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Low SEY laser treated surfaces for mitigation of the electron cloud Task 4.3

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EuroCirCol A key to New Physics

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Why are high SEY materials a problem

- High SEY materials are a problem in positively charged accelerators
- When a charged particle is accelerated it emits Photons
- These photons release electrons in the wall via the photoelectric effect and also ionise residual gas in the chamber

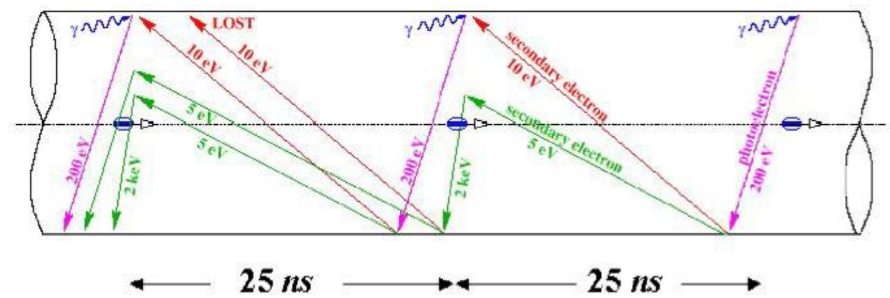

Illustration of electron cloud build up by F.Ruggiero

- The next bunch of protons accelerate the electrons into the opposite wall creating more electrons
- Causes the build up of an electron cloud

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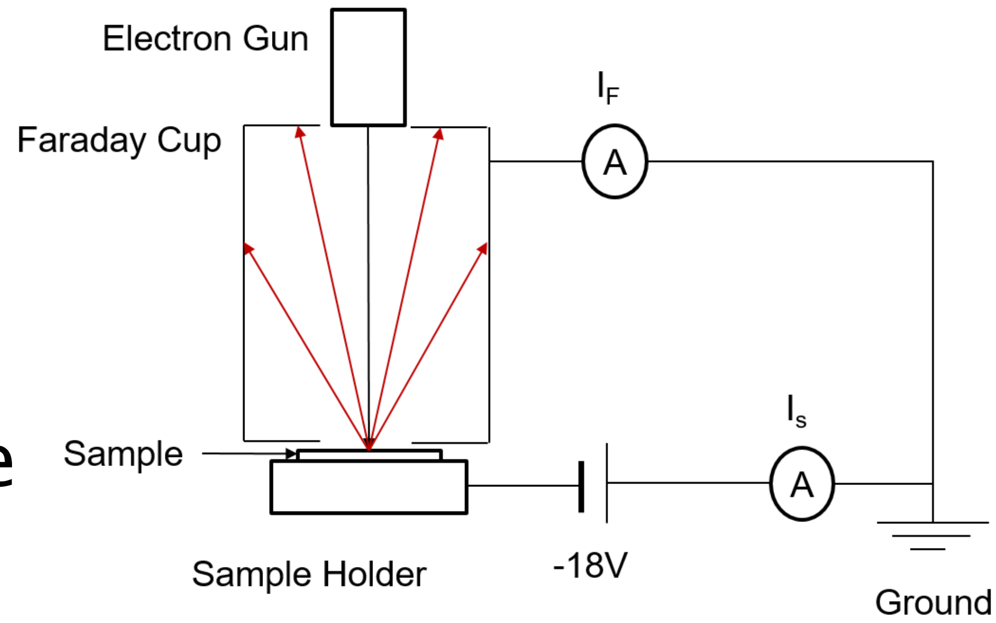
SEY measurement facility

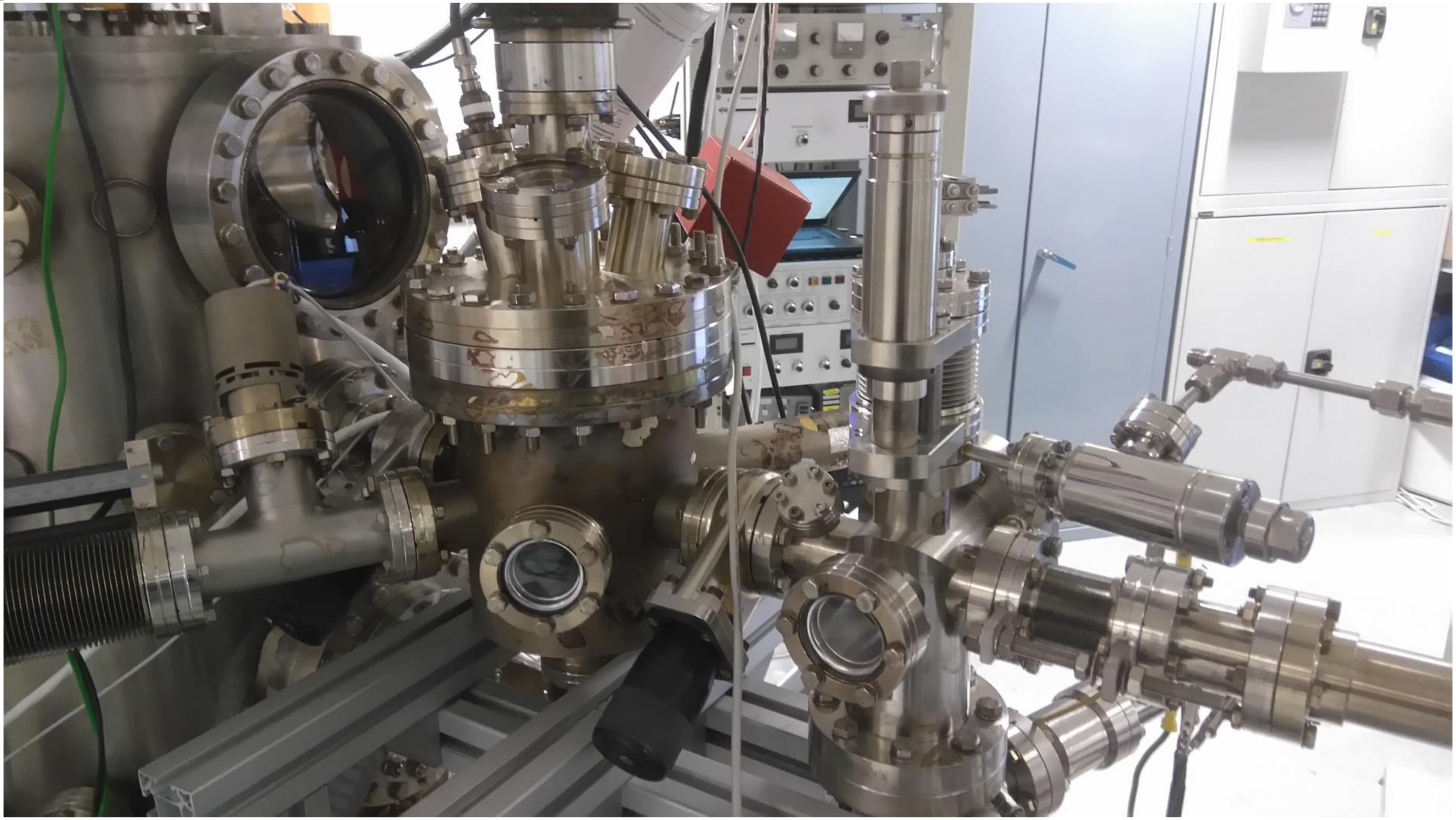
- To calculate the total SEY we use

$$\delta = \frac{I_F}{I_P} = \frac{I_F}{I_F + I_S}$$

- Where:
  δ is the total SEY
  I_F is the current on the cup
  I_S is the secondary electron current
  I_P is the beam current



PIXIE



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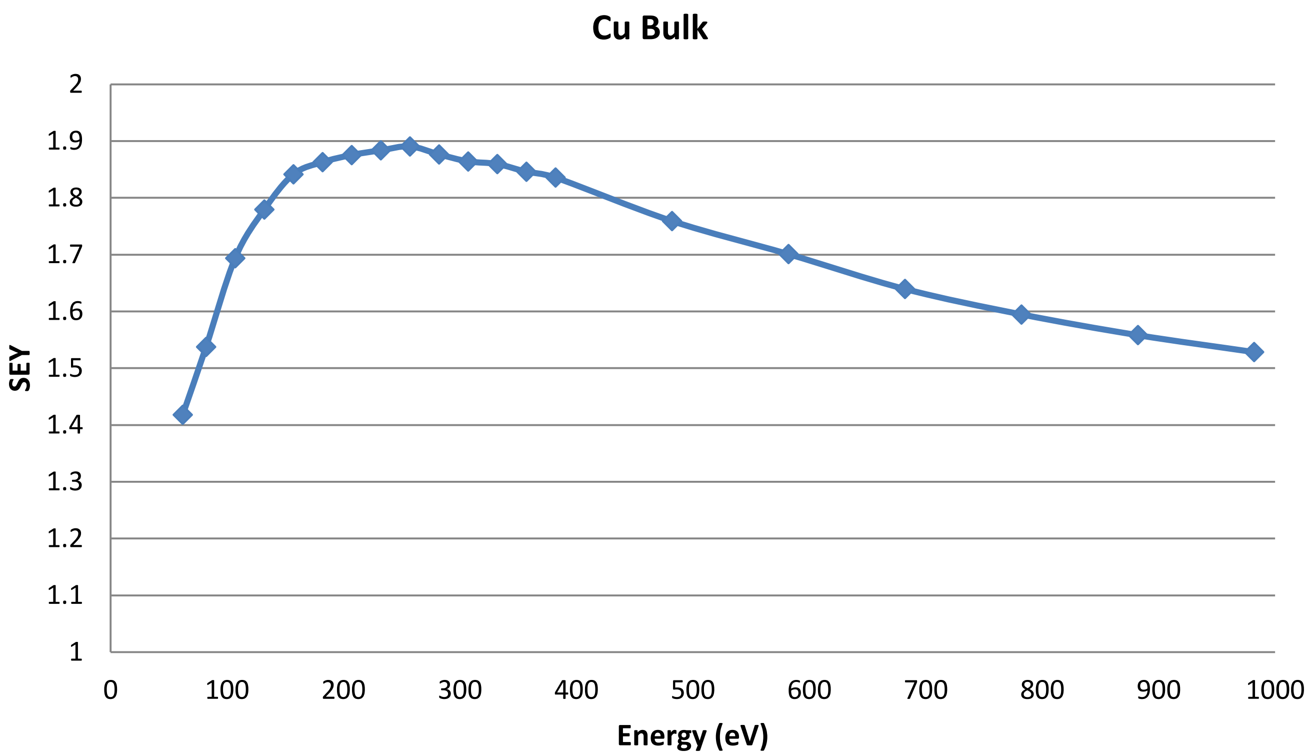
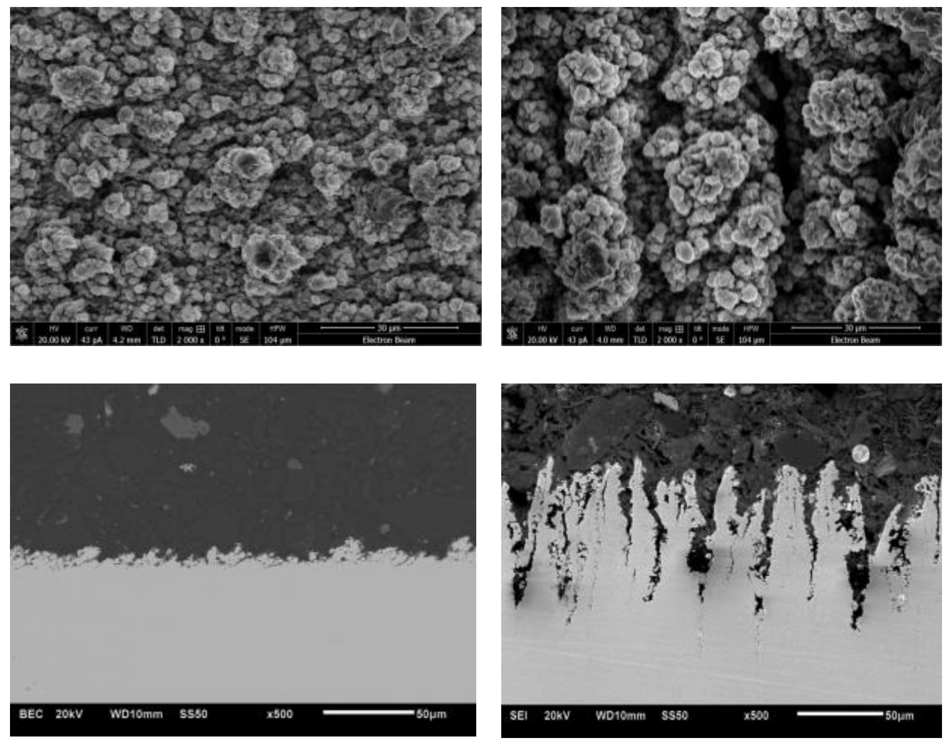
SEY of untreated copper

- As received OFHC copper
- SEY peak at 1.9 at 275 eV



Laser Treated Copper

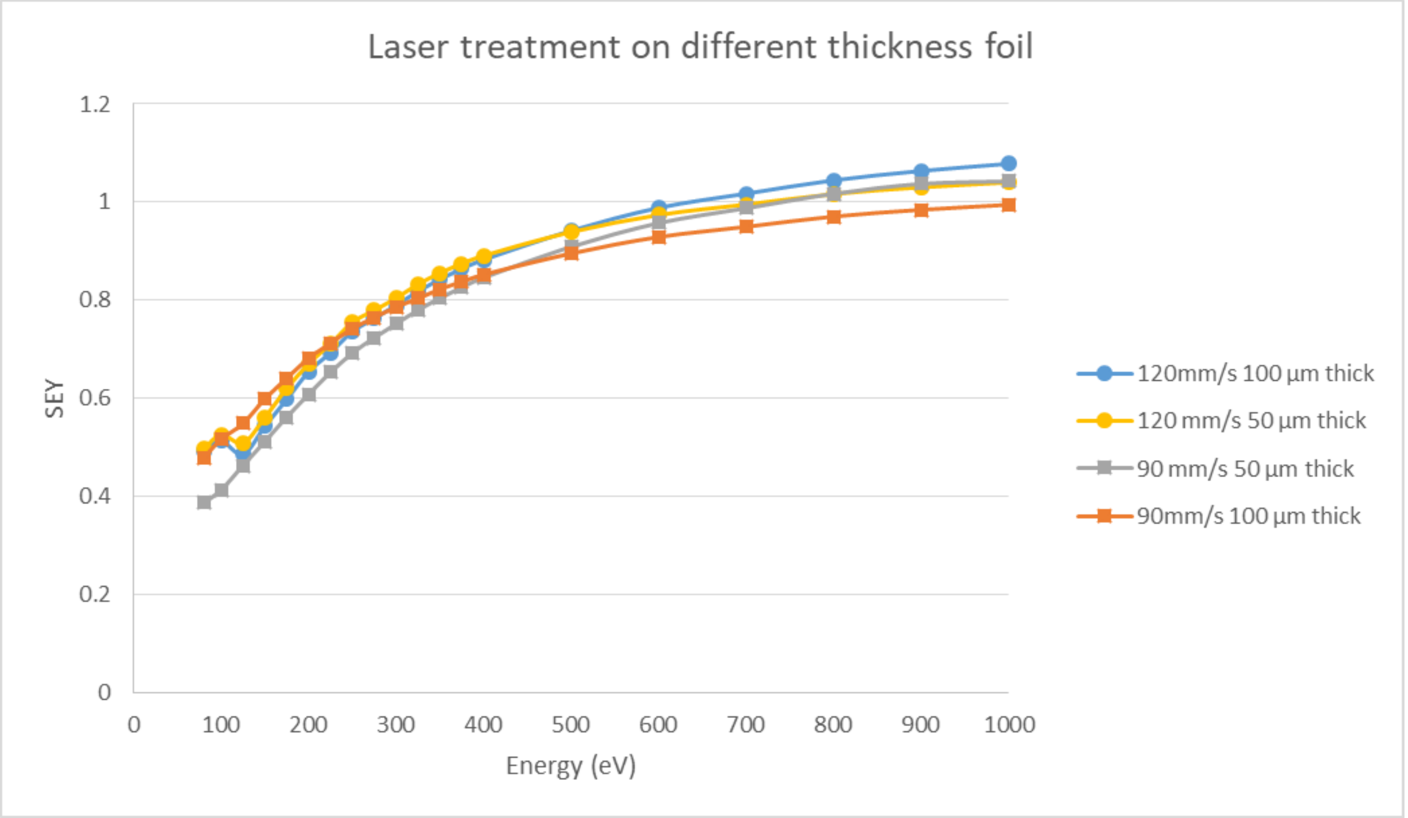
- Surfaces have a micro and nanostructure
- Optically black
- Various laser parameters can be varied to change the topology
- Images (left) are of different scan speeds, 180 mm/s and 30 mm/s shown



My first Micronanics samples

λ=355 nm
P=3 W
τ=70 ns
F=40 kHz
H=5 μm
v=90 and 120 mm/s
Thickness of foil=50 and 100 μm

Produced with Micronanics

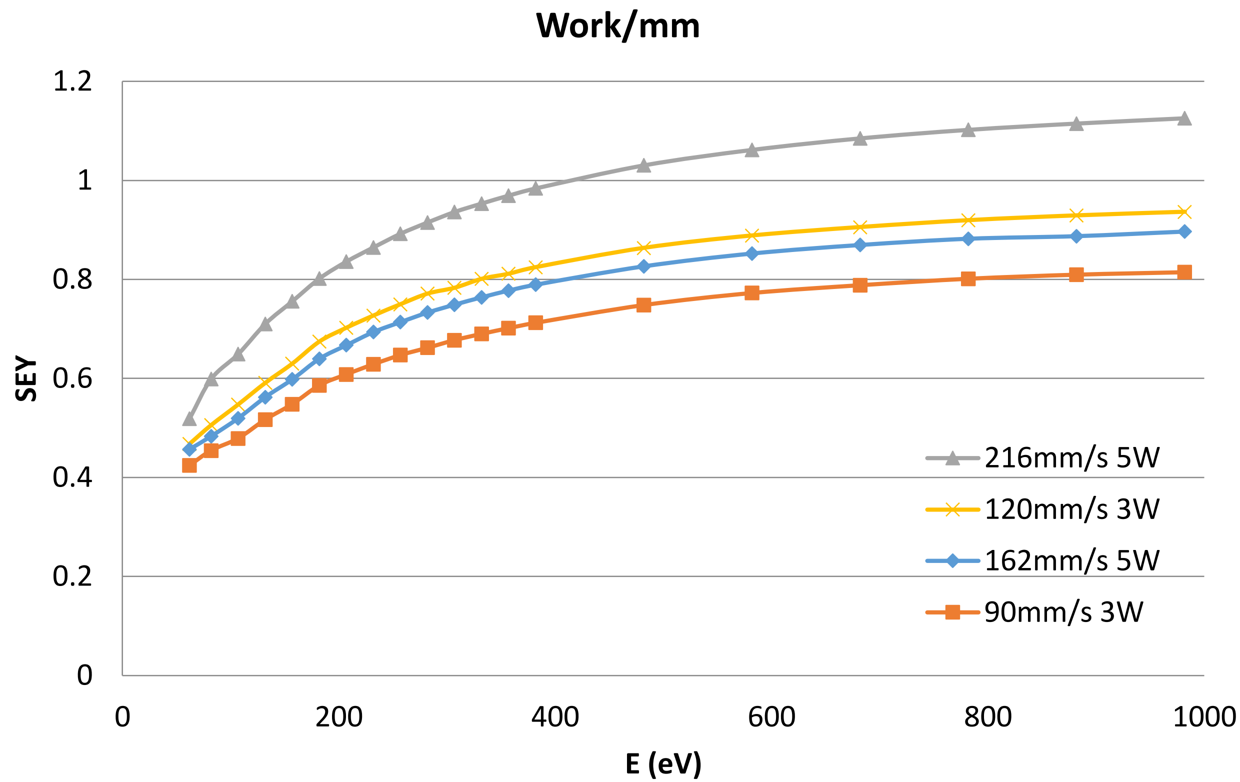


- Laser ablated surface was no deeper than 50 μm

Varying power and scan speed

λ=355 nm
P=3 and 5 W
τ=70 ns
F=40 kHz
H=5 μm
v=216, 162, 120 and 90 mm/s

Produced with Micronanics

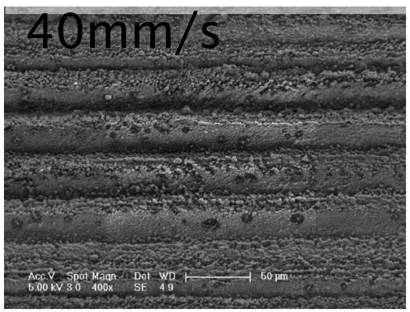


Power (W)	Scan Speed (mm/s)	Work/mm	SEY
5	216	0.023	1.25
3	120	0.025	0.94
5	162	0.031	0.89

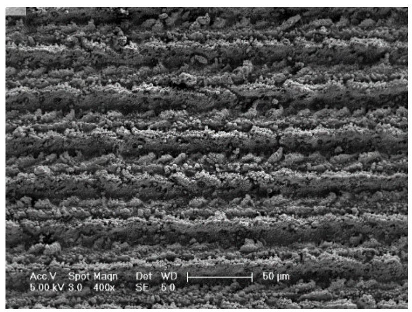
Varying power and scan speed at 1064 nm

λ=1064 nm
P=20 and 10.5 W
τ=2 ns
F=40 kHz
H=0.02 µm
v=80 and 40mm/s

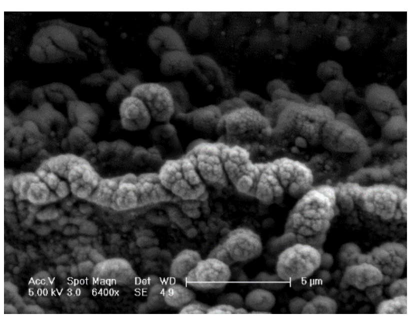
Produced With Micronanics



100µm

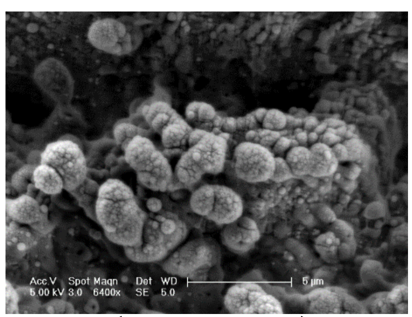


100µm



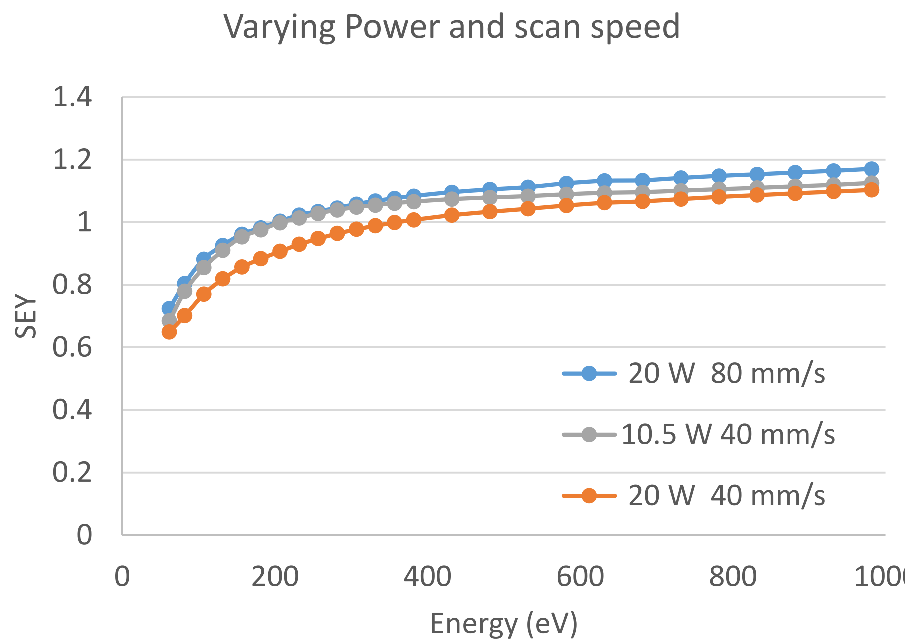
10µm

20 W 80 mm/s



10µm

10.5 W 40 mm/s



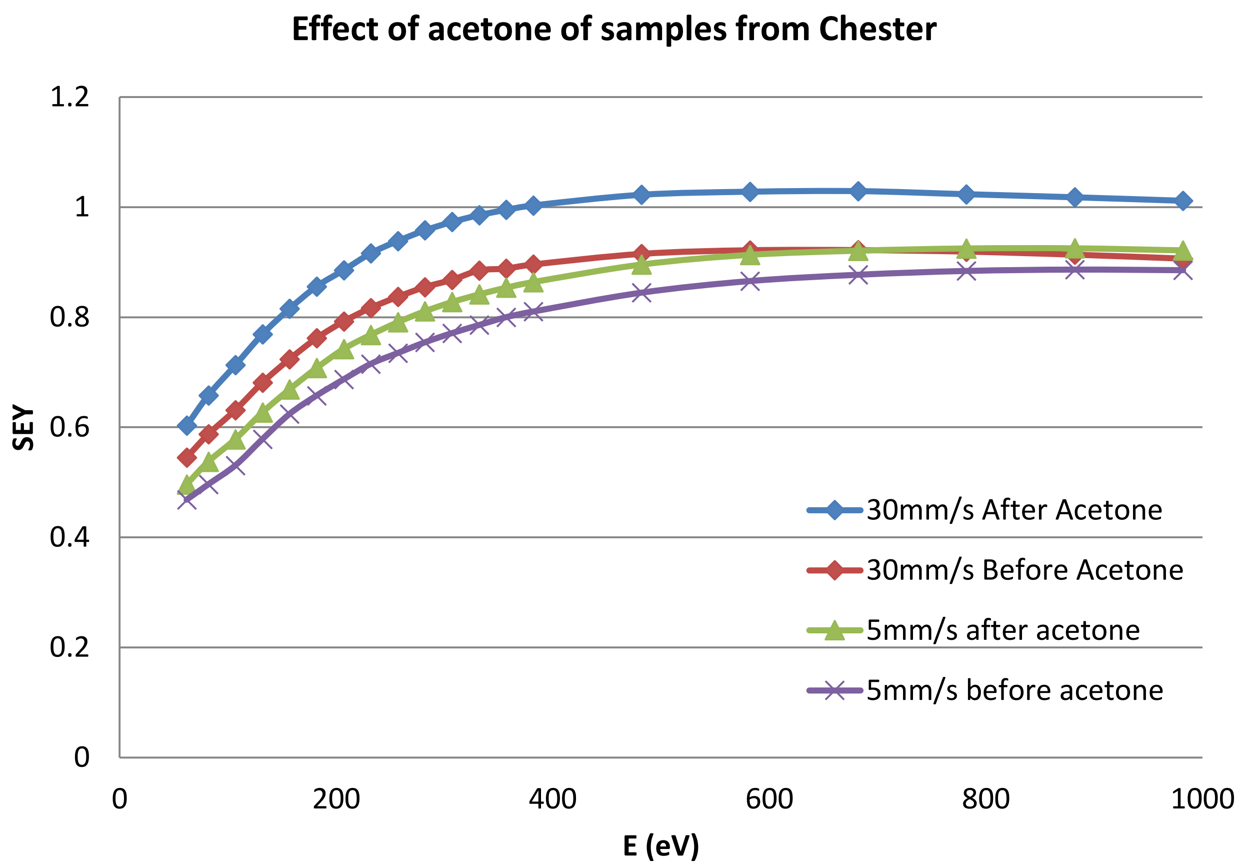
- Power normalised by scan speed give similar results within parameters explored

Effect of ultrasound cleaning in acetone

λ=1063 nm
P=5 W
τ=<5 ps
F=100 kHz
H=5 μm
v=30 and 5mm/s

Produced with Chester university

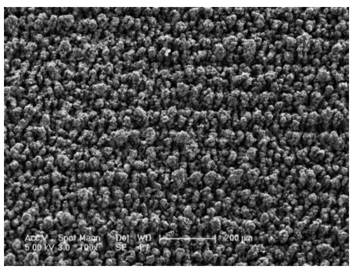
Samples cleaned in ultrasonic bath for 20 minutes



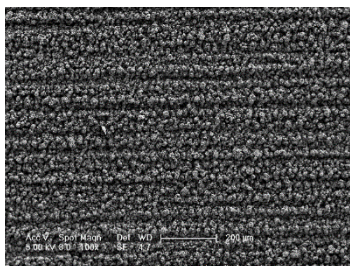
Varying speed and pitch

λ=1064 nm
P=5 W
τ=70 ns
F=100 kHz
H=5 and 10 μm
v=100 and 200 mm/s

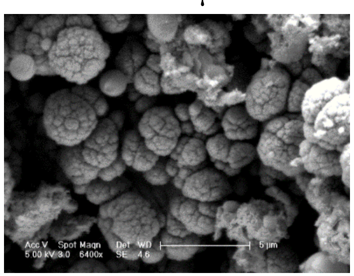
Produced with Micronanics



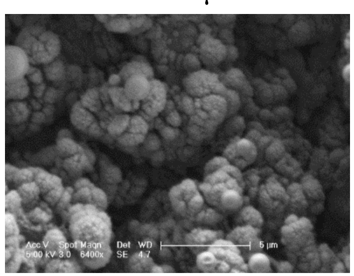
400μm



400μm



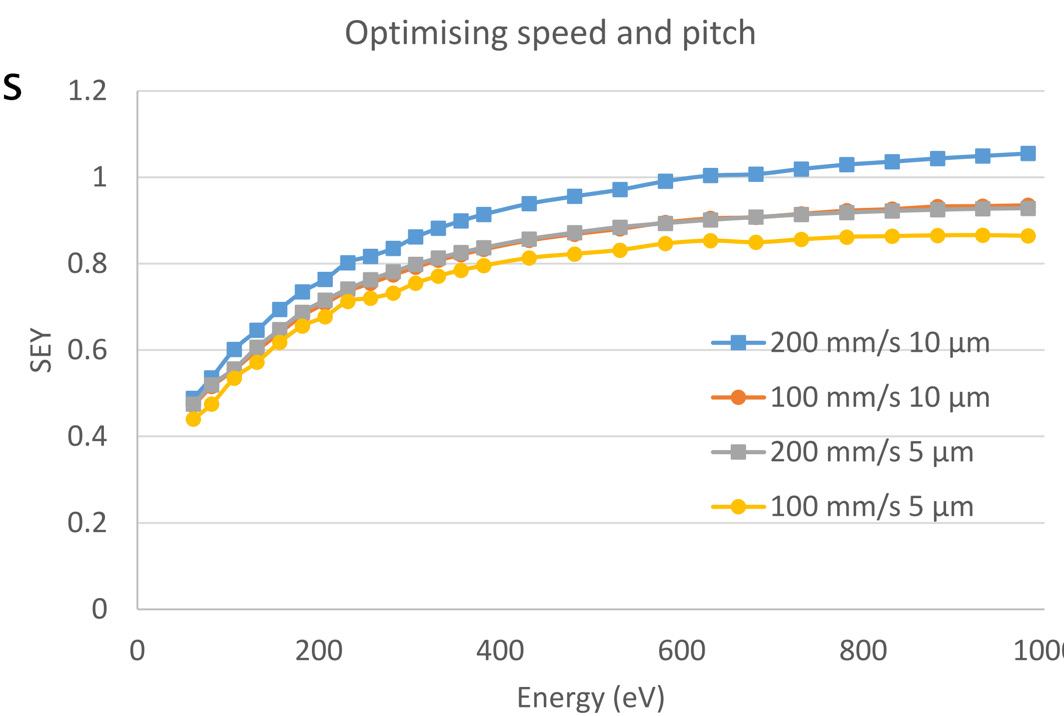
5μm



5μm

100 mm/s 5 μm

100 mm/s 10 μm



- Same SEY observed for faster scan speed when matched with a smaller pitch

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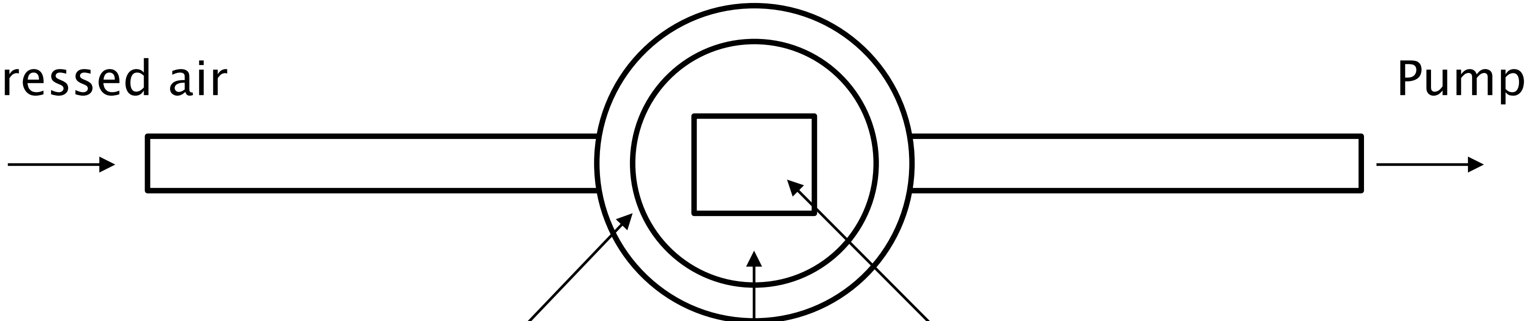
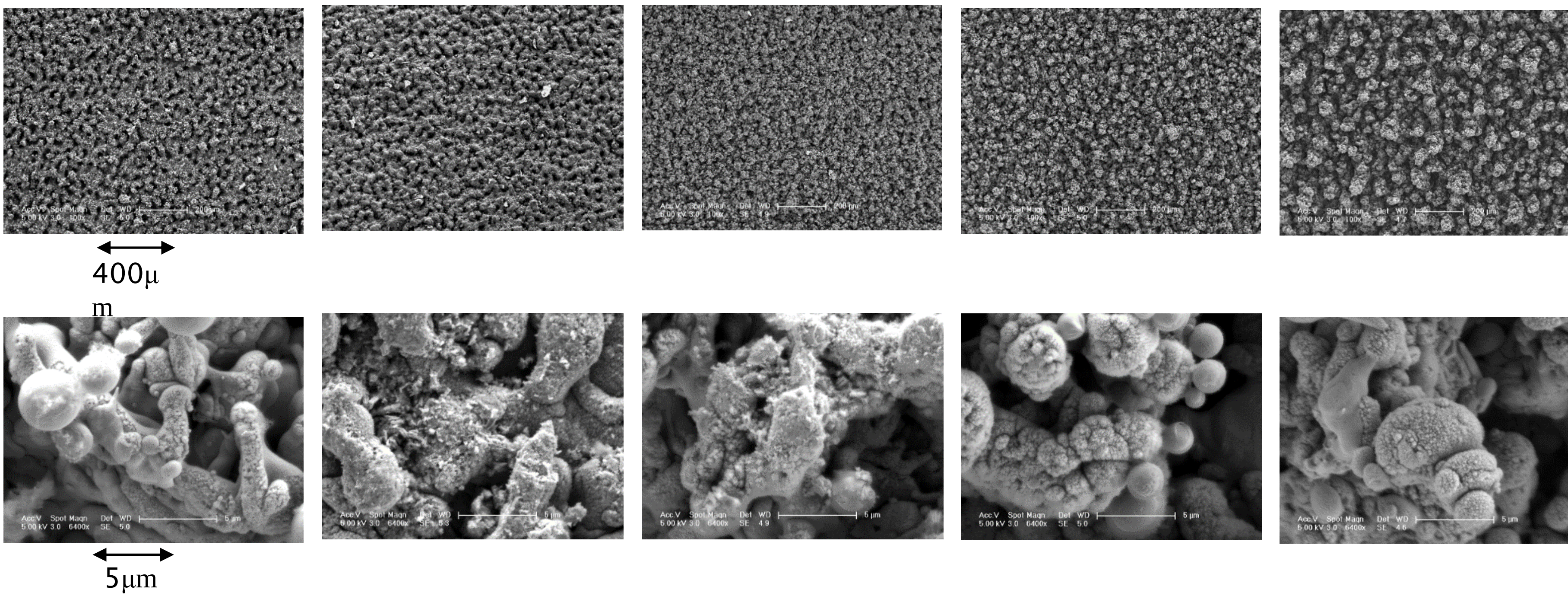
Treatment in different gas flow

- Some samples were prepared in a windowed vessel with compressed air or a pumped flow of air passing over the sample



SEM

Highest SEY→ Lowest SEY



Compressed air with glass

Pumped flow with glass

Air, no glass

Compressed air, no glass

Pumped flow, no glass

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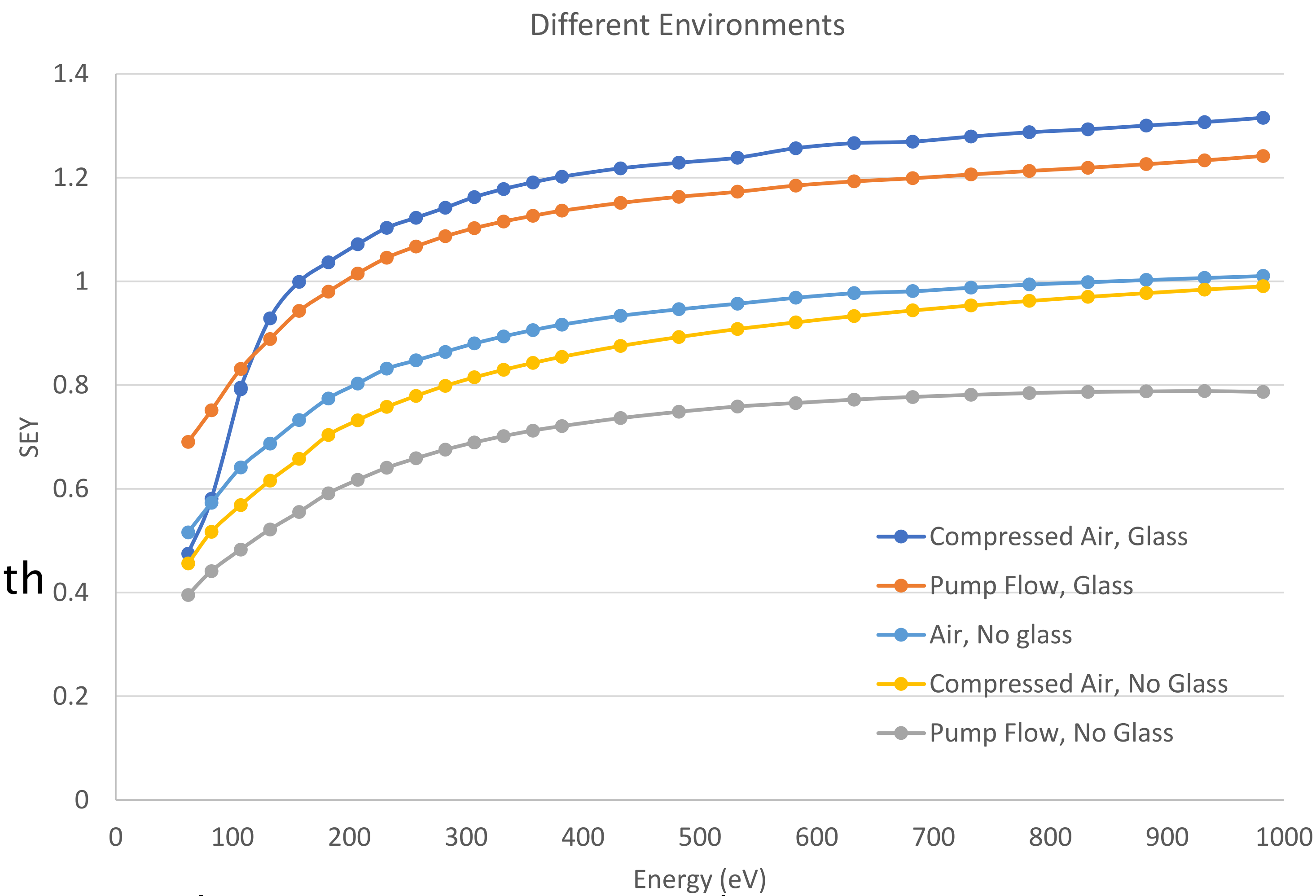
Laser treatment in different environments

λ=1064 nm
P=6.6 W
τ=2 ns
F=40 kHz
H=10 μm
v=30 mm/s

Produced with Micronanics

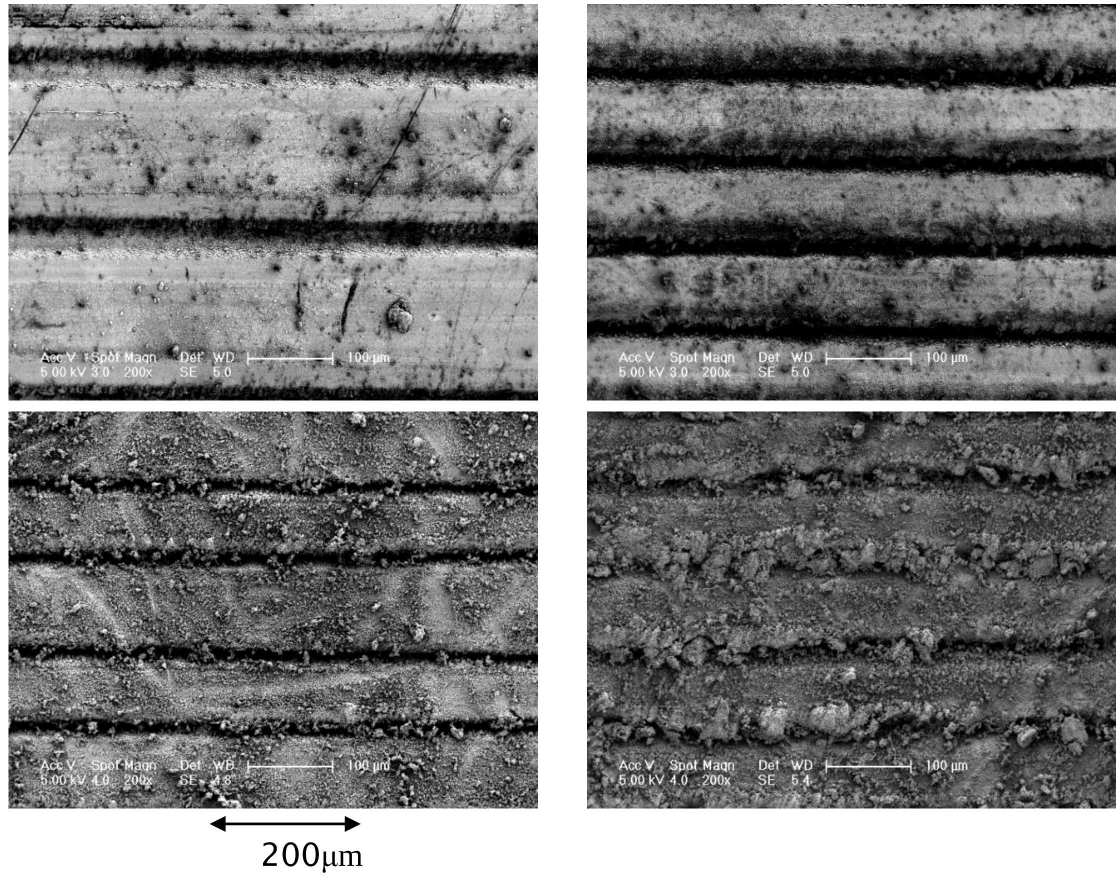


SEM of samples at Manchester

λ=355 nm
P=6.5 W
τ=2 ps
F=404 kHz
H=100, 50 and 25μm
v=200, 100, 50 and 25 mm/s

Still optimising the parameters of this laser

Note the 200 mm/s sample has a spacing of about 200 μm due to problems with the stage movement



200 mm/s (top left), 100 mm/s (top right), 50 mm/s (bottom left) 25 mm/s (bottom right)

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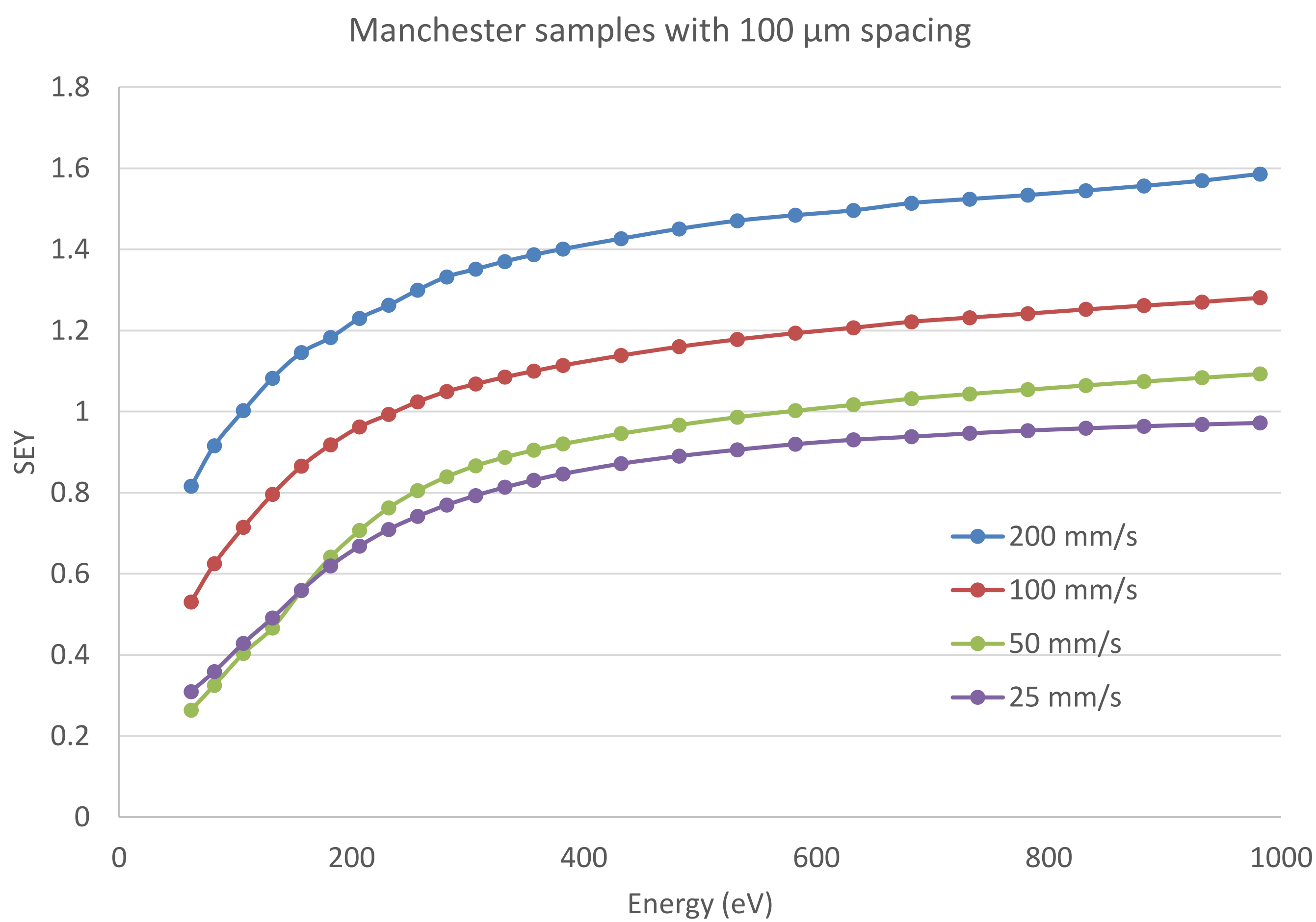
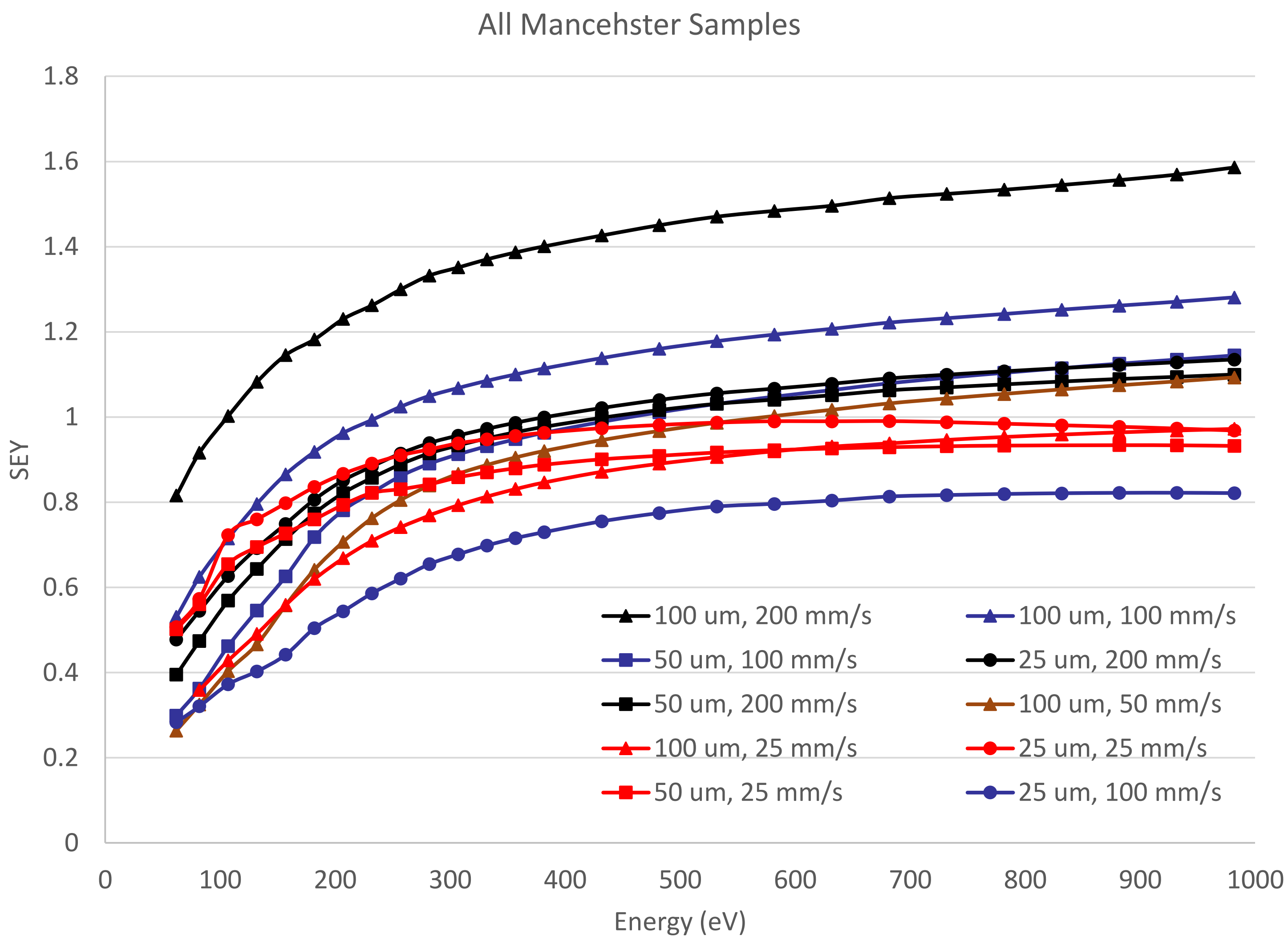
SEY of samples at Manchester

λ=355 nm
P=6.5 W
τ=2 ps
F=404 kHz
H=100 μm
v=200, 100, 50 and 25 mm/s



All Samples at Manchester



λ=355 nm
P=6.5 W
τ=2 ps
F=404 kHz
H=100, 50, 25 μm
v=200, 100, 50 and 25 mm/s

Potential problems of laser treatment

- The LASE treatment increases surface resistance
- ESD will be studied futher at ASTeC
- PSD will be studied within this collaboration
- Dust particulates depending on the chosen micro and nano-structure of the Cu
- Outgassing (Presented by Oleg at CERN, preliminary data shows no problems)
- All new surfaces should be fully tested before application

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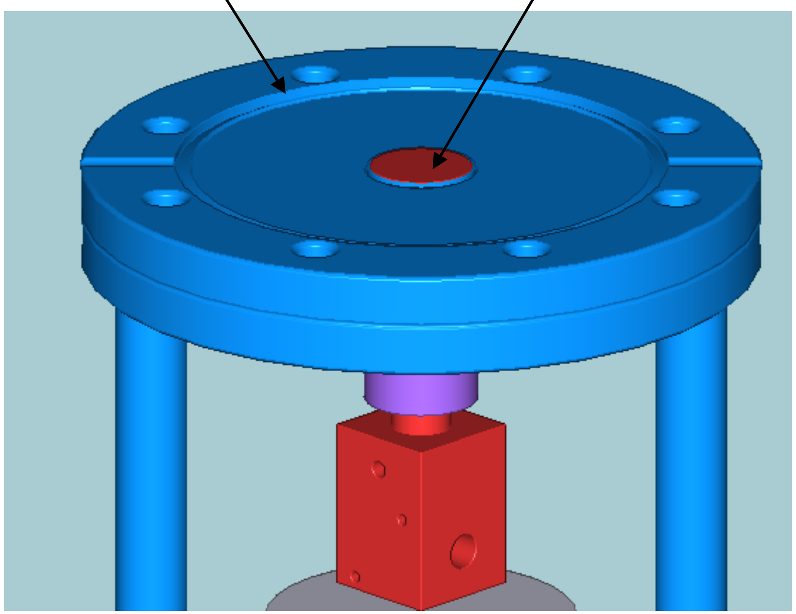
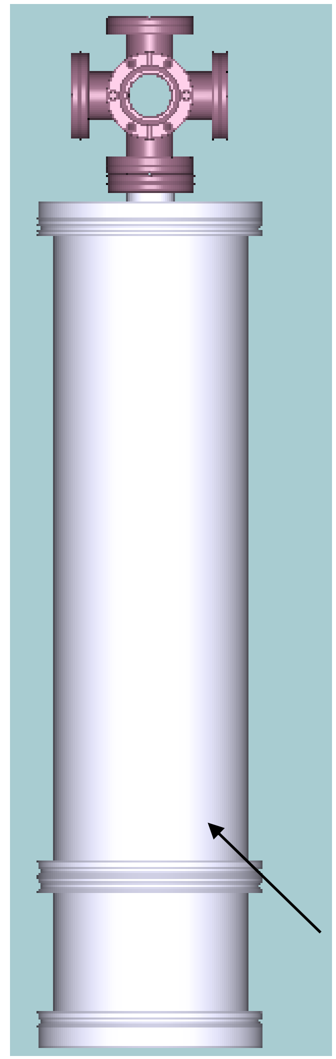
Cryogenic Design

Bottom flange of test chamber at 60-80 K

Sample at 4-80 K





Bellows

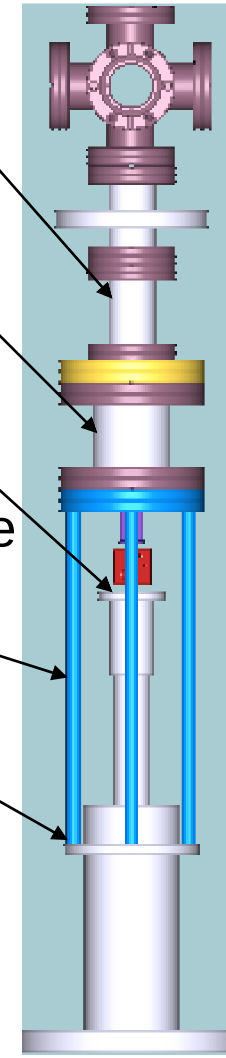
Test chamber

1st stage

Conductor from 2nd stage to heat shield

2nd stage

Insulation vacuum



Cryogenic SEY facility

- Most standard components ordered
- Need to order insulation vacuum parts
- The sample holder and the custom parts are being ordered, I am currently discussing procurement with manufacturers

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List of samples under my investigation

Date		Wavelength	power	spotsize	pulse duration	rep	pitch	speed	thickness		treatment	SEY
	Micronanics											
23/09/2015		355	3		2ns	40 kHz	5	120	50 micron thick			1.04
24/09/2016		355	3		2ns	40 kHz	5	120	100 micron thick			1.08
25/09/2016		355	3		2ns	40 kHz	5	90	100 micron thick			0.99
01/10/2016		355	3		2ns	40 kHz	5	90	50 micron thick			1.04
07/10/2015		355	3		2ns	40 kHz	5	90	50 micron thick		after acetone	1.01
08/10/2015		355				40 kHz		90				0.94
	Micronanics											
30/10/2015		355	3					90				0.815
02/11/2016		355	5					162				0.896
02/11/2015		355	5					216				1.125
03/11/2015		355	3					120				0.936
	Chester Samples											
04/02/2016		1064	5	15	>5ps	100 kHz	5	30				0.921
		1064	5	15	>5ps	100 kHz	5	30			after acetone	1.029
		1064	5	15	>5ps	100 kHz	5	5				0.922
		1064	5	15	>5ps	100 kHz	5	5			after acetone	0.925
29/03/2016		1064	5	15	>5ps	100 kHz	5	5	Argon atmosphere			0.872
09/02/2017	Micronanics Gasket											
14/02/2017		1064	5		70 ns	100 kHz	5	100				0.86
15/02/2017		1064	5		70 ns	100 kHz	10	100				0.94
20/02/2017		1064	5		70 ns	100 kHz	5	200				0.93
23/02/2017		1064	5		70 ns	100 kHz	10	200				1.06

List of samples under my investigation cont.

Date		Wavelength	power	spotsize	pulse duration	rep	pitch	speed	thickness		treatment	SEY
	Micronanics with air flow											
08/03/2017	b	1064	6.6				10	30	air	no glass		1.01
	c	1064	6.6				10	30	pump flow (Flow of air)	glass		1.24
	d	1064	6.6				10	30	pump flow (Flow of air)	no glass		0.79
	e	1064	6.6				10	30	compressed air	no glass		0.99
	f	1064	6.6				10	30	compressed air	glass		1.31
16/06/2017	Manchester											
20/06/2017		355nm	65	23 um	2ps	404 kHz	100	100				1.28
20/06/2017		355nm	65	23 um	2ps	404 kHz	100	200				1.59
21/06/2017		355nm	65	23 um	2ps	404 kHz	100	25				0.97
21/06/2017		355nm	65	23 um	2ps	404 kHz	100	50				1.09
22/06/2017		355nm	65	23 um	2ps	404 kHz	50	200				1.1
23/06/2017		355nm	65	23 um	2ps	404 kHz	25	100				0.82
23/06/2017		355nm	65	23 um	2ps	404 kHz	50	100				1.144
23/06/2017		355nm	65	23 um	2ps	404 kHz	25	200				1.135
23/06/2017		355nm	65	23 um	2ps	404 kHz	100	25				1.01
13/09/2017	IPG 40 Khz Miconanics											
14/09/2017		1064	20		2ns	40kHz	0.02	40				1.1
14/09/2017		1064	20		2ns	40kHz	0.02	80				1.17
19/09/2017		1064	10.5		2ns	40kHz	0.02	40				1.125

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Summary

- Laser treated samples can achieve SEY<1 with different wavelengths and pulse length lasers but laser parameters need to be adjusted
- All parts of the cryogenic system should arrive by end of January so commissioning of the new system can begin