



OneNano Mid-Atlantic | Columbia University

The Next Generation of 100 kV Electron Beam Lithography

50 Years of Electron Beam Lithography

1975

Founded

Five decades of EBL development

400+

EBL systems

Installed worldwide

Global

Installed base

Research • national labs • industry

A focused electron-beam company with a long installed-base history

A Strong North American Install Base



Experience Across Major Nanofabrication Facilities

Norway	NTNU (G100 100kV)	USA (continued)	University of Illinois at Urbana-Champaign (150kV) SUNY Buffalo (100kV) Rice University (100kV) Columbia University (50kV) New York University (50kV) Laboratory For Physical Sciences (100kV) Naval Research Lab (100kV) Sandia National Lab (125kV)
Denmark	University of Copenhagen (2 Units: 125kV, 100kV)	Australia	The University of Sydney (F125, 125kV)
Finland	Tampere University (50kV)	Taiwan	National Taiwan University (2 units: 100kV, 50kV) Academia Sinica National Nano Device Laboratories National Tsing Hua University National Chiao Tung University National Cheng Kung University
UK	University College London (100kV)	Singapore	National University of Singapore Institute of Material Research and Engineering Data Storage Institute
France	Industrial Customer (100kV) ENS Paris (100kV)	Korea	National NanoFab center National Center for Nanomaterials & Technology (2 Units: 100kV, 80kV)
Germany	Technical University Munich (100kV)	Hong Kong	Chinese University of Hong Kong
Ireland	Tyndall Institute (100kV)		
Italy	Politecnico di Torino (50kV)		
Israel	The Hebrew University of Jerusalem (100kV) Bar-Ilan University (100kV)		
USA	Harvard University (3 units: 150kV, 125kV, 50kV) MIT (2 units: 125kV, 50kV) Duke University (50kV) University of Oklahoma(125kV) City University of New York (2 units: 100kV, 50kV) University of Maryland (100kV) Carnegie Mellon University (100kV) University of Rochester (50kV) Georgia Tech (100kV)		

Why Develop a New 100 kV EBL System?

Emerging applications are placing new demands on EBL performance

- Larger, more complex patterns - especially for photonics, metalenses and waveguides
- Higher throughput without sacrificing resolution or pattern fidelity
- Higher beam currents while maintaining a small beam spot size
- Reduced stitching for large area and high precision structures
- More flexible pattern generation for increasingly complex geometries

Improve throughput and writing flexibility while preserving 100 kV precision

Introducing ELS-RAIDEN 100



Our Next Generation 100kV EBL System

- New pattern generator
- Increased scan clock speed
- Higher beam current
- Larger write fields

What Changes with RAIDEN?

Up to 10 ×

Lower PG settling time
(for select patterns)

400 MHz

Scan clock

500 nA

Maximum beam current

3 mm

Write field @ 100 kV

higher current + faster scanning + lower overhead + larger fields.

Designed to improve real writing efficiency for demanding large area and high complexity patterns.

The Pattern Generator Was a Throughput Bottleneck

**~10 × reduction
in settling time**

- Allows users to fully benefit from higher beam current due to the significant reduction in settling time
- Prior PG (settling time) dominated write times - going from 20nA to 40nA didn't provide as much benefit as it should due to this settling time
- Especially important for settling time limited patterns such as metalens
- New primitives: rotated ellipse, rotated trapezoid, polygons up to 256 vertices
- Freehand writing enables simpler data preparation and smaller CAR files

400 MHz: Increased Beam Shots, Better Pattern Fidelity

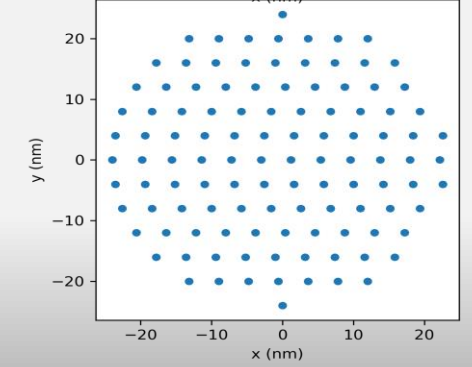
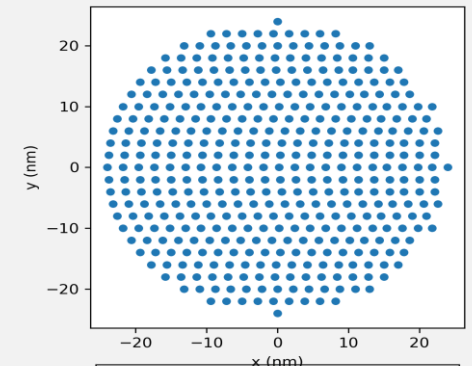
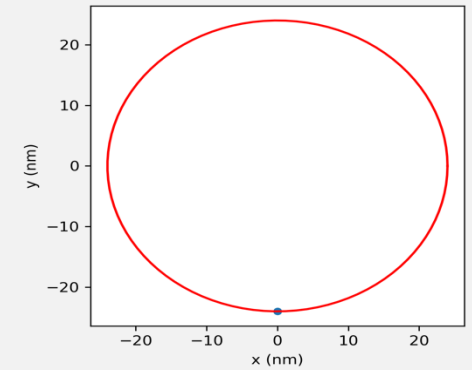
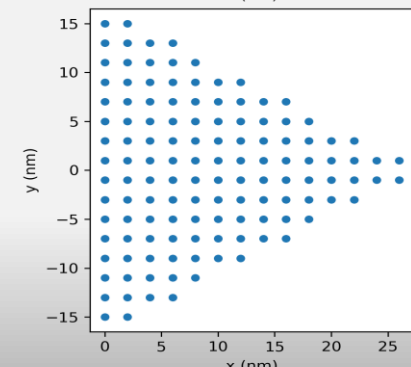
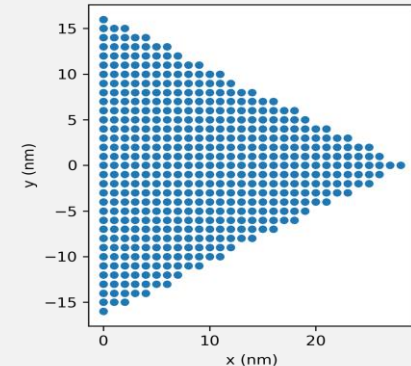
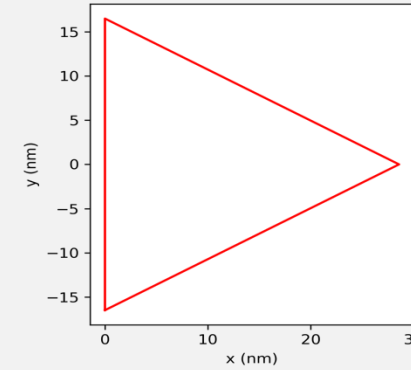
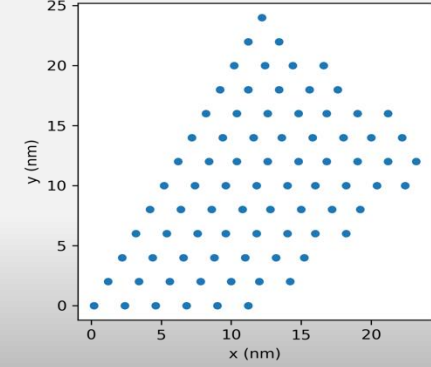
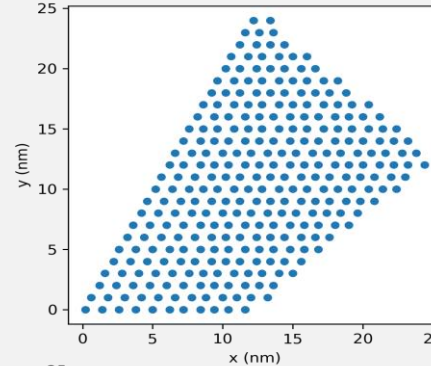
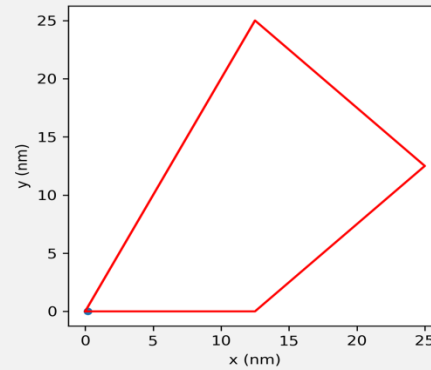
4×

At the same beam current and dose, the 400MHz clock allows for an increase in the number of dots within the same shape by a factor of 4.

Result: better pattern fidelity for complex shapes.

400 Mhz

100 Mhz



400 MHz: Use More Current Without Increasing Beam Step Size

1 nm

Beam step size

 $250\mu\text{C}/\text{cm}^2$

Dose

4 ×

Beam current

250 pA → 1 nA

Example exposure

21 min → 6 min**Up to ~4 × faster for dose time limited patterns**

	100MHz	400MHz
BSS	1nm	1nm
B-current	250 pA	1 nA
dose	$250\mu\text{C}/\text{cm}^2$	250
dosetime	10 ns	2.5 nS
Total Time	21 min	6min

400 MHz: Multipass with Little Time Loss

Single pass

<20 nm

stitching

4 × multipass

<8 nm

stitching

6 min → 7 min total time

Higher clock speed creates room to trade scan time for accuracy

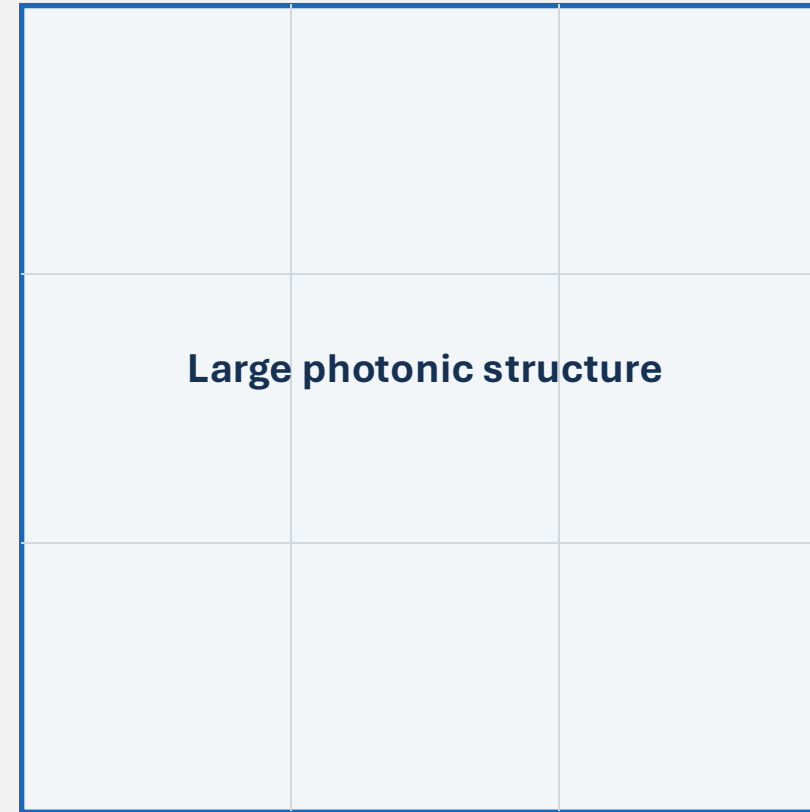
- Same 1 nm beam step
- Same 250 pA beam current
- Same dose
- Four shifted passes reduce stitching error

3 mm × 3 mm Write Fields at 100 kV

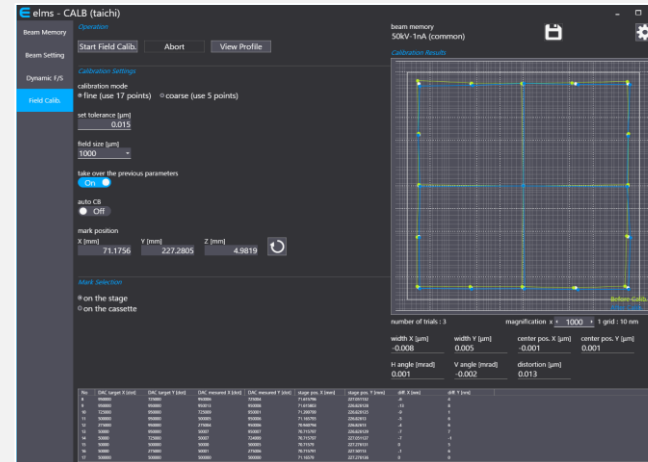
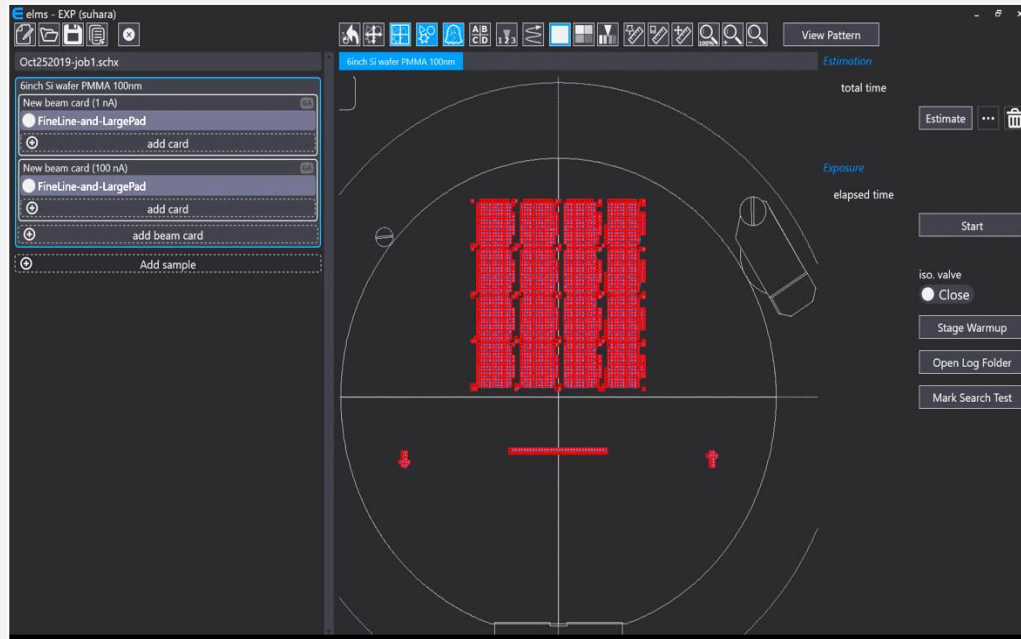
3 mm × 3 mm

**single write field
at 100 kV**

- Fewer stitching boundaries
- Fewer stage movements
- Higher throughput
- Especially useful for waveguides and metalenses

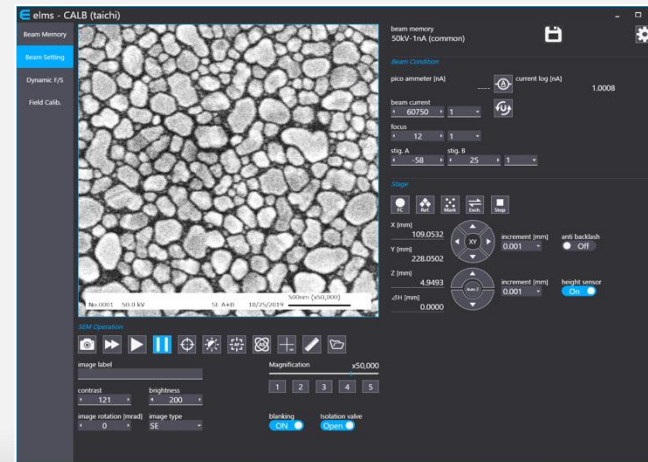
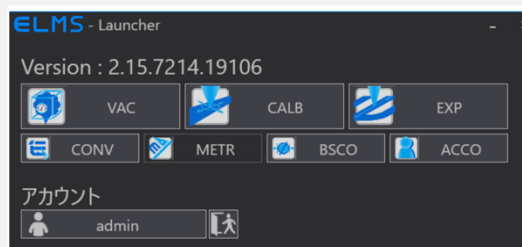


ELMS: One Environment from Data Prep to Exposure



Integrated workflow

- Pattern conversion
- Exposure scheduling
- Beam calibration
- Writing-time estimates
- Account management
- Python scripting
- SEM imaging & analysis
- SEM Metrology Package



ELS-BODEN 100 → ELS-RAIDEN 100

Specification	ELS-BODEN 100	ELS-RAIDEN 100
Maximum beam current	200 nA	500 nA
Maximum write field	1 mm	3 mm
Scan clock	200 MHz	400 MHz
Stage speed	15 mm/s	25 mm/s
Pattern-generator overhead	Previous Generation	Up to ~10× lower
HV tank	Current design	New design

Thank You!