Raydiance
Precision Like No Other

White Paper

The Hole Story

Better, faster, lower cost micro holes

Introduction

Micro holes are critical to many precision parts—fuel injectors, fabric spinnerets and suture holes on implantable heart scaffolds are a few of the applications where added precision can add exponential value to a product. A precision demands grow, the dimensions and geometries get smaller and smaller—too small for tradition micro drilling tools to achieve with sufficient surface and feature quality.

The Raydiance R- Drill solution uses heatless, ultra precise femtosecond laser technology to drill finished micro holes in a single step—in seconds. Without heat, the machining process imparts no thermal damage to the part, so no post processing or rework is needed. The result is a higher quality hole, faster, and with much improved part consistency, all at a much lower price per part than with traditional tools. This paper demostrates how an array of 16 identical 200 micron diameter, zero-taper holes was drilled into small coupons of 250 micron thick 440 stainless steel. The hole quality was excellent, as was the dimensional repeatability of the process.Typical cycle time per hole 1 second.

Precision Hole Drilling

Precision hole drilling at the micron level can be slow and costly. The the legacy technology of choice, Electronic Discharge Machinining (EDM), uses a charged electrode to bore into metal, but as the drilling takes place, the electrode wears out and changes shape slighly, resulting in high part variability. The Raydiance R-Drill uses a femtosecond laser process, programmed to remove specific material to specific demensions, and does so three times faster than an EDM process, with 60 percent better variability.

In this example, an array of 16 identical 200 micron diameter, zero-taper holes was drilled into small coupons of 250 micron thick 440 stainless steel. Ten coupons were prepared in this way to demonstrate the Raydiance R-Drill capability and repeatability. The holes were extremely high quality and free of burrs, recast, melt, discoloration, or other thermal effects to the surrounding material. No post processing was performed other than a brief ultrasonic cleaning in a dilute, aqueous detergent bath. The typical cycle time per hole was approximately 1 second.

To assess repeatability of the process, the dimensions of all entrance and exit holes were measured on one representative coupon. The results are shown in the ***Table 1***. Hole-to-hole dimensional variation of exit holes was on the order of the measurement repeatability of the measuring microscope used for this evaluation (~1 micron). Entrance hole dimensional repeatability was on the order of ± 2 microns, or ± 1 percent of the nominal hole dimension.

The holes generated on these samples are suitable for gas direct injection (GDi) port fuel injection (PFi) and turbo-diesel injection (TDi) applications. Coupled with suitable automated motion control, the Raydiance R-Drill solution provides the flexibility to produce holes of equivalent quality and repeatability for GDi, PFi and TDi components.

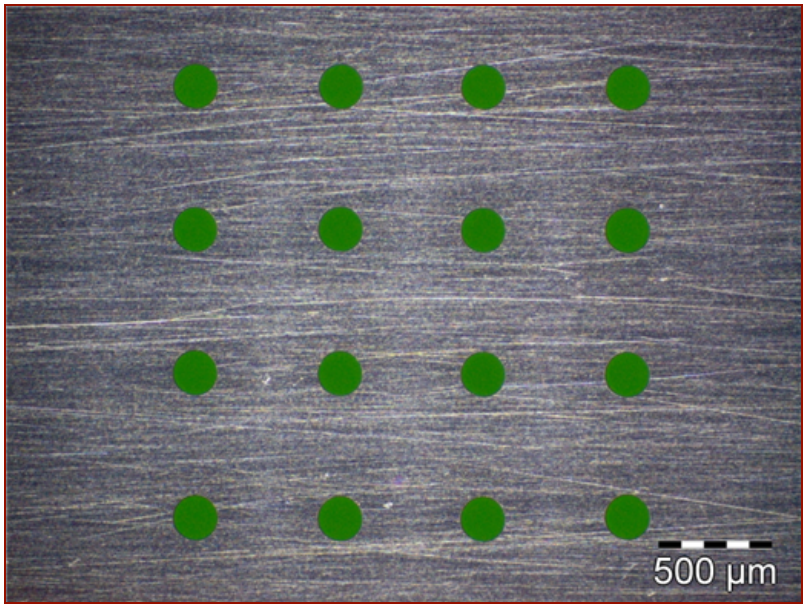

***Figure 1**: 50x dark field image showing all 16 entrance holes drilled in a typical sample*

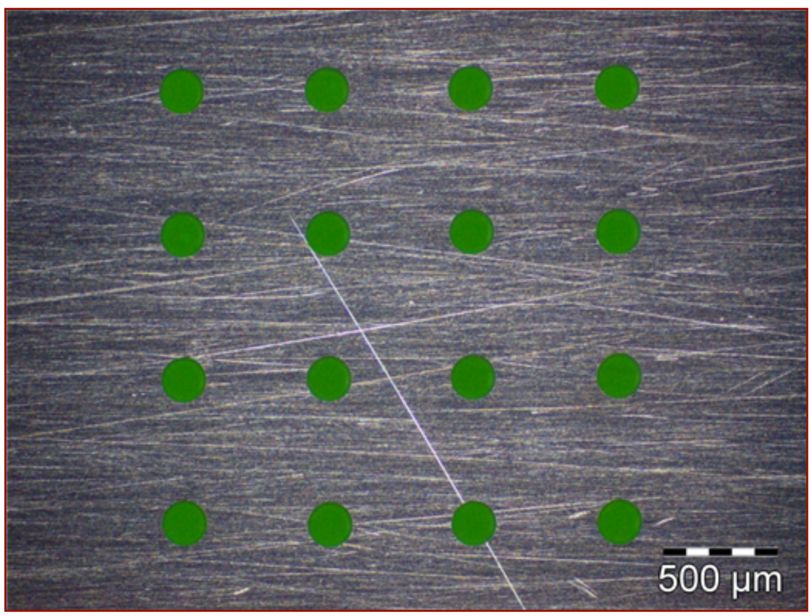

***Figure 2**: 50x dark field visible image of all 16 exit holes in a typical sample.*

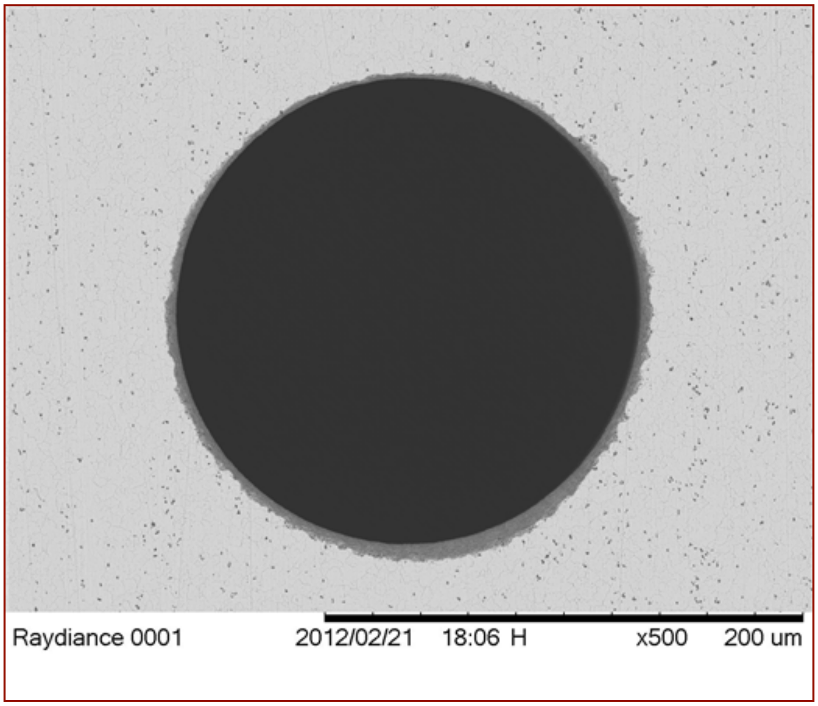

Figure 3*: 500x SEM image of typical entrance hole.*

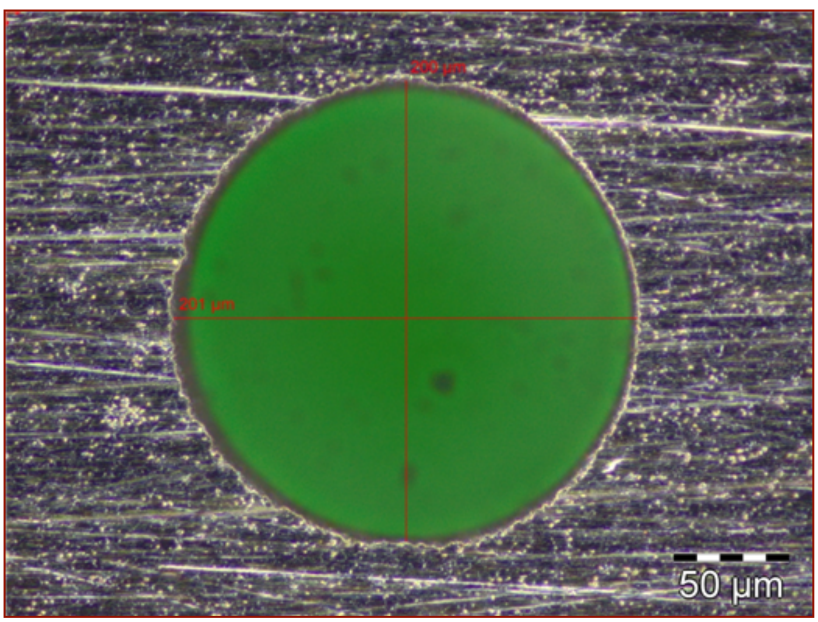

Figure 4*: 500x dark field visible image of typical entrance hole.*

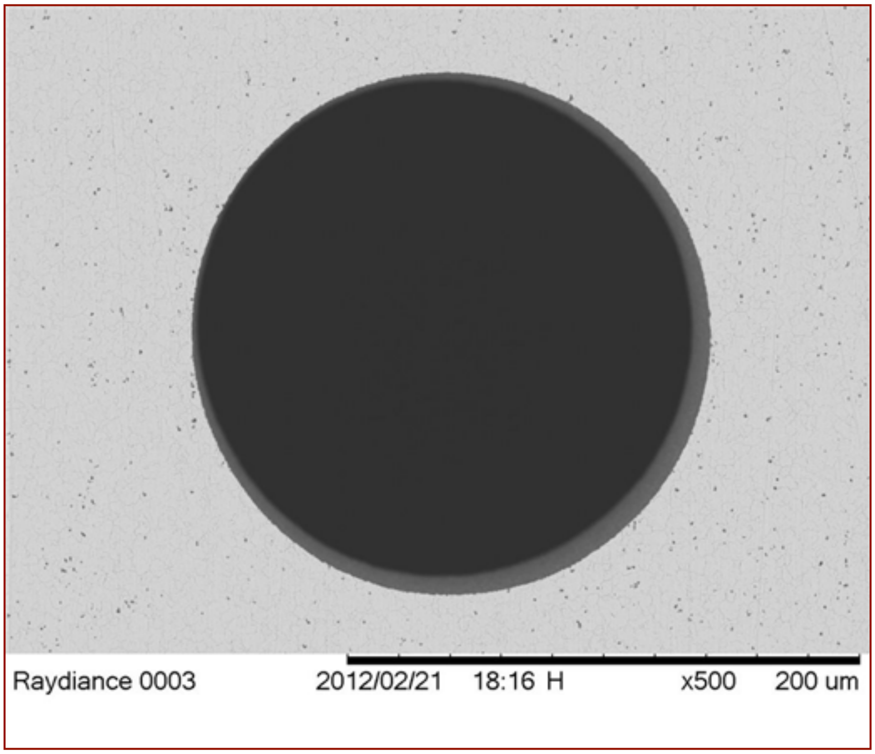

***Figure 5**: 500x SEM image of typical exit hole viewed at normal incidence.*

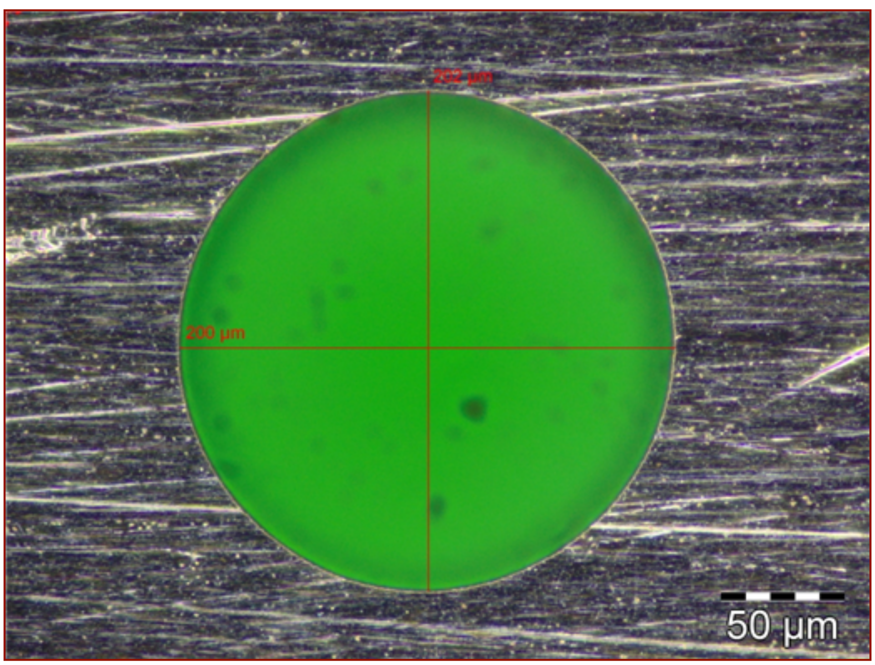

Figure 6**: **500x dark field visible image of typical exit hole.

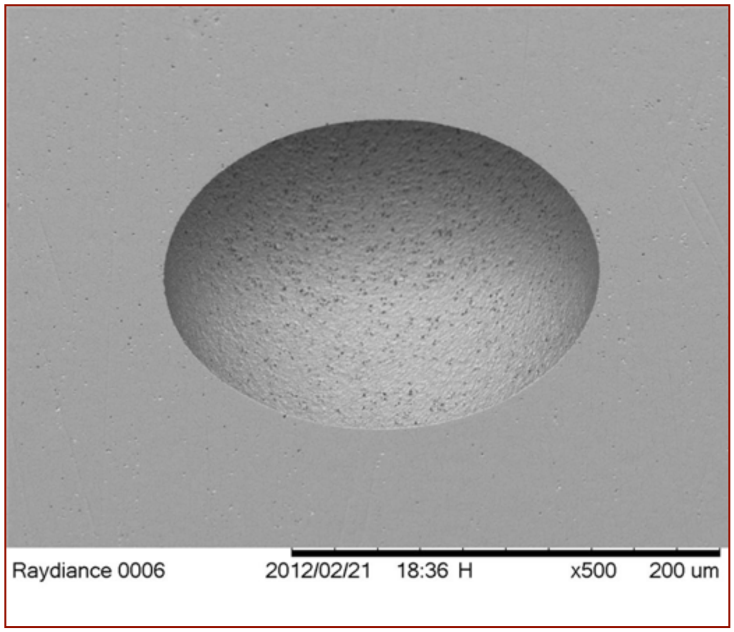

***Figure 7**: 500x SEM image of typical exit hole at 45 degree orientation.It should be noted that the 440 stainless steel material used was quite porous. This could be clearly seen on the surface as well as inside the hole.*

	INPUT FACE				OUTPUT FACE			
HOLE #	X	Y	AVERAGE	CIRC	X	Y	AVERAGE	CIRC
1	200	200	200.0	100.0%	200	202	201.0	99.0%
2	200	203	201.5	98.5%	200	202	201.0	99.0%
3	200	201	200.5	99.5%	200	202	201.0	99.0%
4	201	203	202.0	99.0%	200	202	201.0	99.0%
5	201	203	202.0	99.0%	200	202	201.0	99.0%
6	201	200	200.5	99.5%	200	202	201.0	99.0%
7	200	203	201.5	98.5%	200	202	201.0	99.0%
8	201	204	202.5	98.5%	200	201	200.5	99.5%
9	201	204	202.5	98.5%	200	202	201.0	99.0%
10	202	204	203.0	99.0%	200	202	201.0	99.0%
11	200	203	201.5	98.5%	200	202	201.0	99.0%
12	202	204	203.0	99.0%	199	202	200.5	98.5%
13	203	204	203.5	99.5%	200	202	201.0	99.0%
14	202	204	203.0	99.0%	200	202	201.0	99.0%
15	203	204	203.5	99.5%	200	202	201.0	99.0%
16	203	204	203.5	99.5%	200	202	201.0	99.0%
MINIMUM	200	200	200	98.5%	199	201	200.5	98.5%
MAXIMUM	203	204	203.5	100.0%	200	202	201	99.5%
RANGE	3	4	3.5	1.5%	1	1	0.5	1.0%
AVERAGE	201.3	203.0	202.1	99.1%	199.9	201.9	200.9	99.0%
STDEV	1.1	1.4	1.1	0.005	0.3	0.3	0.2	0.002
VARIANCE	0.56%	0.70%	0.56%	0.48%	0.13%	0.12%	0.08%	0.18%

***Table 1**: Entrance and exit hole dimensions measured on a representative sample.*

Summary

The Raydiance solutions are transforming the technology and economics of micro manufacturing. Creating finished parts in a single process—whether drilling holes, cutting metal or cutting glass—eliminates post processing and its associated material, equipment and labor costs. Improved part quality, consistency and yield add to the value delivered by the Raydiance solution. The result is a typical savings of 50 percent per finished part, along with the ability to realize new designs, new products and new revenue streams.