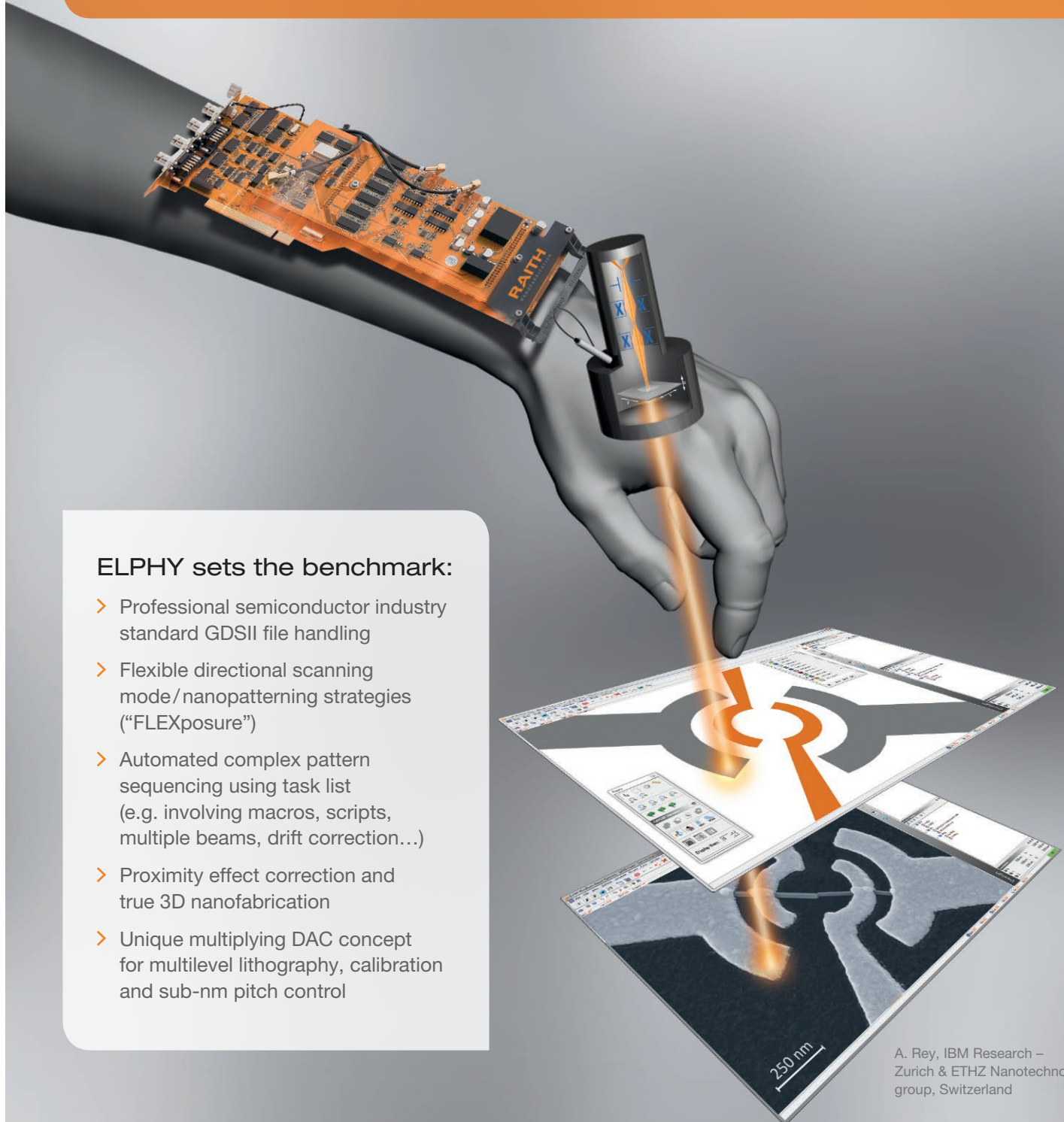# ELPHY

Unlock the full nanopatterning potential of your SEM, FIB-SEM, or HIM

Nanolithography and nanofabrication for all focused electron and ion beam microscopes

RAITH
NANOFABRICATION

ELPHY – Create your own nanolithography system and get free access to Raith's worldwide support infrastructure

ELPHY sets the benchmark:

- > Professional semiconductor industry standard GDSII file handling

- > Flexible directional scanning mode/nanopatterning strategies ("FLEXposure")

- > Automated complex pattern sequencing using task list (e.g. involving macros, scripts, multiple beams, drift correction…)

- > Proximity effect correction and true 3D nanofabrication

- > Unique multiplying DAC concept for multilevel lithography, calibration and sub-nm pitch control

250 nm

A. Rey, IBM Research – Zurich & ETHZ Nanotechnology group, Switzerland

ELPHY® – The key to nanofabrication

Accelerate your SEM / FIB-SEM / HIM

In today's research laboratories, Electron Beam Lithography (EBL) or Focused Ion Beam (FIB) patterning, milling, Focused Electron or Ion Beam Induced Processes (FEBIP/FIBIP) are "must have" technologies.

For more than 25 years, Raith has been pioneering the most economic conversion of virtually any SEM or FIB into nano-lithography/nanofabrication stations in order to fully exploit their nanopatterning potential. ELPHY attachments significantly enlarge the bandwidth, complexity, and degree of automation of possible nanofabrication applications when adapted to these tools.

More than 100 person-years of software development, paired with mature and advanced pattern generator technology, make ELPHY the most comprehensive and successful nanolithography/nanofabrication upgrade kit in the world – given a track record of about 1,000 installations!

Flexibility / Ease of use

Whether adapted to an SEM, a FIB, a FIB-SEM or a HIM, ELPHY is capable of handling a whole range of tasks, from simple single write field tasks to complex and highly automated multi-level and multi-field patterning processes or metrology jobs. Raith´s decades of expertise in the field of nanofabrication with both electrons and ions is embodied in the most comprehensive Raith software. The entire nanofabrication workflow, spanning professional GDSII design, post-processing, alignment, exposure/patterning parameter control, automation, and microscope remote control, is fully integrated into a single intuitive user interface.

Complexity / Automation

In all Raith nanofabrication products – whether using ELPHY or a Raith turn-key system – you will find the same synergetic software platform: the Raith Nanosuite. This ensures that the entire workflow and most advanced nanofabrication functionality is already implemented in ELPHY. For example, every ELPHY system provides proximity effect correction or true 3D nano-fabrication algorithms, flexible directional scanning mode/nanopatterning strategies ("FLEXposure"), multilevel lithography with multiple automatic alignment, overlay and mark recognition features, automatic drift correction – combinable with a comprehensive macro library, script control or process evaluation/metrology functionality.

Purpose-built hardware

Best electronic signal quality resulting in most accurate pattern placement at highest writing speed are the main development targets of every Raith pattern processor. All Raith pattern generators use a dedicated hard-ware concept for multilevel lithography/nanofabrication, calibration, and grating pitch control. Like genuine e-beam writers, Raith's ELPHY system also offers 6 multiplying 16-bit D/A converters in addition to the 16-bit main-deflection D/A converters, yielding a non-compromise writefield alignment, highest overlay precision, and a superior patterning resolution in the sub-nm regime (equivalent to far more than 16-bit).

ELPHY MultiBeam

ELPHY Plus

ELPHY Quantum

ELPHY MultiBeam

The nanopatterning benchmark

### One pattern generator for both electron and ion beam control

ELPHY MultiBeam sets new standards in the market for SEM, FIB-SEM and HIM nanolithography solutions ("attachments"). ELPHY MultiBeam combines the latest technology for three-dimensional IBL and other 3D nanofabrication techniques with the very best EBL performance, and helps to unlock the full nanofabrication potential of your SEM, FIB-SEM or HIM system.

ELPHY MultiBeam includes all comprehensive multiple technique nanopatterning functionality in a single system, relevant for advanced Focused Ion Beam Milling, Etching and Deposition, Ion Beam Lithography (IBL), Electron Beam Lithography (EBL), Gas Assisted Focused Electron Beam Induced Processing (FEBIP) and Helium Ion Beam Patterning.

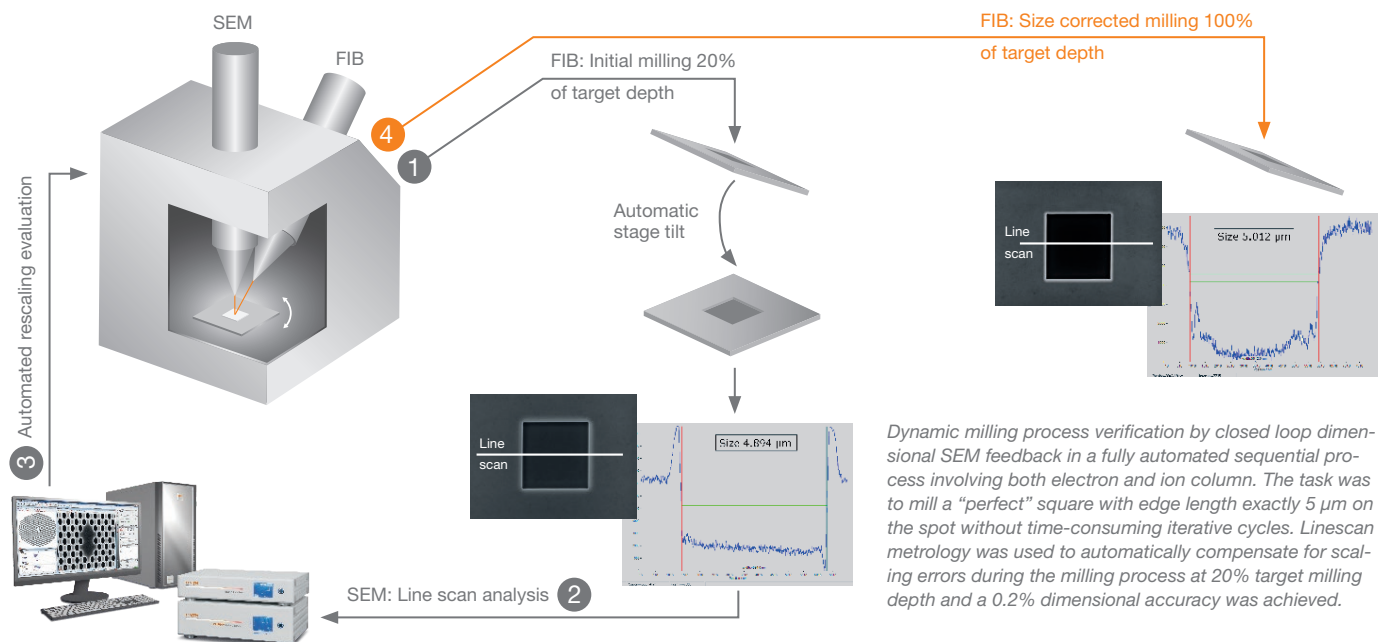### Highest accuracy nanopatterning by advanced process control

Applications with demanding dimensionality and stability requirements need ultimate flexibility with respect to nanopatterning strategy. Raith's "FLEXposure" software modules, using specific directional patterning modes and other patterning attributes such as loops, help you to significantly optimize the definition of your nanostructure. Drift correction functionality ensures highly accurate pattern placement, especially during long term exposures or milling jobs.
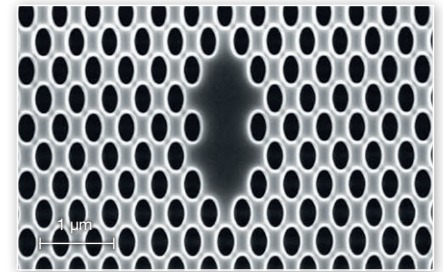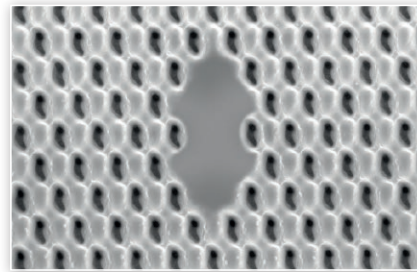
Photonic crystal fabricated in a direct milling process with a FIB-SEM (a) in conventional way and (b) in highest quality using concentric elliptical patterning mode (outwards), drift correction schemes, and GDSII element loops as patterning attributes.

FIB Nanopatterning with fully automated closed loop size control

Dynamic milling process verification by closed loop dimensional SEM feedback in a fully automated sequential process involving both electron and ion column. The task was to mill a "perfect" square with edge length exactly 5 μm on the spot without time-consuming iterative cycles. Linescan metrology was used to automatically compensate for scaling errors during the milling process at 20% target milling depth and a 0.2% dimensional accuracy was achieved.

ELPHY MultiBeam
The nanopatterning benchmark

Unique features for convenient operation

Patterning-on-image ("directalign-design") functionality enables new nanostructures to be inserted into existing features on your sample without the need for alignment routines. After taking an image, a GDSII design can immediately be drawn on top before launching a nanopatterning job with "perfect overlay" and without additional alignment procedures. Standard nanopatterning such as electron beam lithography nanopatterning followed by a complementary FIB process step has been used to create a convenient Hall bar device manufacturing process (see image to the right).

The recipe manager helps to shorten long design/parameter setup cycles; just drag and drop a recipe onto your existing GDSII design elements, thus assigning a specific parameter set from a freely definable database. The Signal Router minimizes the number of one (or more sequentially con-
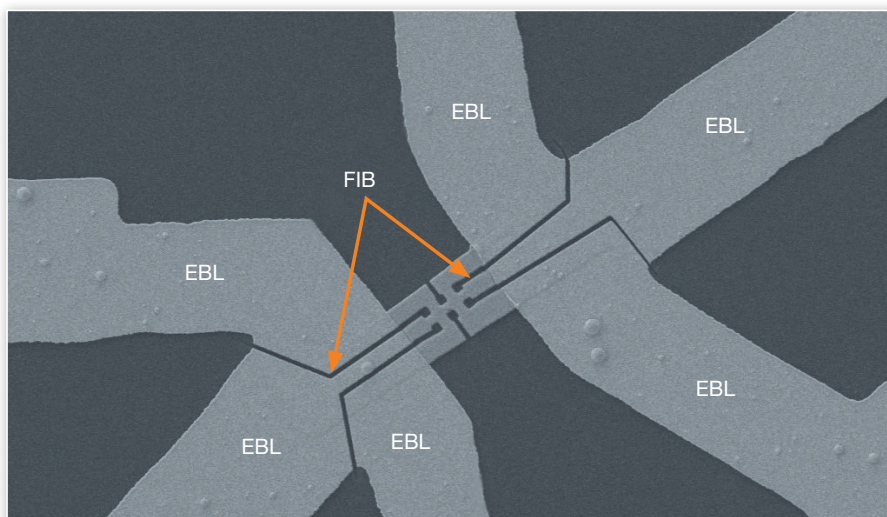

Combined EBL/FIB nanofabrication process of a (Nano) Hall bar (200-500 nm). First Cd_3As_2 nano plates and contacts were fabricated using EBL and metal deposition; in a second step FIB was used to etch the samples into Hall bar geometry; W. Wang et al., Fudan University, Shanghai, China

nected) switchboxes. 4 input and 3 output channels smoothly integrate further accessories such as EDX to be connected to the same or several external scan interfaces. The Signal

Router can also be used for fully automated processes, e.g. involving both FIB milling and SEM metrology, for automated dynamic FIB milling process verification.

A benchmark pattern generator for high-performing sensitive instruments

ELPHY MultiBeam has been designed to match the needs of ultimate patterning performance with highest placement accuracy and resolution. Differential signal outputs ensure maximum signal to noise ratio in conjunction with high-performing sensitive instruments such as helium ion microscopes (HIM).
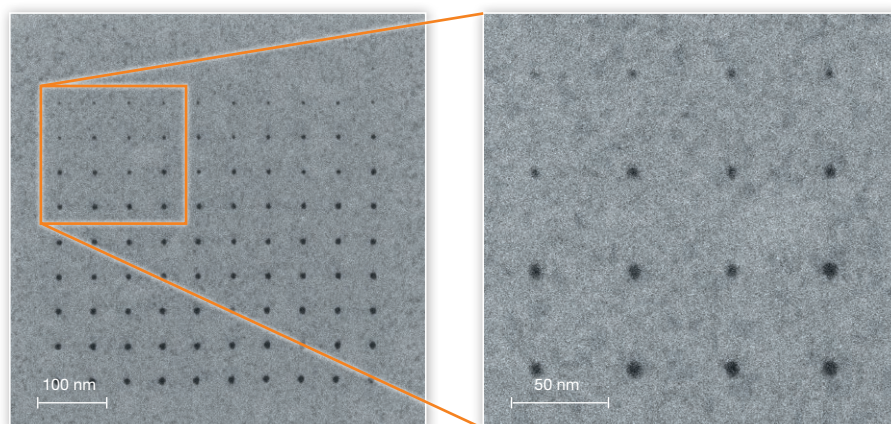
TEM images of nanopores (milled in concentric outwards and dot patterning mode) down to sub 10 nm, 5 nm and ~2 nm diameter respectively, fabricated in thin carbon nano membranes using a helium ion microscope controlled by ELPHY MultiBeam.
D. Emmrich, A.Gölzhäuser et al., Uni Bielefeld, Germany

ELPHY Plus

The professional nanolithography attachment

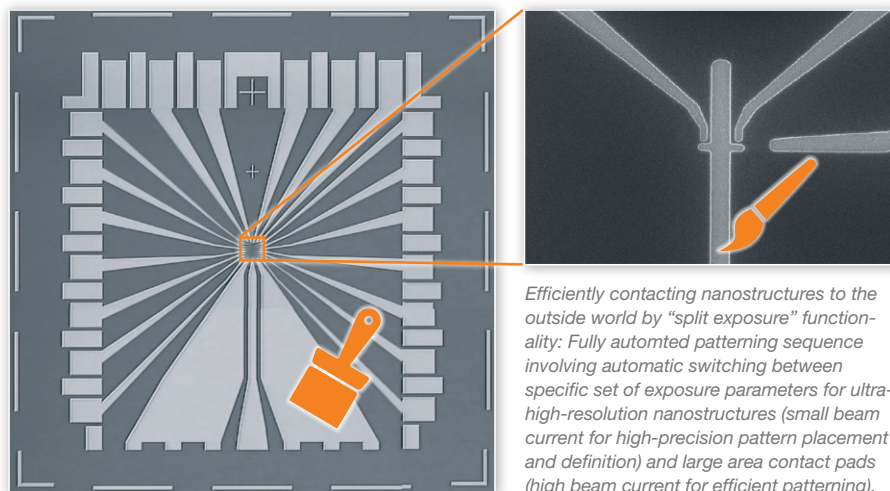### The solution for state-of-the-art SEM or FIB instruments

ELPHY Plus is a truely professional lithography attachment for SEM and FIB systems. Digital signal processor (DSP) technology and Raith's unsurpassed software user interface makes this pattern generator the ideal complement for all state-of-the-art FE-SEM and FIB systems.

Ultimate electronic performance

The ELPHY Plus pattern processor has been designed with utmost care in order to deliver unequalled electronic performance. ELPHY Plus is designed as a separate 19-inch electronic rack unit with meticulous RF shielding and is equipped with Peltier-cooled temperature-stabilized D/A converters. These are undeniable prerequisites for nanolithography with ultimate resolution, precision and stability, especially when it comes to long term nanopatterning jobs.

More results per day

Combining ultra-high resolution nanostructures and large area exposures in a single run (e.g. for contacting nanostructures to the macroscopic world) is a very common application. Both nanostructures and large area structures need to match and have to be exposed in a single, preferably automatic run including alignment routines. ELPHY's split exposure functionality can switch between smallest beam currents for highest-resolution nanostructures patterning and high beam currents for large area exposures in a fully automated exposure sequence. Applying the latter makes ELPHY Plus very efficient, particularly if attached to modern thermal field emission based SEMs with high beam current densities or excellent low kV performance.

Efficiently contacting nanostructures to the outside world by "split exposure" functionality: Fully autometd patterning sequence involving automatic switching between specific set of exposure parameters for ultra-high-resolution nanostructures (small beam current for high-precision pattern placement and definition) and large area contact pads (high beam current for efficient patterning).
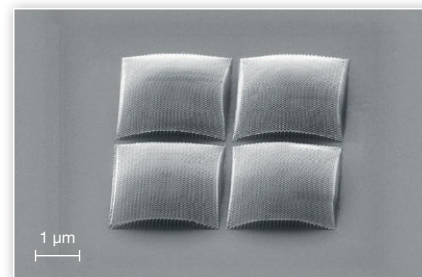
ELPHY Plus Applications
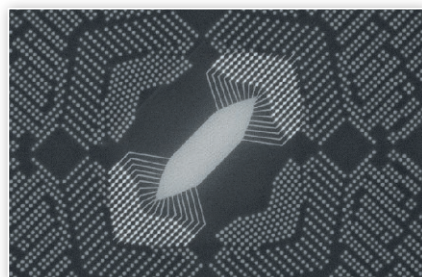
CMOS decoder circuit, aligned e-beam pattern with CMOS Metal 5 vias
Kuk-Hwan Kim, EECS, University of Michigan, USA
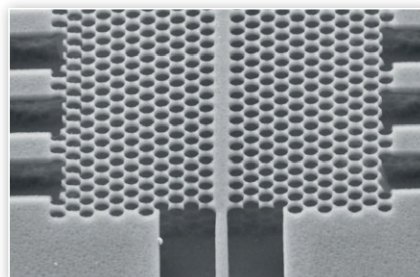
Photonic crystal structure in membrane (underetched)
William Whelan-Curtin, University of St. Andrews, UK

Step-and-Flash Imprint Lithography (S-FIL) imprint of a "motheye" lens, mold fabricated by 3D-FIB-lithography
J. Kettle, Cardiff University, UK

ELPHY Quantum

The universal nanolithography attachment

Optimum value for money

ELPHY Quantum represents the most economical access to professional nanolithography and nanofabrication – providing all you need to get started efficiently!

ELPHY Quantum covers the entire workflow (CAD layout and processing, control of exposure parameters, automation, remote control of each microscope etc.), integrated into a single user interface, the Raith Nanosuite. The proprietary hardware is preinstalled and tested and operates under a high-end workstation, utilizing a most recent Windows operating system.

Proprietary hardware for high-precision nanopatterning

ELPHY Quantum is the most universal and flexible lithography attachment for SEM and FIB systems. ELPHY Quantum consists of advanced PCI-board-based, noise-protected and deglitched scan generator electronics. A 6-fold multiplying DAC matrix modifies the analog output signal from the primary DACs such that the maximum DAC range can still be used for patterning without loss in signal-to-noise ratio at all write field orientations and sizes. Other benefits from the concept arise when applied to specific applications in communication technology and integrated optics such as DFB laser gratings, which can be finetuned to specific wavelengths with sub-nm resolution.

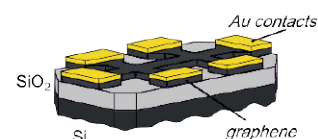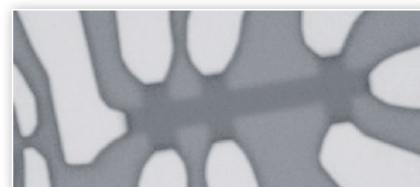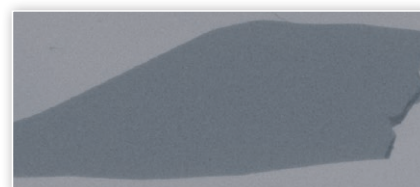### Connecting nanostructures with the macroscopic world

One of ELPHY Quantum's strengths is its simple and flexible overlay functionality, with the help of which nanostructures such as carbon nanotubes, nanowires, nanojunctions, nanodevices, or graphene flakes can be connected to large contact pads for measurement of various physical properties. Sophisticated manual or fully automatic mark recognition and alignment routines help you with these multilevel lithography applications for highest-accuracy nanostructure definition and/or its connection to the outer world.
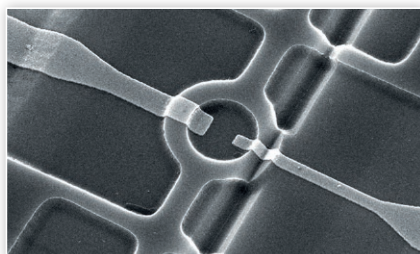
Aharonov-Bohm ring with 1D Quantum Wire (QW) embedded in one of the ring-gate structure arms
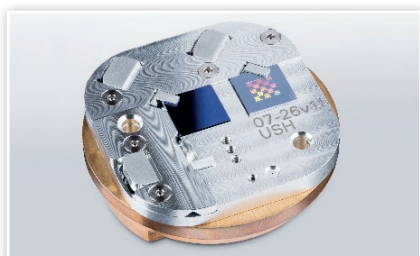A. Tsukernik, Tel Aviv University, Israel

200 nm
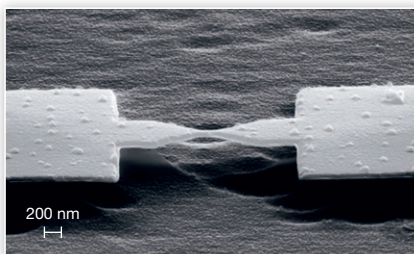
Al nanobridge used as a tunneling contact (after mechanical break)
M. Goffman, CEA Saclay, France; E. Scheer, University of Konstanz, Germany

The Universal Sample Holder

The universal sample holder (USH) can be purchased as an option with all ELPHY systems. It is compatible with almost any instrument in the field and comprises a calibration standard (CHESSY) and an integrated Faraday cup. Three clamps for small ~cm^2-samples or small wafer pieces are provided.

Graphene device fabrication:
a) SEM image of Graphene flake
b) GDSII-design overlay for mesa and contacts
c) mesa and contact formation
Fred Schedin, Andre Geim et al., University of Manchester, England

The Raith Nanosuite

The most comprehensive nanolithography software

### One software platform for all Raith ELPHY products

Whether you use ELPHY Quantum, ELPHY Plus or the premium ELPHY MultiBeam system, all software is based on the Raith Nanosuite, which also serves as a platform for the entire Raith product portfolio. This means, all your designs and processes will be compatible even when using a Raith turnkey system.

All you need to start exposing your first patterns is included in the standard scope of delivery: Professional GDSII CAD layout editor, exposure parameter determination, task list for step and repeat exposures, automated or user assisted mark registration for multilevel lithography, mix & match application, or stage/column control drivers.

If required, proximity effect correction and CAD layout postprocessing are available and seamlessly integrated into your lithography control software. If you need to generate 3-dimensional (grayscale) structures for e.g. integrated optics application, additional software is available to calculate the correct exposure dose distribution.

GDSII viewer/editor

A key advantage of having this fully integrated viewer and editor is to eliminate data conversion steps from external layout software. All changes of dimensions or, especially, patterning parameter doses are made directly in ELPHY's editor. Patterning processes can be started immediately without the need for further compilation. If preferred, standard formats like GDSII, DXF, CIF, ASCII can be imported from AutoCAD, DesignCAD, or other GDSII layout software. Like professional dedicated e-beam writers, ELPHY data management uses the industry standard of (hierarchical) GDSII.
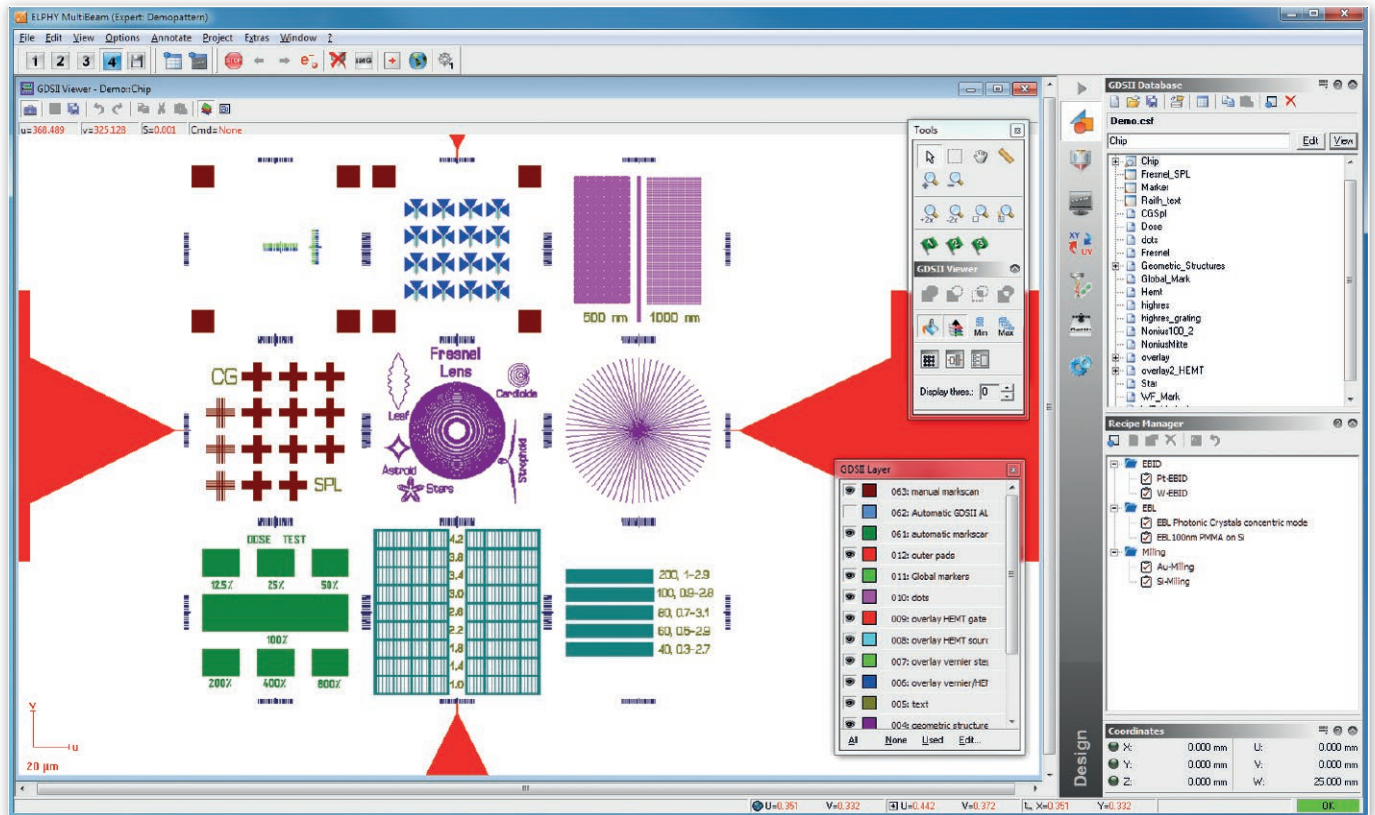
*Raith Nanosuite with Integrated GDSII layout editor*

The Raith Nanosuite

All modules integrated
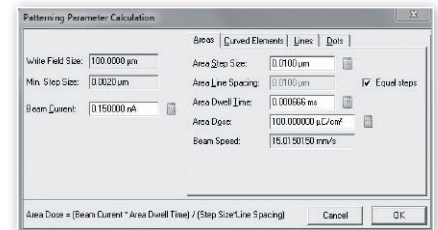
Patterning / Automation

In order to achieve optimum patterning results, writing strategies are kept very flexible. Full control over all exposure or milling parameters is given.

Automated step and repeat exposures are easily controlled by editing a position list (task list) or using drag-and-drop features. They can also be embedded in a complex, fully automated patterning process sequence containing not only the mere patterning jobs, but also macros or scripts for column setup or exposure parameter changes, drift, beam current or focus correction, and automated complex metrology tasks. When finished, the system can even activate a column standby mode and deliver an immediate message to the system operator's office PC to maximize efficiency of system usage with highest job yield.
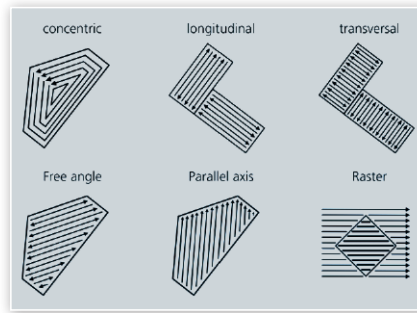
FLEXposure attributing per pattern shape within GDSII, multiple choice of directional patterning – in total 5 main operating modes with 47 submodes


Parameter calculation functionality: Automatic correlated calculation of correct exposure parameters, also taking into account specific dose factors / parameters for curved elements, lines and dots.


Positionlist: Powerful tool to define a task list containing fully automated subsequent jobs – whether type patterning, alignment, parameter changes, calibration, metrology, automated calculation thereof, macro / scripting, or switching the instrument to standby mode after job completion. The system can even send the user an email after job termination.

Multilevel lithography

Many lithography applications require alignment to existing structures / patterns. ELPHY systems offer hardware alignment, meaning the writing field orientation is physically shifted / scaled / rotated relative to the fixed sample with the help of 6 additional multiplying D/A converters. The alignment accuracy achieved is typically to the order of very few 10 nm and is much better than that obtained with virtually any motorized stage. The user can assist during the mark registration procedure or apply fully automated mark registration sequences.
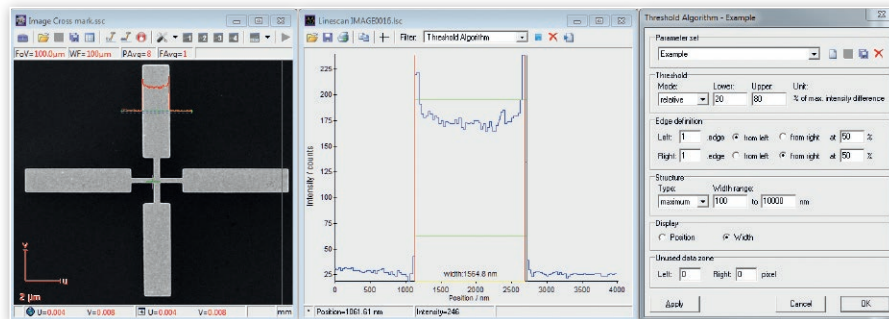
*Optimizing alignment accuracy by means of threshold / edge detection algorithms respectively.*
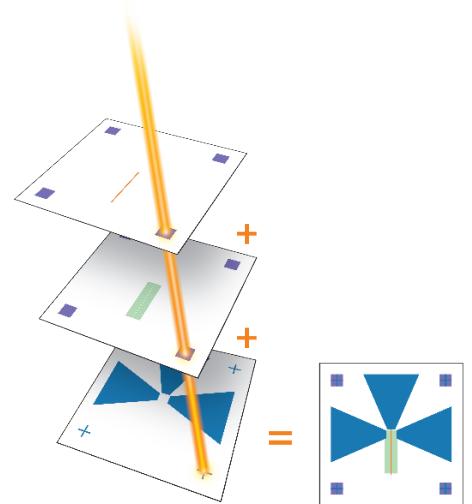
Example for a (subsequent design layer 1-3) multilevel lithography process for high electron mobility transistor (HEMT) fabrication (3-layer GDSII design with alignment marks).

The Raith Nanosuite
Sets the standard

Metrology

Nanofabrication is one task, but efficient dimensionality check and respective subsequent process optimization quite a different one. However, they can all be accomplished using a powerful set of metrology algorithms and filters within the Raith Nanosuite, such as edge or distance detection, threshold, noise reduction, or cross correlation, to name but a few – all automatable and exportable in e.g. histogram format for further analysis and evaluation.
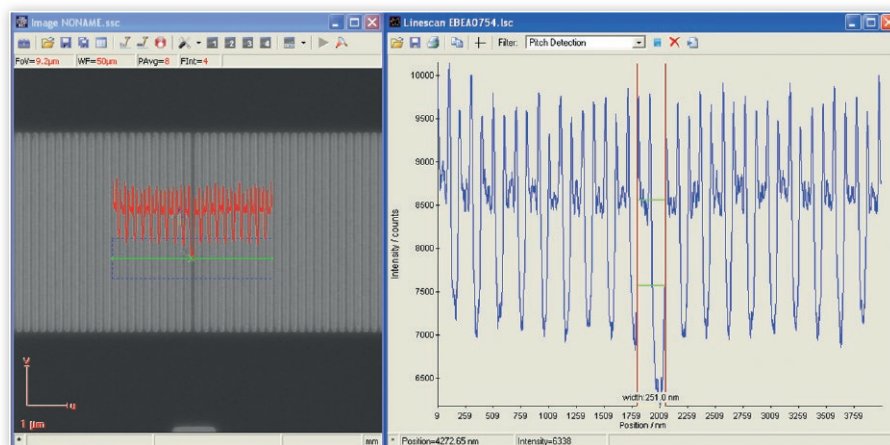

Automatic pitch detection metrology algorithm of a 200 nm grating with λ / 4 phase shift resulting in a distance of ~250 nm at phase shift position.

▲ *Photonic crystal exposure optimization using NanoPECS proximity effect correction package*
a) with the help of 3D resist development simulation for identification of critical areas
b) with the help of proximity corrected dose distribution. ▶

Proximity Effect Correction and 3D resist exposure simulation

Some applications require very accurate dose control in order to deliver optimum clearing doses, which can be crucial for fabrication of dense nanostructures such as optical gratings or photonic crystals. The proximity effect correction package NanoPECS helps to optimize dose distribution for critical parts of your design. In order to identify, model, and optimize those critical parts prior to exposure, a 3D resist development simulation module is an integral part of the Raith Nanosuite.
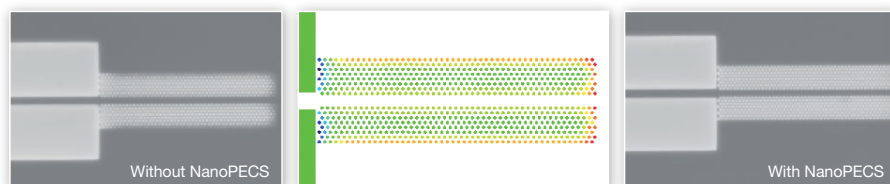
3D lithography

Increasing numbers of 3D (grayscale) applications are finding their way to e.g. optics or optoelectronics. Using the 3LITH software package, you can not only import grayscale bitmap patterns with associated contrast curves, but also design a set of diffractive optical elements, such as lenses, geometric 3D structures, (phase) holograms, and more.
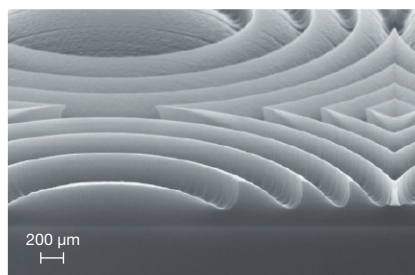

Fresnel lens in thick resist

More than 100 person-years of software development

Given ELPHY's long-standing history of success and related software development, it is impossible to fully display its advantages and benefits in a single brochure – **ask for a software demo and see the difference for yourself!**

How It Works

Create your own nanolithography system

Your SEM, FIB-SEM or HIM
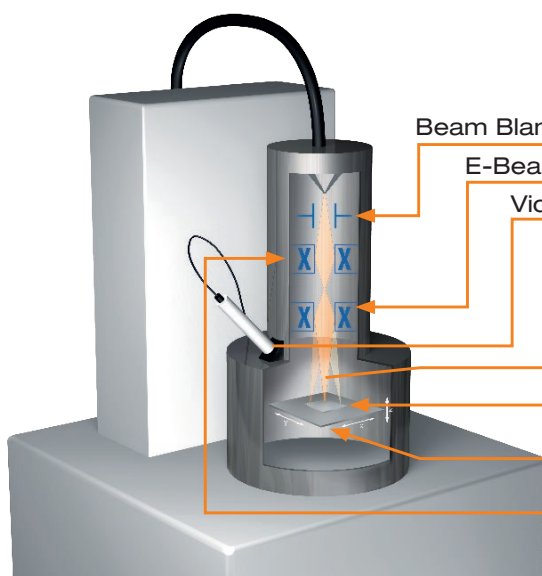
ELPHY MultiBeam

Beam Blank Control*

E-Beam-Deflection** (XY)

Video signal (SE detector)

Beam current monitor

Write field size control

Stage control

Focus Control

ELPHY Workstation

* Beam blanker required for SEM / FIB-SEM / HIM
** Analog external scan interface required for SEM / FIB-SEM / HIM

The illustration shows all hardware and software interfaces required for advanced nanopatterning process and microscope remote control. Please make sure that all the above interfaces are supplied by the microscope vendor; in case of uncertainty please consult Raith! For FIB-SEM all interfaces need to be available (for either column if you intend to employ both columns).

Straightforward adaptation to your microscope

ELPHY simply upgrades your microscope with additional capabilities – with no constraints or other strings attached. Your microscope will remain untouched and will not suffer from any limitation to its original analytical and imaging functionality.

With approximately 1,000 installations worldwide, Raith has considerable expertise with all relevant microscopes in the field. Raith has adopted a seamless philosophy it likes to describe as "no-brainer". ELPHY is designed as a complete package comprising a workstation, the Raith Nanosuite software, the pattern generator, and a monitor, including all connecting cables, installation support and training sessions – all from a single source! This concept enables you to avoid unexpected problems with the installation and get off to an efficient start!

We don't leave you alone

As part of Raith's "no brainer" philosophy, Raith engineers will prepare, install, and test your instrument before you receive comprehensive expert training. Subsequent free-of-charge software hotline, solid application support, and know-how transfer are available in any time zone over the entire lifetime of the instrument.

ELPHY

Unlock the full nanopatterning potential of your SEM, FIB-SEM, or HIM

- Most successful pattern generator in the world
- Most comprehensive software, with more than 100 person-years software development
- Unique hardware concept providing the equivalent of more than 16-bit main DACs only for sub-nm pattern placement control
- Installation, initial system training, and software/application support over entire instrument lifetime included

Product specifications

Features	ELPHY Multibeam	ELPHY Plus	ELPHY Quantum
Hardware concept	Ext. DSP Unit (19")	Ext. DSP Unit (19")	PCI bus vector scan beam deflection board
Max. writing speed	20 MHz	20 MHz	6 MHz
Min. dwell time increment	1 ns	1 ns	< 100 ns
Beam blank control 5V TTL	✔	✔	✔
Proximity effect correction and 3D lithography	Optional	Optional	Optional
Advanced FIB patterning attributes (FLEXposure & GDSII patterning-on-image)	✔	✔	✔
Thermostabilization	✔	✔	–
Differential outputs	✔	–	–
Signal router	✔	–	–
End point detection	✔	–	–
Probe current meter	Optional	Optional	Optional
Beam blank booster (depending on microscope)	Optional	Optional	Optional
Universal lithography sample holder	Highly recommended	Highly recommended	Highly recommended

01-2020

Your challenge is our mission.

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