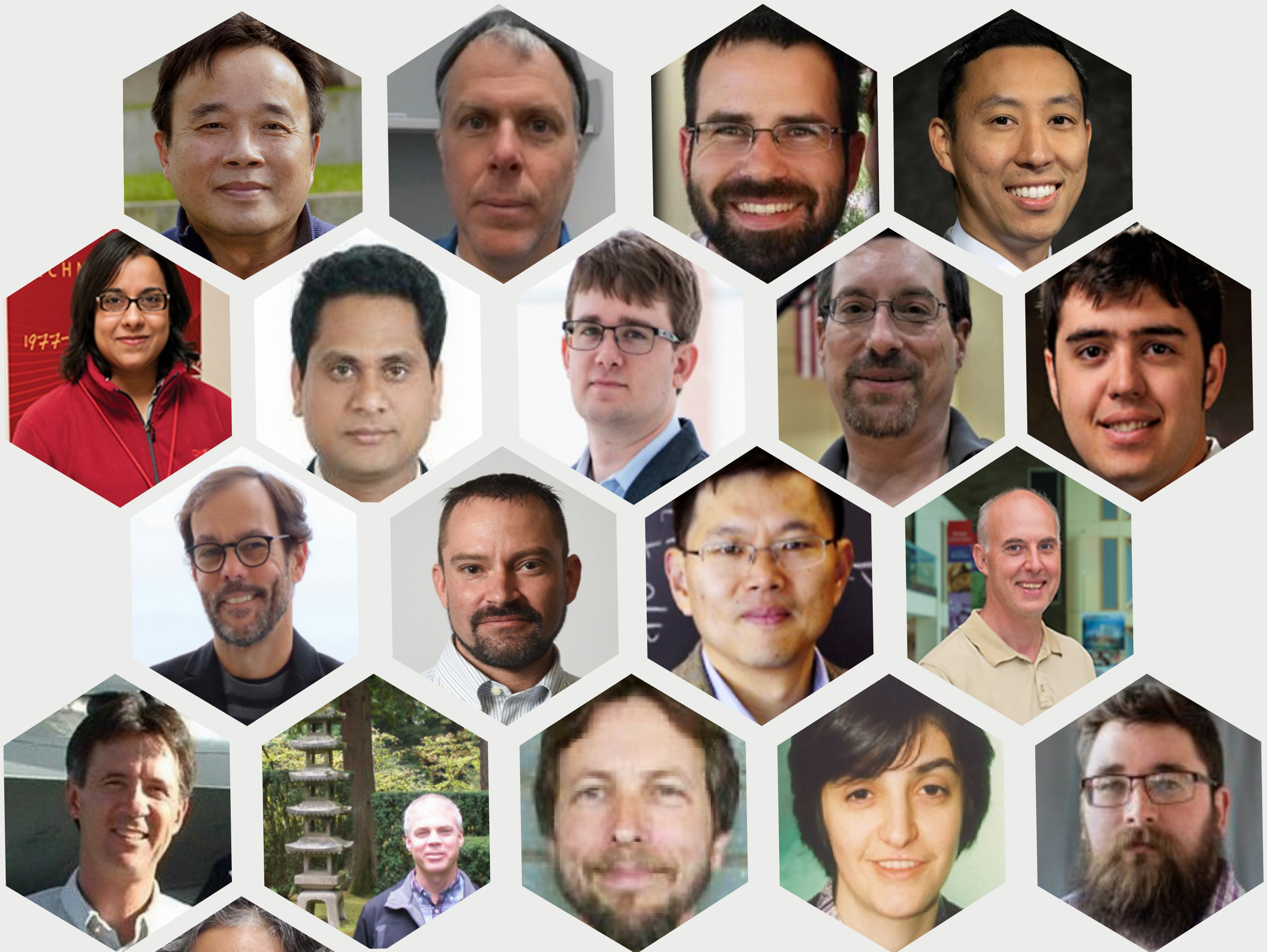
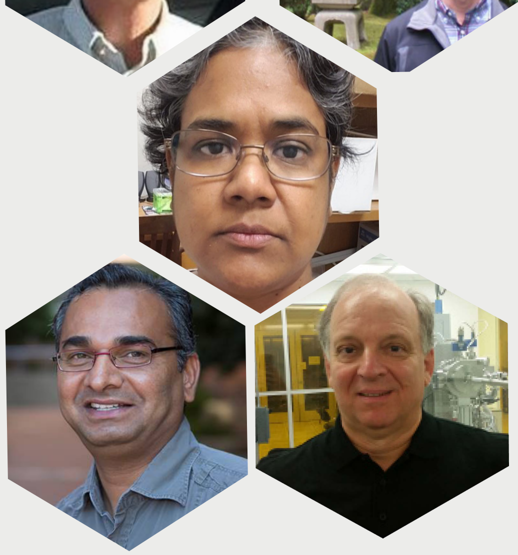
2021 - 2022

National Nanotechnology Coordinated Infrastructure



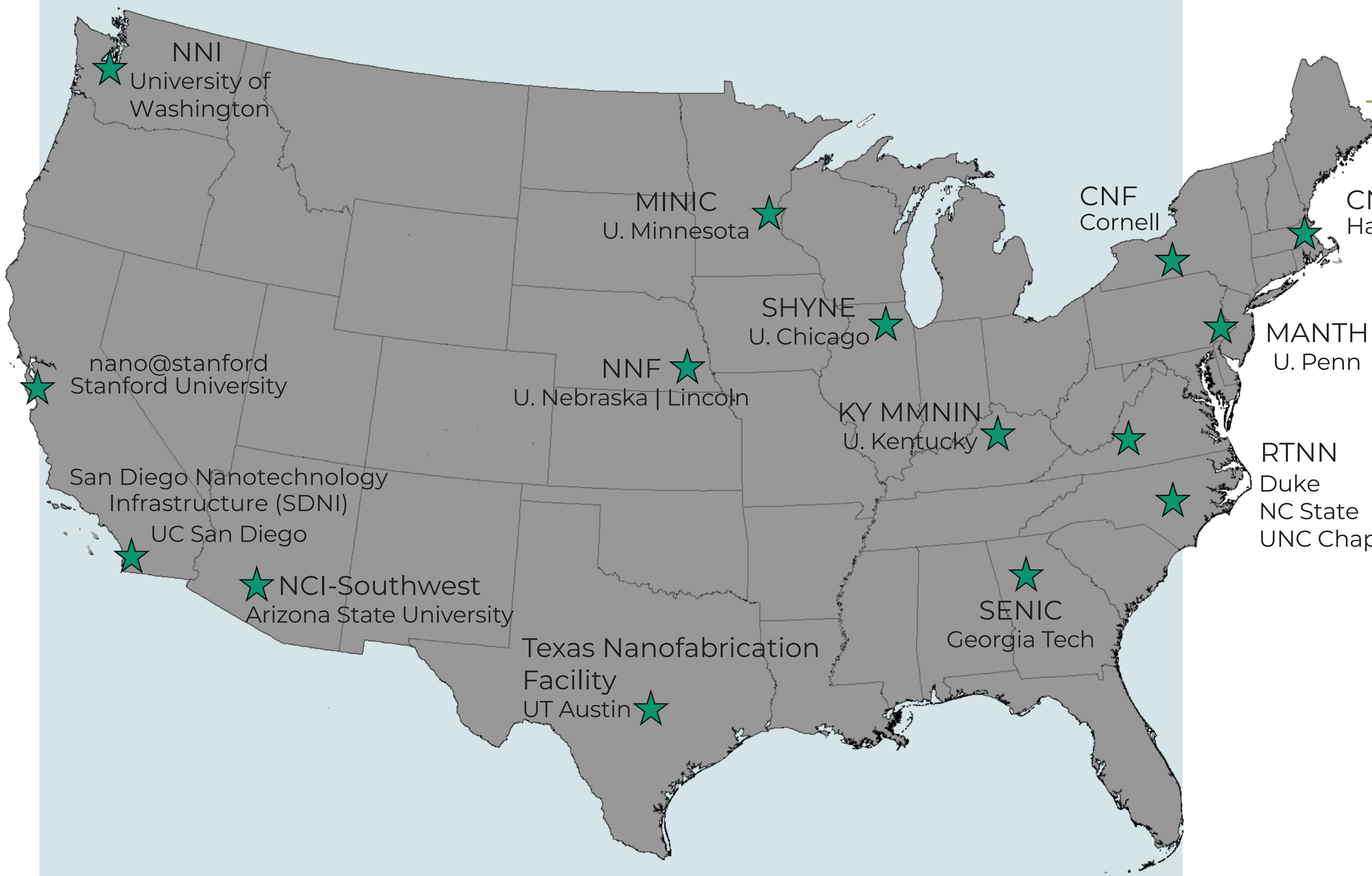


NNCI ELECTRON BEAM LITHOGRAPHY

Working Group Resource Guide

"Solving the world's smallest problems!"

nnci.net



NNCI Shared Resources Overview

One of the pillars of the National Nanotechnology Initiative (NNI), created in 2000 to coordinate the nanoscale research and development activity of more than 20 federal agencies, is the importance of user facilities and networks as part of a robust infrastructure and toolset. Because nanoscale science and engineering often requires expensive equipment and specialized expertise, these facilities tend to be located at research-intensive universities and national laboratories. To help alleviate the lack of these resources in both smaller academic institutions, as well as in the small to medium size commercial sector, the National Science Foundation has supported a network of user facilities for the past forty years. Initially, the National Nanotechnology Facility at Cornell (1977-1993), followed by the National Nanotechnology Users Network (NNUN, 1993-2003), and then the National Nanotechnology Infrastructure Network (NNIN, 2004-2015) provided specialized nanotechnology resources to all researchers who needed them. The National Nanotechnology Coordinated Infrastructure (NNCI), established in 2015, is the latest version of this national resource.

The NNCI site awards are the culmination of a competition conducted by NSF, under Program Solicitation NSF 15-519, which was generated as a result of input from the science and engineering community. Over 50 proposals from potential NNCI sites were submitted, resulting in 16 awards. The total level of funding for NNCI sites and the NNCI Coordinating Office is approximately $16 million annually. The initial cooperative agreements were for a period of 5 years, and the program was renewed for an additional 5 years in 2020 with a total budget of $84 million.

Research undertaken within NNCI facilities is incredibly broad, with applications in electronics, materials, biomedicine, energy, geosciences, environmental sciences, consumer products, and many more. The toolsets of sites are designed to accommodate explorations that span the continuum from materials and processes through devices and systems. Micro/nano fabrication, conducted in cleanroom environments, as well as extensive characterization capabilities will provide resources for both top-down and bottom-up approaches to nanoscale science and engineering.

All of the NNCI facilities (many sites have partners and multiple locations) are open for access by students and professionals from around the country and globally. The facilities within NNCI are research and development facilities, supporting both academic research and product and process development. NNCI sites have experience supporting technology innovation and commercialization, for start-ups as well as larger and more established companies.

NNCI NNCI Electron Beam Lithography Working Group

Co-Chairs

Devin K. Brown
devin.brown@gatech.edu

Stanley Lin
stanleyl@stanford.edu

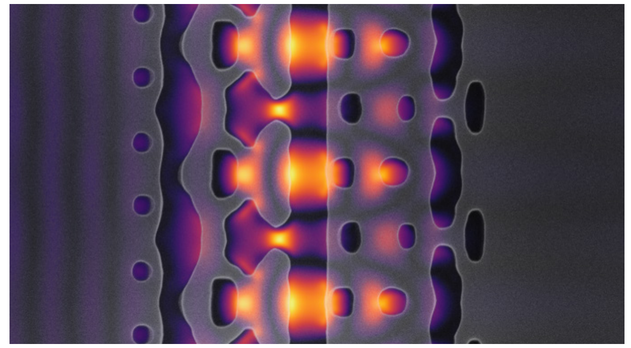
This NNCI Technical Working Group has been established to share information about the proven techniques and unique capabilities of the NNCI member sites in the area of direct write, Gaussian spot, electron beam lithography systems and processing. The purpose of these tools is to enable nanometer scale fabrication and patterning of devices and materials.

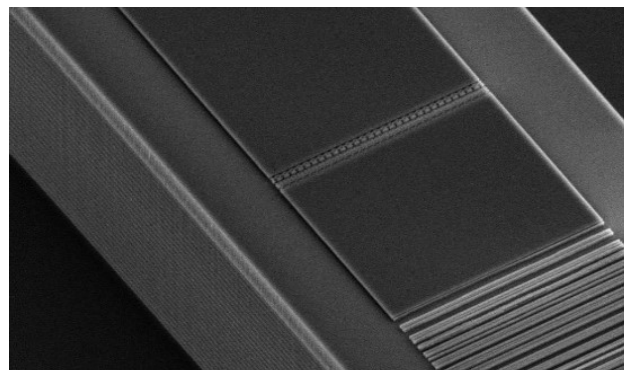
nnci.net

NNCI E-Beam Lithography Research Highlights

Research Highlight

Miniaturizing particle accelerators: Particle accelerators are usually associated with large national facilities. Because photons are able to impart momentum to electrons, there are also efforts to develop laser-based particle accelerators. Sapra et al. developed an integrated particle accelerator using photonic inverse design methods to optimize the interaction between the light and the electrons. They show that an additional kick of around 0.9 kilo–electron volts (keV) can be given to a bunch of 80-keV electrons along just 30 micrometers of a specially designed channel. Such miniaturized dielectric laser accelerators could open up particle physics to a number of scientific disciplines.





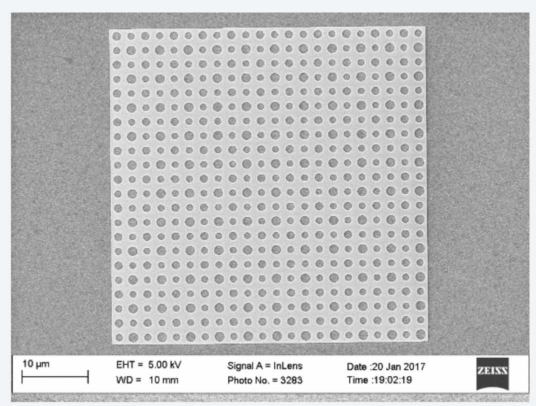
Jelena Vuckovic, Electrical Engineering, Stanford University
nano@stanford: JEOL 6300FS

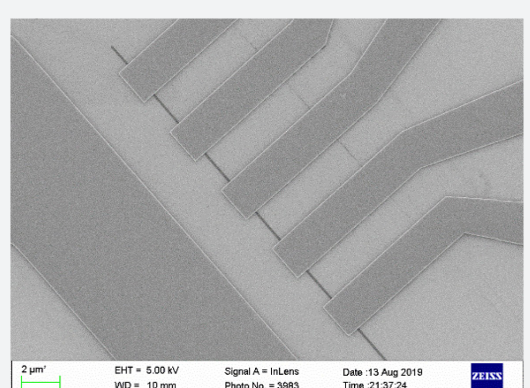
Research Highlight

We are working on the chemical design of novel functional materials for applications in electronics, photonics, sensors and energy storage. Such materials include graphene, carbon nanotubes, inorganic nanowires, colloidal particles, macroporous oxides and some others. Our strategy is to control the structure and composition of these materials at nanoscale to define their properties.

Alexander Sinitskii, Chemistry, University of Nebraska-Lincoln

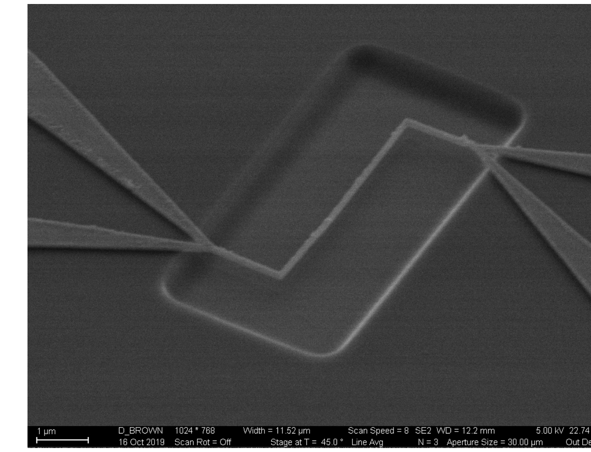
Nebraska Nanoscale Facility: A Zeiss Supra 40 Field-Emission SEM with Raith Pattern Generator

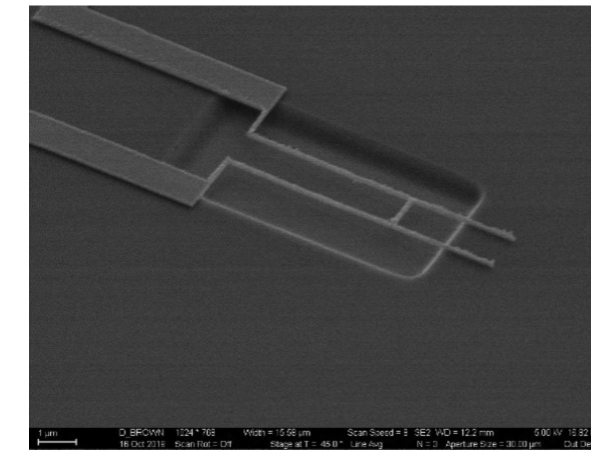




Research Highlight

The images show a nickel wire 100 nm in width, suspended over an etched cavity in a thermally grown 500 nm silicon dioxide film. The nickel nanowire is designed to serve as a piezo-resistive force sensor for blood platelet compressive force transduction. This data would be useful for blood disease diagnosis. The nanowire pattern was created using an Elionix ELS-G100 100 kV electron beam lithography system in combination with a liftoff process. The nanowire metal consists of an adhesion layer of 40 Å of titanium followed by 1000 Å of nickel deposited by a CVC electron beam evaporator.



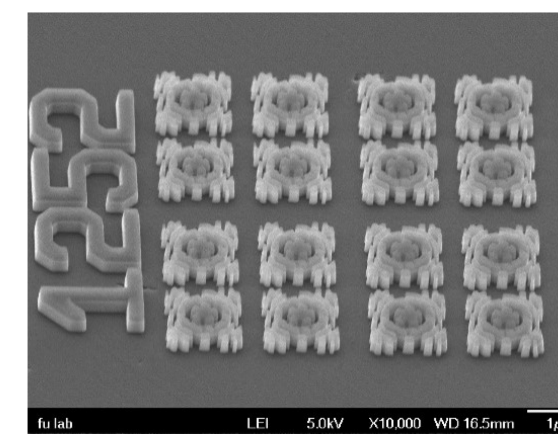


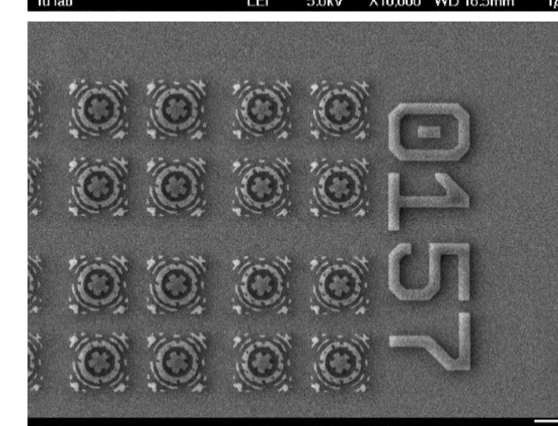
Oliver Brand, Electrical and Computer Engineering, Georgia Tech
Southeastern Nanotechnology Infrastructure Corridor: Elionix ELS-G100 100 kV

Research Highlight

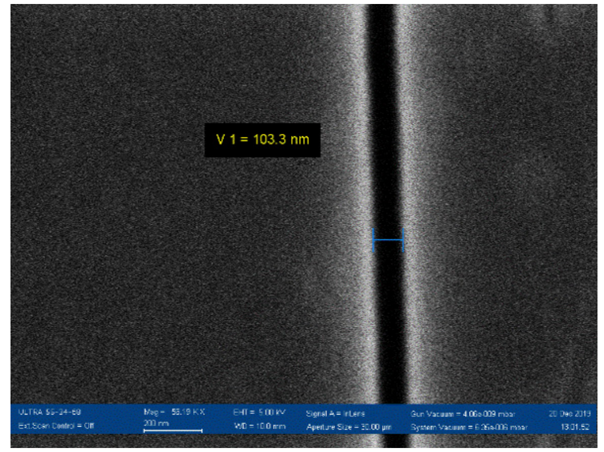
Photon collection efficiency, presents a major challenge for defect qubits in high refractive index host materials. Here we design and demonstrate a compact hybrid gallium phosphide on diamond inverse-design planar dielectric structure coupled to single near-surface nitrogen-vacancy centers formed by implantation and annealing. We observe device operation near the theoretical limit and measure up to a 14-fold broadband enhancement in photon extraction efficiency. We expect that such inverse-designed devices will enable realization of scalable arrays of single-photon emitters, rapid characterization of new quantum emitters, sensing and efficient heralded entanglement schemes.

Kai-Mei Fu Group, Electrical and Computer Engineering, University of Washington
Northwest Nanotechnology Infrastructure: WNF JEOL JBX-6300FS





Research Highlight

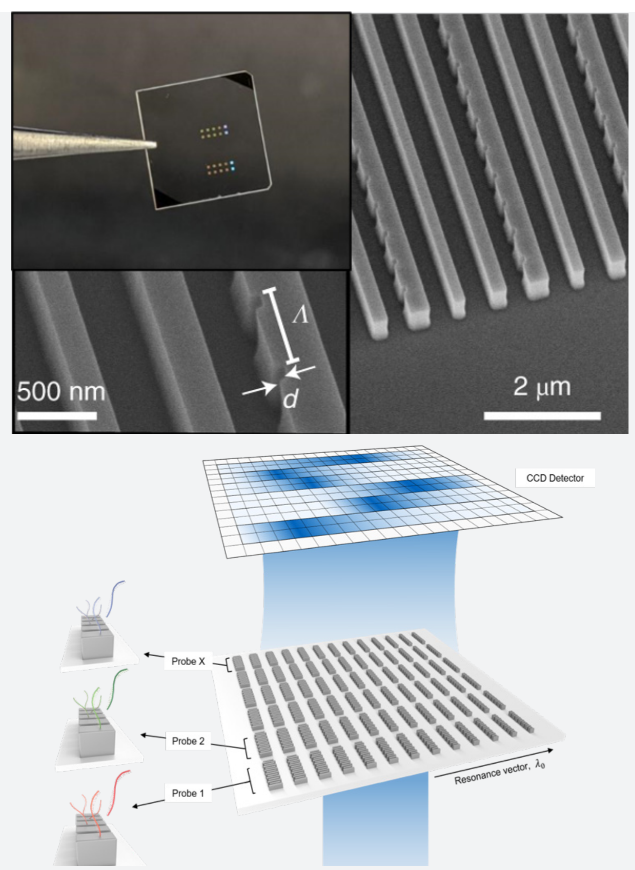


Riehn group explores how DNA behaves in volumes comparable or small relative to its persistence length (about 50-60 nm, roughly the “average bending radius”) of the molecule. Using this knowledge, the group designs nanofluidic devices to study the biomolecular interactions with the single-molecule techniques which are more efficient than the conventional bulk methods. The nanofluidic devices consists of network of nanochannels, which allows the complex manipulation of DNA and fluid. The nanochannels with cross-section of 100x100 nm^2 are patterned using e-beam lithography (Raith 150 Two system at NC State Nanofabrication Facility), and reactive ion etched on the fused silica substrate.

Riehn Group, Department of Physics, NC State University

Research Triangle Nanotechnology Infrastructure: Raith 150

Research Highlight



Silicon nanoantennas confine light and amplify the local electric field, resulting in ultra-high sensitivity for rapid, accurate diagnostics

The precise asymmetry of the nanoantennas “slows” transmitted light, resulting in sharp resonances

When the silicon is functionalized to bind with specific nucleic acids or antibodies (e.g. for SARS-CoV-2 diagnostics), the sharp resonance shifts

In the future, isolated antennas can be functionalized separately for highly multiplexed diagnostics on a scalable silicon-based platform

Dionne Group, Materials Science and Engineering, Stanford University

nano@stanford: JEOL JBX-6300FS

CNF Cornell

JEOL JBX-6300FS

Tool Description

The 6300 is a high speed, high resolution commercial ebeam lithography system operating at 100KV. The unique capability of the JEOL 6300 is that a fifth lens can be used to get a smaller beam spot size and write sub-10 nm features. This is the high resolution writing mode. Writing without the 5th lens in 4th lens mode is called the high speed writing mode.

System Specifications

Operating Acceleration Voltage (kV)
100

Max Scan Speed (MHz)
50

Max Sample Size
150 mm wafer

Min Beam Diameter (nm)
2.5

Max Field Size (mm)
0.5

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
10 nm 5th lens; 30 nm 4th lens

Min Feature Size (nm)
10

Tool Owner | Contact for Rates

Alan R. Bleier | bleier@cnf.cornell.edu | 607.254.4931
https://www.cnf.cornell.edu/equipment

CNF Cornell

JEOL JBX-9500FSZ

Tool Description

The JBX 9500 is the next generation direct write e beam lithography system from JEOL. CNF has one of only two 9500s in the U.S., and the only one in an academic environment. The tool is capable of loading samples from 10 mm up to 300 mm and writing features as small as 6 nm or less at 100 MHz clock speed. The system features dramatically improved stitching and overlay over previous systems.

System Specifications

Operating Acceleration Voltage (kV) 100	Max Field Size (mm) 1
Max Scan Speed (MHz) 100	Overlay Accuracy (nm) 11
Max Sample Size 300 mm wafer	Field Stitching Accuracy (nm) 10
Min Beam Diameter (nm) 4	Min Feature Size (nm) 6

Tool Owner | Contact for Rates

Amrita Banerjee | banerjee@cnf.cornell.edu | 607.254.4855
https://www.cnf.cornell.edu/equipment

CNF Cornell

Nabity Nanometer Pattern Generator System (NPGS)

Tool Description

The Nabity system turns an SEM into a simple ebeam system. The hardware takes control of the deflection system on the SEM and can then be used to expose patterns in resist. This is particularly useful when there is a need for low energy exposures. The tool is very manual, as opposed to the fully automated JEOL systems, and the calibrations are very primitive.

System Specifications

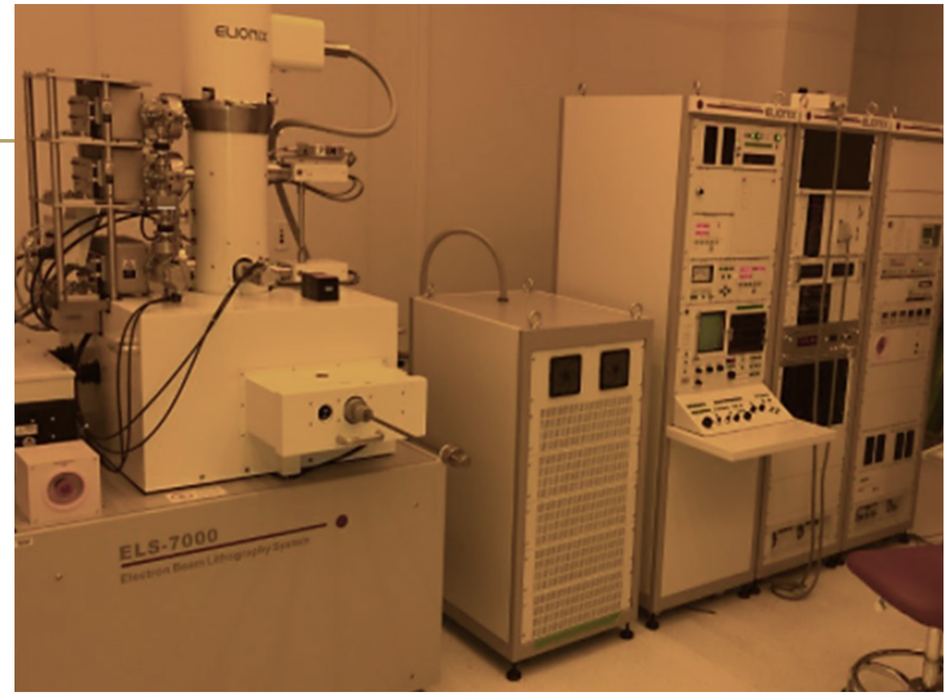
Operating Acceleration Voltage (kV) 20	Max Field Size (mm) n/a
Max Scan Speed (MHz) n/a	Overlay Accuracy (nm) n/a
Max Sample Size 150 mm	Field Stitching Accuracy (nm) n/a
Min Beam Diameter (nm) n/a	Min Feature Size (nm) n/a

Tool Owner | Contact for Rates

John Treichler | treichler@cnf.cornell.edu | 607.254.4949
https://www.cnf.cornell.edu/equipment

CNS Harvard

Elionix - ELS-7000



Tool Description

Ultra high precision 100 keV Electron Beam Lithography System. Minimum line width 7 nm; maximum wafer size 8". Laser interferometer stage with stitching accuracy 30 nm.

System Specifications

Operating Acceleration Voltage (kV)
100

Max Scan Speed (MHz)
10

Max Sample Size
200 mm wafer

Min Beam Diameter (nm)
2

Max Field Size (mm)
0.6

Overlay Accuracy (nm)
25

Field Stitching Accuracy (nm)
30

Min Feature Size (nm)
7

Tool Owner | Contact for Rates

Yuan Lu | ylu@fas.harvard.edu | 617.495.2822
https://cns1.rc.fas.harvard.edu/?post_type=tool&p=7304

CNS Harvard

Elionix ELS-F125

Tool Description

The ELS-F125 provides the power to pattern lines down to 5 nm and the throughput to keep up with the pace of pioneering research.

User-friendly Interface – CAD and SEM interfaces on Windows.

System Specifications

Operating Acceleration Voltage (kV)
125

Max Scan Speed (MHz)
100

Max Sample Size
n/a

Min beam Diameter (nm)
1.7

Max Field Size (mm)
3

Overlay Accuracy (nm)
n/a

Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
5

Tool Owner | Contact for Rates

Dr. Jiangdong Deng | jdeng@cns.fas.harvard.edu | 617.495.3396
https://cns1.rc.fas.harvard.edu/?post_type=tool&p=7432

CNS Harvard

Raith-150 E-Beam

Tool Description

The Raith 150 is an ultra-high resolution electron beam lithography system used for writing complex patterns in resists at resolutions of 50 nm for direct-write lithographic applications.

The system also has a Scanning Electron Microscope to facilitate imaging and navigation of the sample. Ability to direct write for wafer process development at sub-optical resolutions (PMMA <100 nm thick): 50 nm lines and 50 nm spaces and an alignment accuracy of 60 nm (<100 um field).

System Specifications

Operating Acceleration Voltage (kV)
0.2 - 30

Max Scan Speed (MHz)
1

Max Sample Size
150 mm wafer

Min Beam Diameter (nm)
2

Max Field Size (mm)
0.8

Overlay Accuracy (nm)
60

Field Stitching Accuracy (nm)
60

Min Feature Size (nm)
50

Tool Owner | Contact for Rates

Yuan Lu | ylu@fas.harvard.edu | 617.495.2822
https://cns1.rc.fas.harvard.edu/?post_type=tool&p=7246

CNS Harvard

Elionix HS50

Tool Description

Elionix HS50 is an ultra-high speed electron beam lithography system with 50 keV acceleration voltage, 100 MHz high frequency deflector, and strong beam current range of 1 nA to 1 uA. It can handle small piece sample and up to 8" wafer with stiching accuracy 30 nm.

System Specifications

Operating Acceleration Voltage (kV)
50

Max Scan Speed (MHz)
100

Max Sample Size
200 mm wafer

Min Beam Diameter (nm)
2.8

Max Field Size (mm)
3

Overlay Accuracy (nm)
n/a

Field Stitching Accuracy (nm)
30

Min Feature Size (nm)
20

Tool Owner | Contact for Rates

Dr. Jiangdong Deng | jdeng@cns.fas.harvard.edu | 617.495.3396
https://cns1.rc.fas.harvard.edu/tool/high-throughput-e-beam-lithography-system/

CNS Harvard

JEOL 7000F + Nabity V9.0

Tool Description

- Magnification Range: 10X-500,000X
- Deben PCD Beam Blanking System
- Beam Current 10 pA-200 nA
- Computer controlled large eucentric specimen stage
- Nabity's Nanometer Pattern Generation System V9.0
- Thermal FE SEM

System Specifications

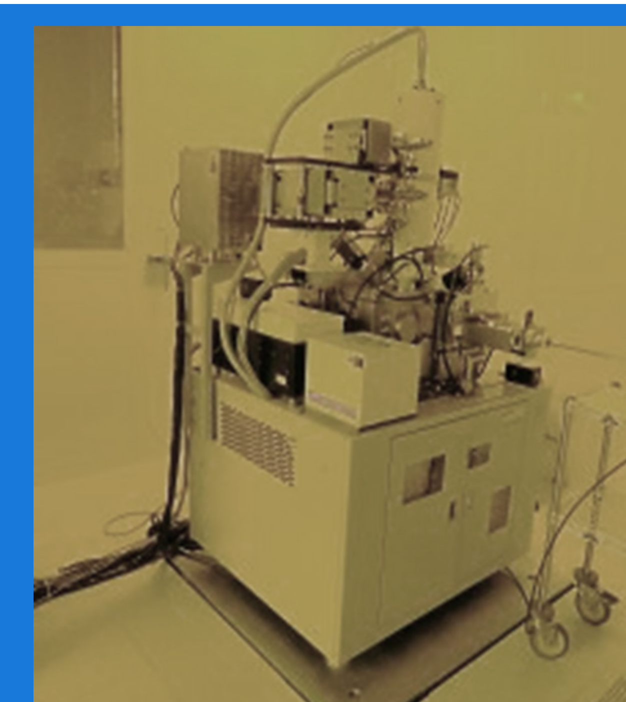
Operating Acceleration Voltage (kV) 1 - 30	Max Field Size (mm) n/a
Max Scan Speed (MHz) 1	Overlay Accuracy (nm) n/a
Max Sample Size n/a	Field Stitching Accuracy (nm) n/a
Min Beam Diameter (nm) 1.2	Min Feature Size (nm) n/a

Tool Owner | Contact for Rates

Yuan Lu | ylu@fas.harvard.edu | 617.4952822
https://cns1.rc.fas.harvard.edu/?post_type=tool&p=7279

MANTH U. Penn

Elionix ELS-7500EX



Tool Description

ELS-7500EX provides ultra-high precision lithography with a resolution of 10 nm and with high stitching and overlay accuracy. The recipe function, with saved optimum beam settings, provides the ease of the operation. The stage with a built-in laser interferometer and beam positioning resolution of 0.31 nm with an 18-bit DAC provide a stitching accuracy of 30 nm.
High performance with compact configuration. Ease of operation with PC control. Integration of a Windows compatible GUI and CAD realizes a small footprint. Electron optical condition control and CAD pattern design can be accomplished by simply using a mouse. A very user friendly system.

System Specifications

Operating Acceleration Voltage (kV) 20 | 30 | 50	Max Field Size (mm) 1.2
Max Scan Speed (MHz) 20	Overlay Accuracy (nm) 30
Max Sample Size 150 mm wafer	Min Feature Size (nm) 10
Min Beam Diameter (nm) 2	
Field Stitching Accuracy (nm) 30	

Tool Owner | Contact for Rates

David Jones | davijon@seas.upenn.edu | 215.898.7124 https://www.nano.upenn.edu/equipment/elionix-els-7500ex/

KY MMNIN

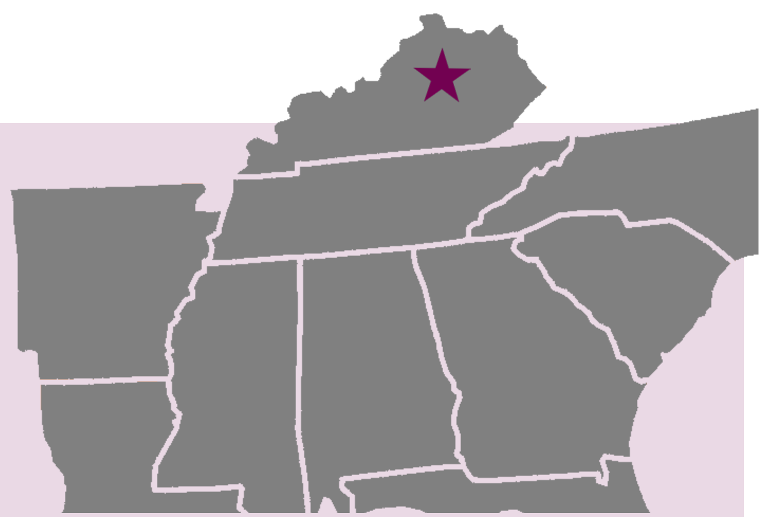
Univ. Kentucky

Raith e-LiNE

Tool Description

The Electron Beam Lithography tool is located in room 045 of the ASTeCC building. Raith e-LiNE is an electron beam lithography tool with a 100 mm by 100 mm travel range. It uses thermal field emission filament technology and a laser-interferometer controlled stage. The system is equipped with a load lock, and a fixed beam moving stage (FBMS).

System Specifications



Operating Acceleration Voltage (kV)
0.1 - 30

Max Scan Speed (MHz)
10

Max Sample Size
100 mm wafer

Min Beam Diameter (nm)
1.6

Max Field Size (mm)
n/a

Overlay Accuracy (nm)
40

Field Stitching Accuracy (nm)
40

Min Feature Size (nm)
8

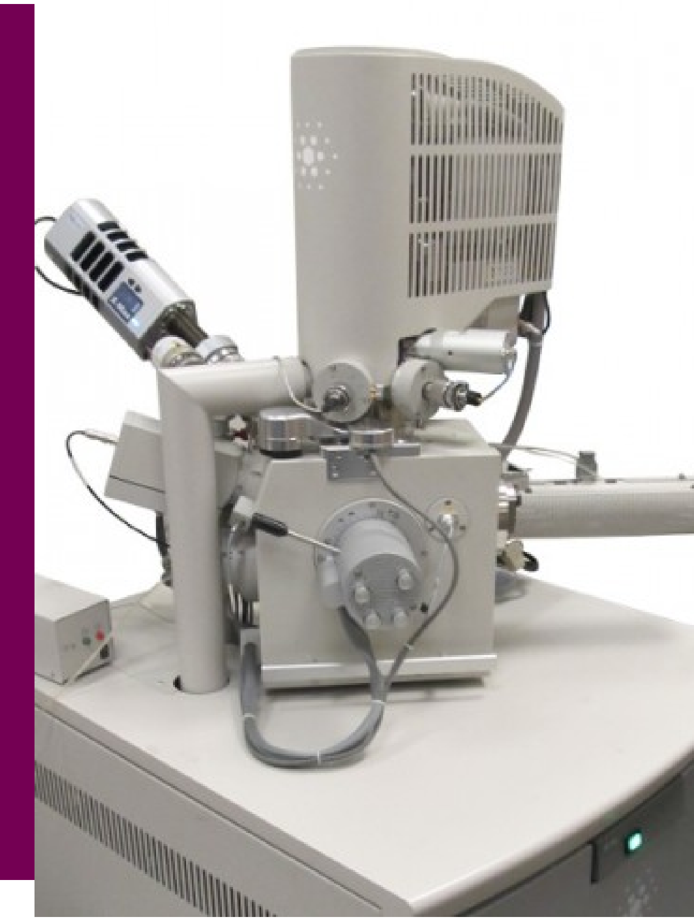
Tool Owner | Contact for Rates

Brian Wajdyk | brian.wajdyk@uky.edu
http://cense.engr.uky.edu/equipment/electron-beam-lithography

KY MMNIN

Univ. Kentucky

Raith Elphy 6 + FEI Quanta VP-SEM



Tool Description

- Filament Type: field emission
- Detectors: SE/BSE/EDX/STEM/E-SEM
- Image Resolution: Secondary Electron = 1.0 nm
- Specimen Stage: X-Y 50 mm
- Tilt angle = + 15° to + 75°
- Rotation = 360° (continuous)
- Max Specimen Size: 19—102 mm (height x dia)
- Low vacuum capability for environmental SEM
- Peltier cooling stage for low temperatures work / heating stage up to 800°C

System Specifications

Operating Acceleration Voltage (kV)
30

Max Scan Speed (MHz)
n/a

Max Sample Size
n/a

Min Beam Diameter (nm)
n/a

Max Field Size (mm)
n/a

Overlay Accuracy (nm)
n/a

Field Stitching Accuracy (nm)
n/a

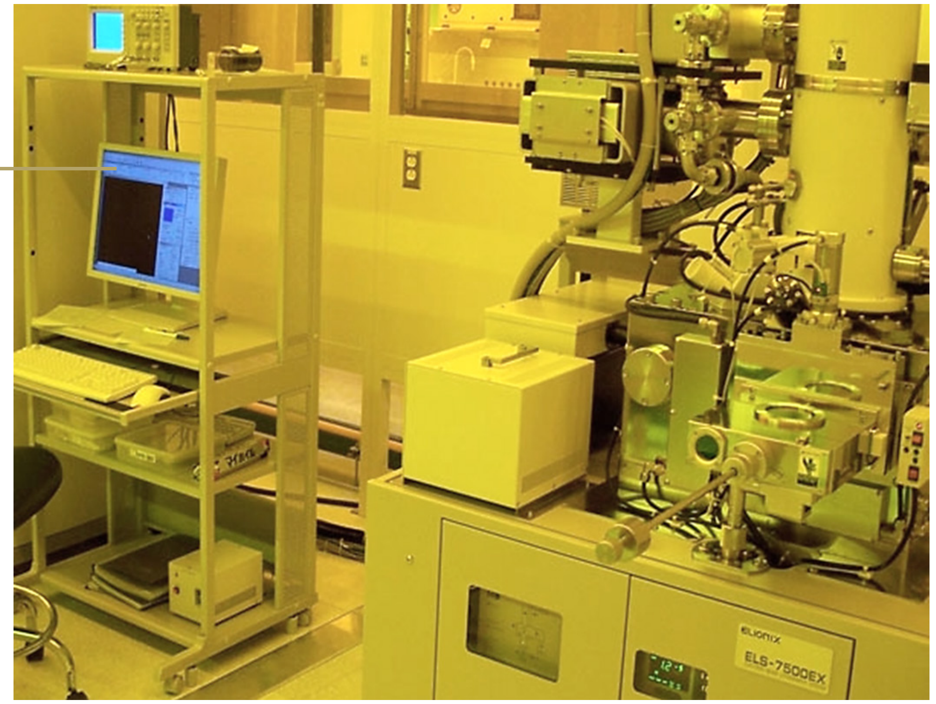
Min Feature Size (nm)
n/a

Tool Owner | Contact for Rates

Brian Wajdyk | brian.wajdyk@uky.edu
http://emc.engr.uky.edu/equipment/equipment-list/scanning-electron-microscopes

RTNN @ Duke

Elionix ELS-7500EX



Tool Description

The ELS-7500EX is capable of producing ultra fine features down to a 10 nm linewidth. It has a Windows based CAD and GUI layout, with a conversion capability for previously generated CAD files. The Laser interferometer stage and 18 bit DAC beam positioning system provide excellent stitching and writing capabilities.

The various stage options allow for patterning of substrate sizes ranging from small pieces (1 cm) up to wafers that are 6” in diameter.

System Specifications

Operating Acceleration Voltage (kV)
50

Max Scan Speed (MHz)
20

Max Sample Size
150 mm wafer

Min Beam Diameter (nm)
2

Max Field Size (mm)
1.2

Field Stitching Accuracy (nm)
10

Overlay Accuracy (nm)
30

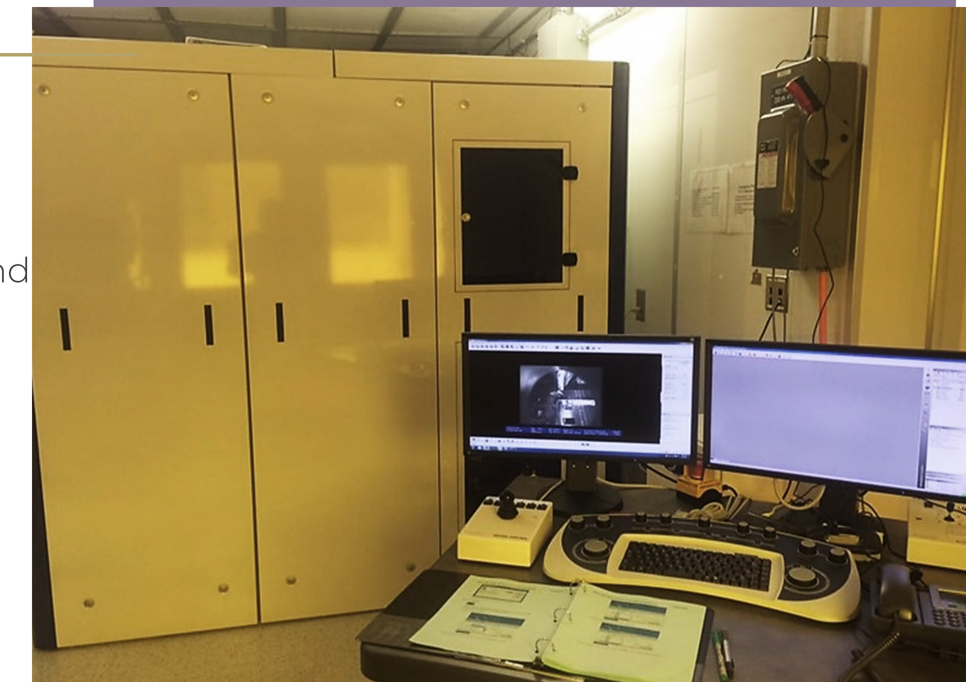
Min Feature Size (nm)
10

Tool Owner

Talmage Tyler | talmage.tyler@duke.edu | 919.660.7987
http://smif.pratt.duke.edu/node/96

RTNN @ NC State

Raith 150 TWO

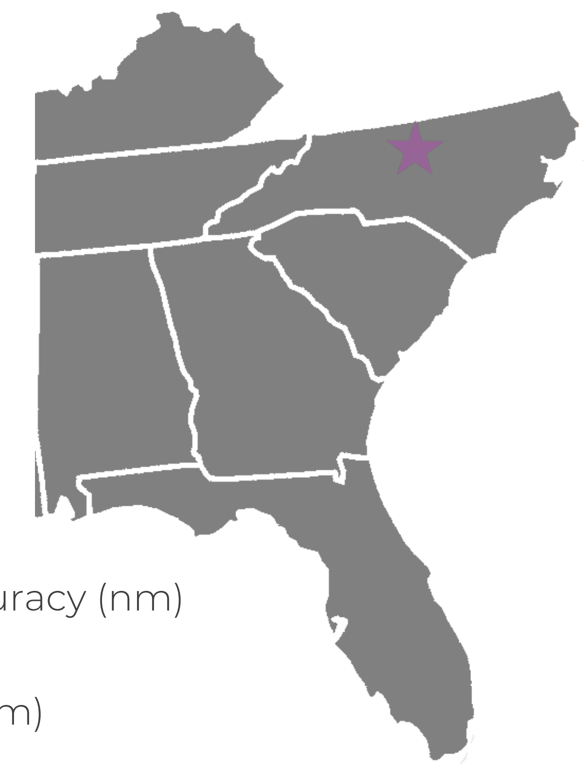


Tool Description

The RAITH 150 TWO exposes structures smaller than 5 nm and works with sample sizes from a few mm to 8-inch wafers.

The system stability, even in difficult environments, required for demanding exposures is made possible by a thermally stabilized and environmentally tolerant shield. Hardware and software automation allow easy and repeatable jobs for small batch production.

System Specifications



Operating Acceleration Voltage (kV)
1 - 30

Max Scan Speed (MHz)
20

Max Sample Size
150 mm wafer

Min Beam Diameter (nm)
2

Max Field Size (mm)
1

Field Stitching Accuracy (nm)
35

Overlay Accuracy (nm)
35

Min Feature Size (nm)
10 - 20

Tool Owner | Contact for Rates

Greg Allion | grallion@ncsu.edu | 919.515.2767
https://nnf.ncsu.edu/lithography/

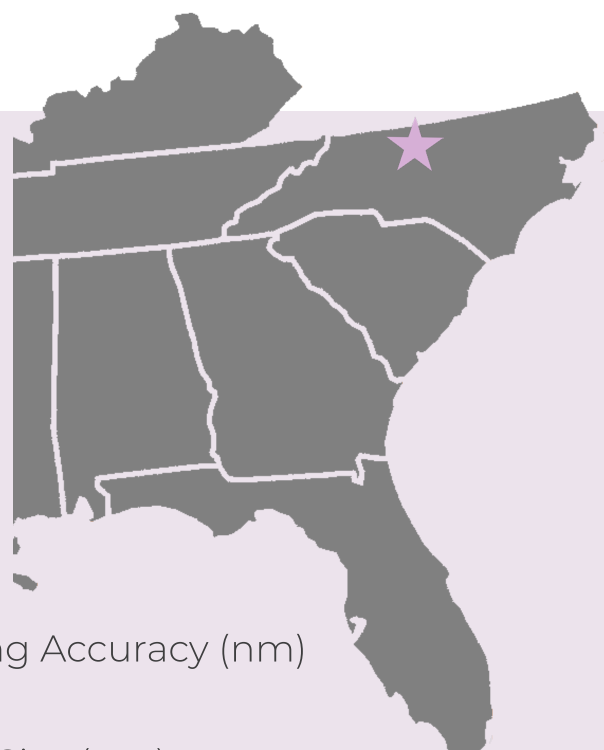
RTNN @ UNC Chapel Hill

FEI Helios Dual + Nabity V9.0

Tool Description

This is an SEM based electron beam lithography system. We did not fully test the capabilities of the tool at this point. Based on the usage history of this tool, a user with good experience with SEM operation can generate 50 nm to 100 nm dot/line arrays quickly. The tool's alignment error is ~30 nm.

System Specifications



Operating Acceleration Voltage (kV)
0.5 - 30

Max Scan Speed (MHz)
n/a

Max Sample Size
150 mm wafer

Min Beam Diameter (nm)
0.9

Max Field Size (mm)
n/a

Field Stitching Accuracy (nm)
n/a

Overlay Accuracy (nm)
n/a

Min Feature Size (nm)
n/a

Tool Owner | Contact for Rates

Amar S. Kumbhar | kumbhar@email.unc.edu | 919.843.8213
https://chanl.unc.edu/instrument/fib/

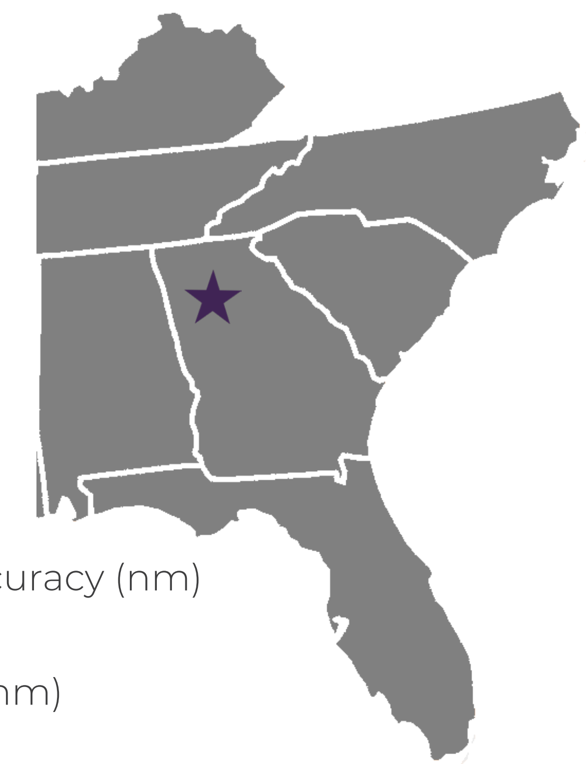
SENIC @ GA Tech

Elionix ELS-G100

Tool Description

- 1.8 nm Gaussian spot electron beam
- 20 pA - 100 nA beam current
- Minimum pattern line width 6 nm
- 20 nm overlay accuracy w/ 100 micron field ZrO/W thermal field emission
- Max. sample = 8" wafers
- Min. sample = mm size pieces
- For use in making photomasks
- For use in SEM imaging

System Specifications



Operating Acceleration Voltage (kV)
25, 50, and 100

Max Scan Speed (MHz)
100

Max Sample Size
200 mm wafer

Min Beam Diameter (nm)
1.8

Max Field Size (mm)
1

Field Stitching Accuracy (nm)
15

Overlay Accuracy (nm)
20

Min Feature Size (nm)
6

Tool Owner | Contact for Rates

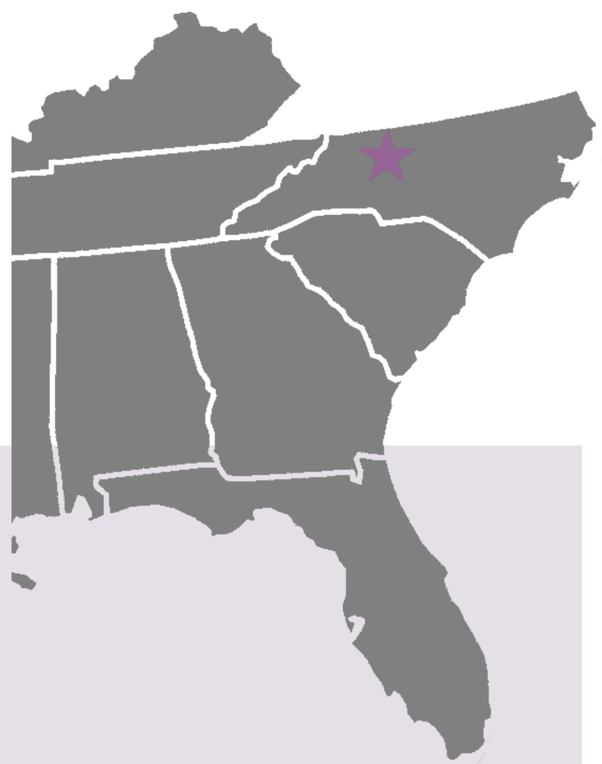
Devin K. Brown | devin.brown@gatech.edu | 404.385.5370
http://www.nanolithography.gatech.edu/

SENIC @ JSNN NCAT/UNC

ZEISS EVO LS 10

Tool Description

The Zeiss EVO LS10 is a variable pressure scanning electron microscope (VP-SEM), commonly called an Environmental SEM. It is located in the bio-lithography bay of the Cleanroom. Capable of 6nm resolution in high vacuum mode and 1-30kV, the EVO produces acceptable high resolution images of traditional SEM samples, but really shines in the analysis of non-conductive, hydrated, oversize, or otherwise unusual samples. In extended pressure mode, imaging can be done at set pressures up to 3000 Pa. If used in conjunction with the Deben CoolStage II, biological and other wet samples may be imaged using the variable pressure secondary electro (VPSE) or backscatter detectors. Elemental analysis using the Oxford Inca EDX can be done in all modes. Available detectors include dual secondary electron detectors (high vacuum and variable pressure), retractable backscatter detector, and Oxford Inca EDX detector for elemental determination.



System Specifications

Operating Acceleration Voltage (kV)
1 - 30

Min Beam Diameter (nm)
6

Tool Owner | Contact for Rates

Steven Crawford | sjcrawford42@gmail.com | 336.285.2880
https://jsnn.ncat.uncg.edu/core-facilities/
http://www.gatewaymaterialstestcenter.com/EVOPopup.html

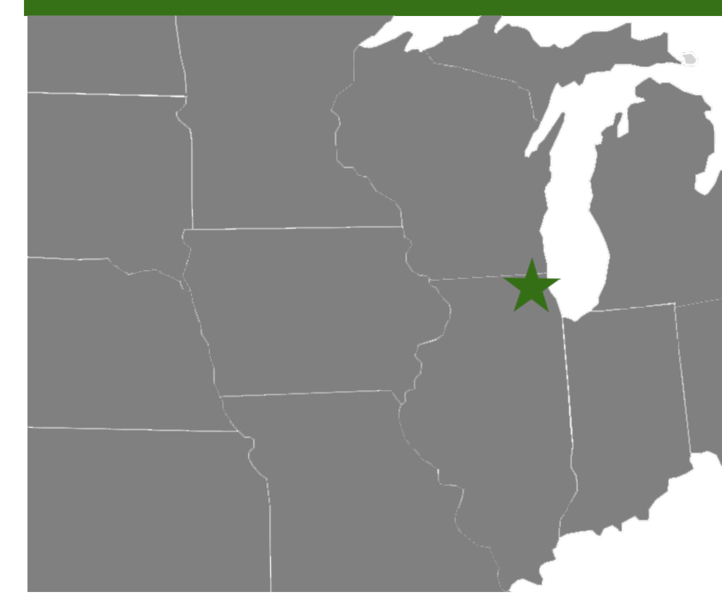
SHYNE @ Univ of Chicago

Raith EBPG 5000+ ES

Tool Description

The Raith EBPG5200 E-Beam lithography system is a high-performance nanolithography system used chiefly for write lithography and R&D mask making. It is the latest model in the EBPG series, preceded by the EBPG 5150 and EBPG 5000.

Key Applications include compound semiconductor applications, vertical resonant tunnel transistors, circular grating resonators



System Specifications

Operating Acceleration Voltage (kV)
20, 50, 100

Max Scan Speed (MHz)
100

Max Sample Size
155 mm wafer

Min Beam Diameter (nm)
2

Max Field Size (mm)
1

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
40

Min Feature Size (nm)
8

Tool Owner Contact for Rates

Peter Duda | duda@uchicago.edu | 773.702.8903
https://pnf.uchicago.edu/equipment/detail/raith-ebpg5000-plus-e-beam-writer/

SHYNE @ Univ of Chicago

FEI Quanta 650 FEG SEM with Nabity Pattern Generator

Tool Description

The FEI Quanta 650 FEG SEM (Scanning Electron Microscope) is a variable pressure microscope used for high resolution imaging. It is capable of resolving features on a scale of less than 5 nm. Equipped with a Field Emission Gun (FEG) the tool allows for bright-field and dark-field sample imaging.

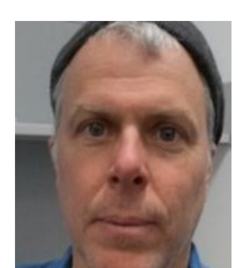
The SEM is equipped with a total of 8 detectors for the purpose of imaging and analysis as well as a Nabity Nanometer Pattern Generation System (NPGS) which allows for advanced electron beam lithography by means of the SEM.

System Specifications

Operating Acceleration Voltage (kV) 30	Field Stitching Accuracy (nm) n/a
Max Scan Speed (MHz) n/a	Min Feature Size (nm) n/a
Max Sample Size 150 mm wafer	Overlay Accuracy (nm) n/a
Min Beam Diameter (nm) n/a	Max Field Size (mm) n/a

Tool Owner | Contact for Rates

Peter Duda | duda@uchicago.edu | 773.702.8903
https://pnf.uchicago.edu/equipment/detail/fei-quanta-with-nabity-pattern-generator/



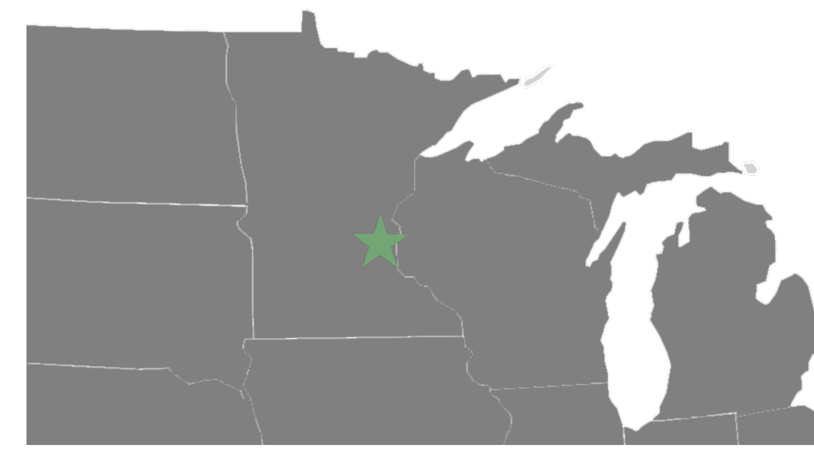
MINIC @ Univ Minnesota

Vistec EBPG5000+

Tool Description

For nanoscale patterning, a Vistec EBPG 5000+ electron-beam lithography system provides 100kV patterning of 10 nm scale devices over six-inch substrates. This electron-beam writer is fully automated, with a laser-guided substrate stage providing 15 nm field stitching, 15 nm overlay accuracy, laser height measurement for automatic focus adjustment, and metrology functions for self-calibration. The EBPG is highly regarded for its ease of use and very flexible control software.

System Specifications



Operating Acceleration Voltage (kV)
100

Max Scan Speed (MHz)
50

Max Sample Size
100 mm

Min Beam Diameter (nm)
2

Max Field Size (mm)
1

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
40

Min Feature Size (nm)
10

Tool Owner Contact for Rates

Kevin Roberts | rober074@umn.edu | 612.624.7092
https://www.mnc.umn.edu/vistec-e-beam

NNF @ Univ of Nebraska Lincoln

Zeiss Supra 40 + Raith PG

Tool Description

This EBL system is composed with a Zeiss Supra 40 field-emission scanning electron microscope and a Raith pattern generator. The Zeiss Supra 40 features electron beam up to 30KeV and provides capability of reproducibly achieving feature sizes as small as 20 nm. It is also integrated with an laser interferometer-controlled wafer stage, which makes it possible to accomplish stitching application and multilayer EBL with overlay accuracy better than 50 nm on a wide variety of substrates.

System Specifications

Operating Acceleration Voltage (kV)
0.1 - 30

Max Scan Speed (MHz)
n/a

Max Sample Size
50 mm^2

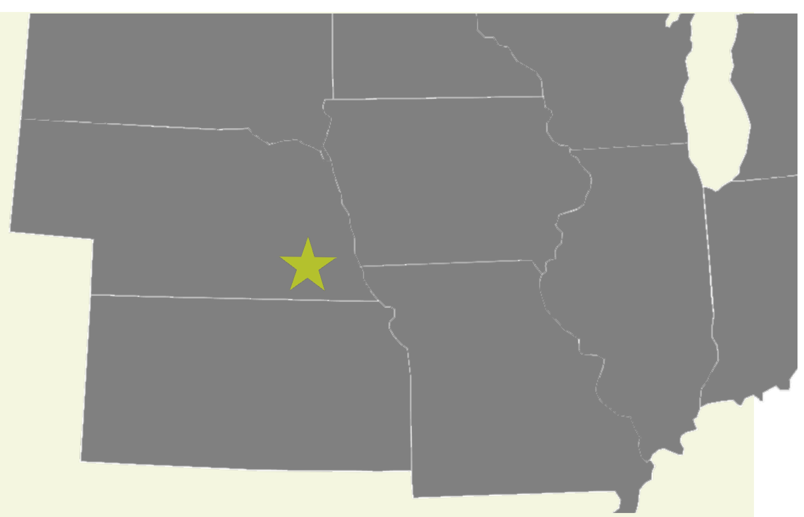
Min Beam Diameter (nm)
2.5

Max Field Size (mm)
n/a

Field Stitching Accuracy (nm)
50

Overlay Accuracy (nm)
n/a

Min Feature Size (nm)
20



Tool Owner | Contact for Rates

Anandakumar Sarella | asarella@unl.edu
https://ncmn.unl.edu/nanofab/EBL.shtml

Texas Nanofabrication Facility at UT Austin

JEOL JBX-6000FS

Tool Description

The JBX-6000FS/E is an electron beam lithography system equipped with a thermal field emission electron gun with ZrO/W emitter. The accelerating voltage is normally operated at 50kV. It is used for research that requires ultra fine pattern exposure with resolution down to 10nm routinely achieved in PMMA resist. It incorporates two different objective lenses with maximum field size of 80 and 800 micron respectively. Field stitching error is typically less than 40 nm.

System Specifications

Operating Acceleration Voltage (kV)
50

Max Scan Speed (MHz)
n/a

Max Sample Size
200 mm wafer

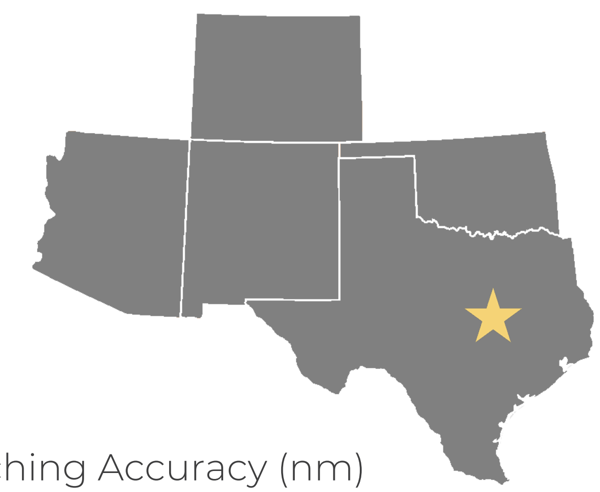
Min Beam Diameter (nm)
5

Max Field Size (mm)
0.8

Field Stitching Accuracy (nm)
n/a

Overlay Accuracy (nm)
40

Min Feature Size (nm)
20



Tool Owner | Contact for Rates

Sarmita Majumder | sarmita@utexas.edu| 512.998.6684
https://www.mrc.utexas.edu/facilities/equipment/photolithography-e-beam-writer-jeol-6000-fse

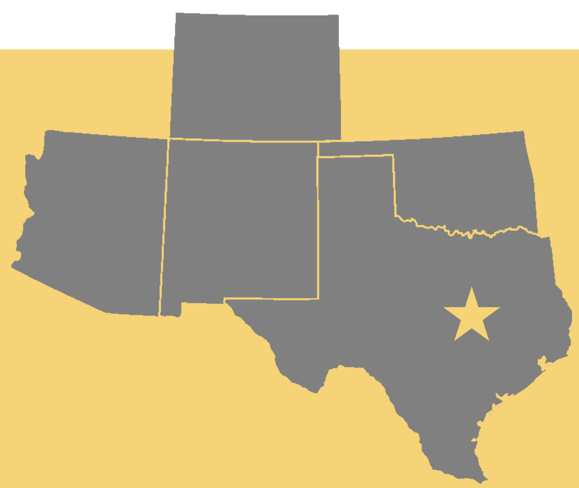
Texas Nanofabrication Facility at UT Austin

ZEISS Neon 40 SEM + Raith Elphy Pattern Generator

- Secondary Electron detector: SE2, In-lens Secondary Electron detector: In-lens and Back scattering detector.
- Travel 50 mm in X and Y direction.
- EDS Bruker probe

- Compatible Materials:
- No Restrictions
- Incompatible Materials:
- Highly degassing material or life sample

System Specifications



Operating Acceleration Voltage (kV)
2 - 30

Max Scan Speed (MHz)
n/a

Max Sample Size
50 mm^2

Min Beam Diameter (nm)
n/a

Max Field Size (mm)
n/a

Overlay Accuracy (nm)
n/a

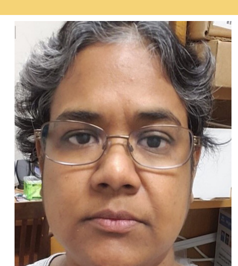
Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
n/a

Tool Owner | Contact for Rates

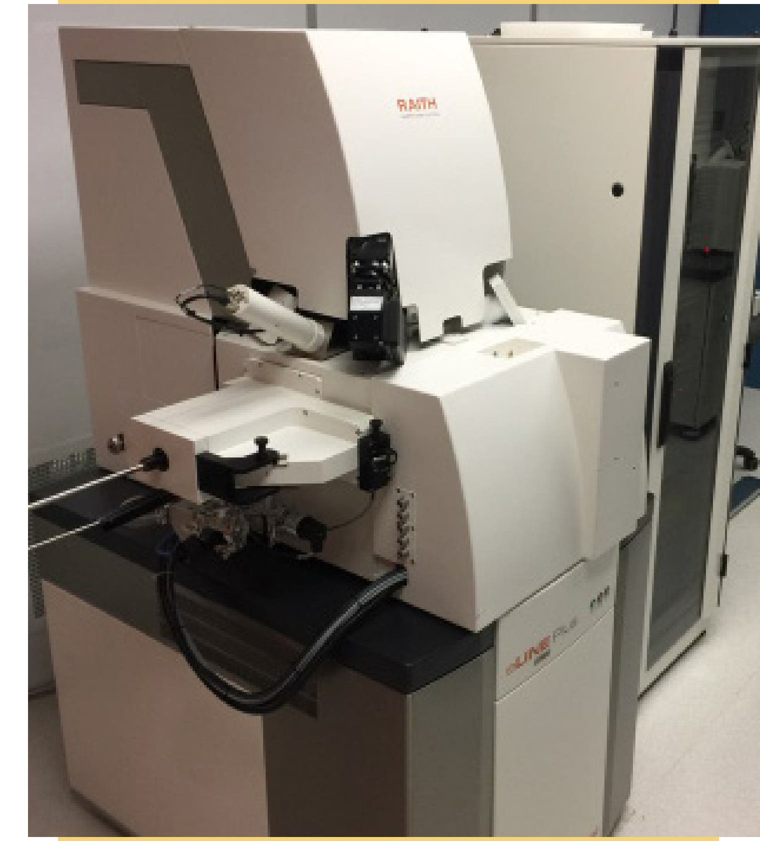
Sarmita Majumder | sarmita@utexas.edu| 512.998.6684

http://www.mrc.utexas.edu/facilities/equipment/sem-zeiss-neon-40-bruker-eds-raith-elphy-pattern-generator



Texas Nanofabrication Facility at UT Austin

Raith e-Line

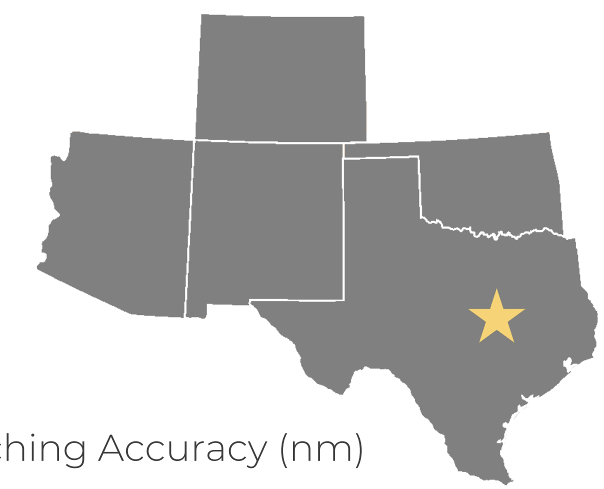


Tool Description

Raith Line Plus with Gemini Column
E-Beam Lithography Features:

- Sample load and unload with loadlock system
- Laser-interferometer controlled stage movement
- High tension 30 kV
- Six aperture selections
- Three detectors; InLense, SE1 & SE2
- Samples can be small pieces up to 4" wafers

System Specifications



Operating Acceleration Voltage (kV)
30

Max Scan Speed (MHz)
20

Max Sample Size
100 mm wafer

Min Beam Diameter (nm)
1.6

Max Field Size (mm)
n/a

Overlay Accuracy (nm)
40

Field Stitching Accuracy (nm)
40

Min Feature Size (nm)
8

Tool Owner | Contact for Rates

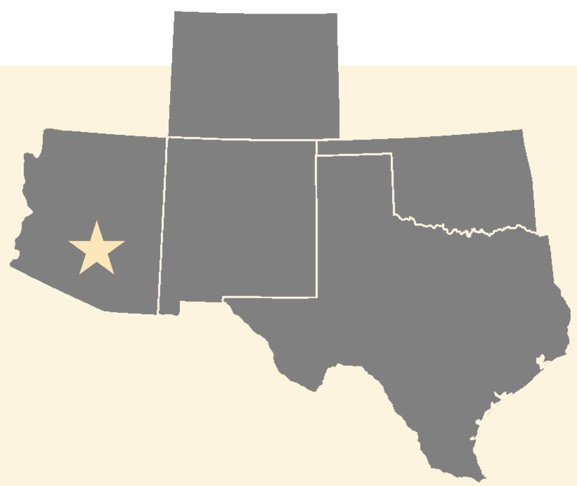
Sarmita Majumder | sarmita@utexas.edu| 512.998.6684

http://www.mrc.utexas.edu/facilities/equipment/e-line-raith-electron-beam-lithography

NCI-Southwest at Arizona State University
JEOL - JBX-6000 FS/E

Tool Description
The JEOL Electron Beam Lithography system is capable of providing patterned features with dimensions down to 20 nm and pattern to pattern overlay of <40 nm. Training on this tool requires pre-requisite training on other techniques: metrology, photoresist coating, metal deposition and SEM analysis.

System Specifications



Operating Acceleration Voltage (kV)
50

Max Scan Speed (MHz)
n/a

Max Sample Size
200 mm wafer

Min Beam Diameter (nm)
5

Max Field Size (mm)
0.8

Overlay Accuracy (nm)
40

Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
20

Tool Owner | Contact for Rates
Kevin Nordquist | Kevin.Nordquist@asu.edu | 480.965.2675
https://cores.research.asu.edu/nanofabrication-and-cleanroom/equipment/jeol-jbx-6000-fse-electron-beam-lithography

nano@stanford
JEOL JBX-6300FS

Tool Description
The JEOL JBX 6300FS lithography system uses a high-brightness field emission electron source, a 100 keV acceleration potential, a 25 Mega-Hertz deflection system and magnetic lenses to define a beam diameter as small as 2 nm and patterns in resist as small as 8 nm. The laser-controlled stage is capable of loading 1 cm square compound semiconductor chips, up to 200 mm (8 inch) diameter silicon substrates. Upcoming nano-device research will include: nano-apertures for near-field optics, photonic crystals, novel laser structures, quantum devices to study transport in compound semiconductors, nano-CMOS. nano-magnetic memory and x-ray zone plates.

System Specifications

Operating Acceleration Voltage (kV)
100

Max Scan Speed (MHz)
25

Max Sample Size (mm)
200

Min Beam Diameter (nm)
2

Max Field Size (mm)
0.5

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
8

Tool Owner | Contact for Rates
Rich Tiberio | nano-ebeam-staff@lists.stanford.edu | 650.505.7483
https://snsf.stanford.edu/equipment/fab/ebl_jeol.html

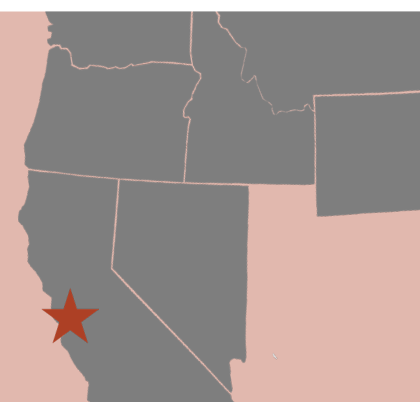
nano@stanford
Raith Voyager

Tool Description

The Raith VOYAGER lithography system uses a field emission electron source, with a variable 10–50 keV acceleration potential, a 50 mega-Hertz deflection system with real-time dynamic corrections and single stage electrostatic deflection to define single line patterns in resist as small as 8 nm.

The laser-controlled stage is capable of loading <1 cm square compound semiconductor chips, up to 200 mm (8 inch) diameter silicon substrates.

System Specifications



Operating Acceleration Voltage (kV)
10 - 50

Max Scan Speed (MHz)
50

Max Sample Size
200 mm wafer

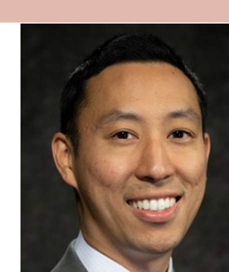
Min Beam Diameter (nm)
2

Max Field Size (mm)
0.5

Overlay Accuracy (nm)
25

Field Stitching Accuracy (nm)
30

Min Feature Size (nm)
8



Tool Owner | Contact for Rates

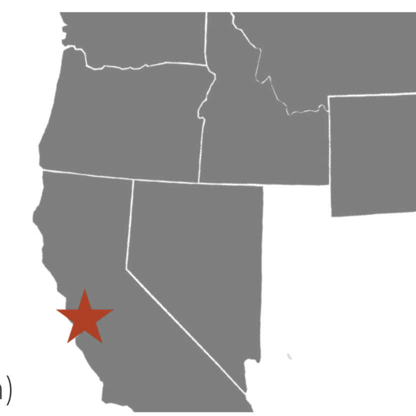
Stanley Lin | nano-ebeam-staff@lists.stanford.edu | 650.391.6975
http://snsf.stanford.edu/equipment/fab/ebl_raith.html

nano@stanford
FEI Nova NanoSEM 450 + Nabity Nanometer

Tool Description

The FEI Nova NanoSEM line of SEMs provides high-quality nanoscale research tools for a variety of applications that involve sample characterization, analysis, nanoprototyping, and S/TEM sample preparation. More samples, including the most non-conducting or contaminating materials, can equally be characterized or analyzed in the Nova NanoSEM 50 series, using its unique low vacuum capabilities. Characterization in low vacuum extends all the way up to ultra-high resolution. For nanoprototyping, the Nova NanoSEM 450 series offers the most extensive set of integrated tools, including a 16-bit on-board digital pattern generator and dedicated patterning software, a high speed electrostatic beam blanker and gas injection systems for direct electron beam writing of nanostructures.

System Specifications



Operating Acceleration Voltage (kV)
1-30

Max Scan Speed (MHz)
n/a

Max Sample Size
100 mm^2

Min Beam Diameter (nm)
2

Max Field Size (mm)
0.5

Overlay Accuracy (nm)
n/a

Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
50

Tool Owner | Contact for Rates

Stanley Lin | nano-ebeam-staff@lists.stanford.edu | 650.391.6975
http://snsf.stanford.edu/equipment/fab/nova.html

SDNI at UC San Diego

Raith - EBPG 5200

Tool Description

High-resolution Gaussian beam system with a thermal field emission source that can be operated at 50/100 kV beam energies. System can be run automatically in a course - fine mode of operation without the need for final aperture exchange which optimizes system throughput with exposure current range from 100 pA to 200 nA.

Write field size up to 1 mm with stitching <30nm. Sample holders: 2”, 3”, 4”, 6”, 8” wafers and pieces, 6” mask. 50 MHz pattern generator.

System Specifications

Operating Acceleration Voltage (kV)
50, 100

Max Scan Speed (MHz)
50

Max Sample Size MM
200

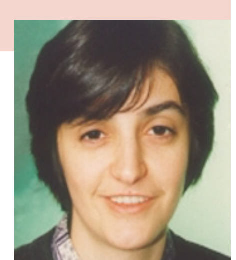
Min Beam Diameter (nm)
2.2

Max Field Size (mm)
1

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
30

Min Feature Size (nm)
8

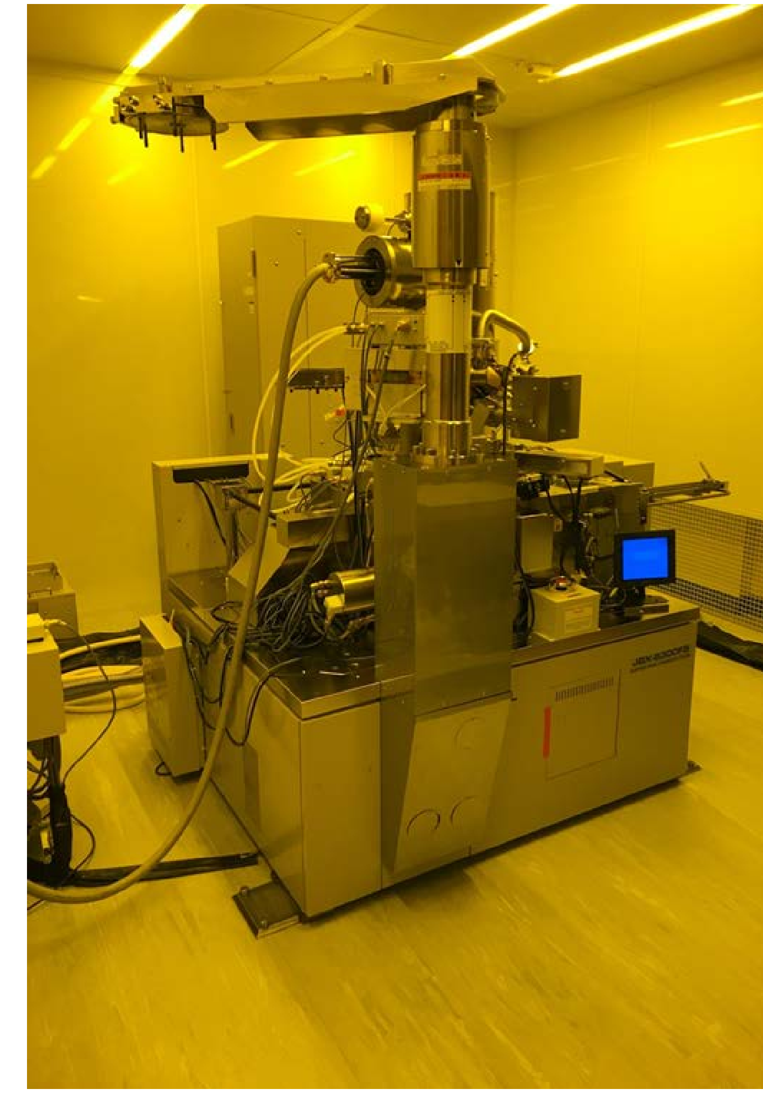


Tool Owner | Contact for Rates

Dr. Maribel Montero | mmontero@ucsd.edu | 858.534.4222
https://nano3.calit2.net/ebeamlitho/

NNI at University of Washington

JEOL JBX-6300FS

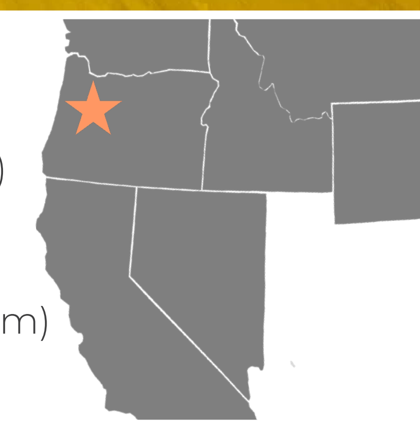


Tool Description

Direct-write 100 kV Electron Beam Lithography capable of feature sizes as small as 10 nm, and layer-to-layer registration better than ~30 nm +3 sigma.

Substrates from small chips to 150 mm wafers. A wide range of beam currents, choice of two objective lenses, and a wide range of resist processes provide significant flexibility for a variety of needs. Sophisticated data preparation software provides advanced functions including full shape and dose proximity correction.

System Specifications



Operating Acceleration Voltage (kV)
100

Max Scan Speed (MHz)
50

Max Sample Size
150 mm

Min Beam Diameter (nm)
2

Max Field Size (mm)
0.5

Overlay Accuracy (nm)
30

Field Stitching Accuracy (nm)
n/a

Min Feature Size (nm)
8

Tool Owner | Contact for Rates

N. Shane Patrick | patricns@uw.edu | 206.221.1045
https://ebeam.wnf.uw.edu/ebeamweb/index.html

National Nanotechnology Coordinated Infrastructure

More About NSF Award & NNCI

Over the past decade of its authorized award life, the National Nanotechnology Infrastructure Network (NNIN) has enabled major discoveries, innovations, and contributions to education and commerce by providing researchers from academia, small and large companies, and government with open access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering, and technology. The National Science Foundation is now moving forward with the new National Nanotechnology Coordinated Infrastructure (NNCI) as the successor to the NNIN.

NNCI exists to help scientists and engineers from around the country access the state-of-the-art resources necessary to participate in the nanotechnology revolution.

NSF

nnci.net