REPORT: Hole drilling by Laser MicroJet®

for Anonymous

by Florent Bruckert, Synova SA

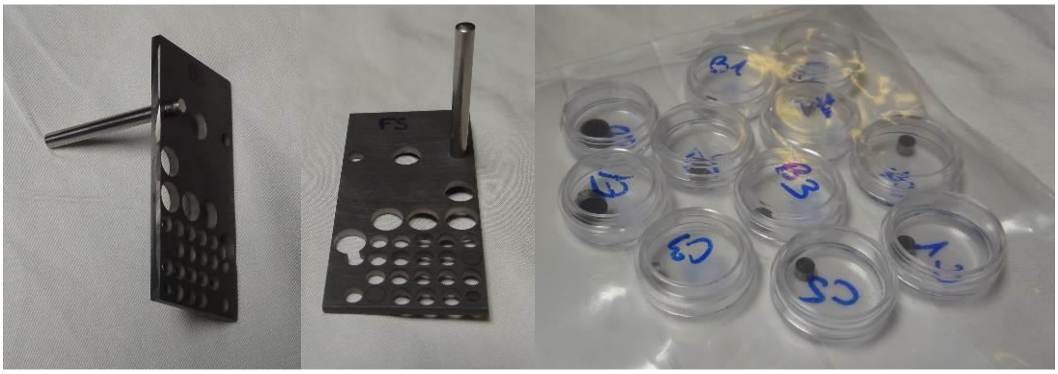
TASK

The Laser MicroJet® technology has been tested for drilling holes in a tungsten-carbide substrate. The aim was to prove that the Laser MicroJet® technology permits to cut holes without taper effect (more specifically, with diameter difference between fronts side and back side less than 3 µm).

SAMPLE DESCRIPTION

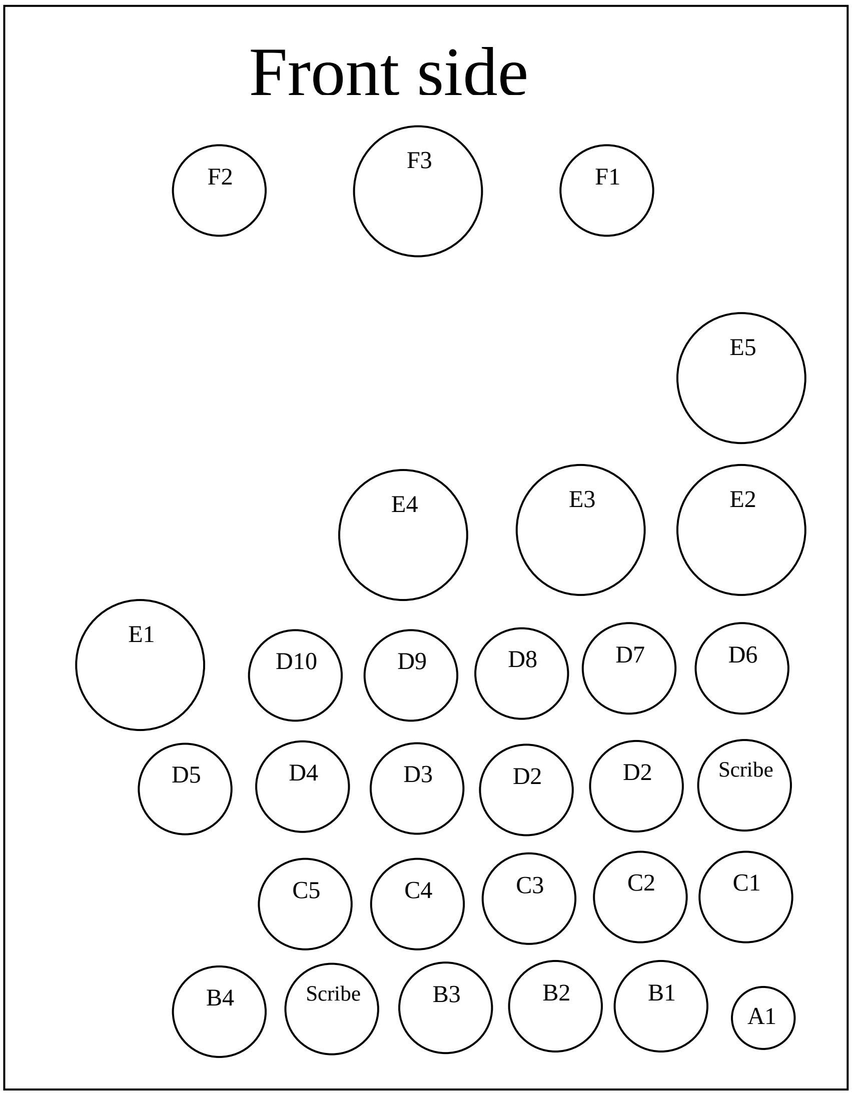
Several holes were cut in the provided plate, as shown in Picture 1. Each hole is identified with a letter and a number, presented in Picture 2.

SUPPLIED MATERIAL	Material	WC0.91, Ni0.09
	Thickness	2.000 mm
	Description	24 X 47 mm^2
	Quantity	1



PICTURE 1: Pictures of the processed sample and its remaining parts

Release of application report			
	Project Leader		Industry BU Responsible
Name:	Mr Florent Bruckert	Name:	D^r Carron Benjamin
Date:	12.08.2013	Date:	12.08.2013
Visum:	FBR	Visum:	ROM

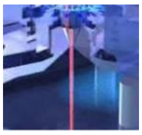


PICTURE 2: Positioning of the tests

PROCESS: INSTRUMENT & TEST PARAMETERS

For this application, an LCS300 equipped with a frequency-doubled, Q-switched, Nd:YAG laser, has been selected as the best machine configuration available in the lab.

The table below summarizes the general parameters used in the experiments. The process parameters specific to each hole are given further in the next section.

	**SYSTEM**	Machine type	LCS300
		Fixture	Clamped
	**MICROJET® PARAMETER**	Nozzle diameter	40 *µm*
		Kerf width	33 *µm*
		Working distance	9 *mm*
		Assist gas	He
	**LASER AND CUTTING PARAMETERS**	Laser type	L51G
		Wavelength	532 *nm*
		Laser repetition rate	6 *kHz*
		Pulse width	140 *ns*
		Power in the water jet	12 *W*

RESULTS

Please see below the table which summarizes the specific parameters and the results of all tests. For most of the tests, the aim was to drill a hole with a diameter of 3.000 mm without taper effect.

Please note that all diameter measurements were done with a *Micro-Vu* "Manual vision system". The accuracy is +/-5 microns which can be quantitatively improved by using always the same measurement protocol (same focus, same zoom, and same illumination). The samples D1 to D4 were processed with the same parameters in order to check the repeatability. The difference is +/- 3 microns.

The samples A1 to C5 were processed with a standard multi-pass strategy. Since the taper was too high, a finishing pass was been added to remove the taper effect in the other tests. The tests indicate that plasma is larger than the water jet when cutting the hole using the multi-pass strategy. However, the plasma seems to be about the same size as the water jet when doing the finishing pass. (Please see Pictures 3 and 4 for an illustration.)

The sample D8 passes the functional test; a calibrated cylinder can go through the hole. It means we need at least a functional slack of 10 µm for your application. (Quality Code H7g6)

The water pressure can greatly affect the cutting speed. The optimum value is 460 bar (samples A1 to B4).

The motion speed does not affect the processing time or the cutting quality. A high motion speed permits only to stabilize the process (limitation of bridges on backside).

<table>
<tr><th rowspan="2">Hole ref.</th><th>Pressure</th><th>Tool path diameter</th><th>Finishing path offset</th><th>Motion speed</th><th>Cutting time</th><th>Ø Front side (measured)</th><th>Ø Back side (measured)</th><th>ΔØ (calculated taper)</th></tr>
<tr><th>[bar]</th><th>[mm]</th><th>[µm]</th><th>[mm/s]</th><th>[min-s]</th><th>[mm]</th><th>[mm]</th><th>[µm]</th></tr>
<tr><td>A1</td><td>440</td><td>2</td><td rowspan="11">N.A.</td><td rowspan="5">10</td><td>1’20s</td><td>2.0734</td><td>2.0390</td><td>34.4</td></tr>
<tr><td>B1</td><td>440</td><td rowspan="20">2.9432</td><td>2’10s</td><td>3.0201</td><td>2.9818</td><td>38.3</td></tr>
<tr><td>B2</td><td>300</td><td>2’45s</td><td>3.0214</td><td>2.9845</td><td>36.9</td></tr>
<tr><td>B3</td><td>370</td><td>2’28s</td><td>3.0119</td><td>2.9756</td><td>36.3</td></tr>
<tr><td>B4</td><td>460</td><td>1’49s</td><td>3.0277</td><td>2.9821</td><td>45.6</td></tr>
<tr><td>C1</td><td rowspan="5">440</td><td>5</td><td>2’21s</td><td>3.0177</td><td>2.9862</td><td>31.5</td></tr>
<tr><td>C2</td><td>20</td><td>1’52s</td><td>3.0238</td><td>2.9884</td><td>35.4</td></tr>
<tr><td>C3</td><td>30</td><td>1’54s</td><td>3.1337</td><td>2.9854</td><td>44.6</td></tr>
<tr><td>C4</td><td rowspan="2">50</td><td rowspan="2">1’56s</td><td>3.0302</td><td>2.9856</td><td>44.6</td></tr>
<tr><td>C5</td><td>3.0302</td><td>2.9890</td><td>41.2</td></tr>
<tr><td>D0</td><td rowspan="11">460</td><td>20</td><td rowspan="11">1’56s
+
1’30s</td><td colspan="3">Not measured</td></tr>
<tr><td>D1</td><td rowspan="4">10</td><td rowspan="10">10</td><td>3.0195</td><td>2.9860</td><td>33.5</td></tr>
<tr><td>D2</td><td>3.0252</td><td>2.9847</td><td>38.1</td></tr>
<tr><td>D3</td><td>3.0223</td><td>2.9866</td><td>35.7</td></tr>
<tr><td>D4</td><td>3.0212</td><td>2.9891</td><td>32.1</td></tr>
<tr><td>D5</td><td>3</td><td>3.0255</td><td>2.9921</td><td>33.4</td></tr>
<tr><td>D6</td><td>13</td><td>3.0266</td><td>2.9939</td><td>32.7</td></tr>
<tr><td>D7</td><td>20</td><td>3.0105</td><td>3.0015</td><td>9</td></tr>
<tr><td>D8</td><td>30</td><td>3.0125</td><td>3.0178</td><td>5.3</td></tr>
<tr><td>D9</td><td>28</td><td>3.0192</td><td>3.0141</td><td>5.1</td></tr>
<tr><td>D10</td><td>26</td><td>3.0182</td><td>3.0152</td><td>3.0</td></tr>
</table>

The parameters used for the hole D6 gave the best results, and were therefore used for the “final” holes F1, F2 and F3.

<table>
<tr><th rowspan="2">Hole ref.</th><th>Pressure</th><th>Tool path diameter</th><th>Finishing pass offset</th><th>Motion speed</th><th>Cutting time</th><th>Expected diameter</th></tr>
<tr><th>[bar]</th><th>[mm]</th><th>[µm]</th><th>[mm/s]</th><th>[min-s]</th><th>[mm]</th></tr>
<tr><td>F1</td><td rowspan="3">460</td><td rowspan="2">2.9432</td><td rowspan="3">10</td><td rowspan="3">10</td><td rowspan="2">3’27s</td><td rowspan="2">3.000</td></tr>
<tr><td>F2</td></tr>
<tr><td>F3</td><td>5.3212</td><td>6’22s</td><td>5.398</td></tr>
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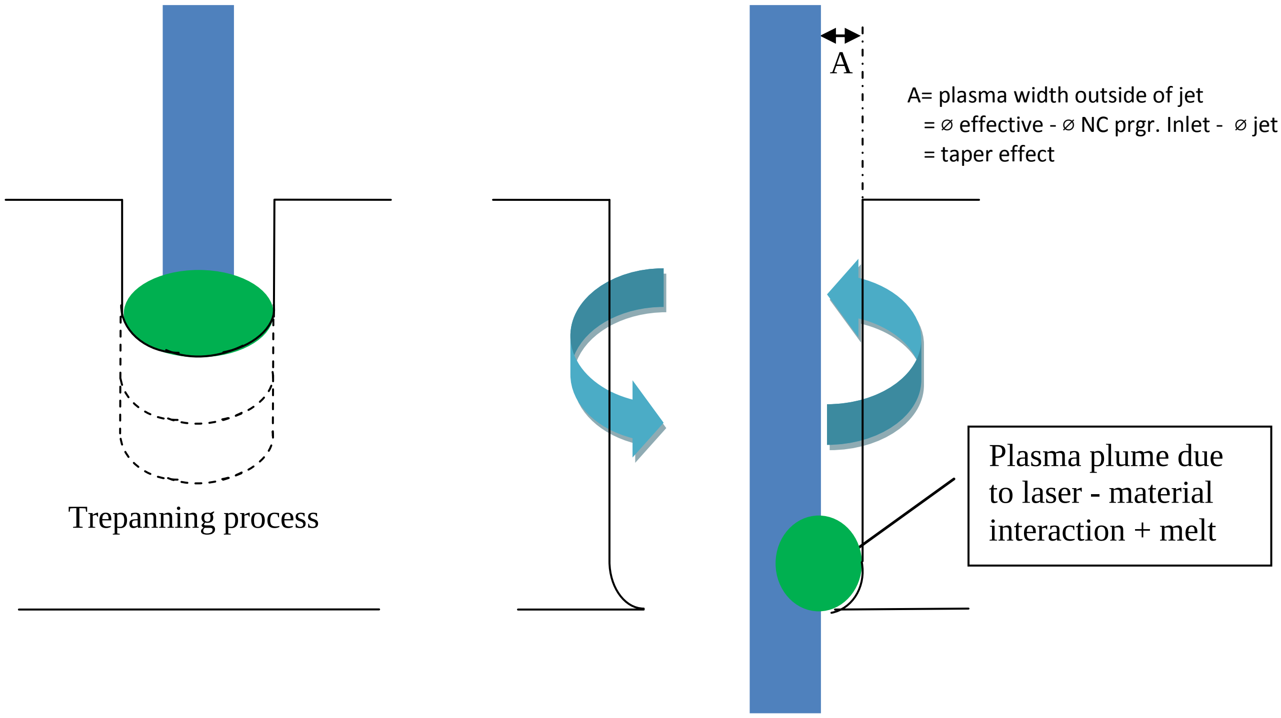
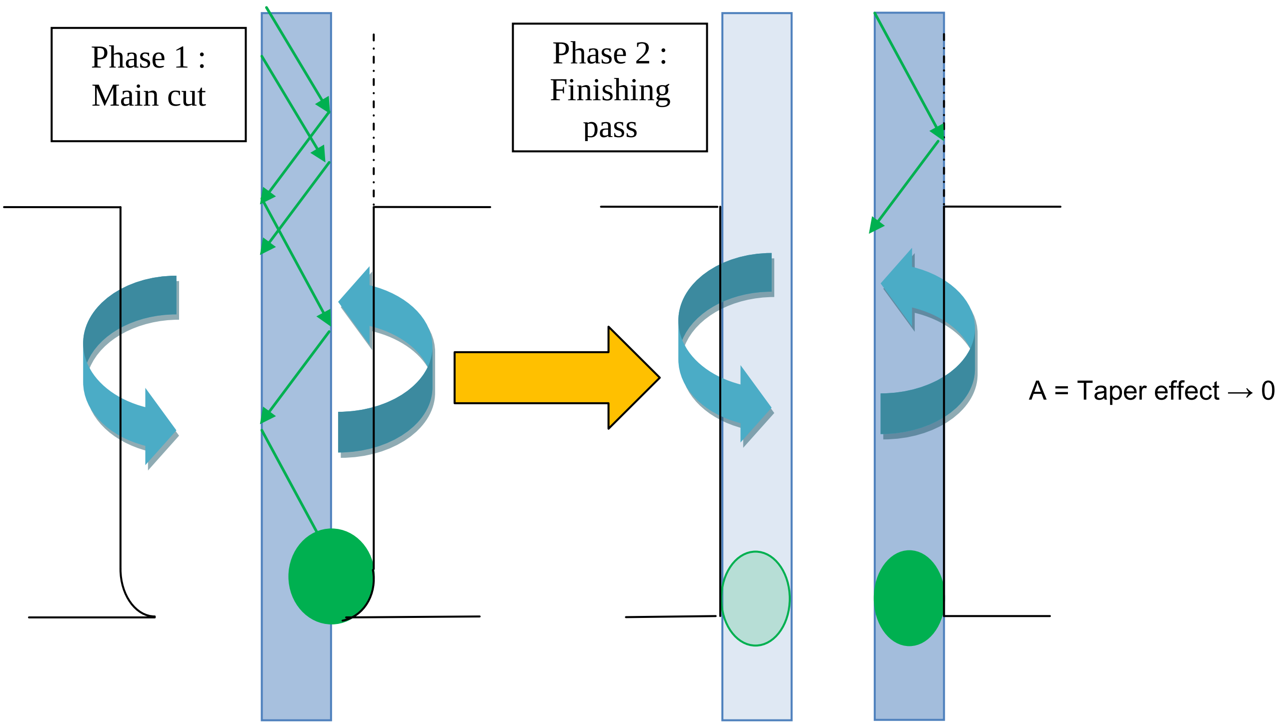
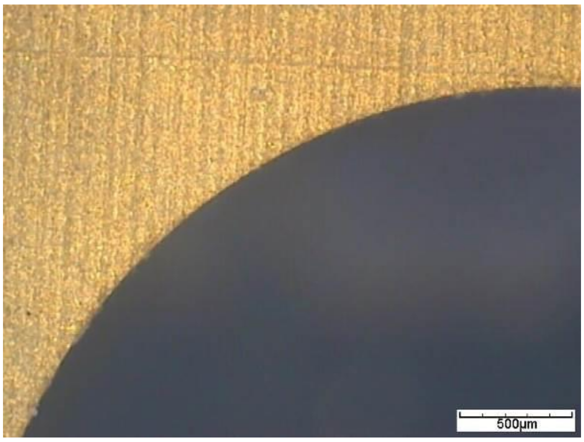


PICTURE 3: Illustration of the multi-pass strategy

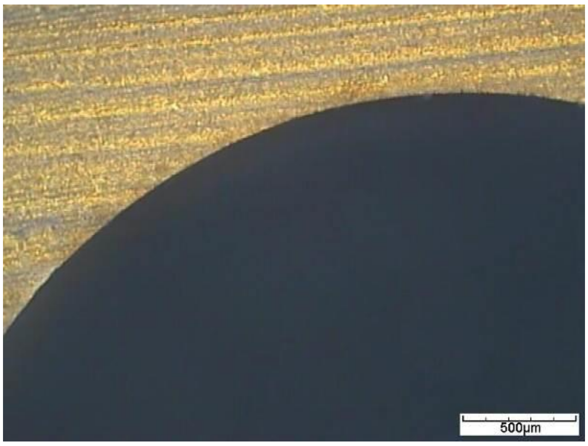


PICTURE 4: Illustration of the finishing-pass strategy

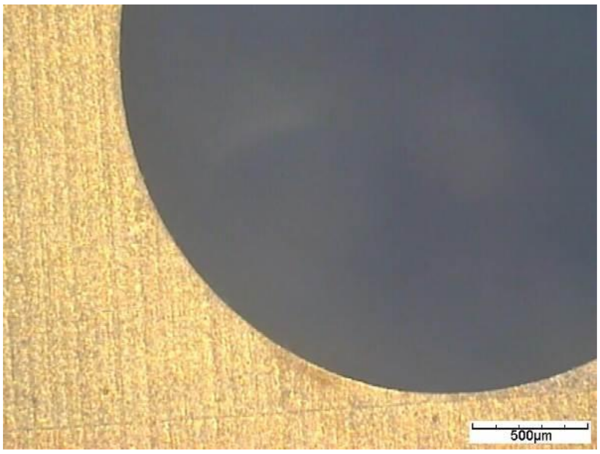
You can see below the pictures related to the previous tests.



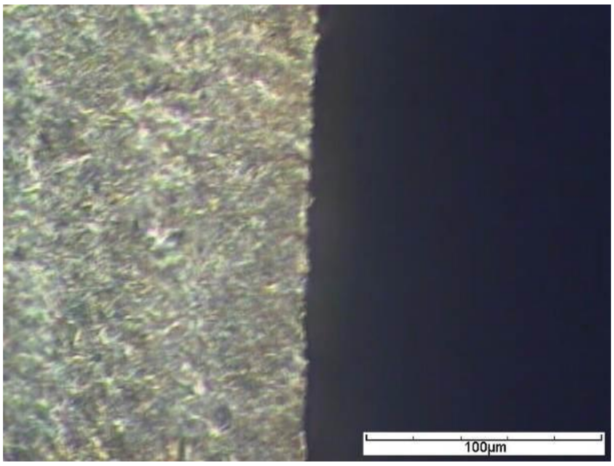
PICTURE 5: Microscope image of the sample F3 (back side view)



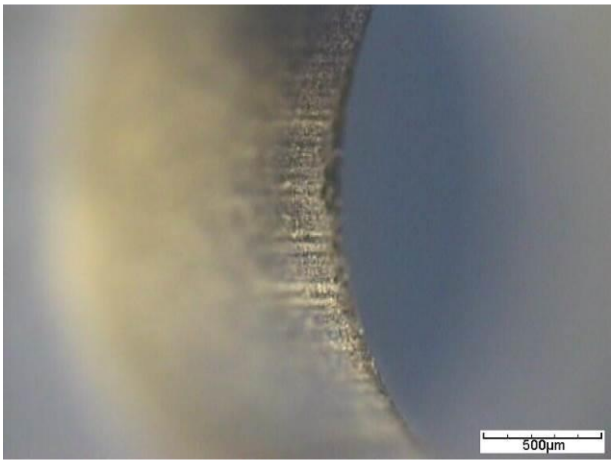
PICTURE 6: Microscope image of the sample F3 (front side view)



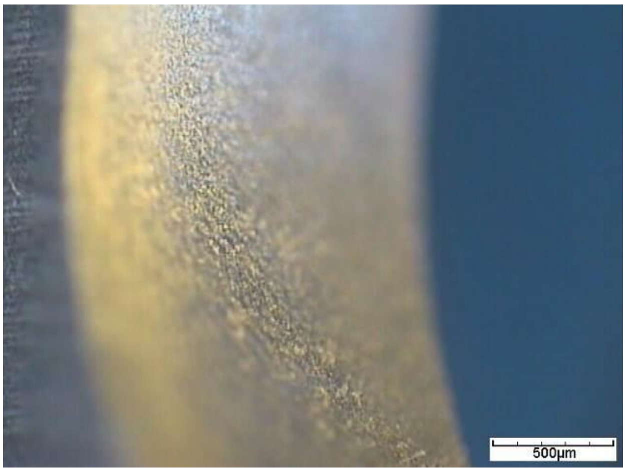
PICTURE 7: Microscope image of the sample F2 (back side view)



PICTURE 8: Microscope image of the sample F2 (back side view)



PICTURE 9: Microscope image of the sample C2 (edge view)



PICTURE 10: Microscope image of the sample F3 (edge view)

CONCLUSION

The hole-drilling in a tungsten-carbide substrate has been performed with a Synova LCS300. This machine is based on the Laser MicroJet® technology and combines the advantages of a high-energy pulsed laser with a hair-thin water jet. While the laser is used for material ablation, the water jet is used for guiding the laser light, cooling the edges and preventing the sample from particle contamination, advantages that are essential for drilling with high quality.

These tests show that:

- It is possible to limit or avoid the taper effect thanks to a finishing-pass strategy.
- The process is finely tunable to reach an expected quality.

We are open to further discuss your needs regarding:

- The process time.
- The final dimensions of the workpiece.

We thank you for your interest in our technology and we hope our results meet your requirements. Our sales agent will contact you soon to obtain a feedback about the analysis of these results and to discuss with you the further steps.