

# VELION

## FIB-SEM beyond limits

Multi-ion-species FIB on a true lithography platform



FIB-SEM NANOFABRICATION

# RAITH

NANOFABRICATION



## VELION is all about FIB in perfection

- › Unique multi-ion-species FIB technology (IONselect)
- › Vertically mounted FIB column and horizontal 4" laser interferometer stage
- › Large-area FIB patterning capabilities on a true lithography platform
- › Automated, stable nanofabrication over several days
- › Ga-free TEM sample preparation
- › Ion microscopy and imaging with light ions
- › Sample analysis & in-situ process monitoring enabled by tailored SEM column

# VELION – Multi-ion-species FIB on a stable lithography platform

VELION is all about FIB in perfection. This unique multi-ion-species FIB nanofabrication system combines a vertically mounted FIB column with a unique laser interferometer stage to offer many standout benefits.

Ultra-precise, direct patterning of smallest features over large areas – this is what makes VELION stand out.

VELION is your choice for dedicated nanofabrication applications.

- Use the dedicated cutting-edge nanoFIB column for nanofabrication
- Utilize unlimited process pathways to tailor nanostructures
- Make use of unique FIB patterning capabilities on a lithography platform
- Practice unattended, uninterrupted, stable nanofabrication over several days

## Configurable multi-species FIB technology

VELION's configurable multi-ion-species FIB technology enables you to tailor various nanostructures according to your application-related challenge. Simply choose various ion species from universal ion sources and switch between them fast and easily. This approach paves the way for unlimited process pathways.

## Cutting-edge FIB performance

The cutting-edge FIB column comes with outstanding beam characteristics enabling sub-10 nm FIB cutting at highest resolution and lowest beam tails. And with dynamic beam corrections for excellent write-field calibration, it is clear that VELION is all about FIB in perfection.

## FE-SEM column

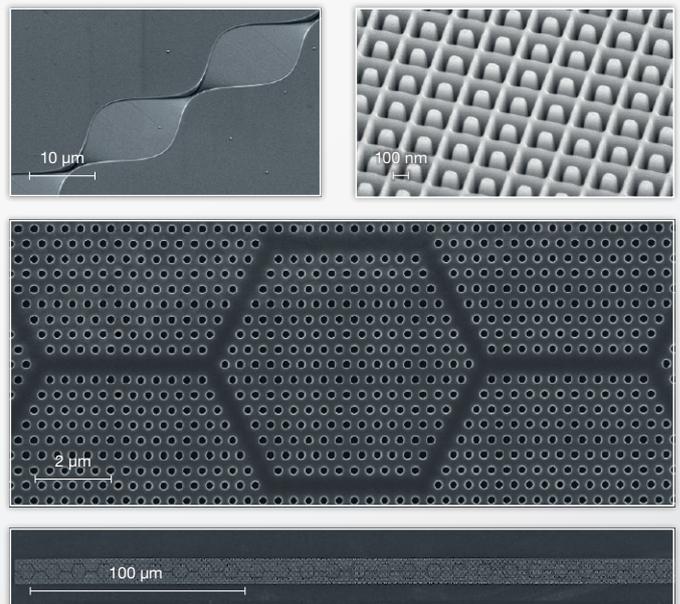
The low kV FE-SEM column expands VELION's FIB application range by enabling high-resolution result analysis of processes. In-situ metrology for FIB process control, such as endpoint detection or cross-section analysis, TEM sample preparation and sample analysis, can easily be performed.

## Comprehensive automation

VELION utilizes comprehensive automation to enable unattended, uninterrupted reliable nanofabrication over several days. The instrument is thus the ideal companion for machine-driven nanofabrication in your lab. Profit from CAD-based navigation with stable, reproducible, and ultra-accurate sample positioning, blind navigation, and much more.

## Unmatched large-area FIB patterning

The system enables stable direct patterning of diverse features over large areas based on its lithography architecture. Unmatched large-area FIB patterning and unlimited perfect write-field stitching become feasible for the first time. VELION bridges small-feature and large-area nanofabrication.



# It's all about FIB in perfection

Configurable multi-species FIB technology & cutting-edge FIB performance

## nanoFIB multi-species ion column

The nanoFIB ion column provides multiple ion species from a single source, delivering highest resolution for nanofabrication and ion imaging. Different ion species are emitted simultaneously from a universal ion source and are separated in a downstream Wien filter. It is optimized for nanofabrication, with excellent spot characteristics and lowest beam tails for sub-10 nm FIB cutting.

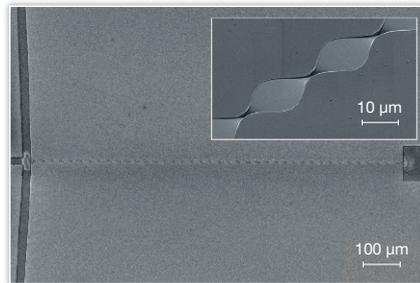
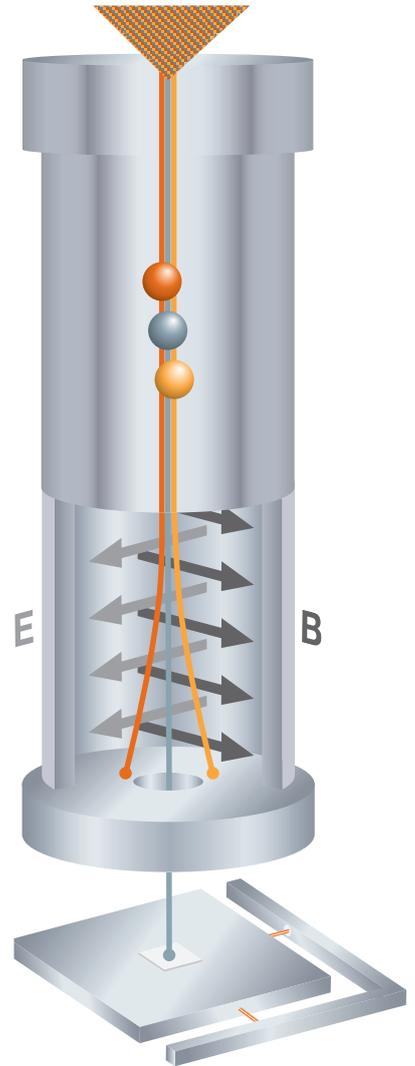
## Cutting-edge FIB performance

The nanoFIB technology stands out for the exceptional long-term stability of its liquid-flow optimized ion source and its emission control.

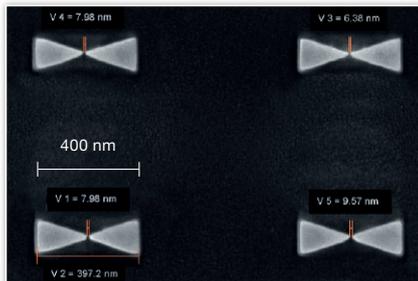
The guaranteed low drifts in probe current and beam are mandatory for reproducible long-term processes. Perfect write-field calibration with dynamic distortion correction naturally creates superior conditions for unprecedented multiple FIB write-field stitching results.

## Best ion species for unlimited process pathways

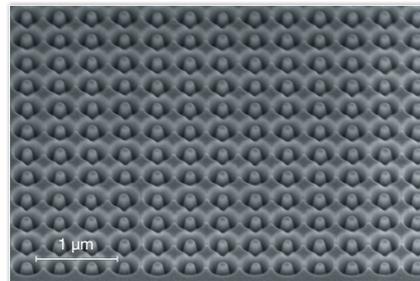
Select light or heavy, slow or fast ions from universal ion sources for various patterning techniques. Universal ion sources like GaBiLi or AuGeSi help in tailoring nanostructures by picking the best ion species for a vast number of applications. Switch between different ion species within a second and utilize for unlimited process pathways.



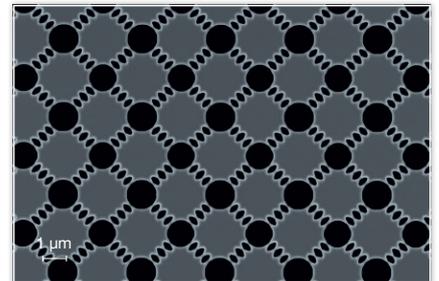
*True 3D patterning of a microfluidic mixer: Many base units of the mixer are stitched accurately over 1 mm. Multiple design elements are directly milled into the substrate with simultaneous lateral shape and dose variation to control channel depth and width changes.*



*Direct patterning – 2-step nanofab/Bi large-volume milling, Li for fine shaping and gap optimization*



*Direct 3D patterning – Broad band absorber*



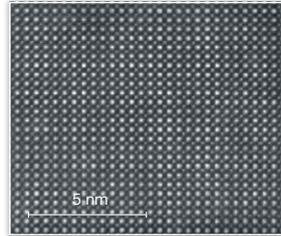
*High-resolution patterning of thin Si membrane by Au-FIB (Courtesy of Dr. Giuseppe Romano, Institute for Soldier Nanotechnologies, Massachusetts Institute of Technology)*

# Tailored low-kV FE-SEM column

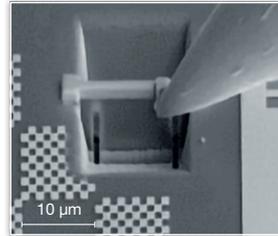
Result inspection, process monitoring, and in-situ analysis

## Advanced TEM sample prep

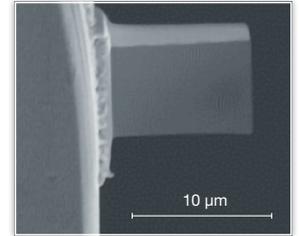
VELION FIB-SEM offers reliable TEM sample prep workflows to prepare state-of-the-art TEM samples. Ga-free TEM sample prep becomes possible by using LMAIS to prepare critical ROI at the highest success rate.



STEM HAADF image (obtained on Titan Themis by Dr. Aubrey Penn, MIT.nano)

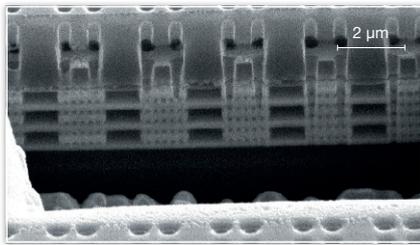


TEM sample with undercut welded to nanoneedle for lift-out



TEM sample welded on a grid

## Cross-sectioning

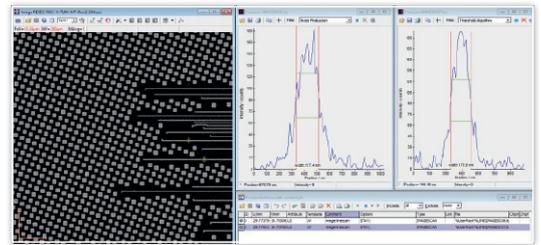


Cross-section area of CMOS device (Image courtesy of Dr. Yong Hu, Quantum Photonics Group, Materials Research Laboratory, Massachusetts Institute of Technology)

## Process monitoring

SEM supports process development by automated evaluation of results while improving process parameters.

Fully automated line width measurements and metrology functionality support the optimization of process parameters to achieve desired design goals.



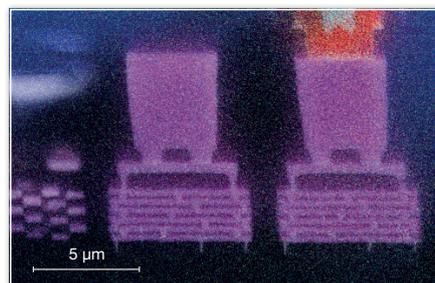
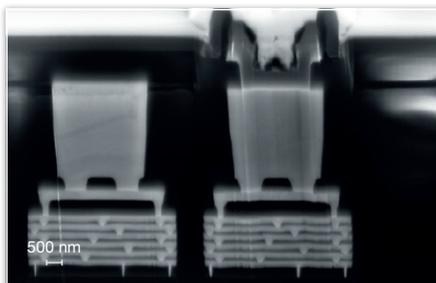
SEM metrology and automated line width measurement to control FIB fabrication processes

## State-of-the-art EDX spectrometer for qualitative and quantitative sample analysis

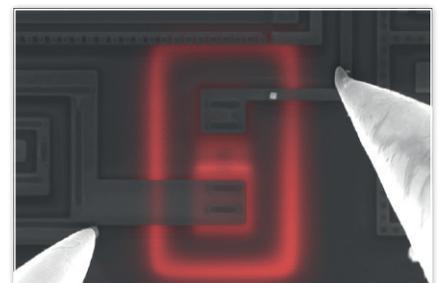
This is a valuable option for chemical characterization to provide compositional sample information. EDX package is fully software-integrated and supports image acquisition and ultra-fast X-ray mapping or line scans.

## Resistive Contrast Imaging (RCI) module

Electron Beam Induced Current (EBIC) and Electron Beam Absorbed Current (EBAC) help in locating and analyzing failures inside semiconductor devices.



SEM cross-section of semiconductor device and associated EDX images (SEM and EDX images courtesy of EMFT Fraunhofer Munich, Germany)



(Image courtesy of point electronic GmbH, Germany)

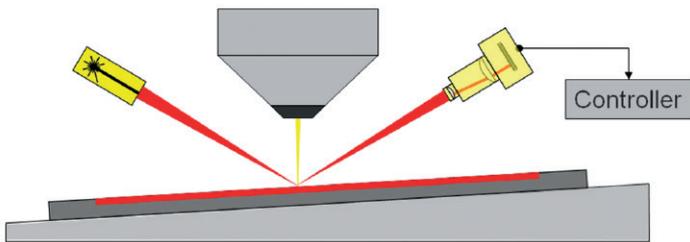
# Comprehensive automation

Unattended, uninterrupted stable nanofabrication and ion imaging

## Automated workflows

The interaction of long-term stability, highest accuracy in placement and CAD navigation supports workflows and processes for unattended, uninterrupted reliable nanofabrication and ion imaging.

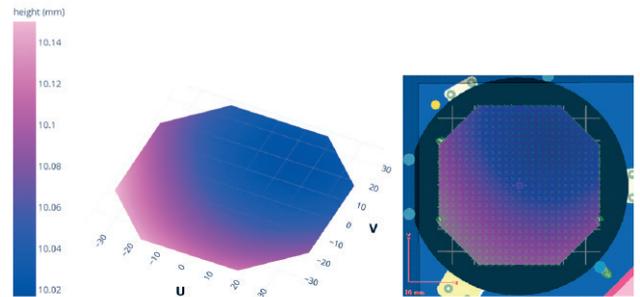
Using Raith's proprietary Nanosuite software, various components are operated to automatically perform complex processes that take the VELION FIB-SEM to the next level of machine-controlled nanofabrication.



Laser beam shines onto the sample and measures the distance between sample surface and FIB to adjust the focus depending on sample height

## Automated height sensing

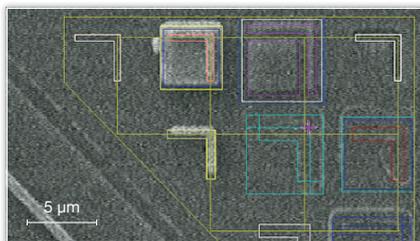
Laser-based measurement and correction of working distance: Sample surface height variation is detected and focal plane is automatically corrected. This allows for patterning at high fidelity over the entire 4" sample area with e.g. wafer bow or small tilt.



Height map of a wafer, acquired by >500 data points

## CAD overlay

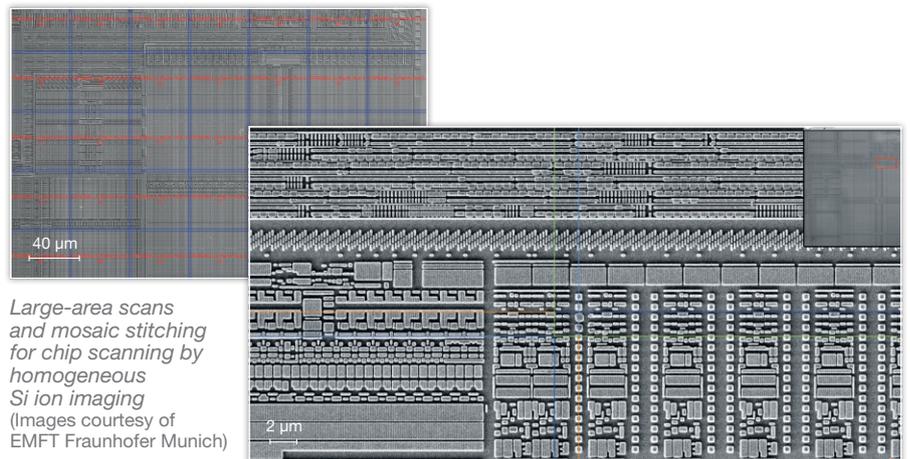
FIB applications with write field stitching, multi-layer alignment overlay, extended GDSII files, step & repeat, and optional continuous patterning are performed at highest precision and absolute accuracy. Automated workflows simplify the overall nanofabrication process to achieve outstanding results.



Layout for CAD-based sample navigation, blind navigation and patterning overlay

## Large-area FIB imaging

Homogenous mosaic views of large areas can automatically be obtained at highest signal-to-noise ratio with high contrast by using Focused Ion Beams with light ions for imaging. Write fields and FIB images are automatically corrected to merge images to create a large-area-sample mosaic-view representation.



Large-area scans and mosaic stitching for chip scanning by homogeneous Si ion imaging (Images courtesy of EMFT Fraunhofer Munich)



# 3D ion microscopy

Highest-resolution 3D images – easy, fast, and reliable without stage tilt

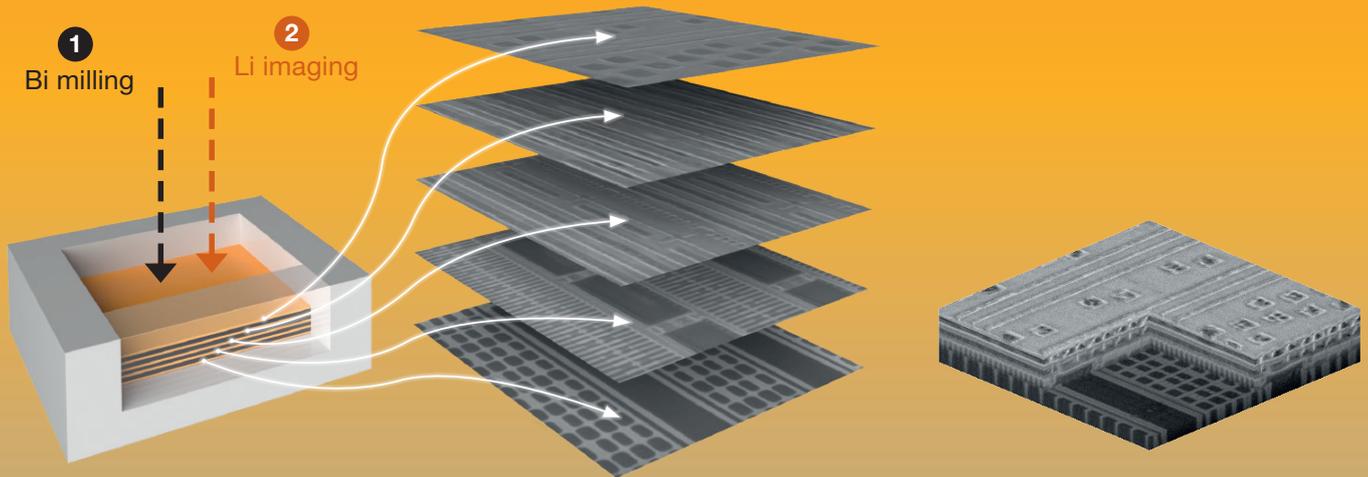
## Fast and easy switching between different ion species

VELION’s configurable multi-ion species FIB technology switches between different ion species fast and easily. Heavy ions are utilized for sample delayering, while light ions take advantage of damage-free imaging of the exposed structure.

This workflow advances 3D sample analysis by providing highest-resolution 3D images easily, fast, and reliably.

VELION’s lithography architecture facilitates smart nanofabrication approaches for smooth and uniform sample delayering.

Light and heavy ions are applied alternately to achieve high-resolution 3D models of the sample. The single images can then be stacked together for a 3D reconstruction of the sample.

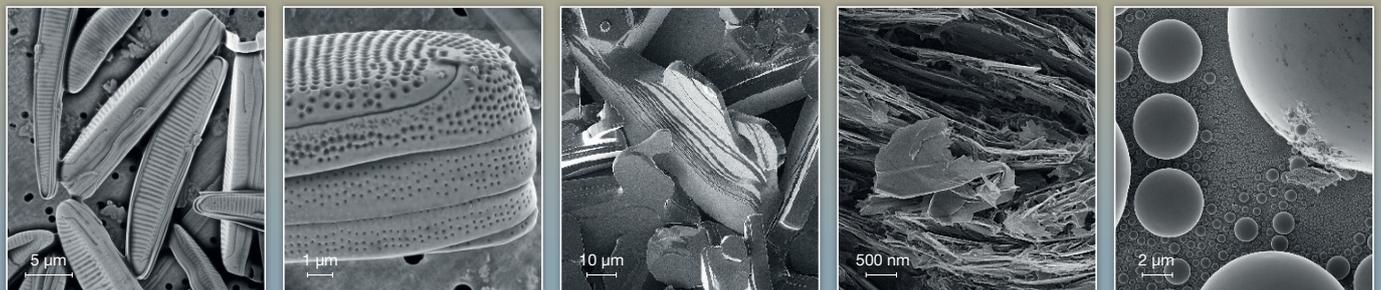


Top-down geometry for milling and imaging

3D reconstruction

## 2D ion imaging with lithium

VELION’s configurable multi-ion species FIB technology enables high-resolution ion imaging with light ions such as lithium.



Lithium ion images of diatoms, Bi<sub>2</sub>-Ca<sub>2</sub>-Co, graphite, and Sn/C, showing the high depth of focus, the high surface sensitivity, and the high image resolution

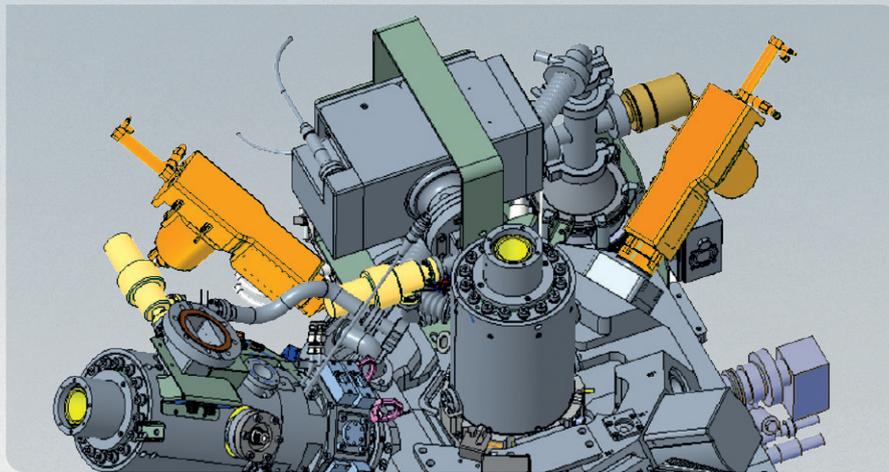
# Configurable setup

Nanoengineering options for various applications

## Multiple universal ports on the vacuum

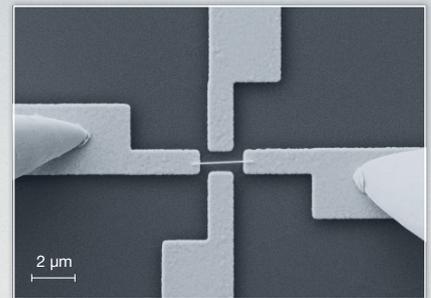
VELION provides all the capabilities expected of a state-of-the-art FIB-SEM system for a variety of nanoengineering tasks.

With key options including gas injection systems and nanoprobers, the system layout can be configured to set up the desired process and analysis throughout the 100 mm x 100 mm sample area.



## Nanomanipulators

Up to 4 nanomanipulators are fully integrated into the Nanosuite software for convenience in electrical measurements or manipulation of nm-sized particles. They can be combined with other options and allow probers to be precisely positioned using visual and digital control at a positioning accuracy of a few nm.



Tungsten deposit between prefabricated gold contacts used for electrical conductivity measurements with nanoprobers

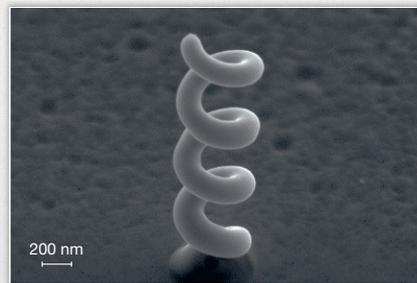
## Gas injection systems

As must-have component for a FIB system, gas injection systems (GIS) provide local flow of precursor gas over the sample.

GIS systems are necessary for increasing removal rates in gas-assisted etching, but also for electron or ion-beam-induced deposition.

Precursor gases can be applied from different positions and angles for X-sectioning, TEM sample preparation, masking for subsequent processing, and wiring of nano objects.

GIS systems are fully integrated into Raith's proprietary Nanosuite software for ease of use.



FIBID of helix-shaped 3D structure, Pt precursor, Si ion beam, and linear dwell time variation

## Various sample holders

A range of sample holders is available to serve the needs of different applications.



Layout of e.g. tilt rotation module for compucentric sample tilt and rotation

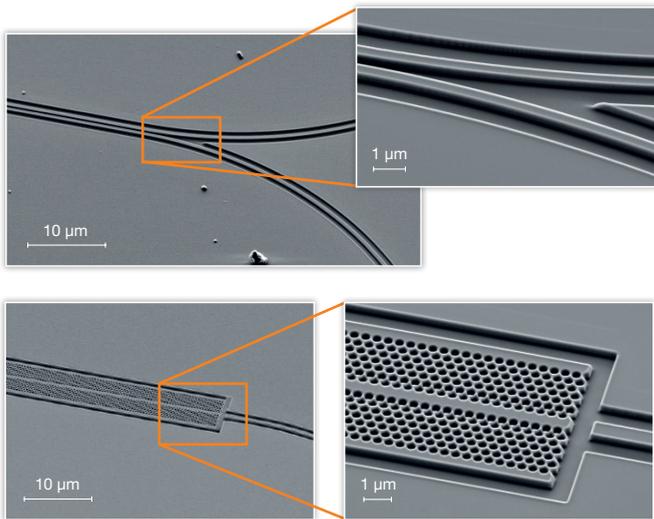
# Unmatched large-area FIB patterning

Unique stage design for FIB SEM/

4" Laser Interferometer Stage for stability, accuracy, and precision

## Unlimited write-field stitching

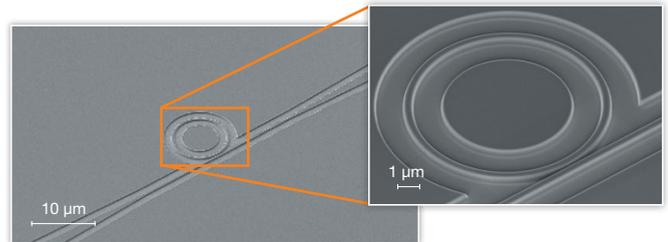
Unlimited numbers of write fields can be stitched to form devices of waveguides and photonic crystals on mm scale at nm precision. Smart stitching strategies based on LIS precision and accuracy facilitate results automatically for rapid prototyping or small batch production.



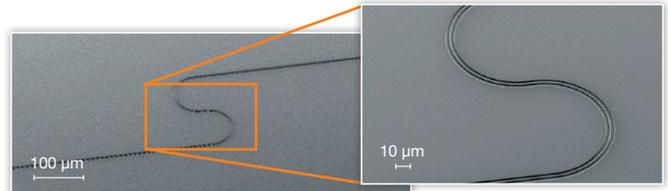
Various features of waveguides and photonic crystals were directly milled into 200 nm silicon on an insulator spread over 175 single write fields on a 2.5 mm x 0.7 mm working area. Automated workflow with smart stitching strategies enables an unattended fabrication process. (Courtesy of UC Santa Barbara, USA)

## Continuous writing modes for seamless nanopatterning

Raith's unique continuous and stitching-error-free writing modes avoid stitching errors for features extending the single write field. Fixed-beam moving stage (FBMS) and modulated-beam moving stage (MBMS) technology allow seamless fabrication of structures by setting up writing strategies to outperform conventional step and repeat workflows.



Photonic device (wavelength and coupler) in a silicon substrate created by direct milling with a focused gallium ion beam. (Image produced by Raith for Professor Peng, Peking University, China)



2 mm-long waveguide directly milled into 300 nm Lithium niobate on an insulator using Fixed Beam Moving Stage (FBMS) (Courtesy of Roland Salut, Institut FEMTO-ST, France)

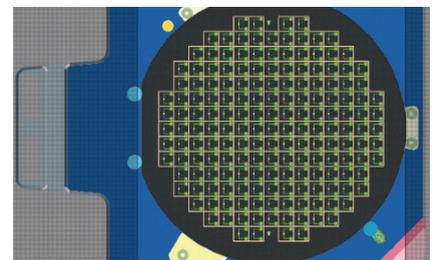
## Rapid prototyping

Large design files can be handled by VELION's pattern generator and directly transferred onto the substrate. Designs can be adapted quickly and easily according to changing requirements. High fidelity and highest patterning resolution are maintained over extended areas.

## Full 4-inch wafer processing for small batch production

Accurate sample navigation combined with precise beam positioning enables reproducible production of identical features spread over a full 4" wafer.

Wafer layout for small batch production of 175 chips over a 4" wafer to drill nanopores on chips in fully automated and unattended processes



# VELION

## Features at a glance

- Dedicated nanoFIB column for nanofabrication and ion microscopy
- Unique, multi-ion species FIB technology
- IONselect for unlimited process pathways for nanofabrication and imaging
- Stable lithography platform with laser interferometer-controlled sample stage for features from single-digit nm to cm scale
- Outstanding beam current and beam position stability
- Long source lifetime
- Raith's proprietary Nanosuite software
- Environmental enclosure suitable to any lab condition



## Support and service worldwide

### Sustainable long-term support channels

There is more to take into consideration than specifications and system performance only. Raith ensures optimal use over a whole system lifetime, with a team of professional trainers and a global support infrastructure from the market leader for lithography systems.

### High quality service worldwide

Wherever you are, a service engineer is always nearby. Raith has locally based engineers and spare parts stocks in all major regions. Regular training is held at the factory to ensure consistent levels of expertise worldwide.

VELION is a modular system that can be field-upgraded later if your requirements change. This safeguards your long-term investment in the FIB system in combination with our unique long term full service and spare part availability guarantee.

### Trainings

We help you benefit from your FIB system quickly, with comprehensive onsite training included at every VELION installation, free-of-charge site survey, and advanced facility check. In addition, our Service Centers provide application support. Our expert training courses help experienced customers reach the next level or retrain new colleagues.

### User meetings

Raith organizes several yearly international user meetings and symposia where you can present your results, meet Raith experts, discuss the latest developments, and improve your knowledge.

**Join the largest nanofabrication user and support network in the field!**

## Sales

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05-2023

Your challenge is our mission.

# RAITH

NANOFABRICATION