it possible to create minute part features with extreme precision and quality. The figure below shows how ultrafast lasers with extremely short pulse width are able to remove material before heat can be absorbed by the part, creating high-precision micro holes.

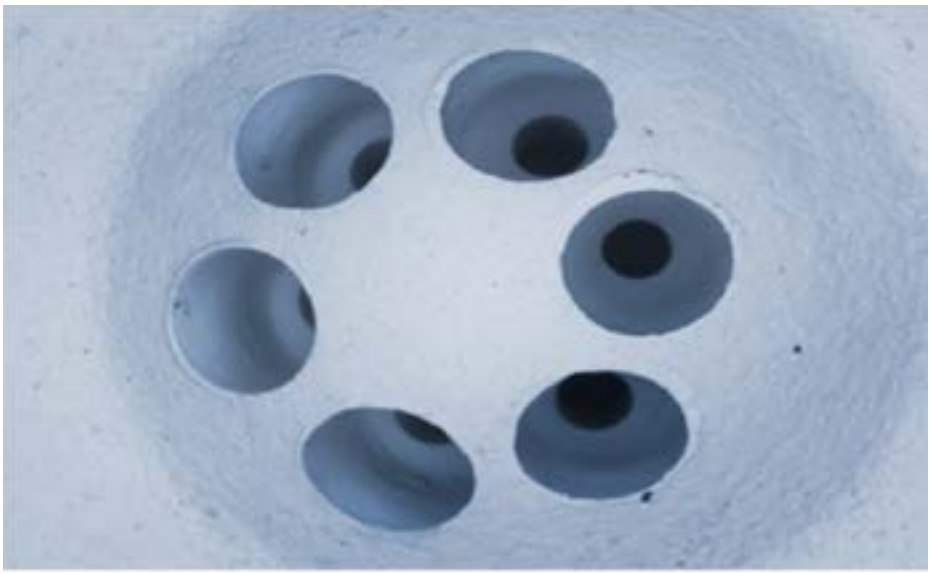


However, it takes more than a laser to create precise features on precision parts produced at scale. A major advancement in today's sophisticated micro-manufacturing solutions is the ability to integrate multiple machining technology, including part characterization, metrology data, visual inspection and finishing, into a consolidated ultrafast laser manufacturing solution. These new integrated ultrafast laser micro-manufacturing systems seamlessly load, position, measure, machine, finish and unload parts within a single work cell. With the capacity to adjust machining processes in response to real-time measurement data, these machines can create identical parts even from dissimilar raw pieces – all at production speeds. The result is higher yields and lower cycle times for finished parts fabricated with best-in-class precision.

New micro-manufacturing solutions integrate ultraprecise laser micro-drilling and milling technologies with high-speed, multi-axis motion control, real-time measurement and part validation for superior part-production results and rapid cycle times. As a result, exciting new products are now manufacturable in the automotive, medical device, semiconductor and aerospace industries.

Automotive Solutions

Engine manufacturers have pursued serious research and development efforts to create the manufacturing technology necessary for the fuel economy and emissions required in an increasingly regulated industry.



Gasoline direct injection (GDI) fuel systems are increasing in popularity for their ability to better control the fuel atomization process, which in turn leads to improved fuel economy and reduced emissions. However, the production of GDI components, particularly the fuel nozzle, demands unprecedented levels of machining accuracy and precision as well as increased process flexibility. To maximize fuel economy and minimize emissions, tight control is needed over flow, spray angle, drop size distribution, fuel mass distribution and spray tip penetration.

To help automotive manufacturers overcome these challenges, Microlution, Inc., has developed the ML5, a single-station solution for GDI fuel nozzle production. The compact, robust machine design is factory tested to maintain the tightest flow control throughout high-volume serial production. It is capable of being fully automated while maintaining positional accuracy of ±1 µm.

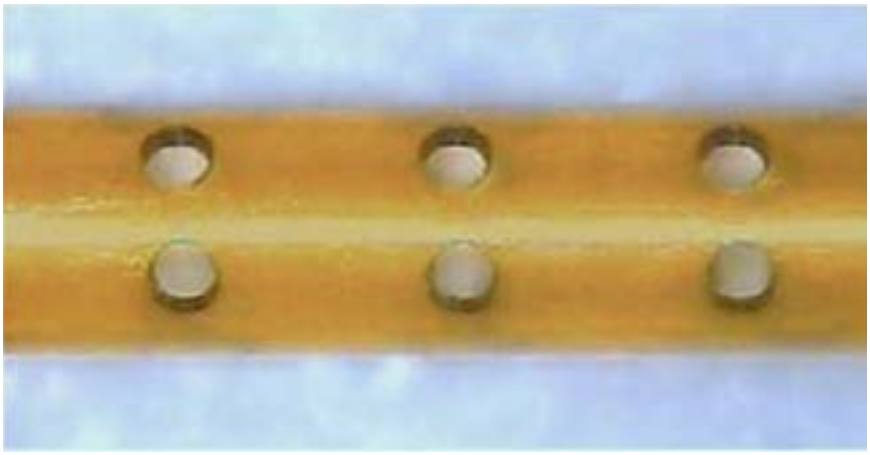
For high-volume micro-scale hole drilling, Microlution has also developed a multi-station platform capable of processing up to 6 GDI fuel nozzles in parallel. It features one laser drilling station and two measurement stations. The information gathered from the measurement stations is used to automatically adjust the laser drilling process, correcting for any variance for outstanding precision.

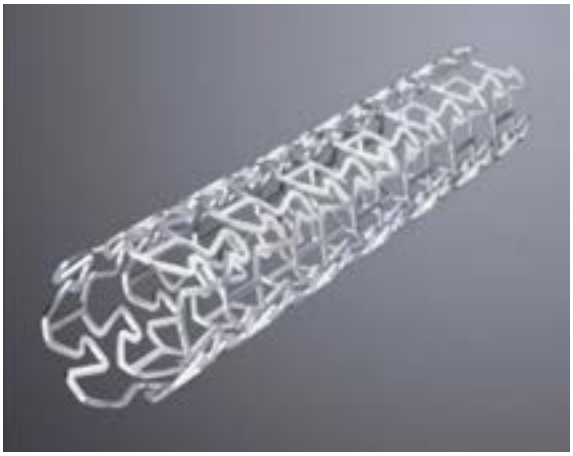
Both solutions are flexible enough to:

- Vary hole-to-hole diameter
- Fine-tune each spray pattern separately
- Quickly prototype/test new combustion designs
- Develop prototypes on production equipment

Medical Device Solutions

In the medical device industry, precision laser micromachining enables exciting new products by making it possible to machine next-generation materials ranging from soft polymers to extremely hard metals.

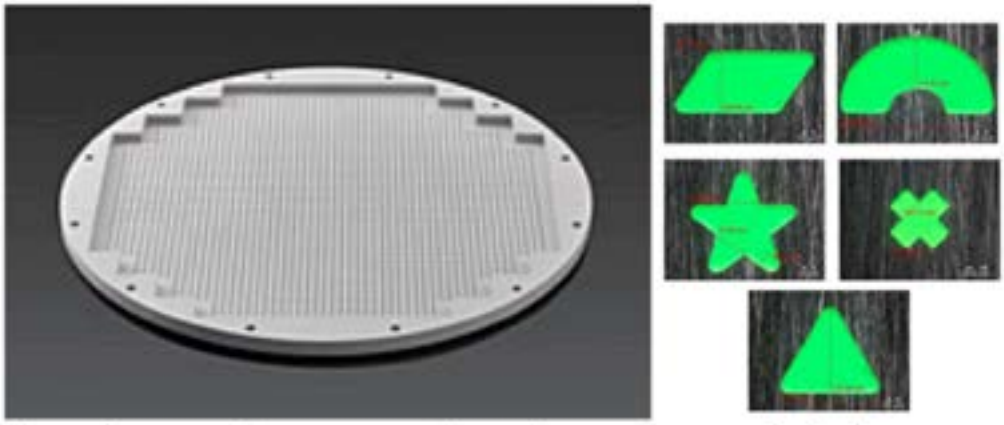




Tiny implantable devices allow physicians to create new treatment modalities that can save lives – and the materials involved could not be cost-effectively machined with legacy equipment. Currently, there are several ultrafast laser solutions for applications that would not be technically or economically feasible with traditional machining technologies, including:

- Ablation tip machining
- Catheter milling
- Hypotube drilling
- Marker band cutting
- Stent creation

While these applications represent the current state of the art, the medical device industry is constantly developing new products that will further challenge the limits of manufacturing technology. For medical device manufacturers, process flexibility and the ability of the manufacturing equipment to adapt to unforeseen future demands is paramount.

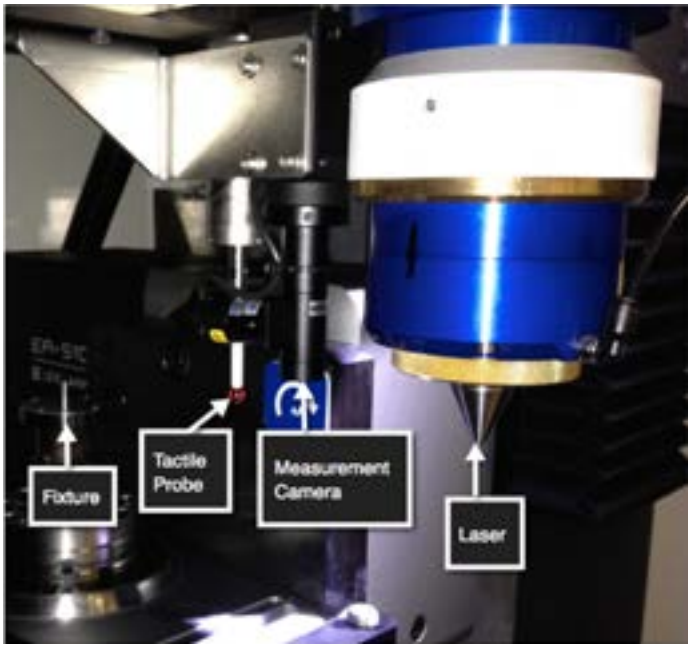


Semiconductor Solutions

Manufacturing micromachined probe cards is one of the most grueling, technically challenging applications in the semiconductor industry, for any micro-machining platform.

Probe cards have traditionally been milled mechanically, even though the significant time and tooling investment required for each probe card makes any flaws or errors hugely expensive.
A single ceramic probe card can require:

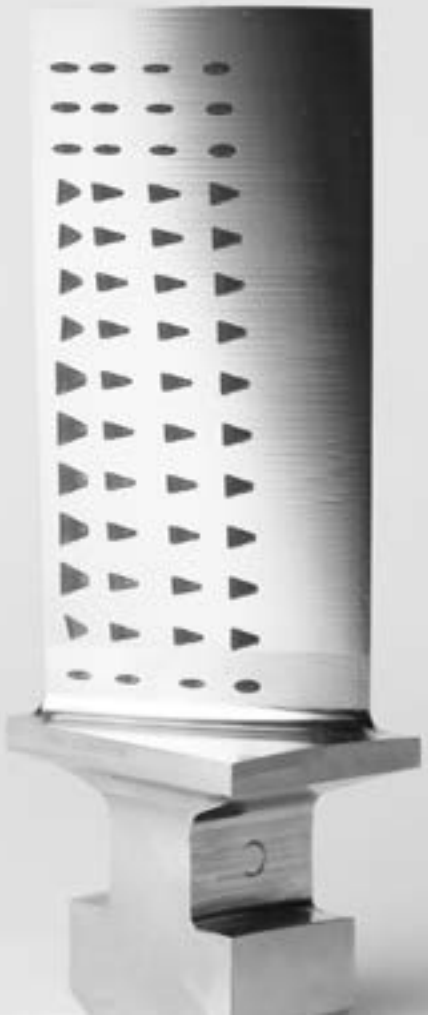
- Over 50,000 micro-scale holes in a 1 x 1 in (25 mm x 25 mm) area
- Micron-level accuracy, nanometer-level repeatability
- Several days of machining time for a single probe card



As if traditional probe cards weren't challenging enough, the latest trend in probe card design – square holes – has necessitated the development of new manufacturing methods. This simple change from circles to squares has been problematic for traditional machine tools, which begs the questions: what shape will become the industry standard, and how will manufacturing technology adapt?

While the latest demands of the probe card industry have made traditional mechanical milling systems obsolete, the requirements are still limited to 3-axis hole operations. Microlution has developed a 3-axis ultrafast laser solution that meets the specific challenges of probe card machining. The solution is flexible enough to create an endless variety of different features, all without any re-tooling, significantly reducing the cost of prototyping while expanding R&D capabilities.

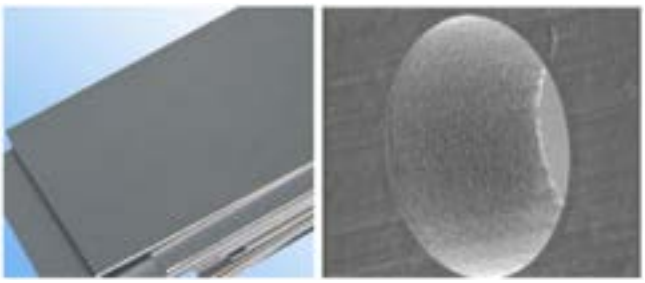
Aerospace Applications



The requirement for micron-level accuracy and part-to-part consistency in superalloys makes the serial production of aerospace turbine blades especially difficult.

Principally, the hardened materials needed to survive the harsh environment of a jet engine pose many problems for traditional machining methods. Luckily, the ablation process of ultrafast lasers can create fine features in materials ranging from ceramics to metals and other composites. The remaining challenge involves achieving acceptable accuracy and consistency while maintaining the flexibility needed to micromachine a variety of different feature shapes and sizes.

Microlution has developed a 5-axis platform that provides all of the necessary advantages of an ultrafast laser drilling unit while delivering process flexibility, micron-level accuracy and a variety of automation integration options. Integrated micro-manufacturing solutions have been combined to give manufacturers access to multiple machining processes within a single, high-speed production system. This approach reduces the equipment, floor space and cycle time required to create precision parts.



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