

Electron Beam Technology



## EBPG Plus

Performance that matters

Lithography with an extra Plus in precision, throughput, and automation

DEDICATED ELECTRON BEAM LITHOGRAPHY

RAITH  
NANOFABRICATION



The holistic design of the EBPG Plus meets the diverse performance requirements without compromise and maximizes application bandwidth for advanced nanolithography.

#### Top-class features for leading-edge EBL:

- Best signal quality, ultra-fast and low-noise system
- Extremely high beam current for high throughput
- Superb performance with world's best overlay specs
- Ultra-precise large-area patterning with unrivalled stitching values
- Excellent waferscale CD uniformity and long-term repeatability
- Unparalleled automatic calibration and job execution

# EBPG Plus Lithography Systems

## Technology for A+ performance

The EBPG Plus is an ultra-high-performance nanolithography system with full 200 mm writing capability. It is the system of choice in many of the world's leading universities, research centers, and manufacturing sites for a wide range of applications. Field-proven over generations, it plays an integral part in nanofabrication processes of all kinds.

The EBPG Plus transforms lithography progress into nanotechnology innovations and manufacturing output, pushing the boundaries of what is possible in modern nanofabrication.



### Application Performance

**Tune your devices: EBPG Plus offers best device performance at high yield**

With enhanced key specifications such as 5 nm overlay and 8 nm stitching, the EBPG Plus offers superior application results. From ultra-high resolution, accuracy, and uniformity for single- or multi-field applications over the full chip and wafer, to successful long-run exposures – the EBPG Plus delivers it. You can adapt the writing strategy to your design and directly expose even complex formula-based large-area patterns with no need for time-consuming creation of GDSII design files. The EBPG Plus's low-noise and high-throughput pattern generator transfers your ideas to the substrate with unmatched fidelity.

### Workflow Support

**Focus on your application: EBPG Plus simplifies lithography**

The EBPG Plus is known for its truly outstanding intuitive user interface. New users can operate the system independently and achieve first results after only a brief introduction. GenSys Beamer layout preprocessing software supports unique and proprietary functions for the EBPG Plus, including workflow automation right from pattern design. Advanced users benefit from powerful scripting. Full system automation and unmatched stability free users up from time-consuming system setup and repetitive manual recalibrations. The user-friendly pre-alignment station provides an easy and errorproof substrate setup. In the multi-user environment, EBPG Plus always works with your personalized system and parameter settings – even in a shared facility.

### Throughput

**Go! EBPG Plus delivers the highest throughput in the market**

The EBPG Plus offers the unique combination of a powerful and stable beam with up to 350 nA beam current and fully automated calibration and alignment procedures, ultrafast stage with short settling times, advanced fracturing capabilities, and Firebird multi core pattern processor technology. The result: the fastest EBL system even for complex applications. We removed all bottlenecks by providing automated system setup and self-calibration, fast beam switching between high and low currents, and a thermocontrol system for maximum position stability. Full 8" capability providing for a patterned area of up to 210 mm x 210 mm with waferscale pattern uniformity, a wide range of sample holders, the automated 10-holder loader, and a powerful job manager ensure high productivity, support unattended 24/7 operation, and deliver repeatable high-yield results.

### Partnership

**Benefit from Raith expertise: EBPG Plus is our commitment**

Raith is the market leader in direct-write Electron Beam Lithography. Half of our employees work in customer and application support or technical service, always looking after the needs of our users. We partner with our customers by providing pre-installation support, user trainings, and experienced service engineers located worldwide, as well as individual application support. Raith has been shaping the nanofabrication world for over 40 years and has built up the largest active user community in the field, organizing international user meetings, lithography training courses, tutorials, and webinars. Be a part of it and benefit from this community.

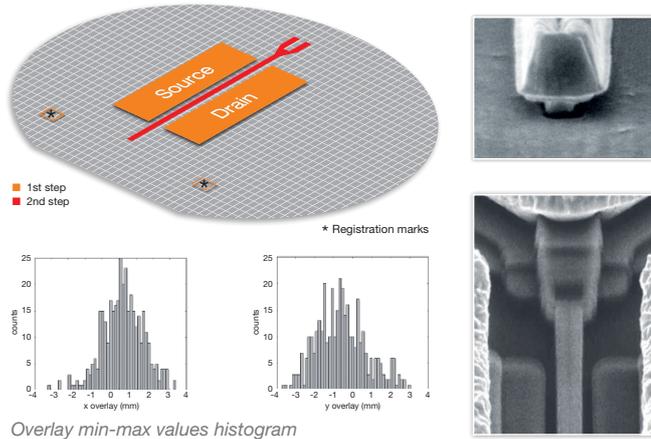
# Leading in applications

## Integrated harmonization of throughput, stability, fidelity and precision

The enhanced key specifications of the EBPG Plus now offer a new level of performance. Well-balanced system tuning ensures perfect interaction between the various tool performance dimensions to deliver optimum nanolithography results.

### 5 nm overlay for ultimate gate placement precision in HF devices

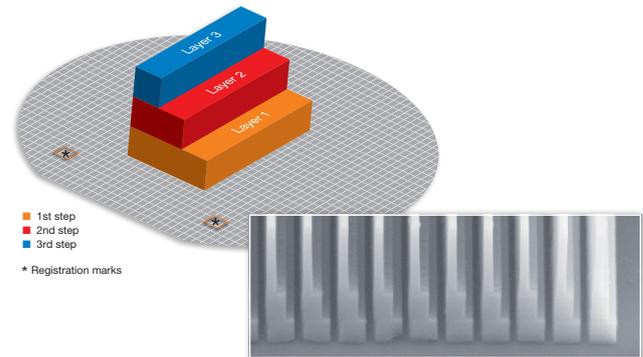
With excellent resolution and overlay better than 5 nm, the EBPG Plus writes highest-definition T-Gates for the ultra-fast high electron mobility transistors (HEMT) required for THz technology. The high-speed laser interferometer stage (up to 60 mm/s) ensures superior throughput for these sparse patterns. In combination with its longterm stability and waferscale uniformity, these features make the EBPG Plus the production tool of choice in the industry.



### Ultimate overlay, stitching and long term stability for large-area 3D stacked X-ray lenses

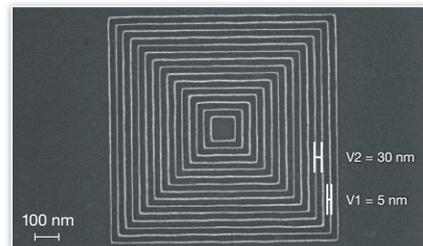
Large-area 3D stacked X-ray lenses consisting of nano-structures require three main prerequisites for good device performance. The EBPG Plus combines them all:

- 1 Ultimate stitching quality for sufficient lateral pattern placement accuracy.
- 2 Excellent overlay performance to perfectly match subsequent layers to previous ones in the 3D design
- 3 Excellent thermocontrol for maximum stability over multiple hours.



### Ultra-high resolution

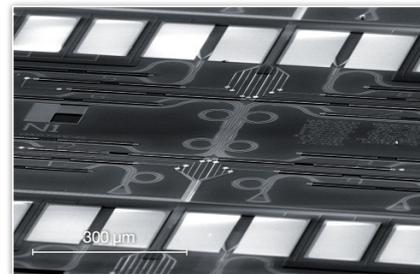
The EBPG provides excellent minimum linewidth quality down to 5 nm and below. The highly accurate focus and beam control, using automated height sensing, ensures linewidth homogeneity over the entire patterned area on wafer scale – even for large write fields.



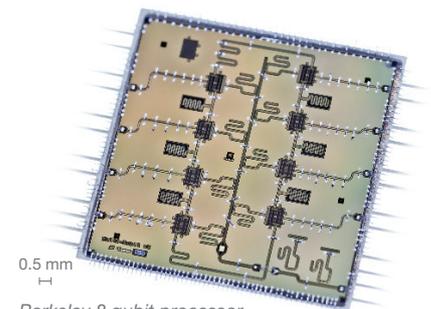
Test pattern with ultra-high resolution lines (5 nm) with 30 nm pitch. Pattern homogeneity is maintained over an entire wafer.

### State of the art devices for quantum technology

The EBPG Plus delivers the ultra-high resolution capabilities, fast and automatic switching of beam currents within minutes for fine and coarse structuring with <15 nm overlay, smart fracturing, smallest step sizes, excellent stitching, and overlay accuracy necessary for production of cutting-edge quantum devices. All these capabilities help to increase process time efficiency, result in smooth waveguides (see advanced fracturing at the right), and have come into play in the examples below.



Photonic CNOT quantum gate  
 Menno Poot, Yale University, USA



Berkeley 8 qubit processor  
 Fabrication: J. M. Kreikebaum, E&M design:  
 K. P. O'Brien

## More options for advanced applications

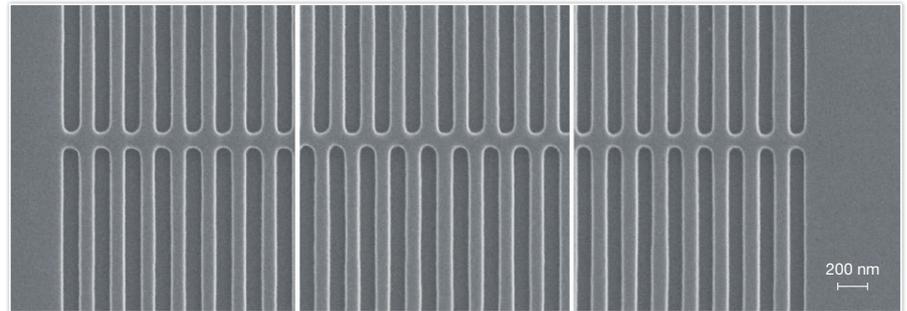
### Efficient design, data processing and fracturing modes

In-depth understanding and control of all EBL process parameters is essential to push nanofabrication limits. EBPG Plus supports highly efficient data processing and multiple approaches for adapting the exposure sequence to geometric properties of the design, resulting in highest pattern fidelity with minimum time and effort.

#### Sub-nm-pitch tuning for 5G DFB laser gratings

Electron beam lithography is the method of choice for manufacturing highly advanced laser gratings for the tight wavelength separation specifications required by current and upcoming telecom standards. The EBPG Plus achieves superior pitch control in the sub-Å regime and makes your production incredibly flexible – transfer a new design idea to production immediately!

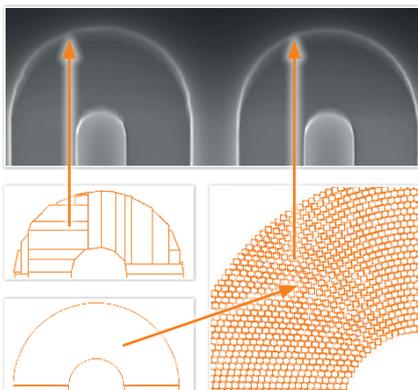
You can even use different pitches on the same wafer to shorten your development cycles. The EBPG Plus typically writes 20,000 laser devices per hour while maintaining waferscale uniformity, and reliably handles all your production demands.



Start, middle and end section of two 1 mm long gratings of 5,000 and 4,999 lines with periods of 200.000 nm and 200.040 nm. The tiny 40 pm period difference is clearly visible in the middle section as a half period phase shift. The pitch variation was measured with a Raith CHIPSCANNER.

#### Advanced fracturing for low-loss photonic waveguides

Low loss waveguides are key elements for photonic integrated circuits (PICs). The EBPG Plus has an ultra-low noise pattern generator that supports new advanced fracturing modes to generate smooth waveguides (conventional and tapered) with lowest line-edge roughness. High-performance large-area PICs can be manufactured rapidly thanks to excellent stitch results.

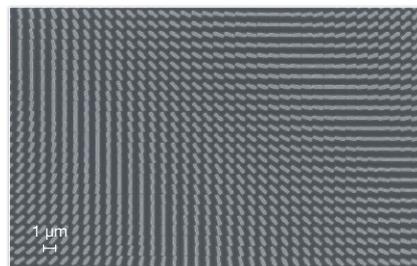


#### Throughput scales with beam current

Applying higher beam currents can save a lot of exposure time. In conjunction with the high-speed pattern generator, the EBPG Plus can apply the very small dwell times required for exposures with up to 350 nA beam current.

#### Metalens and large AR/VR gratings with Firebird and algorithmic pattern generation

High-resolution Electron Beam Lithography is basically well suited for creating small sub-wavelength-sized elements of metalenses with very high fidelity. However, the specific requirements can pose a significant challenge for EBL systems and their data preparation software. EBPG Plus's data processing solutions can handle the huge number of elements and achieve perfect fidelity for perfect optical performance of metalenses. Algorithmic patterning technology supports convenient generation of exposure data directly using proprietary shape elements and without conventional data files like GDSII. Special fracturing features and Firebird, our new EBPG multicore pattern processor technology, ensure ultimate pattern fidelity and a speedier process. TB-sized designs that were previously unattainable can now be produced effortlessly.



Above and right: Centimeter scale metasurface structure – shapes and related exposure shot sequences are aligned to specific varying design geometries resulting in highest pattern fidelity

Left: Line edge smoothness and throughput improvement by use of the high resolution fracturing mode

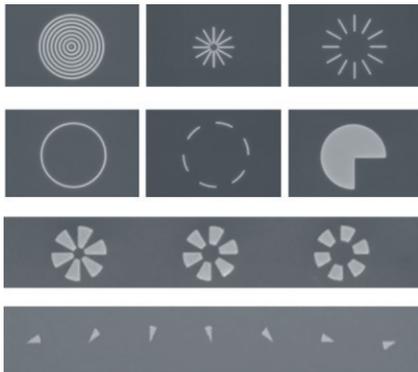
# Facilitating workflows

## Smart hardware and software support at every step

Lithography has evolved over many decades. Modern Electron Beam Lithography is its most sophisticated form, reaching nanometer precision. For ambitious EBL applications to succeed, a complex process involving numerous adjustments must be carried out. The EBPG Plus helps you to overcome all hurdles.

### 1. Data preparation: good data in – good and fast results out

Unique proprietary functions of the EBPG Plus are supported in GenISys BEAMER, including workflow automation right from pattern design. Growing demands for pattern fidelity and throughput call for additional specifics from the EBPG Plus. In response, a host of new elementary shapes like circle, cube, polygon, and derivatives thereof have been developed. Complex designs can reach several 100 GB and require smart data handling. Firebird, the new EBPG Plus multicore pattern processor technology, handles them with ease. Other applications such as large metalenses, AR/ VR gratings, and non-repetitive OVD, DOE, or hologram patterns, can easily result in TB file sizes and may cause extensive fracturing and data transfer overhead. For such patterns, EBPG users can use algorithmic patterning instead of layout files. Here, designs and corresponding shapes are directly created in the pattern generator using a programming code. This significantly reduces total exposure process time.



EBPG Plus supports a wide range of configurable primitive shapes

### 2. Automated wafer and multiple sample exposure

The EBPG Plus provides an unrivalled degree of automation. Where smart alignment and calibration routines are involved, multiple exposure jobs can be automatically executed on the same sample/wafer or on different samples/wafers mounted on a multiple sample holder or separate holders.

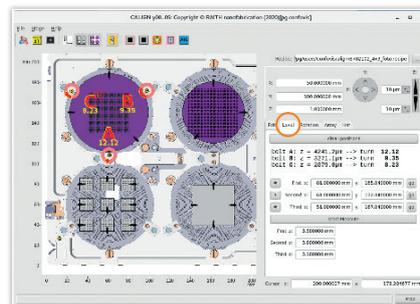


Easy to operate graphical user interface

### 3. Sample alignment made quick and easy

The new workflow of sample prealignment and related job setup is ergonomic and reliable, and improves efficiency. A new advanced confocal optical alignment microscope with motorized stage, separate screen, and digital connection to the EBPG Plus system makes sample alignment convenient, fast, and error-free. Further benefits are:

- Intuitive and smart software wizard supporting sample leveling and rotation
- Efficient user training and sample alignment monitoring on-screen, particularly convenient for eye-glasses wearers
- Digital alignment data transfer to and remote control of the EBPG Plus system
- Simple navigation and speed-up of alignment process thanks to the superfast motorized stage
- Scripting capabilities and recipes for advanced alignment routines
- Additional microscope capabilities for analytical purposes, such as imaging of transparent samples and 3D imaging



Software wizard supporting substrate leveling



Compact alignment station setup

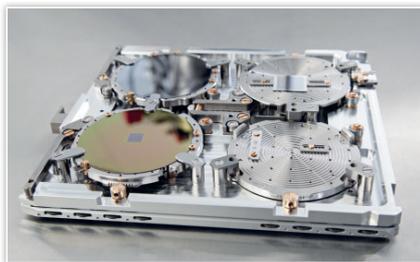
# Automating workflows

## Our building blocks for highest productivity

Highest-quality results require optimum system control and precise calibration processes. EBPG takes away the effort and provides comprehensive and fully automated self calibration routines at every process step.

### 4. Sample holders

Raith offers a wide range of holders for every purpose and all wafer and mask sizes. Multi-wafer holders increase throughput, whereas flexible piece-part holders enable processing of many samples with varying size and thicknesses in a single job. Choose between top-reference and bottom-reference holders to process fragile III/V materials like InP. Customized holders are also available on request.



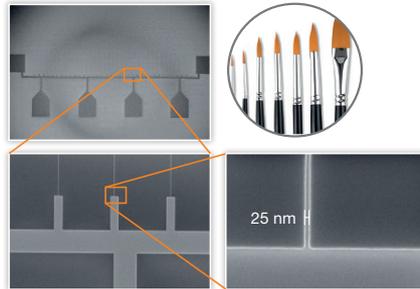
Multi-sample holder

### 5. Sample load and immediate exposure job start

EBPG Plus comprises a thermocalibration system using multiple thermosensors on sensitive EBPG Plus subsystems. As a result, temperature gradients in the system can be minimized, thus avoiding long waiting times before exposure start.

### 6. Automatic system self-calibration and exposure

No need for users to supervise the system or acknowledge any calibration processes, system parameter settings, or alignment procedures for exposure. The EBPG Plus runs completely unattended and fully automatic self-calibration routines directly prior to exposure. Exposures are controlled by the low-noise high-speed pattern

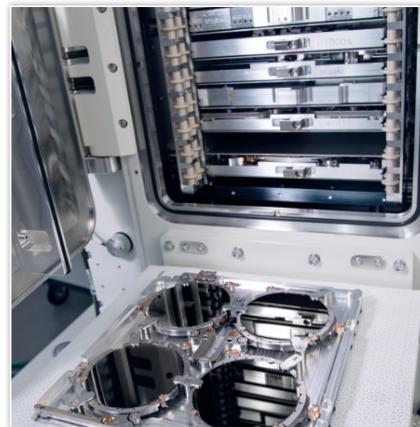


Automatically switch from 1 nA to 80 nA and immediately continue writing

generator, offering ultimate signal quality without compromising on precision or speed. A motorized aperture changer can switch between various beam currents in fully automated operation for complex jobs involving split exposures with fine and coarse structures.

### 7. Efficient batch processing

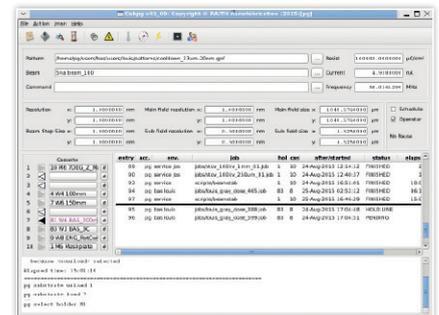
A high-throughput site, be it for production jobs running on many wafers or a multi-user facility running many different jobs, needs the right tool to keep up with demand. The EBPG Plus with the 10x holder airlock enables 10 holders with up to 40 wafers (or even more piece parts) to be loaded, thus allowing the tool to be fully utilized even at nights or weekends without operator



attendance in batch mode. The job queue function even allows new jobs to be added while the tool is running or priorities and setups of waiting jobs to be adjusted – both at the tool, or remotely from anywhere in your network.

### 8. Multi-user environment

The EBPG Plus software stores all settings including personalized jobs and parameters, so operators always find the tools they are used to without inconveniencing other users. Different user levels are supported such that significant and sensitive parameters can only be accessed by tool owners or service engineers.



Multi-user Jobmanager

### 9. Multiple choices

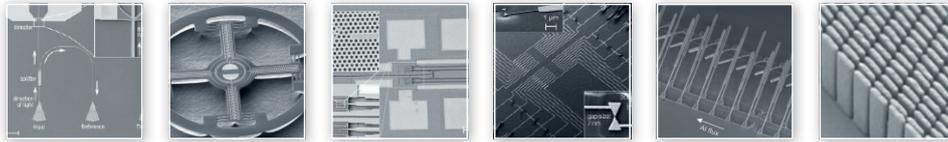
EBPG Plus offers the choice of using the intuitive graphical user interface guiding through the job setup or to use the powerful command line interface – or both. An operator can switch between modes to open or edit a job. An interface to Python and C libraries accesses even more functions like mark detection and processing or script-based job creation to start complex jobs quick and error-free. Jobs can be verified in advance with the EBPG Plus simulator. For a predictable operation, different fracturing and exposure settings can be tested without taking up valuable system time.

# EBPG Plus Series

## Performance that matters

### Product features

- Acceleration voltage 100kV and 50kV
- Overlay  $\leq 5$  nm
- Stitching  $\leq 8$  nm
- Maximum beam current 350 nA
- Full 8" or 6" exposure, 210 mm x 210 mm or 155 mm x 155 mm stage travel
- Automated 10-holder airlock



### Partnership

#### Support and service worldwide

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

#### High quality service worldwide

Wherever you are, a service engineer is always nearby. Raith has locally based engineers and spare parts in all major regions.

Regular training is held at the factory to ensure consistent levels of expertise worldwide. The EBPG Plus is a modular system that can be field-upgraded later if your requirements change. This safeguards your long-term investment in the EBL system in combination with our unique long term full service and spare part availability guarantee.

#### Trainings

We help you benefit from your EBL system quickly with comprehensive onsite training included at every EBPG Plus 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 re-train 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 lithography user and support network in the field!**

## Sales

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NANOFABRICATION