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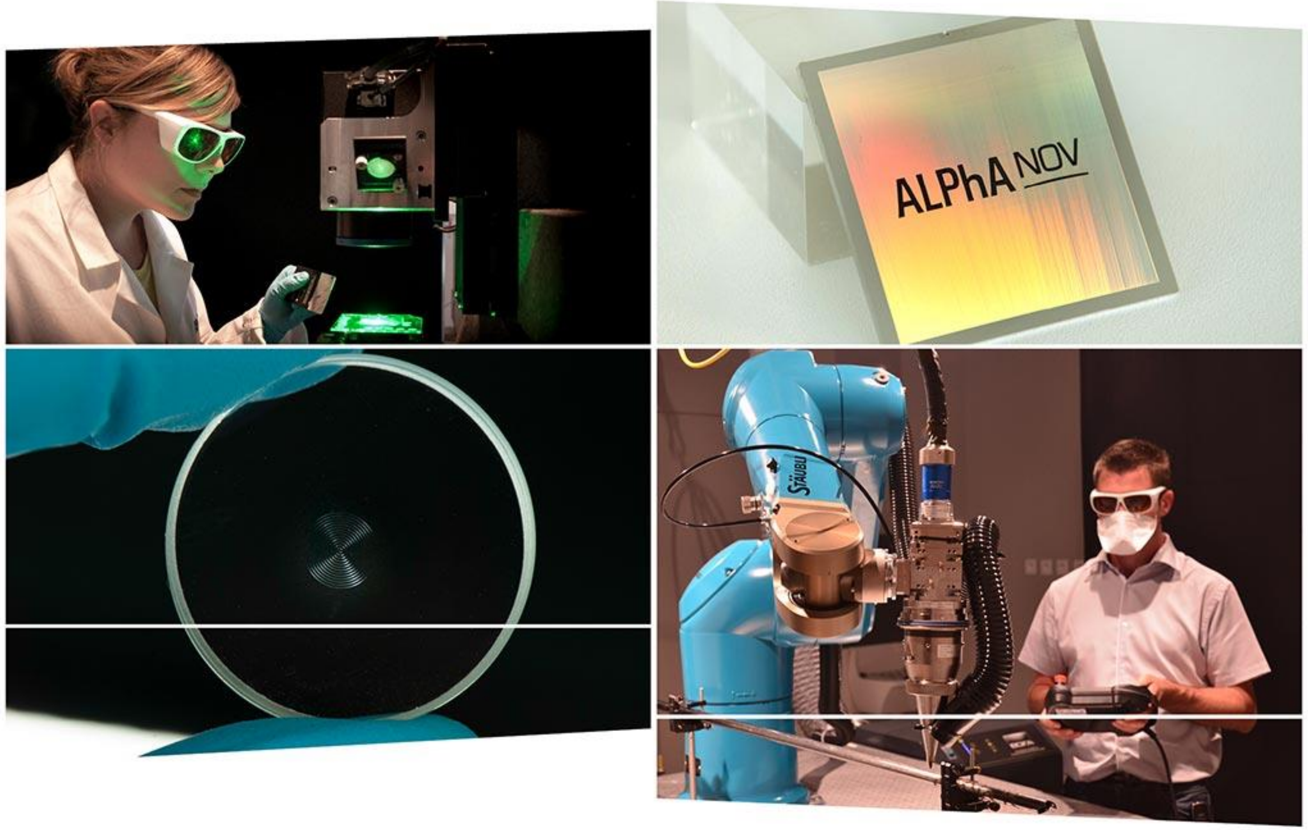
Optics & Lasers Technology Center



Laser Structuring of Battery Foils

Rainer Kling, Aurelien Sikora, Girolamo Mincuzzi, Marc Faucon

ALPhANOV after 15 years

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19 running collaborative projects

19

12 patents
incl. 7 in co-ownership, all are licensed or exploited

12

1 company hosted

1

20

3

3 shared facilities

Joint R&D projects

96 FTE
Non-profit organization founded in 2007

96

8.2

20 Start-Ups supported
over the past 15 years

8.2 M€ turnover in 2022
Over 1 000 customers/partners in total from SMEs to international companies

ISO 9001:2015
BUREAU VERITAS
Certification

CRT

Overview of laser applications in battery production

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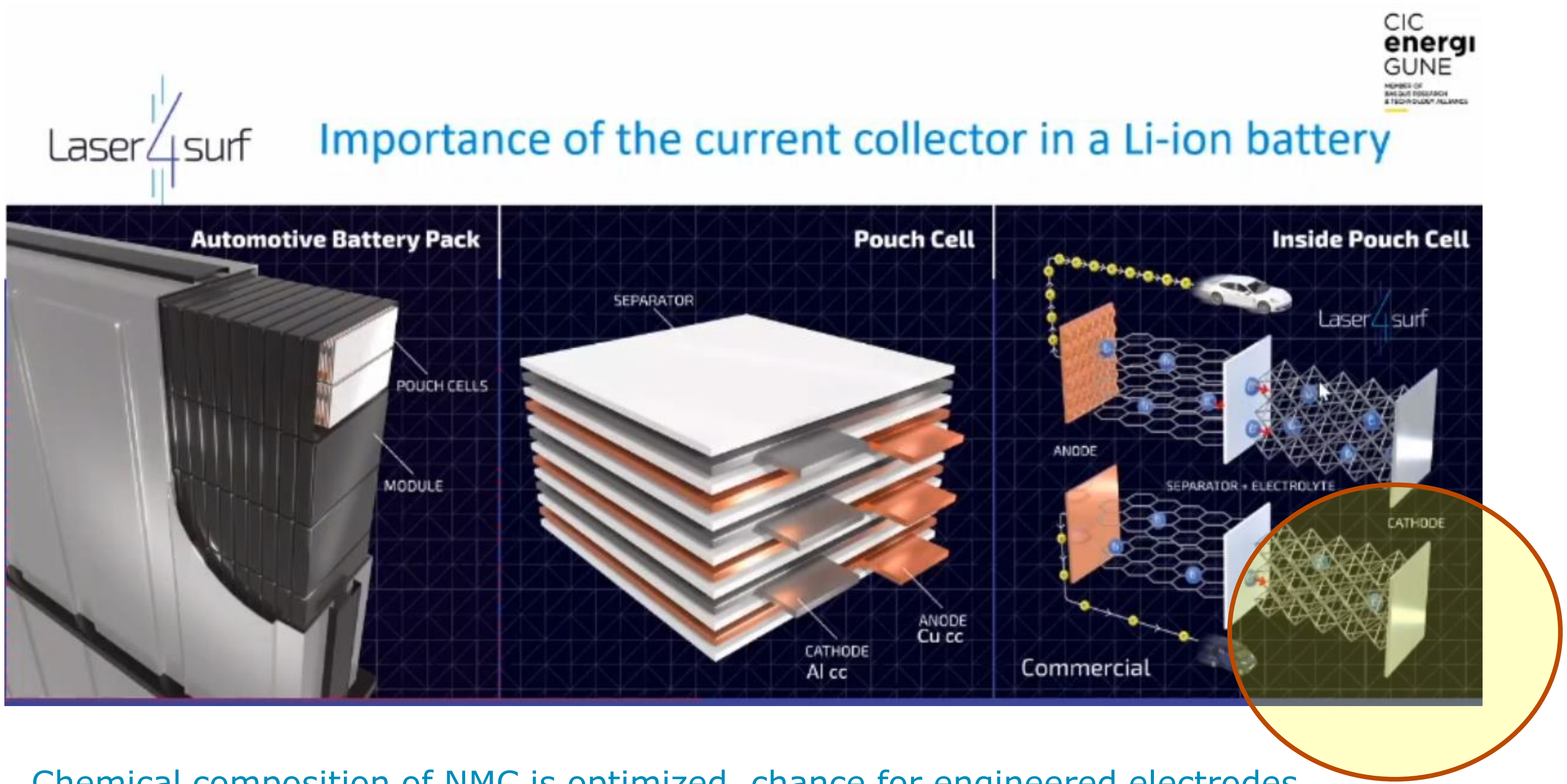


Chemical composition of NMC is optimized, chance for engineered electrodes
Focus on NMC on Al
Objective: reduction of Li+ diffusion in NMC layer

Motivation

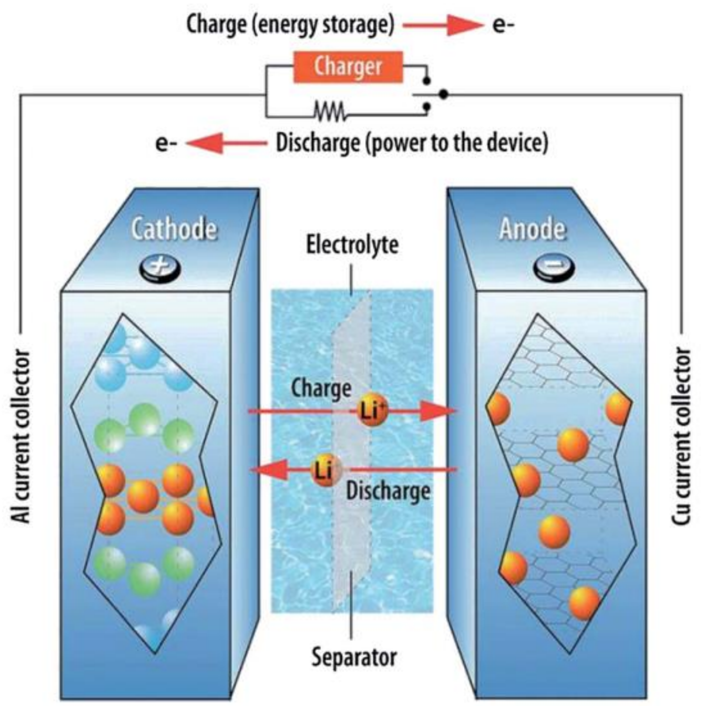
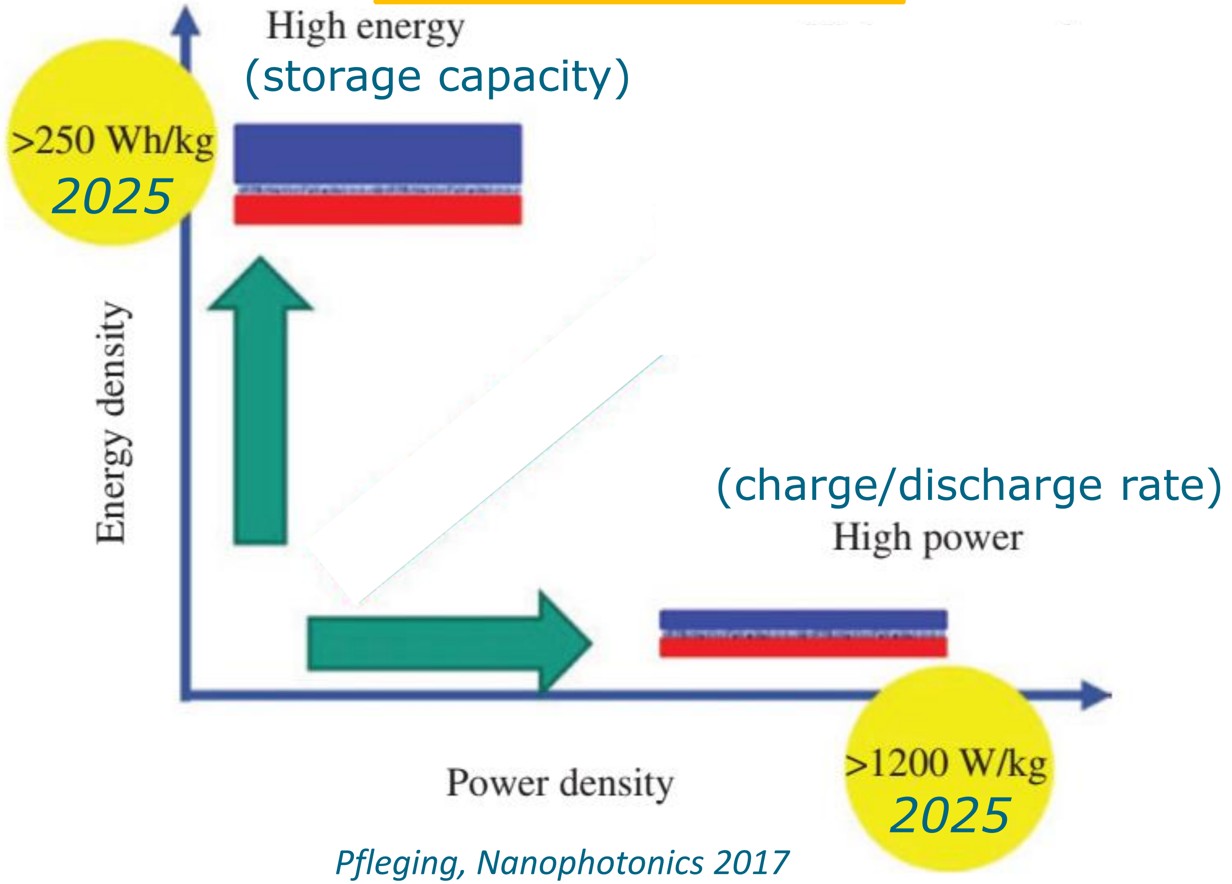


Fig. 1 Structure and principle of operation of a Li ion battery.

Better electrochemical performance than conventional 2D :

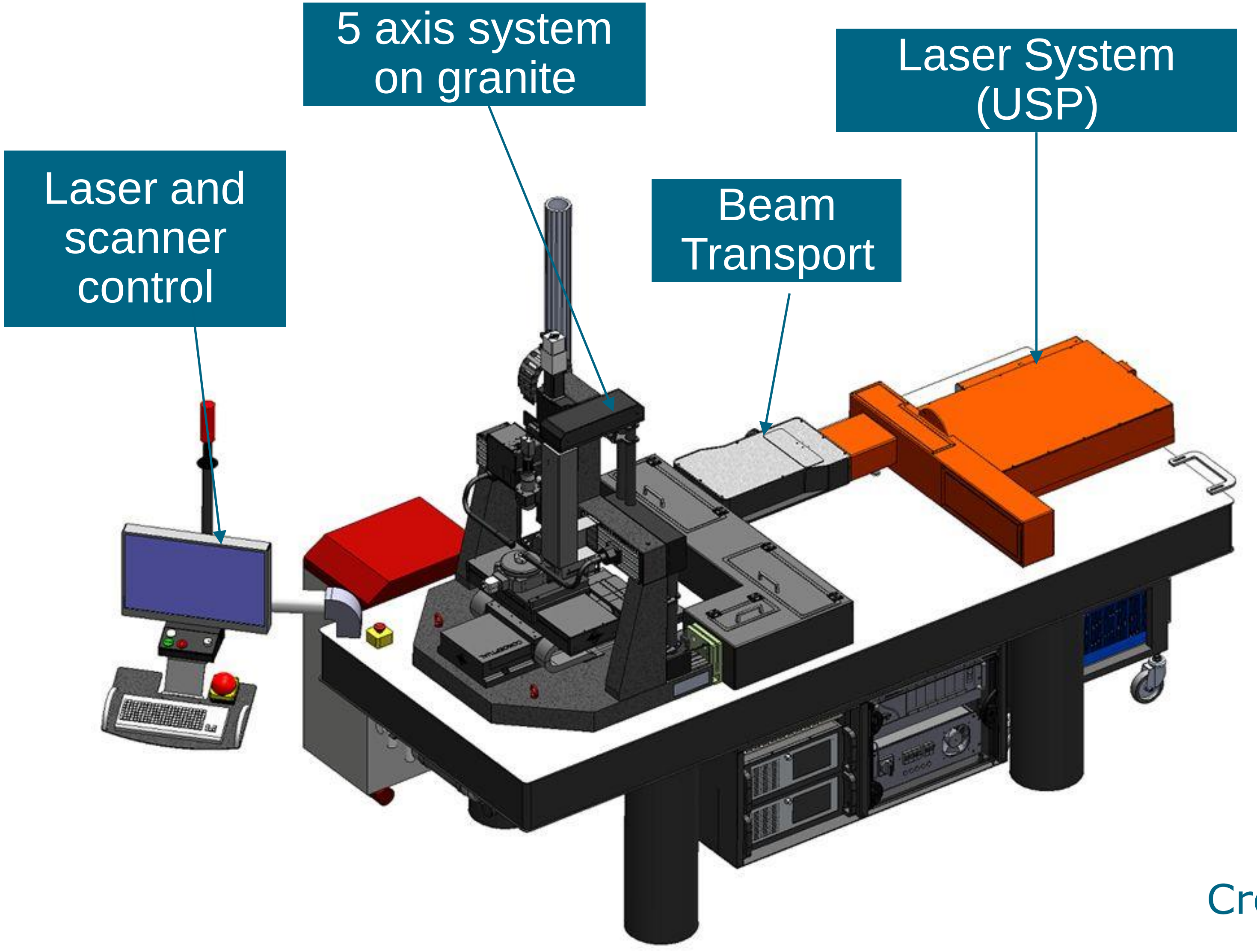
- **Reduced cell impedance**
- **Li+ transfer ↘ when thickness ↗ => power density ↘**

Industrial target:
Energy density x2.5
Specific power x1.5



Pfleging, Nanophotonics 2017

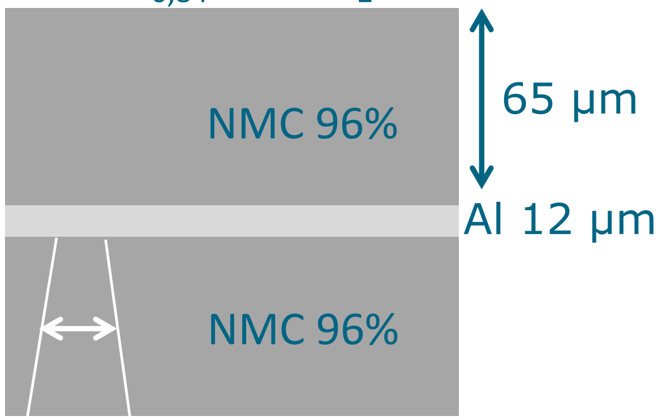
Electrode structuring setup



Samples from Automotive Pouch Cell

Cathode

($LiNi_{0,84}MnCoO_2$)



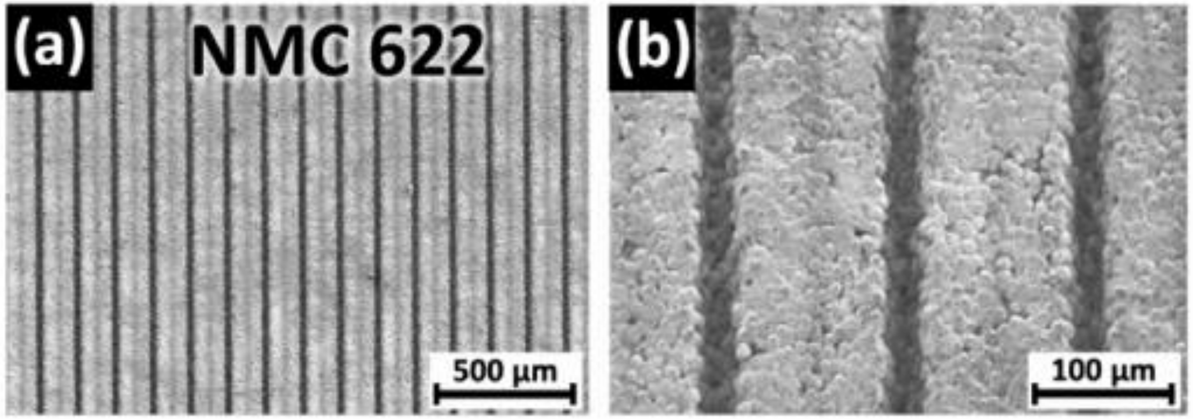
lines & holes

conditions to reach the collector

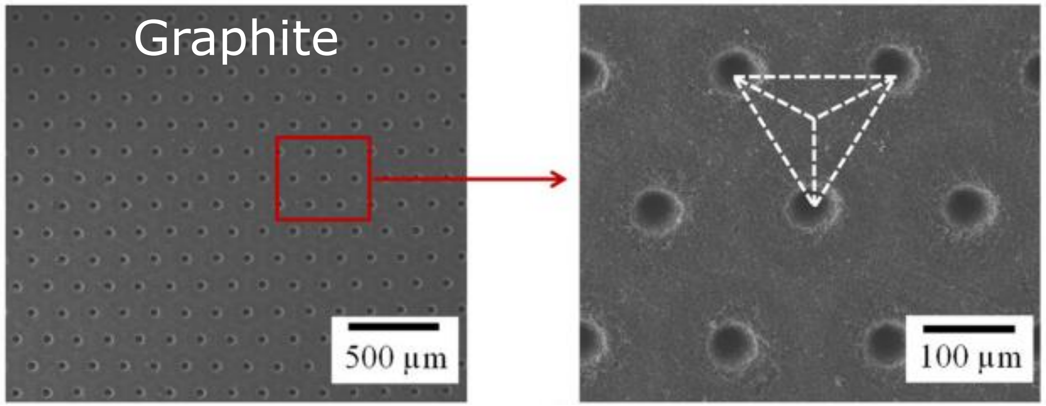
Cross sections for line and hole width(FWHM)

Ideal structuring geometry?

Lines		Holes	
☺	☹	☺	☹
Easier upscaling	Fragility risks	Homogeneous distribution (equidistance)	Positioning constraints/ harder upscaling
Rapid electrolyte diffusion	Heterogeneous electrolyte spreading	Mechanical integrity	Complex System Technology



Dunlap et al., JPS 2022



Kim et al., Ionics 2018

Comparison of geometries: Holes vs Lines

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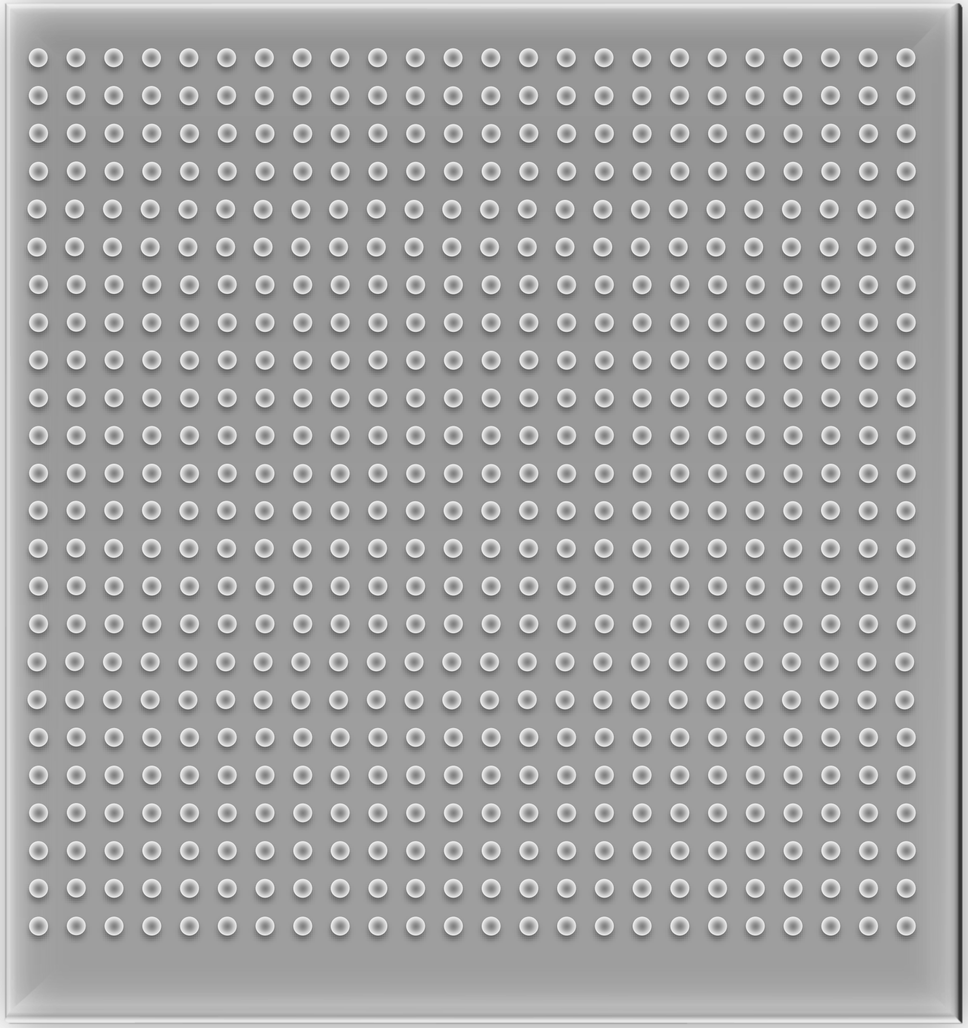
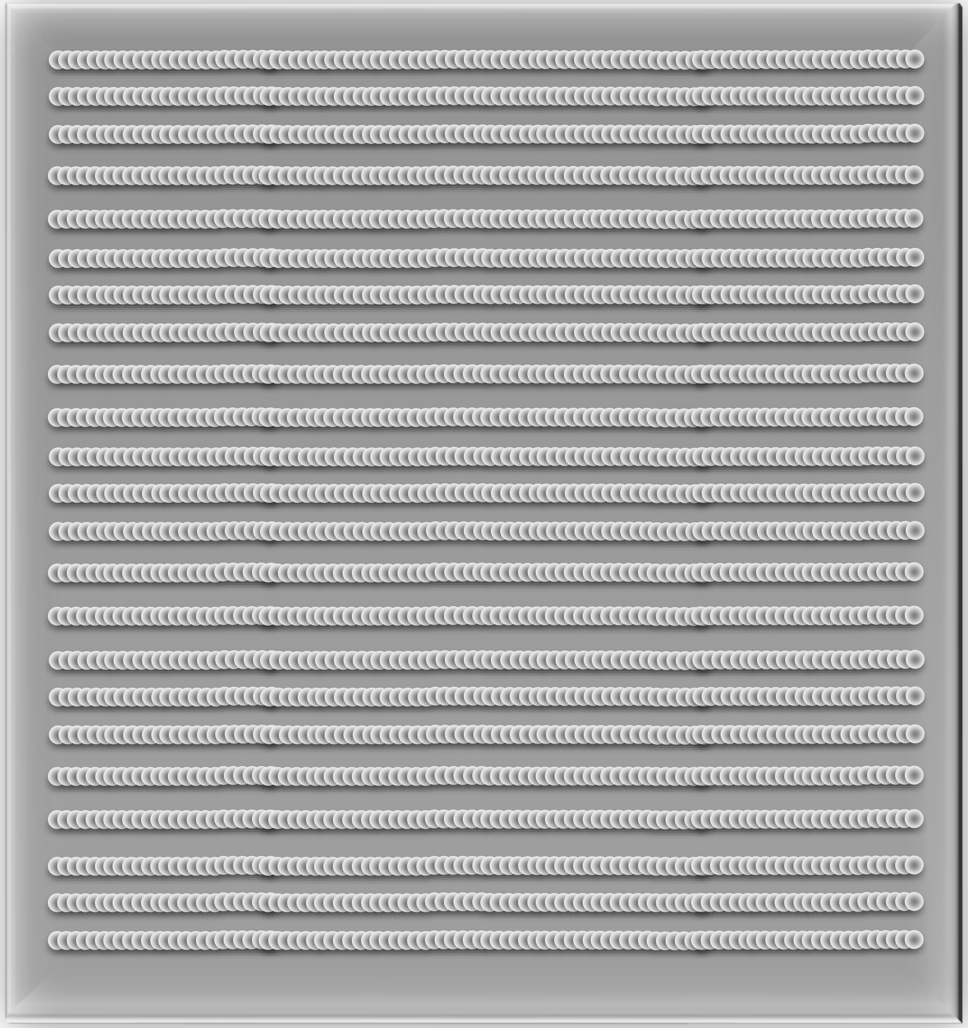
Foil 100 mm, 10 holes/mm -> 1.000 holes

Foil 100 mm



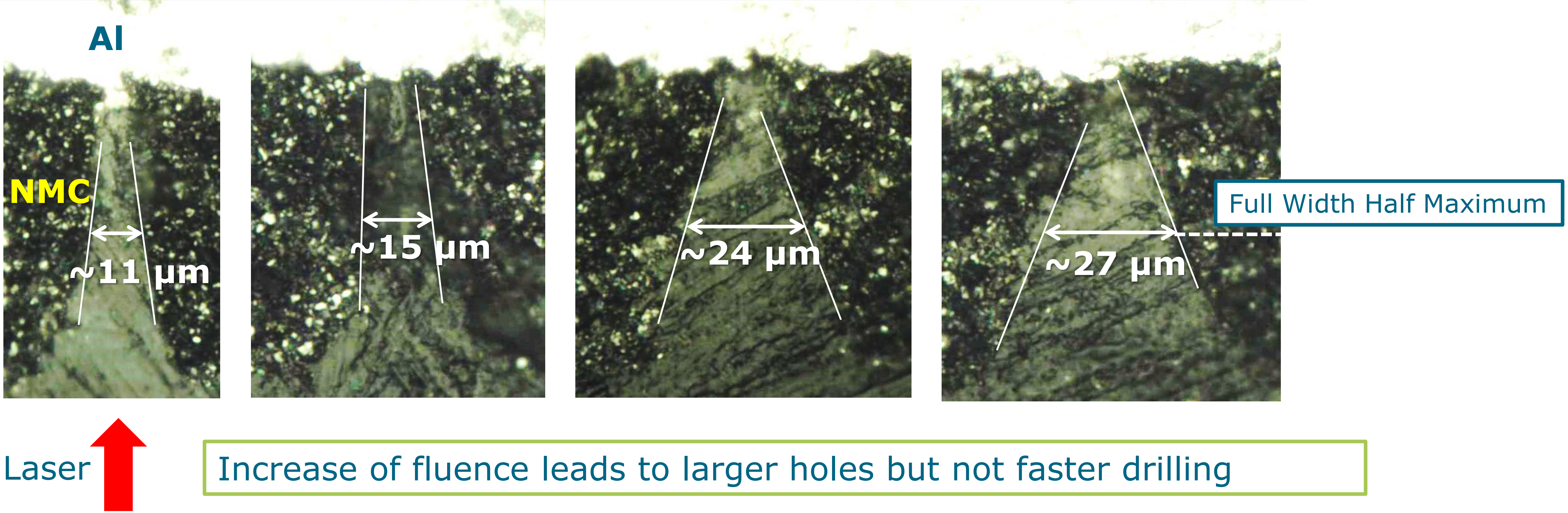
Foil 100 mm, 10 lines/mm -> 1.000 lines



NMC hole structuring, fluence effect

87 kHz, drilling to collector

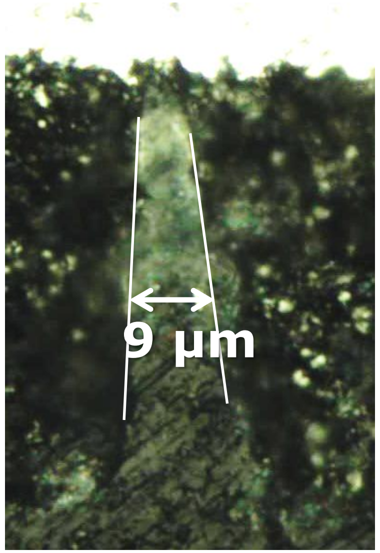
1.0 W, 1500 µs 3.2 J/cm²	2.1 W, 1000 µs 6.5 J/cm²	3.3 W, 1000 µs 10.4 J/cm²	4.8 W, 1000 µs 15 J/cm²



Increase of fluence leads to larger holes but not faster drilling

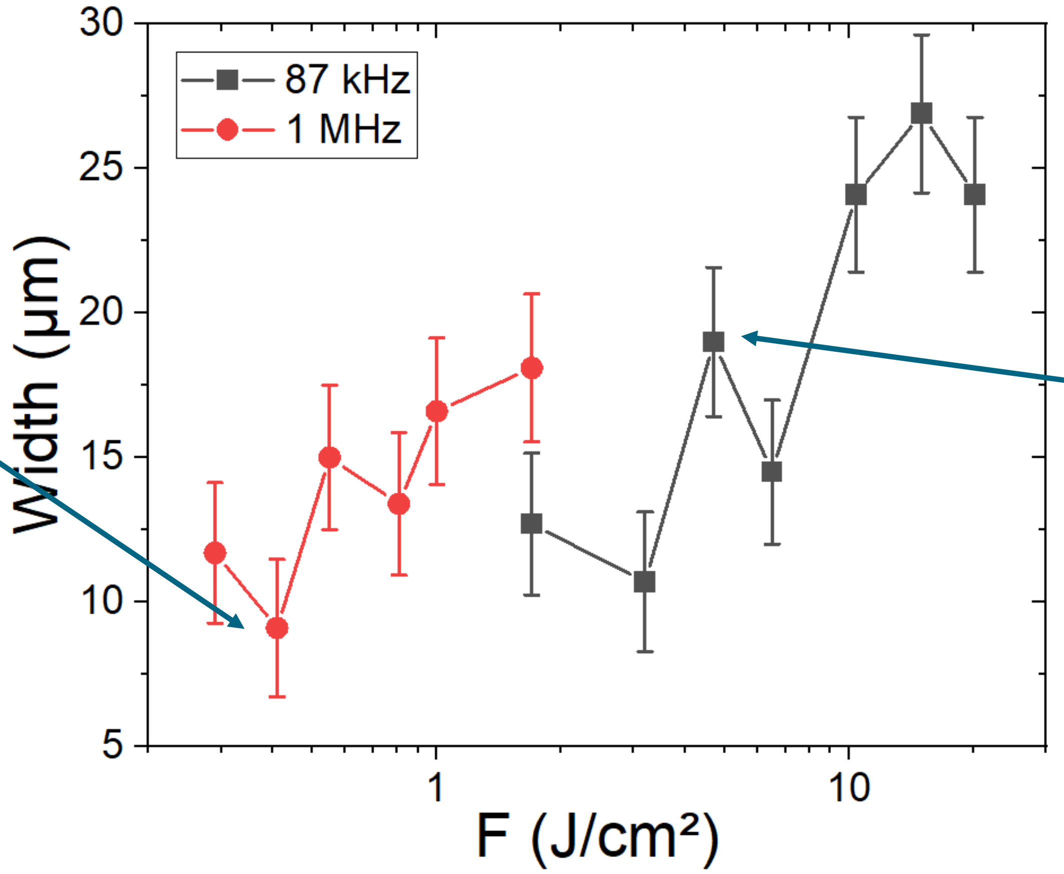
NMC hole structuring, fluence effect

1.06 W, 1000 µs



Dose: 1.1 mJ / hole

Drilling to collector



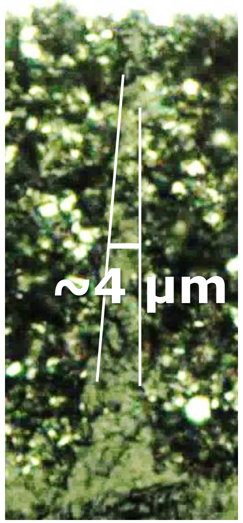
6.47 W, 600 µs

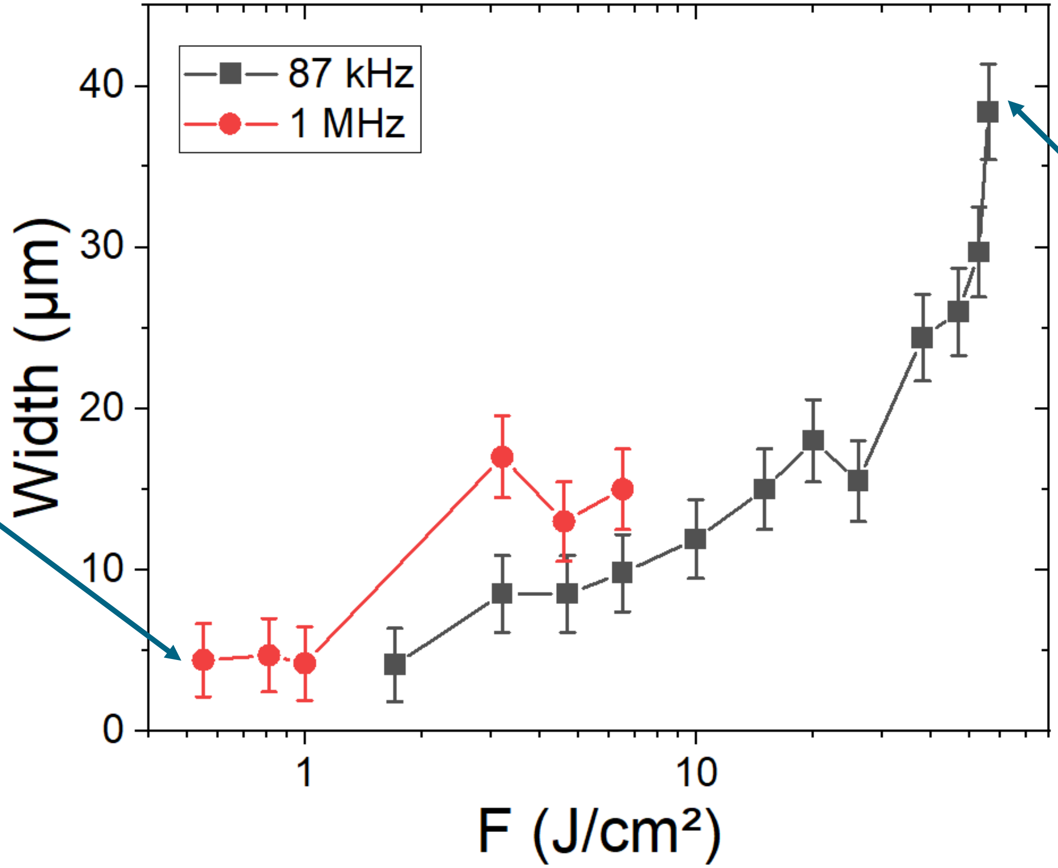
Dose: 3.9 mJ / hole

Higher RR leads to smaller and lower tapered holes
Lower fluence and dose required@1 MHz

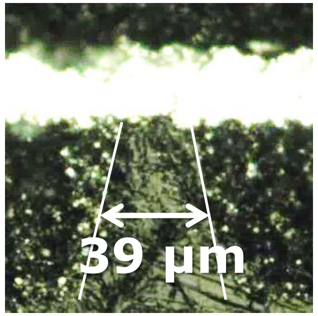
Scribing to collector

2 W, x5000





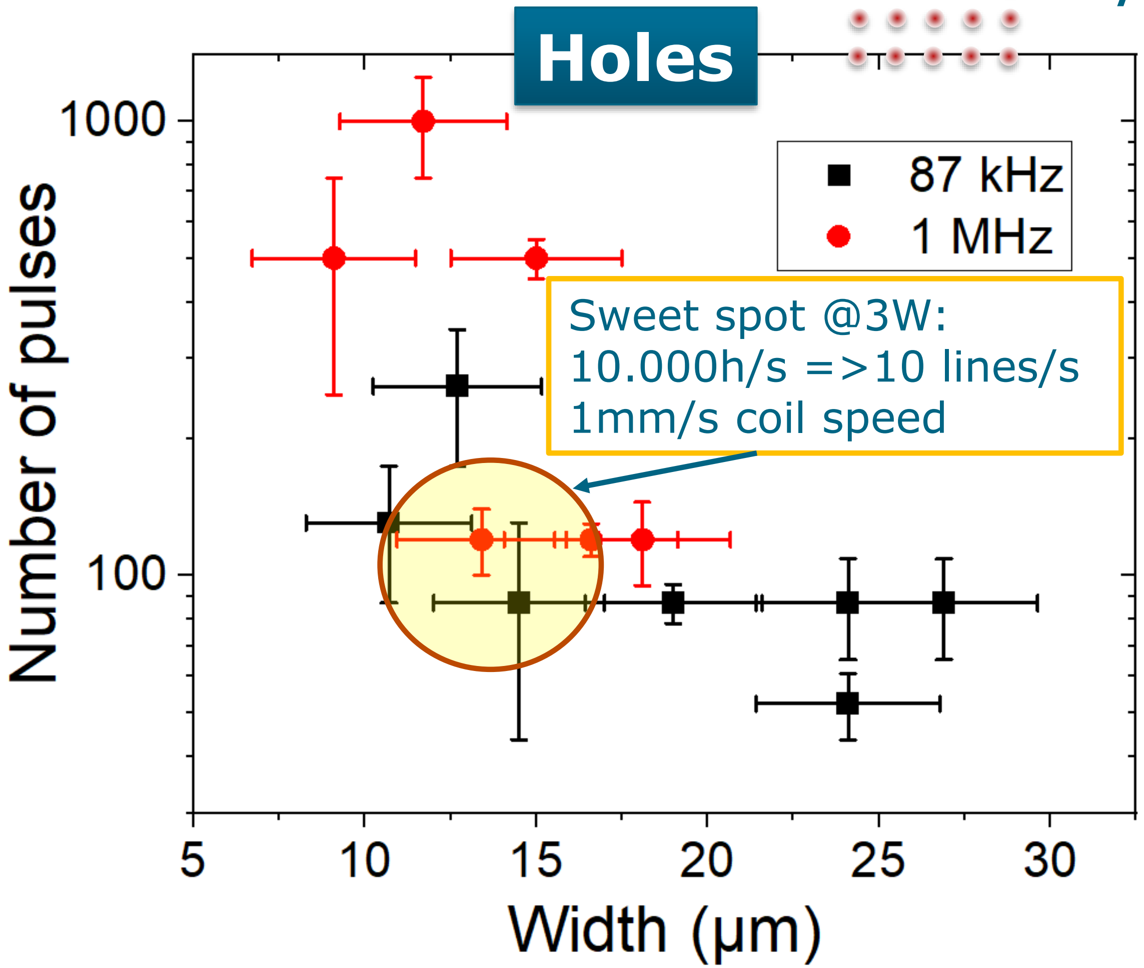
17.8 W, x13

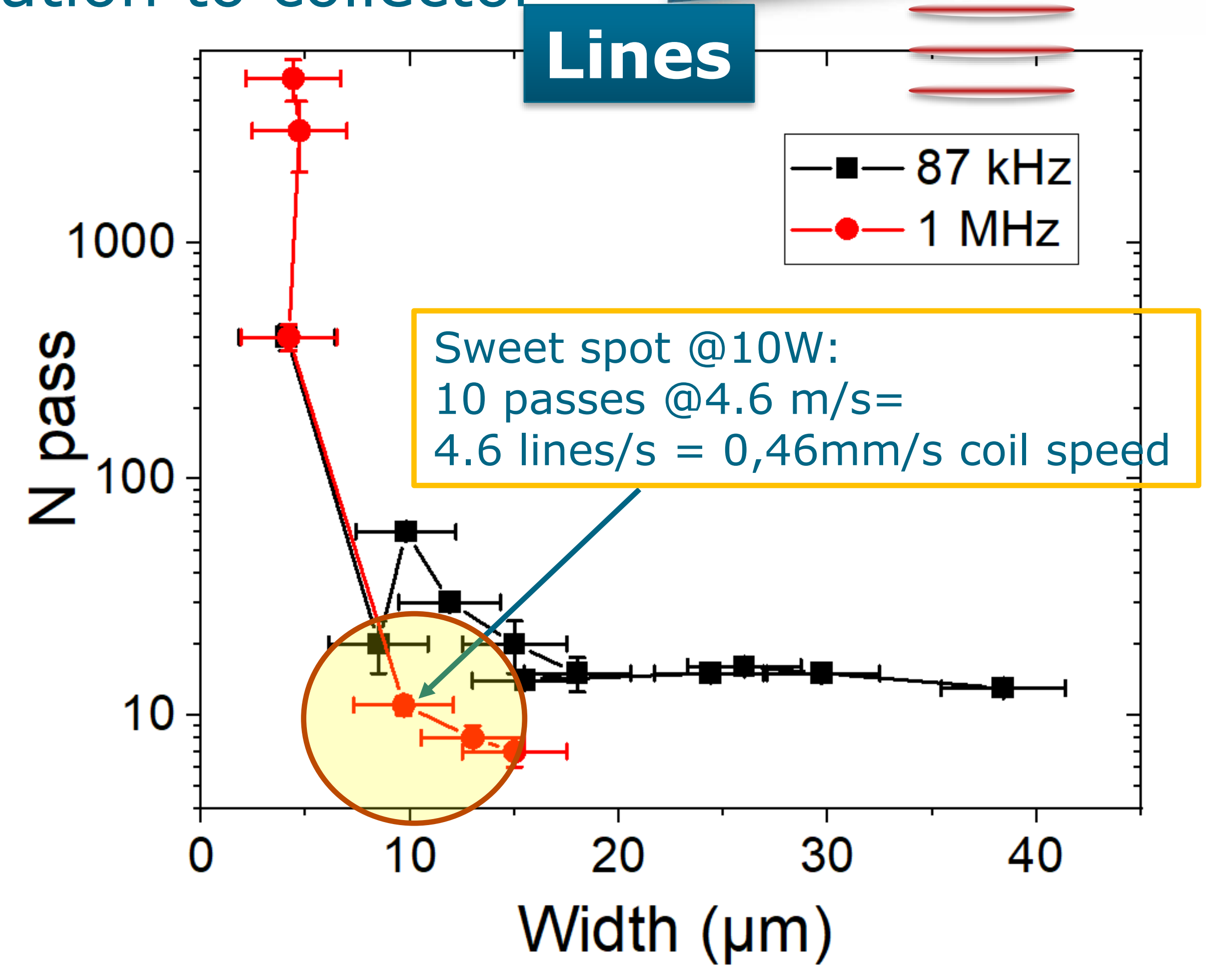


Tailoring of line width with fluence at 87 & 1000 kHz
Slight size increase @1 MHz

NMC structuring: process time

Ablation to collector

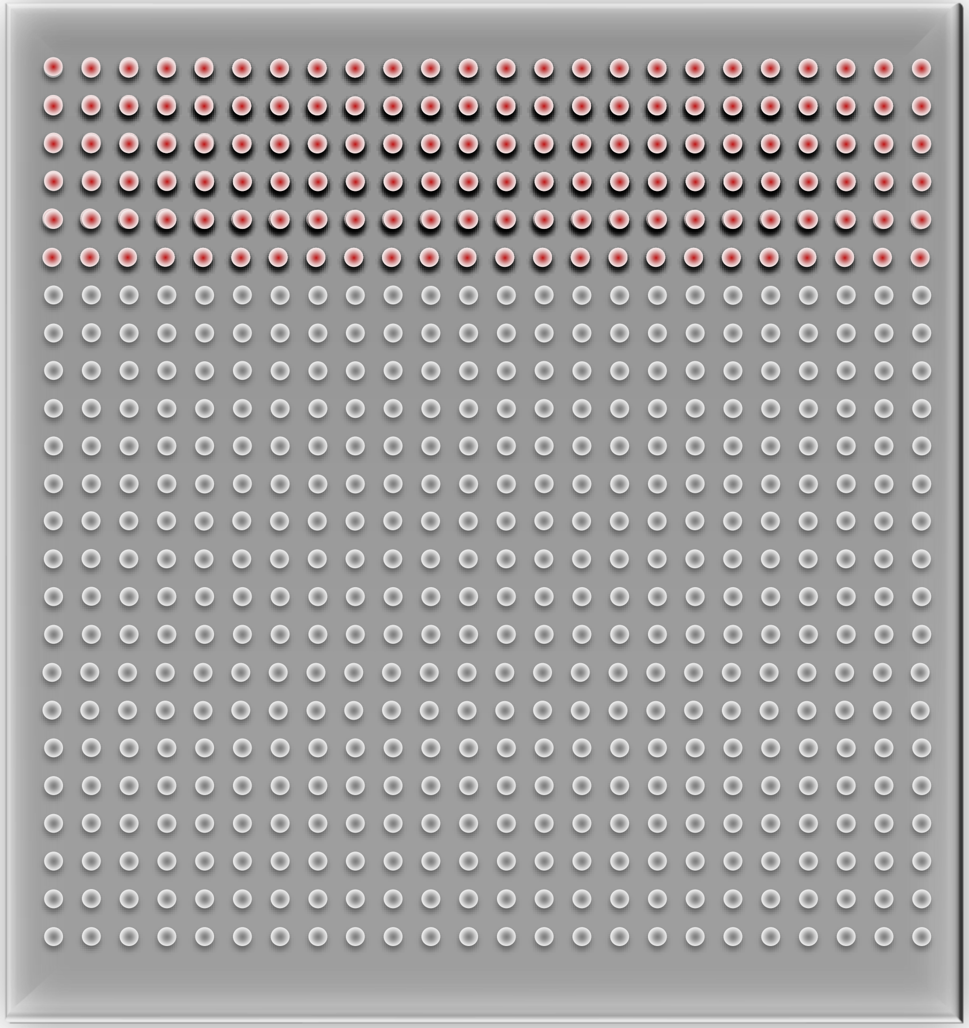




Best process efficiency @ 3W: 100s foil

Best process efficiency @ 10W > 200s foil

On the Fly Drilling by Multi Spot Elements



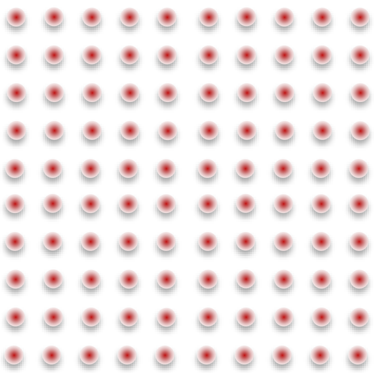
Courtesy of B. Neuenschwander, BfH

- Ablate multi-spot pattern (DOE) with $10x10$ equally spaced spots
- Move pattern by one spot – spot distance $100\mu m$ between two pulses @1 MHz
  => 100 m/s scan speed
- Timing jitter less than 100ns required to hit the spot with less than 10µm deviation

Upscaling Potential for 300W fs Laser

	Holes		Lines	
	☺	☹	☺	☹
@ 3W level	>0,1 ms/hole= 100s for 1Mio holes (1 foil)	Syc and Positioning Is critical	Homogeneous distribution (equidistance)	5s/ line= 500s for 1000 lines
@ 300W level	1s @100X100mm² electrode size	100m/s scan speed required	5s @100X100mm² electrode size	High loss of active material

Take-home Messages



- Laser structuring promising tool for enhanced battery performances
- USP Laser essential to avoid sintering effects (sealed porosity)
- Holes are faster, lines are easier to machine, both without visible collector damage at high speed
- Multi-spot elements (holes) and/or polygon scanners (lines) inevitable for upscaling

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Offer

Seeking

Partnership on performance evaluation and

Electrode structure optimization

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