REPORT: Ceramic cutting by Laser-MicroJet®

for Anonymous

by Stephane Delahaye; Synova SA

TASK

The Laser-MicroJet® technology has been tested for cutting many different materials. For this first evaluation of our cutting process the goal is to evaluate different topics:

- Cutting quality
- Process time

So the purpose of this report is to give a summary of the parameters used during the various tests.

Release of application report			
	Project Leader		Responsible Application Group
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Date:	29.01.2013	Date:	29.01.2013
Visum:	SDE	Visum:	BC

SAMPLE DESCRIPTION AND PREPARATION

Anonymous supplied different materials:

SAMPLE A	**PZT plate**
SAMPLE B	**ADC brick**
SAMPLE C	**Al2O3**
SAMPLE D	**WC tungsten carbide**
SAMPLE E	**AL2O3 and gold coating**
SAMPLE F	**ALN**
SAMPLE G	**SiC**
SAMPLE H	**SiN**
SAMPLE I	**PZT**
SAMPLE J	**Alumina 99.3-5%**

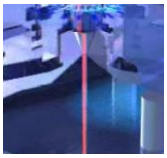
PROCESS: INSTRUMENT & TEST PARAMETERS

For these experiments, the LCS 300 equipped with a single cavity Nd:YAG laser has been used as the machine configuration in our lab.
It is a manually loaded clean-room compatible machine, allowing to cut, drill, groove, scribe, trench, mark, or grind different kinds of materials.

Major advantages of Laser-MicroJet® technology with regards to your application are:

- Cutting of arbitrary shapes
- Limited heat damage to the material
- Parallel and smooth cut walls
- Limited slag/burr formation
- Negligible contamination / re-deposition
- Advantageous process rates

In the table below, the optimized processing parameters used in the experiments are summarized. More details concerning each sample are given in their respective sections.

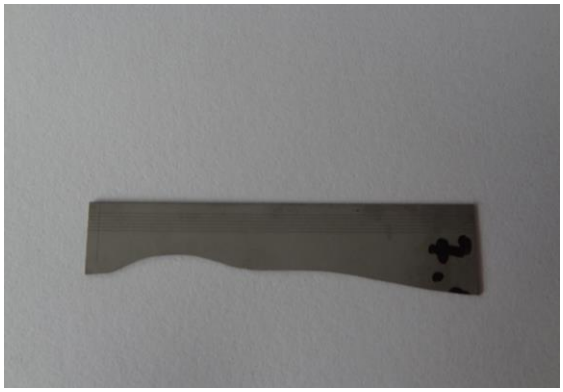
	**SYSTEM**	Machine type	LCS 300
	**MICROJET® PARAMETER**	Nozzle diameter	30 (sample A) *µm* 40 (sample C, D, E, F, G, H, I) 60 (sample J) 80 (sample B)
		MicroJet® diameter	24/32/48/64 *µm*
		Water pressure	200/300 *bar*
		Assist gas	He
	**LASER PARAMETER**	Laser type	L101G/EO21G
		Wavelength	532 *nm*
		Pulse frequency	6--40 *kHz*
		Average power	8--23 *W*

RESULTS

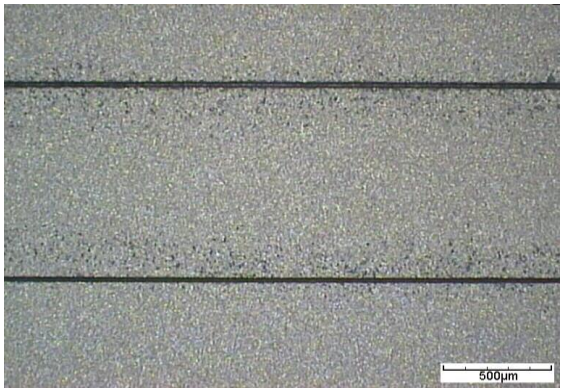
The following microscope pictures give an overview on the quality obtained with the Laser Microjet® technology.

Sample A: PZT plate

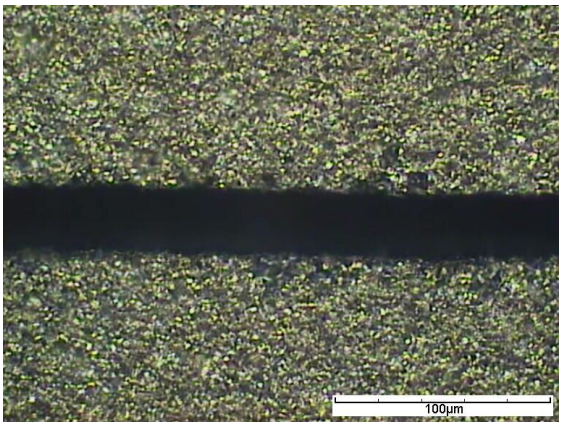
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Grooving 30µm with a kerf of ~30µm **(A)**	300	300	8	50	1	~ 2s by line
2	Grooving ~25µm with a kerf of ~25µm **(B)**	400	300	5	50	1	~ 2s by line
3	Grooving ~25µm with a kerf of ~25µm **(B)**	400	300	7	50	1	~ 2s by line



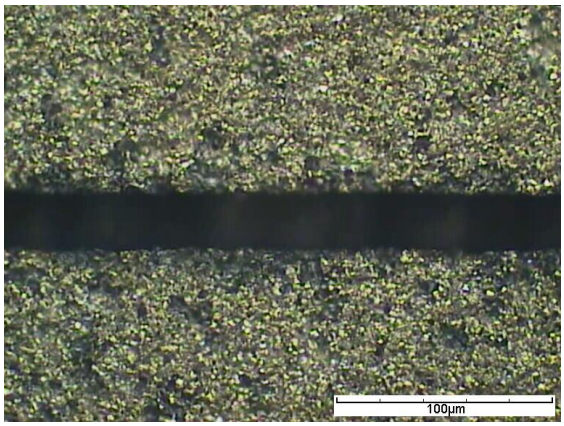
PICTURE 1: Digital camera picture of the sample A



PICTURE 2: Microscope image of the 2 lines grooved on the sample B (dark field illumination; front side view)



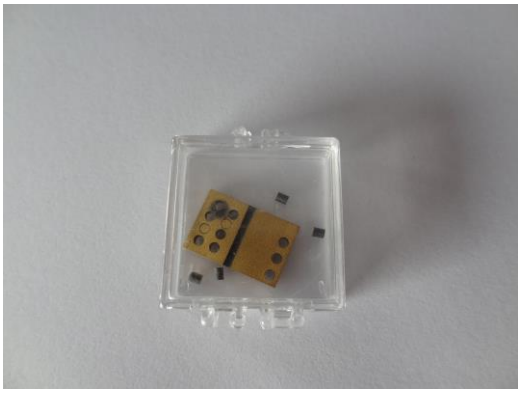
PICTURE 3: Microscope image of the sample A (dark field illumination; front side view)



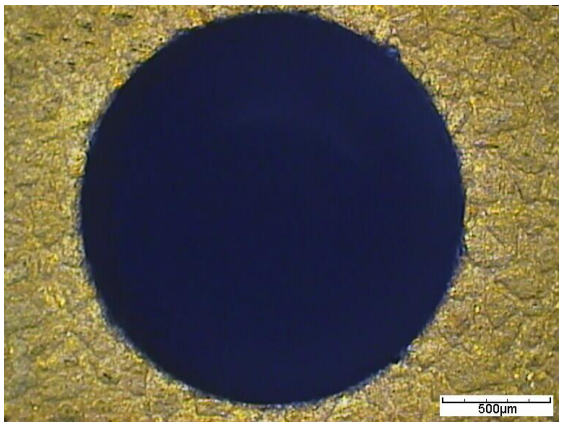
PICTURE 4: Microscope image of the sample B (dark field illumination; front side view)

Sample B: ADC brick

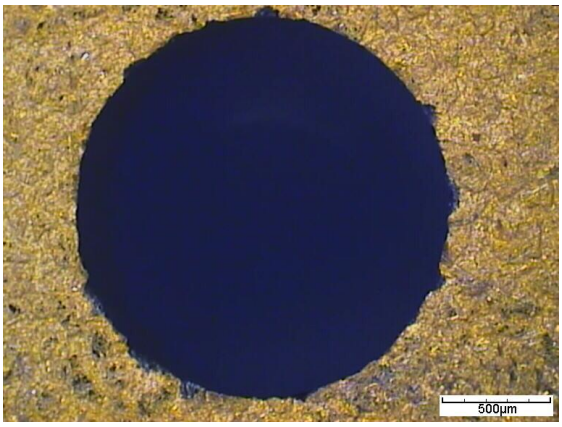
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	3 holes of Ø 1.8mm (right side)	300	6	42	10	200	~70



PICTURE 5: Digital camera picture of the sample



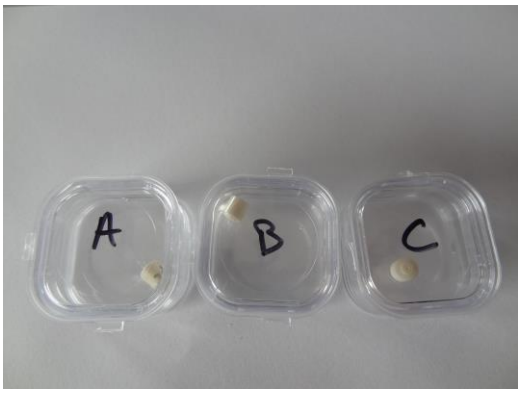
PICTURE 6: Microscope image of the sample (dark field illumination; front side view)



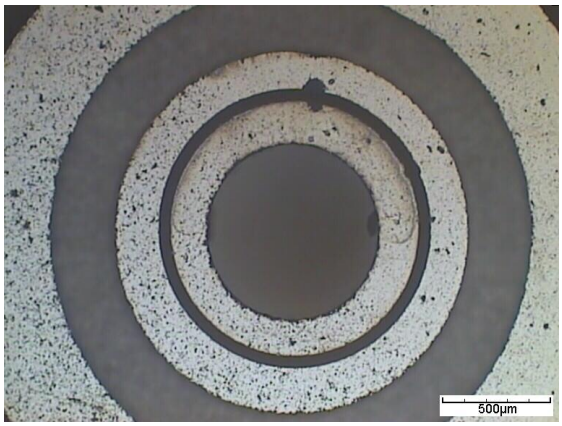
PICTURE 7: Microscope image of the sample (dark field illumination; back side view)

Sample C: Al2O3

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	A	300	10	19	10	100	~70
2	B	300	10	19	10	150	~100
3	C	300	6 (120ns pulse width)	12	5	100	~130



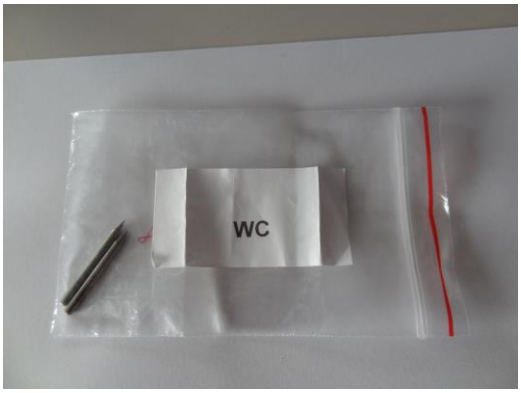
PICTURE 8: Digital camera picture of the sample



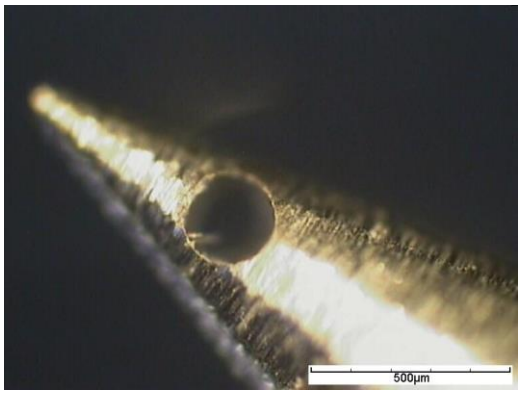
PICTURE 9: Microscope image of the sample (dark field illumination; front side view)

Sample D: WC tungsten carbide

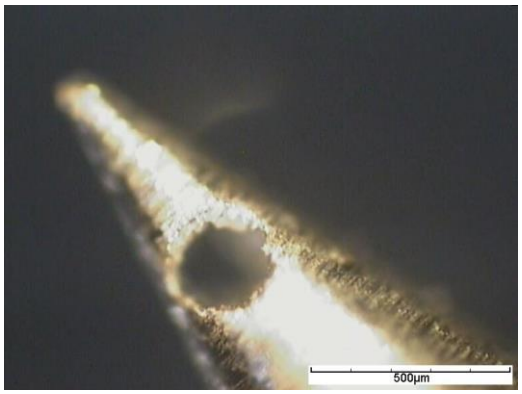
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Small hole (~0.2mm)	300	6 (120ns pulse width)	14	5	100	~30
2	Big hole	350	6 (120ns pulse width)	12	2	60	~30



PICTURE 10: Digital camera picture of the sample



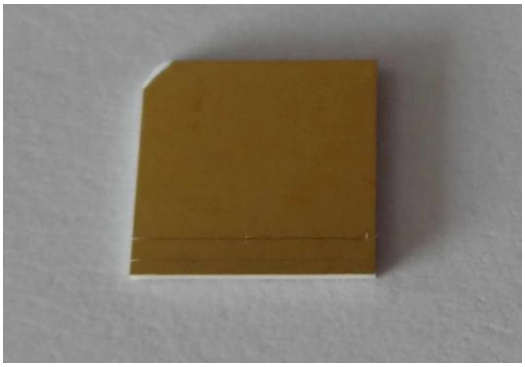
PICTURE 11: Microscope image of the sample (dark field illumination; front side view)



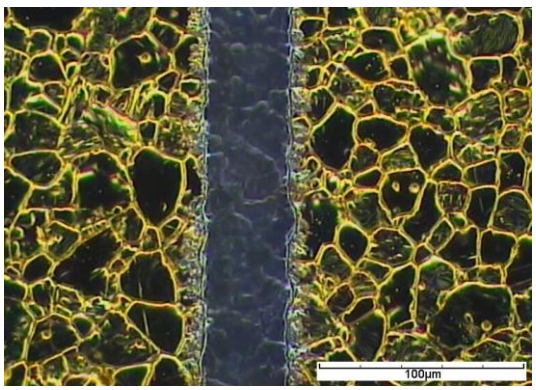
PICTURE 12: Microscope image of the sample (dark field illumination; back side view)

Sample E: AL2O3 and gold coating

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Line 1 (close to the edge)	200	40	6	80	1	1
2	Line 2	200	40	6	100	1	1



PICTURE 13: Digital camera picture of the sample



PICTURE 14: Microscope image of the sample (dark field illumination; front side view)

Sample F: ALN

Two columns with different hole diameters were processed in the thinner plate. The parameters for each column are given in the table below.

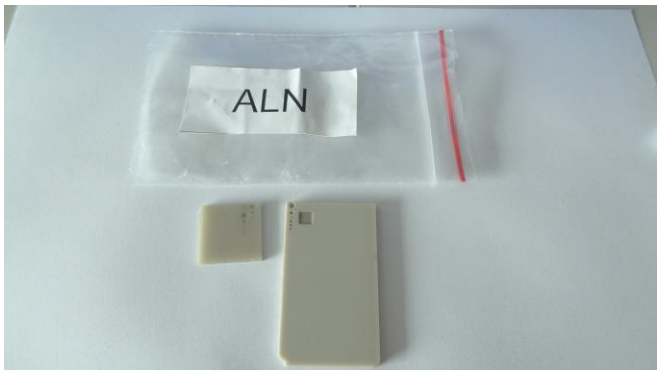
Thin plate

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	**First column** Circle Ø 2 mm	300	6	14	10	88	~54
2	Circle Ø 1 mm	300	6	14	10	80	~25
3	Circle Ø 0.5 mm	300	6	14	10	150	~25
4	Circle Ø 0.4 mm	200	6	14	10	350	~60
5	**Second column** Circle Ø 2 mm	300	10	12	10	--	Non cut
6	Circle Ø 2 mm	300	10	18	10	54	~33
7	Circle Ø 1 mm	300	10	18	10	55	~32
8	Circle Ø 0.5 mm	300	10	18	10	--	Non cut
9	Circle Ø 0.8 mm	200	10	18	10	120	~25
10	Circle Ø 0.6 mm	200	10	18	10	120	~22

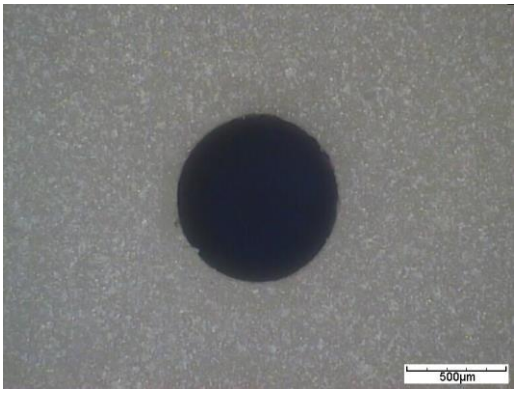
Thick plate

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Circle Ø 2 mm	300	6	16	10	132	~82
2	Circle Ø 1 mm	300	6	16	10	130	~40
3	Circle Ø 0.5 mm	300	6	16	10	200	Non cut
4	Circle Ø 0.8 mm	300	6	16	10	175	~43
5	Circle Ø 0.7 mm	300	6	16	10	200	~46
6	Circle Ø 0.6 mm	300	6	16	10	300	~80

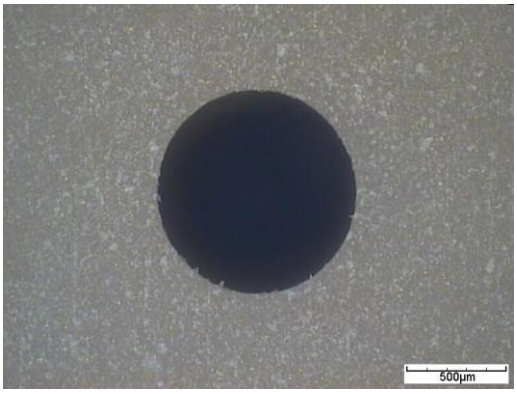
7	Grooving 5*5mm	300	10	23	10	4	~7min40 ~300µm deep



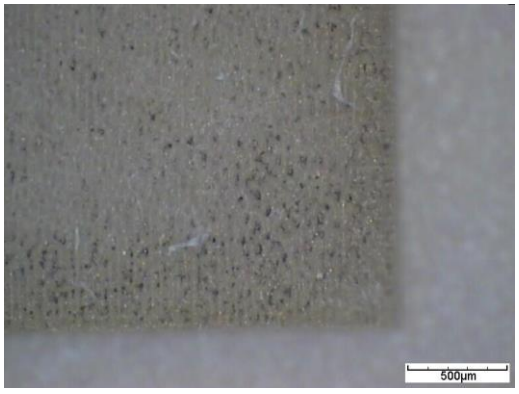
PICTURE 15: Digital camera picture of the sample



PICTURE 16: Microscope image of the sample (dark field illumination; front side view)



PICTURE 17: Microscope image of the sample (dark field illumination; back side view)



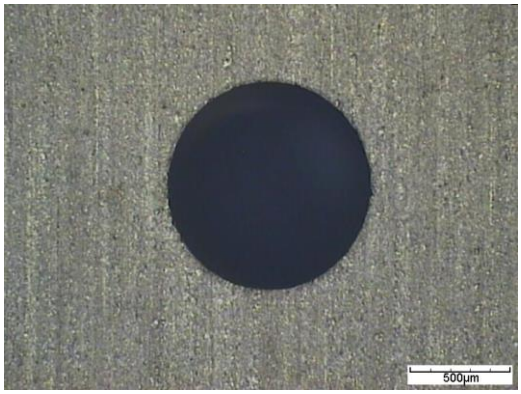
PICTURE 18: Microscope image of the sample (dark field illumination; front side view)

Sample G: SiC

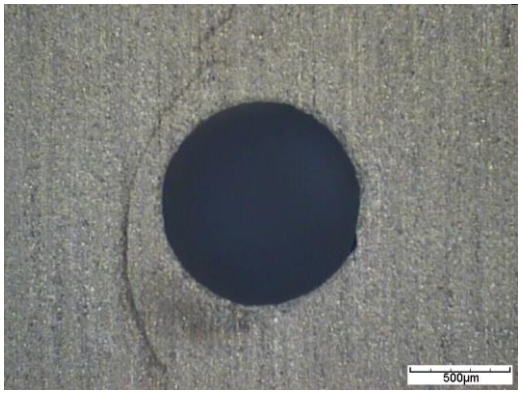
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Circle Ø 2	300	10	15	10	200	Non cut

	mm						
2	Circle Ø 2 mm	300	6	15	15	174	~73
3	Circle Ø 1 mm	300	6	15	10	200	~78
4	Circle Ø 0.6 mm	300	6	15	10	255	~80
5	Circle Ø 0.4 mm	300	6	15	10	800	~120
6	Circle Ø 0.2 mm	300	6	15	10	1400	non cut
7	Circle Ø 0.3 mm	300	10	23	10	500	~94
8	Grooving 5*5 mm	300	10	12	10	4	~7min40 ~150µm deep
9	Grooving 5*5 mm	300	10	12	10	6	~10min ~250µm deep

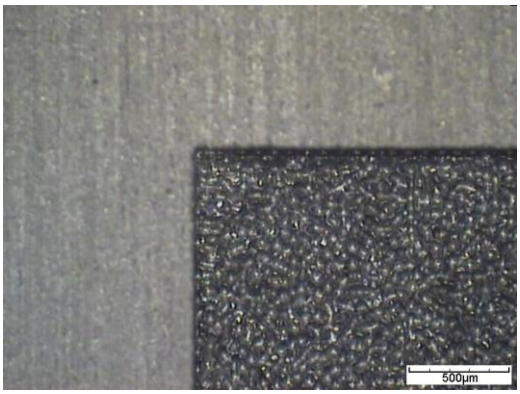
PICTURE 19: Digital camera picture of the sample



PICTURE 20: Microscope image of the sample (dark field illumination; front side view)



PICTURE 21: Microscope image of the sample (dark field illumination; back side view)

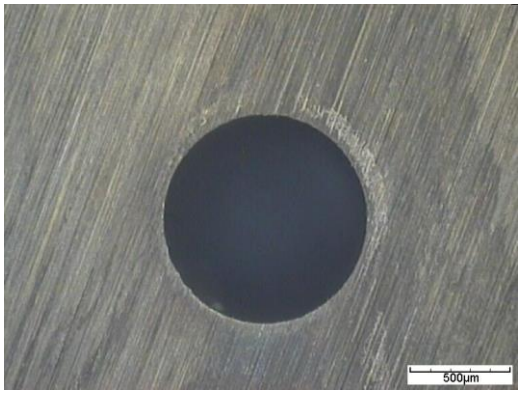


PICTURE 22: Microscope image of the sample (dark field illumination; front side view)

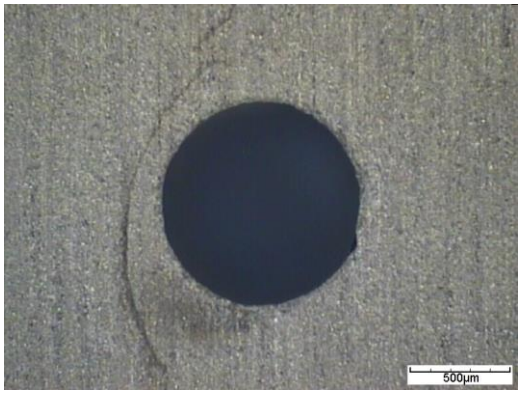
Sample H: SiN

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Circle Ø 2 mm	300	10	15	15	200	Non cut due to a bridge
2	Circle Ø 2 mm	300	6	15	15	140	~54
3	Circle Ø 1 mm	300	6	15	10	120	~37
4	Circle Ø 0.6 mm	300	6	15	10	200	~70
5	Circle Ø 0.4 mm	200	6	15	5	320	~80
6	Circle Ø 0.3 mm	200	6	15	5	1100	~200
7	Circle Ø 0.2 mm	200	10	23	3	1500	~310
8	Circle Ø 0.16 mm	200	10	23	1	2000	~16m48 non cut
9	Grooving 5*5 mm	200	10	12	10	4	~7min40 ~400µm deep
10	Grooving 5*5 mm	200	10	10	10	3	~6min ~250µm deep

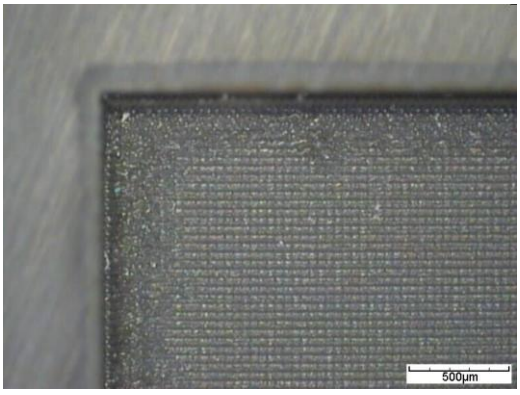
PICTURE 23: Digital camera picture of the sample



PICTURE 24: Microscope image of the sample (dark field illumination; front side view)



PICTURE 25: Microscope image of the sample (dark field illumination; back side view)



PICTURE 26: Microscope image of the sample (dark field illumination; front side view)

Sample I: PZT

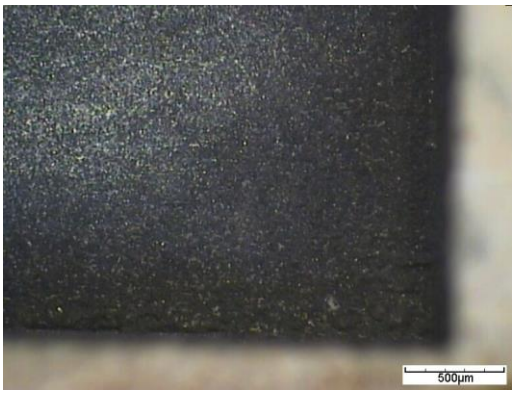
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (s)
1	Circle Ø 2 mm	300	10	15	10	28	~17
2	Circle Ø 2 mm	300	10	15	10	43	~13

3	Circle Ø 0.6 mm	300	10	15	10	51	~9
4	Circle Ø 0.3 mm	200	10	15	5	56	~9
5	Circle Ø 0.2 mm	200	10	15	5	250	~30
6	Grooving 5*5 mm (right sample)	200	10	10	10	2	~5min49 ~500µm deep
7	Grooving 5*5 mm (right sample)	200	14	8	10	1	~3min ~300µm deep

PICTURE 27: Digital camera picture of the sample

PICTURE 28: Microscope image of the sample (dark field illumination; front side view)

PICTURE 29: Microscope image of the sample (dark field illumination; back side view)



PICTURE 30: Microscope image of the sample (dark field illumination; front side view)

1mm plate

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (min)
1	Circle Ø 3.6 mm	300	6	30	2	66	~6
2	Circle Ø 3.6 mm	300	6	30	5	183	~7
3	Circle Ø 2 mm	300	6	30	2	72	~4
4	Circle Ø 1mm	300	6	30	2	75	~2

3mm plate

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (min)
1	Circle Ø 3 mm	300	6	30	2	220	~17
2	Circle Ø 2 mm	300	6	30	5	210	~11
3	Circle Ø 1 mm	300	6	30	2	-	No cut
4	Circle Ø 1.6 mm	300	6	30	2	300	~15
5	Circle Ø 1.2 mm	300	6	30	2	230	~7

5mm plate

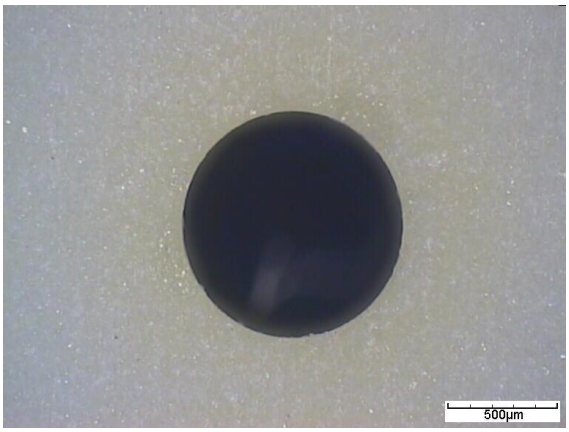
	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (min)
1	Circle Ø 3 mm	300	6	30	2	411	~32
2	Circle Ø 2 mm	300	6	30	2	380	~20

3	Circle Ø 1.4 mm	300	6	30	2	520	~30

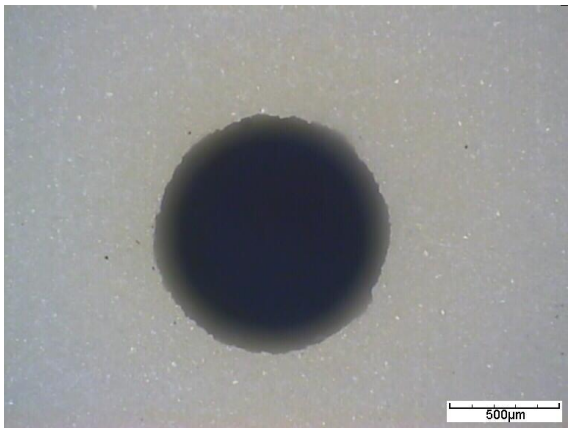
7mm plate

	Type	Pressure (bar)	Frequency (kHz)	Power (W)	Speed (mm/s)	Passes	Time (min)
1	Circle Ø 2 mm	300	6	30	2	600	No cut
3	Circle Ø 3 mm	300	6	30	2	600	No cut
4	Grooving 5*5	300	10	30	10	4	~9min 300 µm deep

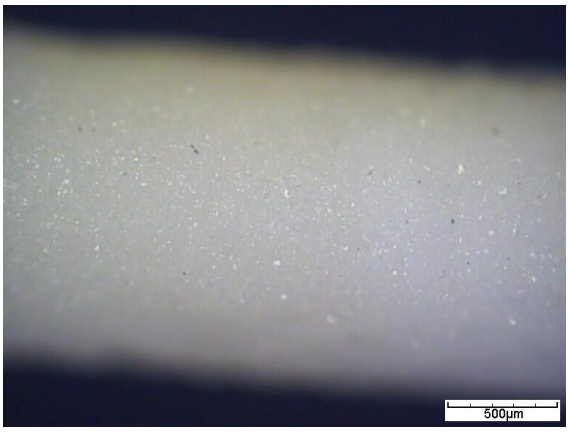
PICTURE 27: Digital camera picture of 1mm sample



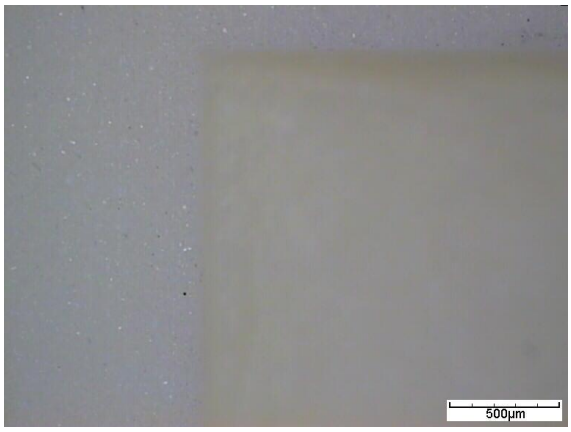
PICTURE 28: Microscope image of the sample (dark field illumination; front side view)



PICTURE 29: Microscope image of the sample (dark field illumination; back side view)



PICTURE 28: Microscope image of the sample (dark field illumination; front side view)



PICTURE 29: Microscope image of the sample (dark field illumination; back side view)

The following table shows the results that we obtained so far.

	Results
Burrs/HAZ/Chipping	Sample A: very good cutting quality with no chipping and sharp edges. Kerf of ~30 µm is achievable with a 30 µm nozzle. Sample B: good cutting quality. Only limited chipping on the back side is visible. Sample C: some chipping is visible on the front side. Cutting quality can be improved with further developments. Sample D: very good front side quality. Backside shows some burrs. Cut quality can also be improved if necessary. Sample E: excellent overall cutting quality. No peeling/delamination is visible on the gold coating Sample F G and H: excellent overall cutting quality. Edges are sharp and the grooved surface is smooth. Some discoloration around the edges is visible for sample H. Sample I: good cutting quality with very limited chipping on both sides is achievable. The marks located on the top of the samples can be avoided by using a water-jet shutter. Sample J: very good front side quality is achievable while some chipping is visible on the backside.

	Please not that high purity alumina samples require very high peak power (pulse width of 100-120ns) and drilling holes into 5mm thick plate is close to the limit of our process capability. Finally a double cavity green laser (not available for the tests) could improve process time.

CONCLUSION

The feasibility of cutting various kinds of ceramics was investigated on SYNOVA LCS300. This machine is based on the MicroJet® technology and combines the advantages of the high energy pulsed laser with a hair-thin water jet.

These tests show that it is possible to cut all the materials with a good overall quality. Nevertheless the cutting quality and the process time can be optimized specifically for each of them in a next step.

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