Raith

INNOVATIVE SOLUTIONS FOR NANOFABRICATION AND SEMICONDUCTOR NAVIGATION

Technical Description
e_LiNE



Ultra-High Resolution E-Beam Lithography and Nanoengineering Workstation

Technical Description

Product: *e_LiNE*

Document number: 07-9-9912-404-1.10

Date generated: Thursday, September 06, 2007

The information in this document should not be copied or its contents relayed to a third party without written permission from Raith GmbH or their accredited representative.

Advancements and improvements to the instrument and available options are an ongoing process. As a result, some specifications and some information regarding the product are subject to change or modification without notice.

All statements, information, and recommendations in this document have been carefully prepared and are believed to be accurate and complete. If doubts exist about any detail or additional information is necessary, please inquire Raith GmbH or their accredited representative.

Raith GmbH
Hauert 18
44227 Dortmund
Germany

Tel.: +49 231 97 50 00 – 0
Fax.: +49 231 97 50 00 – 5
WWW: www.raith.com

Windows and Windows XP Professional are the registered trademark of Microsoft, Inc.

GDSII is the registered trademark of Calma GE.

1 Introduction 5
2 System description 8
2.1 General overview 8
2.2 Electron optical column 8
2.3 Secondary electron detectors 9
2.4 Deflection system 9
2.5 Scan generation 9
2.6 Laser interferometer stage 11
2.7 Sample handling 12
2.8 Chamber and options 12
2.9 Vacuum system 13
2.10 Control data system 13
2.11 User interface and system control software 13
2.12 Training 17
3 *e_LiNE* specifications 19
3.1 Electron beam column and optics 19
3.2 Secondary electron detectors 20
3.3 Deflection system 20
3.4 Scan generation 21
3.5 Laser interferometer stage 23
3.6 Sample handling 24
3.7 Chamber and options 25
3.8 Chamber and vacuum system 26
3.9 Control data system 27
3.10 User interface and system control software 28
4 Acceptance specifications 32
4.1 Qualification test criteria 32
4.2 Qualification test procedures 33
5 Installation requirements 36
5.1 Electrical services 36
5.2 Gas services 37
5.3 Cooling requirements 37
5.4 Room conditions 37
5.5 Room layout 39

5.6 Transport and packing **39**
5.7 Summary of utility and environmental requirements **40**

1 Introduction

The *e_LiNE* is the most versatile e-beam system for uncompromised nanostructuring using for example lithography, etching and deposition processes, or direct manipulation. No other nanoengineering system is as cost effective, combining high performance, exceptional versatility, and ease of use. The versatility is a result of the many options dedicated for nanoengineering applications. The extent to which an *e_LiNE* can be customized is only limited by the needs for the following options:

- Gas-injection system with up to 5 nozzles to inject gases for electron-beam induced deposition (EBID) and etching.
- Up to 4 needles for electrical probing with < 150 nm positioning.
- EDX system and/or BSE detector.
- Height sensing to keep the sample in focus automatically.
- Microscope with macro-tele lens and projection correction for navigation.
- A loadlock for applications where surface cleanliness is critical.

The *e_LiNE* electron column comprises the ultimate in electron optical development. The thermal field emission filament technology offers ultra-high resolution capabilities in all operation modes. A unique cross-over-free beam path gives extremely high beam current density and exceedingly low aberrations. This results in top quality lithography performance. In addition, the *e_LiNE* electron optics offers unsurpassed low voltage inspection and metrology below 1 keV.

Software integration is the key asset of the *e_LiNE*. No other system can match the Raith software suite in terms of flexibility, ease of use and safety in a multi-user environment. The Raith software platform continues to improve and evolve, through years of continued development and useful customer feed-back. The system operates under two high-end PCs utilizing the Windows XP Professional operating system.

The *e_LiNE* is completely built-up and fully tested at the Raith factory. The system undergoes two complete acceptance procedures: one before it leaves the factory and the other on-site after the instrument has been installed. The system is designed and intended for “turnkey” operation once it is delivered and installed. A smooth installation and setup is guaranteed since all mechanical, electronic, and software components are under the control of a single vendor.

The main target applications for this tool are:

- If corresponding options are attached, electron-beam induced deposition, in-situ electrical measurements, EDX, and more to come.
- Full coverage of 4" masks and wafers, i.e. 100 mm by 100 mm travel range.
- Direct write applications like III/V and II/VI compound semiconductor devices as well as next generation CMOS devices with sub-50-nm structure sizes.

- Process development for next generation sub-50-nm lithography, e.g. EUV.
- Fully automated Mix and Match operations within selected dies or over entire wafers and masks up to the full 100 mm by 100 mm travel range.
- Nanolithography of mesoscopic devices, e.g. Josephson junctions, and quantum device fabrication, e.g. single electron transistors. General ultra-high resolution structuring.
- Integrated optics, e.g. Photonic Crystals, beam splitters, gratings, distributed feedback (DFB) lasers, and waveguides including curved structures.
- Scanning-electron-based metrology, inspection, and sample navigation.

The main hardware features of this tool are:

- Ultra-high resolution, thermal field emission Schottky-source.
- Patented electron optics: 8 kV beam booster giving state-of-the-art low kV performance. Cross-over free beam path with extremely high beam current density and compound electromagnetic-electrostatic immersion lens for exceedingly low beam aberrations.
- Fully digital electron optics column with beam energy selectable between 100 V – 30 kV and a wide range of selectable writing field sizes.
- Fast electrostatic beam blanking.
- Laser-interferometer controlled stage with 2 nm positioning resolution over 100 mm by 100 mm travel range.
- Stage controlled in closed-loop mode with DC-motors for the highest speed and shift piezos for the finest positioning control at all column settings. A calibration of stage movement or standard is not required.
- Kinematic, stress-free, 3-point sample mounting with several optional sample holders like, wafer and mask holders, rotation-tilt inspection modules, etc.
- Optional automated height sensing for automated focus setting using the objective lens or stage z-travel.
- 10 MHz high speed Pattern Generator with digital signal processor technology and dynamic correction. Writing speed up to 10 MHz, minimum dwell time increment of 1 ns and 0.1 nm addressing increment.
- Dry vacuum system with optional loadlock.

The main software features are:

- Flexible control of system with two PCs.
- Multi-user software platform for lithography patterning as well as metrology runs.
- Interface with scripting language for extensive automation and customizing.

- Pattern generation: GDSII hierarchical editor with dose assignment. Flexible graphical editor for "any shape design" with fully integrated proximity effect correction and post-processing.
- Lithography functions: esy-to-learn Windows-based exposure control with the capability for automation.
- Metrology functions: line width, pitch detection, etc. methods can be combined to execute intra-field and long-range measurements with laser interferometer accuracy.
- Second software license for off-line PC data preparation.

2 System description

2.1 General overview

The *e_LiNE* consists of the following subsystems:

- The patented electron optical column with Schottky thermionic field emission filament.
- Deflection system with scan generators for lithography and scanning-electron-based imaging.
- High precision X-Y-Z stage with laser interferometer for X-Y positioning.
- High performance options such as automated height sensing.
- Vacuum system and plinth.
- PC-based lithography user interface. Process control of lithography applications, scanning-electron-based imaging and functions for metrology.
- Configurable Nanoengineering tool set as an option.

The *e_LiNE* consists of a self standing plinth which supports the chamber, stage, and electron optical system as well as the high vacuum system, high voltage units and system control electronics. It is equipped with an integrated vibration isolation system. An optional anti-vibration platform and an acoustic enclosure are available to reduce the effect of poor environments.

The column and lithography control PC systems are located at a console desk. The small footprint of the machine offers it's advantageous when clean room space is at a premium.

2.2 Electron optical column

The *e_LiNE* has an ultra-high resolution, solid and robust electron optical column. The column is carefully shielded to prevent interferences from stray electro-magnetic fields. The Schottky thermionic field emitter combines high beam brightness with high stability. At short working distances, the column and electron source are designed to provide a Gaussian beam of 2 nm size at 20 kV with a probe current of 300 pA. Combining these two quantities, one can easily calculate a beam current density of 7500 A/cm² at 20 kV at this smallest beam size. At the same time, the beam current is stabilized, exhibiting a drift less than 0.5% in 8 hours.

The patented electron optics with a beam booster ensures that the beam voltage never drops below 8 kV until reaching the final objective lens. The cross-over free design is also an unique feature of innovative column. In addition, aberrations are markedly reduced allowing the *e_LiNE* to deliver excellent beam size performance at low voltages. Under optimum conditions, a 4 nm beam size at 1 kV is possible. The relevance of this feature is most pronounced when considering

applications in which the proximity effect can be a limiting factor in the desired structure resolution.

Many parameters can be freely changed and optimized by the user. Column parameters such as beam voltage can be freely selected within the range 100 V to 30 kV in steps of 10 V. The working distance can also be freely adjusted. Six beam defining aperture settings are easily selected through the software interface. The apertures are changed electromagnetically providing a current range from 5 pA to approximately 20 nA. The wide selection of available parameters makes the *e_LiNE* an ideal choice for a wide range of patterning requirements in research and development.

The gun head is differentially pumped and protected by an automated gun isolation valve, which significantly increases the life-time of the filament.

All settings are digitally controlled and can be stored for future recall.

2.3 Secondary electron detectors

The *e_LiNE* comes with two secondary electron detectors. The patented in-lens detector is mounted into the column and provides shadow- and distortion-free images for voltages below 20 kV. The second detector is an off-axis, Everhart-Thornley secondary electron detector. Contrast and brightness can be set automatically as well as manually.

2.4 Deflection system

The write field size is continuously variable from 0.5 µm to 2 mm, controlled directly from the lithography computer. Magnification settings of approximately 20 times to 1,000,000 times are possible. Field errors such as rotation, orthogonality, and scaling are compensated.

Digital addressing in the writing field is possible up to 16-bit by 16-bit. The scan coils of the column can be driven via the digital pattern generator to a maximum speed of 10 MHz using dynamic corrections for accurate pattern placement.

An electrostatic beam blanker is located under the accelerating anode and is synchronized to the exposure process via the digital pattern generator unit.

2.5 Scan generation

There are two methods of scan generation: the digital pattern generator, which is primarily used for lithography, and an independent raster scan generator used for imaging.

2.5.1 Lithography digital pattern generator

The *e_LiNE* digital pattern generator (DPG) is based on digital signal processor (DSP) technology with 33 MHz clock frequency. The data are transmitted over a fast, SCSI-like data link of up to 5 MB/s and cached within an internal memory of 32 kBytes static RAM. In addition, the core exposure program code is uploaded with each program start, making it easy to keep the system up-to-date with the most recent software developments.

Excellent analogue signal quality is ensured by signal deglitching, shielding against high frequency noise, and integrated temperature control.

Several operating modes are available. By default, the system operates in vector scan mode with the possibility to fill trapezoids in a meander mode or in a line-by-line mode. A second mode allows the operator to draw arbitrarily shaped lines and to address single dots with random addressing. In addition, for perfectly round elements a circular mode was implemented, which is ideal for photonic crystals. A raster scan mode is also available. It can be used to expose images in a bit-by-bit way. As a result of the vector scan mode, elements of any shape and any orientation can be exposed. This includes rectangles, triangles, any polygons, as well as special elements like randomly distributed dots and lines or curves of any orientation. For circles, one can choose to use the circular mode or fracture them into trapezoids. Text and mathematically generated elements complete the set of possible shapes.

Digital addressing in the writing field is possible up to a maximum resolution of 16-bit by 16-bit with a minimum increment of 0.1 nm. The software automatically calculates a metric step size to ensure the best fit to the design data. For example, in a 100 µm write field the minimum step size is 1.6 nm and the step size can be set to any step size larger than this in 0.1 nm increments.

The scan coils of the column can be driven via the DPG to a maximum speed of 10 MHz. The exposure dwell time can range from 100 nsec up to 500 msec in 1 nsec increments. Maximum flexibility is then available for different resist types and sensitivities. Dose levels are applied to all structures in the pattern, in the form of a factor or ratio. The dose factor can be controlled almost continuously in the range from 0.001 to 17797.500. This is especially important for proximity effect corrections.

The DPG also controls the electrostatic beam blanker. Blanking occurs between individual elements of exposed structures, e.g. fractured trapezoids or line segments, and at the end of an exposure sequence. In addition, the beam blanker is used in the process of data acquisition, e.g. during flyback.

Writing field alignment to compensate for rotation, orthogonality, and zoom corrections is done with 6 multiplying, 16-bit D/A converters. This hardware design assures that the resolution and speed of an exposure are not degraded by making software corrections. For example, this has the important consequence that for all rotations and for all orthogonalities, the minimum step size can be used. Likewise, stair-case effects do not exist as in some form of software alignment routines. In addition, rotation and orthogonality corrections are indispensable for an exposure having several write fields stitched together. The process of the write-field adjustment itself can be performed automatically utilizing the laser interferometer, or the values can be entered

manually. In total, an electronic alignment fully implemented by the hardware guarantees high pattern fidelity.

The DPG is also capable of recording images and intensity profiles along lines. The maximum speed is 4 images/sec with 256×256 pixel resolution and no signal averaging. Intensity profiles along lines, i.e. waveforms, can be recorded at any angle with a maximum signal resolution of 12 bit.

2.5.2 Scanning-electron-based imaging and display functions

For scanning-electron-based imaging, the *e_LiNE* provides raster scans with 15 non-interlaced scan speeds and a TV rate scan with optional line-by-line or frame averaging. It is also possible to scan a reduced raster window, adjustable in both size and position, for fine adjustments of stigmation, focus, etc. A spot mode with a freely defined position is also available. The pixel resolution of images can vary from 512 × 384 to 3072 × 2304 with up to 16-bit.

The scanning-electron-based images are completely processed on a computer running Windows XP Professional and are displayed on a standard PC LCD monitor.

2.6 Laser interferometer stage

An X-Y-Z stage utilizing a laser interferometer in the X-Y plane provides area coverage of a 4" wafer, i.e. 100 mm by 100 mm travel range.

In the X- and Y-direction, a sophisticated and superior design combines DC motors and shift piezos mounted on spindles. The DC motors are used for coarse positioning within a few hundreds of nm, whereas the piezos are used for fine adjustment. The associated control electronics drives the stage in a closed loop mode and provides a resolution of 2 nm. The advantages of combining DC-motors with piezos are:

- The positioning resolution of 2 nm can be achieved without any calibration, regardless of the write field size, the field of view, or working distance. This approach supercedes the old and inflexible technique of applying the fine-adjustment to the beam.
- This drive technology allows smooth movements at all operation modes and produces no heat, even when stopped. Therefore, temperature changes and induced position drifts do not exist.

The Z-axis is also equipped with a DC motor. The laser signal for the XY position control is guided with a fiber optics into the interferometer. This enables the free selection of the desired working distance, with the full accuracy of the laser interferometer, over the complete Z-range of 30 mm. This design is ideal for exposures with large working distances and nanoengineering experiments.

2.7 Sample handling

Sample loading/unloading is done quickly and easily be securing the samples directly onto sample holder. To minimize the time the chamber is open, samples can be mounted in an “off-line” fashion onto a sample holder provided with the system. The sample holder can then be quickly placed onto a kinematic mounting platform with three ceramic alignment balls on top of the stage. The sample holders itself is equipped with adjustable Sapphire inserts for leveling and long-term position stability. Additional electrical contacts are standard on the sample holder.

A universal sample holder for wafers up to 2", small samples and stubs comes with the system. Additional sample holders, including holders for all standard wafers and mask plates up to 4" size as well as a rotation-tilt module for inspection purposes, can be ordered as options. Custom-made sample holders are available on request.

Calibration marks can be mounted on the sample holder for automatic field calibration and stage drift corrections. Using automated procedures, automatic field calibration and drift corrections can be referenced. A Faraday cup is provided on the sample holder for beam current measurement. Variations in probe current can be measured and automatically compensated for via the exposure dwell time.

2.8 Chamber and options

The design of the *e_LiNE* system combines its highest electron-beam resolution with an unsurpassed versatility, without any compromises. An **infra-red CCD chamber camera** has been integrated for safe sample handling and coarse navigation. One **in-lens detector** and an additional **SE2 detector** are standard. This versatility is a direct result of careful system design, so that the following options can be adapted to the system.

- **Optical microscope with tele-macro lens:** Integrated optical macro optics for observation of the sample surface at the beam position and for pre-positioning, in particular useful to allow direct stage addressing in the image as well as careful positioning of the nanomanipulators and the gas injection system. The lens system includes a projection corrected optical arrangement. Option, see separate description.
- **Gas injection system** with up to 5 nozzles for ion beam induced deposition and etching. Option, see separate description.
- Up to 4 digitally controlled **nanomanipulators**, each with < 100 nm positioning under secondary electron view, e.g. for electrical probing. Option, see separate description.
- **EDX system** and **BSE detector**. Option, see separate description.
- **Height sensing** to automatically keep the sample in focus. Option, see separate description.
- A **Loadlock** for applications where surface cleanliness is critical.

2.9 Vacuum system

The oil-free high vacuum system is automatically controlled and monitored via the control computers. An ion getter pump maintains the gun pressure while an automatically operated pneumatic column isolation valve separates the gun from the chamber. The main chamber is pumped by a 240 l/s turbomolecular pump that gives a working vacuum better than $2 \cdot 10^{-6}$ mbar. The turbo pump is backed by a dry vacuum pre-pump to avoid sample contamination.

Vacuum readings, vacuum ready and valve status are shown in the vacuum menu and optionally in the status menu of the column control. Penning gauges are used for high vacuum measurement.

2.10 Control data system

The *e_LiNE* comes with two state-of-the-art computers. The first computer is used to perform all the tasks for an exposure, i.e. layout editing, lithography job setup, starting exposures, and subsequent metrology measurements. The second computer controls the column settings and is used for scanning-electron-based imaging, i.e. acquiring and storing images. Both computers run under Windows XP Professional and come with large flat panel displays. Digital control of all parameters is accessible through one keyboard and one mouse.

2.11 User interface and system control software

The *e_LiNE* lithography software suite is graphically based and includes a multi-user management. The software consists of a variety of functional modules that also provide a seamless link to the system control.

2.11.1 Lithography capabilities

Wide-ranging applications are reflected in the software user interface. First, the design can easily vary from single structures in isolated, freely selectable writing fields up to large, complicated exposures composed of multiple writing fields. Second, the exposures can be single-level direct write applications up to wafer-scale Mix & Match tasks. Larger areas are automatically fractured into corresponding equally sized stitching fields. And finally, the system can be customized for specific applications using its automation capabilities, e.g. exposing different parts of one design and changing column and other parameters in between.

Multi-user platform

The system is designed for multi-user access. The platform supports distinct users, each having their own files, settings, and complete tasks. In addition to this, the system settings are stored so

that the user can start the software from the last "state". Each user can have various desktop settings, e.g. windows arrangements, according to their preferences.

Automation

Automation capabilities are embedded into the Raith software infrastructure, allowing the user to create their own application-specific tasks using Microsoft scripting language. The syntax is easy to handle and straightforward to use. Storing and recalling these user-defined scripts allows for powerful job automation.

Without learning a scripting language, a sequence of tasks is generated simply by using the drag-and-drop functionality incorporated into the *e_LiNE* software. These tasks can be exposures, metrology measurements, simple drive commands, and even execution of macros. In addition, between each exposure step it is possible to change various parameters, e.g. the exposure dose, making it easy to run unattended batch lithography or metrology jobs. The sequence of tasks can be stored and recalled for later use.

Exposure module

The central part of the software is the exposure module for exposing all types of design data directly from the extended GDSII database.

The main exposure mode is vector scan. Structures can be exposed line-by-line or in meander mode. The direction of the scan can also be selected in either X or Y directions, or automatically chosen by the system according to the geometry and orientation of the structure. Special exposure modes can be chosen such as single-pixel lines, i.e. exposed lines having a width of one pixel, as well as single dots. These can be exposed in any orientation. Additional exposure schemes exist for special applications: exposing bit maps in raster mode, e.g. for holograms, and circular mode, e.g. for zone lenses and photonic crystals.

Mix & Match - mixing optical lithography and matching e-beam lithography has been employed for many years. Taking advantage of optical lithography throughput capabilities, Mix & Match adds the full benefits that an e-beam system can supply, in particular ultra-high resolution and precise pattern placement. There is no limitation to the size of the optical pattern to which the e-beam structures must be matched in order to define the necessary devices. This functionality is summarized in the module **write field and overlay alignment**. The module includes the scanning, graphical representation and evaluation of up to four marks per write field, with operator assisted or fully automatic field calibration.

Pattern placement follows via automatic local mark registration or relying only on accurate stage positioning, or a combination of both. This registration functionality is covered by the **sample to stage alignment**. Using an automated or manual procedure up to three global marks can be scanned and the coordinate transformation is calculated automatically.

Both alignments take advantage of the **mark recognition** functionality. This part of the software provides the possibility to define and to scan mark fields with any pixel size. To evaluate the recorded intensity, the same functions as for metrology are used.

In addition, the ability exists to actively **correct the dwell time** by measuring the beam current at user-defined places within the exposure sequence.

Field stitching is generally required for defining larger scale patterns covering an area on the substrate of the order of a few millimeters to many 10's of millimeters. A typical application is the generation of optical devices like gratings, filters, and zone lenses. Fracturing the layout into write fields is then made in real-time or during a pre-processing run, reducing overhead time in large area exposure sequences. The module for **automatic field stitching** is integrated into the exposure module and allows automatic fracturing of large designs into smaller write fields.

GDSII editor and viewer

A significant software component of the *e_LiNE* software suite is the GDSII database viewer and editor. Hence, structures can be designed and exposed within the same software platform making it unnecessary to switch between different software packages for multiple tasks. Naturally, both the editor and the viewer possess a graphical interface.

The GDSII database is hierarchically organized. The hierarchical format can handle large files up to 2 GByte, storing them efficiently, and hence allows flexible and extremely fast data handling. In addition to pattern creation, the editor handles importing files in AutoCAD DXF, ASCII, or CIF format.

The software uses a special extension to set freely selectable dose factors for each structural element. The GDSII editor is also utilized in the exposure sequence. Patterns are fractured automatically into basic trapezoid-shaped elements as the data is processed for the Pattern Generator.

The extended GDSII format also enables the user to automatically insert updateable text fields, e.g. time and date, similar to popular office programs.

Extensive post processing features are available. These features include shrink, overlaps out, and frame all, to aid the optimization of pattern processing. The various functions can be applied on a hierarchical level.

Stage and column control

The integration of stage and column settings by remote control functions greatly increases the overall functionality of the instrument. The software package contains various modules that give greater control over the column's functions and of the sample stage.

From the lithography computer it is possible to set all pertinent column parameters: These parameters include beam alignments, lens settings, beam voltage, and current settings. They can also be freely chosen and stored along with all other settings independently in a multi-user environment.

For the stage absolute and relative addressing commands are available. Two different coordinate transformations support the addressing in stage coordinates or sample coordinates. The current

stage position is continuously updated on the PC's display screen. Positions can be entered and stored within a list for recall operations.

Proximity effect correction software package

Complex, high quality e-beam patterns often require proximity effect correction. This is especially important for closely packed, differently sized pattern elements. The *e_LiNE* software suite includes a proximity effect module. This unique tool has been specifically designed for nanolithography and gives the benefits of accurate pattern exposure in an easy and quick manner. This alleviates any lengthy, time consuming, and sometimes impossible guesswork.

The algorithm divides an originally designed pattern automatically into substructures and assigns the correct dose to each. Two modes are possible: to correct for an evenly distributed dose or the same dimension of all elements throughout the complete pattern. Alternatively, the pattern can be subdivided by framing routines and the optimum dose will be assigned to each new structure element by the proximity effect correction module. An included simulation feature is a valuable tool to inspect the pattern with respect to proximity effects. The results can be directly used for small redesigns of a critical pattern by means of the integrated graphical editor.

2.11.2 Scanning-electron-based imaging capabilities

Separate scanning-electron-based imaging software comes with the *e_LiNE* system. It provides all the functions for recording, modifying, and saving the scanning-electron-based images. The software runs on a Windows XP Professional platform. The images are aquired in a digital format, allowing digital processing. Standard display possibilities include: split screen view, display using pseudo colors, overlays of scaling bars, column settings, and user-defined text. The use of standard computer technology also makes it easy to archive and print images.

2.11.3 Wafer and CAD layout navigation

Navigation schemes and their associated alignment routines are available for quick and easy review of written structures and complete patterns. This feature is particularly useful in the handling of wafers or masks to avoid time consuming and stressful manual searching for particular structures. Or it can be used as an aid to visualize the relative locations of an exposure sequence.

Wafer layouts can be generated or optionally imported for easy navigation. Notch, flat, and chip numbering can be defined. CAD layout data can be superimposed onto scanning-electron-based images for navigation purposes.

2.11.4 Metrology

Metrology modules for accurate measurement of previously written nanostructures are part of the delivered system and are also used for internal system characterization. With these enormous capabilities, these functions become very important when using the *e_LiNE* for process control. The metrology modules can be used for measurements on any substrate suitable for scanning-electron-based imaging.

Features can be measured using routines for short-range, i.e. within field of view, and long-range measurements utilizing the highly precise laser stage. Edge detection algorithms are applied to the intensity profiles in order to yield precise coordinates or pitches. 1-dimensional and 2-dimensional cross-correlation algorithms are available for very robust position detections on difficult to image samples.

Results are graphically displayed and can be exported to EXCEL or ASCII file formats.

2.11.5 Surface Editor

As an add-on module, the Surface Editor enables milling or deposition of structures by direct definition without any additional alignment task. In the edit mode, objects are drawn and placed directly on-top-of an acquired image. The following objects are available: boxes, polygons, lines, points, and wedges of all angles. Besides dwell time and step size it is also possible to define the number of loops and how often a line is repeated. The process time can be calculated in advance.

2.11.6 Protocol and error handling

Actions performed on the system are documented by a rolling protocol and saved to a logger file. This also includes the documentation of all warnings and error messages within a working session. Critical errors are presented to the operator for evaluation and potential corrective action.

2.11.7 Windows-based help function

The reference manual can be accessed through the help menus and modules are linked directly to their related help files. These help files inform the user about the functionality, syntax and operation of the activated function. In addition to the integrated help menus, the system is delivered with a detailed operation manual in hardcopy and software formats.

2.12 Training

Typically five days will be used for detailed training of the various features of *e_LiNE*. On request it is possible to give talks covering all aspects of electron-beam lithography. The hands-

on training will be done using the Raith standard training pattern which is available on request. It covers all aspects of possible applications, like the various alignment procedures, stitching overlay, ultra-high resolution and much more. A detailed overview is available on request. The training covers also the various tasks to administrate the tool, like bake-out procedures, creating user accounts, etc.

3 e_*LiNE* specifications

3.1 Electron beam column and optics

Electron source	Schottky field emitter ZrO/W.
Operating vacuum of source	$< 1 \cdot 10^{-8}$ mbar.
Filament life	5000 hours typical.
Beam energy range	100 V to 30 kV in 10 V steps.
Beam current range	Selectable between approximately 5 pA – 20 nA.
Beam blanker	• Electro-static beam blanker directly under acceleration anode. • 30 ns rise time. • 200 kHz repetition frequency in continuous operation. • 1 MHz repetition frequency for 30 seconds.
Beam size	• 2 nm at 20 kV at 3 mm working distance. • 4 nm at 1 kV at 3 mm working distance. • Gaussian beam.
Beam current density	> 7500 A/cm² at 20 kV.
Normalized brightness	$1 \cdot 10^7$ A/cm² · sr · kV.
Beam current stability	≤ 0.5% in 8 hours for room temperature variation < ±0.5 °C.
Beam position stability	≤ 300 nm/hour for room temperature variation < ±0.5 °C.
Gun control	• Automatically controlled emission ramp up to the preset gun conditions.

	• Two stage electromagnetic beam alignment with emission imaging.
Lenses	• Patented electromagnetic/electrostatic objective lens system. • Thermally stabilized by water cooling.
Stigmator	Eight pole electromagnetic.
Apertures	Six apertures with electromagnetic selection and independent adjustment parameters for precise alignment: 7.5 µm, 10 µm, 20 µm, 30 µm, 60 µm, and 120 µm.

3.2 Secondary electron detectors

In-lens detector	• For beam energies below 20 kV. • Annular scintillator mounted into column with optically coupled photomultiplier. • Distortion-free with high collection efficiency at low WD.
Off-axis Detector	Chamber mounted Everhart-Thornley secondary electron detector.
Controls	Automatic contrast/brightness with manual override.

3.3 Deflection system

Principle	Single step, high speed electromagnetic scan system, optimized for minimum field distortions, hysteresis and dynamic effects.
Writing field size range	• From 0.5 µm up to 2 mm field size possible.
Magnification range	20 times to 1,000,000 times, depends on voltage and working distance
Field size adjustment	• Corrections made for rotation, orthogonality and zoom.

	• Corrections can be entered manually or in an automated mode using metrology of laser interferometer stage.
Minimal addressable step size	Field Size / 65536 (16-bit)

3.4 Scan generation

e_LiNE scan generations are based on a digital pattern generator for lithography and an independent raster scan generator for imaging with the following specifications:

3.4.1 Lithography digital pattern generator

Principle	• Real time, high speed, and digital pattern generator with digital signal processor of 33 MHz and 32 kBytes static cache memory. • Fast, SCSI-type data link with 5 MB/s data transfer rate. • Synchronized control of electrostatic beam blanker unit.
Operation	• Vector scan as standard, trapezoids exposed line-by-line or by meander scan. • Can expose arbitrarily shaped single pixel lines and dots. • Circular exposure mode for circles and rings. • Also capable of bit-map/raster scan.
Shapes of individual patterns.	• Rectangles, triangles, any polygons of any orientation and shape. • Dots, lines and single pixel wide curves at any orientation. • Alphanumerical text. • Shapes generated by mathematical functions.
Digital analog converter	• Resolution 16 bit for X and Y. • Bandwidth 25 MHz with additional deglitch circuits thermally controlled and shielded against high frequency noise.

Minimum step size	Field Size / 65536 (=16-bit) rounded up to the next smallest metric step size.
Step size increment	Minimum step size increment 0.1 nm.
Dwell time and resolution	• 100 nsec minimum dwell time. • 500 msec maximum dwell time. • 1 nsec increment
Writing speed	• 2 Hz to 10 MHz pixel frequency in area mode. • Maximum 5 MHz for random addressing of pixel, i.e. both DACs are addressed simultaneously.
Dose control	Dose for each individual element can be varied using a dwell time factor ranging from 0.001 up to 17797.500.
Beam Blank control	Precisely synchronized to the exposure. Software provides for programmable lead and stop times to compensate time effects from the electron beam scanning system.
Field alignment	• Automated and integrated write field corrections. • Writing field calibration and correction is performed by a matrix of six 16-bit D/A converters. Adjustments are accessible in both axes for offset, scale, and angular orientation. This method of field alignment does not affect either the accuracy or the speed of any exposure. • Thermally controlled and shielded against high frequency noise.
Data acquisition	• Based on SE image or line scan acquisition using the in-lens or the ET-SE detector. • 12 bit A/D conversion with 0.5 µs sampling time for each pixel. • Freely selectable angle for intensity profiles along lines. • Up to 4 images/sec with 256×256 pixels, no averaging.

3.4.2 Scanning-electron-based imaging and display functions

e_LiNE imaging operation	• Raster scan: 15 non-interlaced scan speeds and TV rate scan with optional line-by-line or frame averaging, reduced raster, adjustable in size and position • Spot mode: Freely defined in X and Y. • Line scan: Repetitive scan of line on sample. • Scan rotation: up to 360° scan rotation at all scan rates.
Image processor	Pixel resolution of images: 512 × 384, 1024 × 768, 2048 × 1536, and 3072 × 2304, with up to 16-bit grey scale resolution.

3.5 Laser interferometer stage

Type of stage	• 3-axes X-Y-Z high vacuum stage. • Laser interferometer position sensing in X and Y with precision L-shaped reference mirror. • Interferometer measuring path completely inside the vacuum, hence no environmental compensation required. • Rotary encoder position sensing in Z.
Travel range	• 100 mm travel in X and Y. • 30 mm travel in Z without loosing laser interferometer control.
Motor drive	DC motors directly mounted on drive spindles for X-, Y-, and Z-axes. X- and Y- axes equipped with piezos for fine-adjustment.
Laser interferometer resolution	2 nm
Closed loop positioning control	• Coarse motion with DC tacho motors to within 0.2 µm of destination position followed by integrated fine movement with piezo elements, both operating in closed loop with interferometric position sensing.

	• 8 µm piezo fine shift range. • 2 nm positioning resolution. • 1 kHz update frequency.
Controller	Motors enabled through microprocessor controlled motor controller, which also incorporates manual joystick control.
Stage travel velocity	Up to 3 mm/second for X and Y.
Laser source	Frequency stabilized 632.8 nm HeNe laser.

3.6 Sample handling

Patterning area	100 mm by 100 mm symmetrical.
Current measurement	• Faraday cup built into top of sample holders. • Pico-Ammeter with IEEE interface.
Sample loading	Samples are placed directly onto a sample holder. The sample holders are equipped with Sapphire inserts and are placed on a platform on top of the laser stage. The platform consists of three ceramic balls designed to match the positions of the Sapphire inserts. This is designed for long-term stability and acts as a kinematic mount for the sample holder.
Height sensing (1-0R100-AHM)	• Automatic control of sample height to maintain focus after each stage movement. • Laser diode light source, 670 nm wavelength for use with III-V and II-VI semiconductors. • 1024-pixel line-CCD camera detector. • 2 mm Z travel range of operation. • Reproducibility 1 µm.
Universal sample holder (1-0R100-USH) Please note one unit	• Universal holder for small pieces up to 50 mm or 2". • 13 mm stubs and other types of specimens.

included in standard delivery.	• 45°sample mount for samples of 10 mm width and 10 mm maximum height. • 90°sample mount for samples of 10 mm by 7 mm maximum sample size. • Sapphire inserts for improved position repeatability and long-term stability. Leveling cannot be guaranteed.
Wafer holders (1-0R100-W4)	• Separate holders for 4" wafer diameter according SEMI standard. • Sapphire inserts for improved position repeatability and long-term stability. Leveling cannot be guaranteed.
Mask plate holders (1-0R100-M4)	• Separate holders for 4" mask plates according SEMI standard. • Thickness of mask plate must be specified by customer, maximum 250 MIL. • Sapphire inserts for improved position repeatability and long-term stability. Leveling cannot be guaranteed.
Rotation-tilt module (1-0R100-RT)	• Maximum tilt angle 90°, rotation continuously. • Maximum sample size 10 mm by 10 mm. • Controlled by joystick and fully integrated into software.

3.7 Chamber and options

EDX flange	Additional flange to adapt an EDX system, see separate description.
Gas-injection flange	Additional flange to add a gas injection system, see separate description.
Mass spectrometer flange	Additional flange to add mass spectrometer, see separate description.
Optical microscope flange	May be used for optical microscope with illumination, see separate description.

Height sensing flanges	May be used for height sensing option (laser and detector with optics and camera).
Nano-manipulators (optional)	Chamber designed for up to 4 XYZ nanomanipulators with 2 nm resolution linear encoder position sensing, see separate description.
Loadlock (optional)	Samples are introduced to the stage via a loadlock for samples up to 4".

3.8 Chamber and vacuum system

Chamber dimension	Inside width by depth by height = 490 mm by 380 mm by 300 mm.
Interior observation	Built-in infrared camera system with optics for visual control and orientation purposes.
Vacuum control	Fully automatic high vacuum system with column isolation valve.
Pumping scheme	• Main chamber: Dry vacuum pre-pump in combination with 240 l/s turbomolecular pump. • Electron gun: Ion getter pump for continuously maintaining ultra-high vacuum in gun region secured by a pneumatic gun isolation valve.
Gauging	• Penning gauge for high vacuum measurement in main chamber. • Ion current pressure readout in UHV region.
Vacuum	• The base pressure in the specimen chamber is better than $2 \cdot 10^{-6}$ mbar. • The base pressure in the gun region is better than $1 \cdot 10^{-8}$ mbar.
Indication	Vacuum readings, vacuum ready and valve position shown in the

	menu and optionally in the status menu.
Bakeout	Integrated bakeout control and equipment for UHV region at electron gun head.

3.9 Control data system

Lithography pattern generation and scanning-electron-based imaging are based on a networked dual computer data system with the following specifications.

3.9.1 Column control data system

In the following the minimum configuration is described.

Central processor	Intel Pentium 4.
Memory	Minimum 512 MB RAM.
Operating system	Microsoft Windows XP Professional.
Application software	Software package for recording, modifying, and saving images.
Disk drives	≥ 80 GB hard disk, CD-RW / DVD-RW drive.
Networking	RJ45 network card.
Display	19" high resolution flat panel.

3.9.2 Lithography control data system

In the following the minimum configuration is described.

Central processor	Intel CPU, newest technology with ≥ 2.4 GHz.

Memory	Minimum 2 GByte RAM.
Operating system	Microsoft Windows XP Professional.
Application software	*e_LiNE* lithography package.
Disk drives	≥ 300 GB hard disk, and CD/DVD-RW drive.
Networking	RJ45 high-speed network.
Display	19" high resolution flat panel.

3.10 User interface and system control software

3.10.1 Lithography capabilities

Multi-user platform	• Setting, files, and tasks stored separately for each user. • Automatic restoration of settings after next log on.
Automation	Interface to Microsoft scripting capabilities for generation of powerful, unattended batch jobs.
Exposure module	• Automatic, real-time division of arbitrarily shaped pattern directly from GDSII format into trapezoids. • Exposure of all types of arbitrarily shaped areas and curves in fast vector scan mode. • Exposure of single pixel lines and dots. • Exposure of bitmaps in raster scan mode. • Exposure of circles in circular mode. • Selection between several exposure modes, e.g. meander scan, line scan, or scan orientation. • Graphical and alphanumerical on-line status control.

Write field and overlay alignment.	• Up to four marks in each write field. • Automatic and semi-automatic mark detection. • Calculation and automatic download of the writing field correction parameters. • Reduction of beam drift effects in extended exposure runs by automated re-adjustment procedures employing fixed reference marks.
Sample to stage alignment	• Automatic or manual registration to known global marks on every sample, e.g. complete wafers and fractions of wafers. • Complex navigation within die on wafer is supported by means of two independent coordinate systems. • Read of up to three marks. • Alignment allows direct navigation in CAD design and in images.
Mark recognition	• Free selection, definition and scanning of mark fields with any pixel size. • Usage of metrology functions for mark recognition. • Manual, semi-automatic and fully automatic mark recognition and assignment.
Dwell time correction	• Automatic dwell time correction by measuring beam current during exposure.
Automatic field stitching	• On-line data preparation of hierarchical GDSII layout by fracturing into individual writing fields. • Pre-preparation of large pattern data for faster exposure.
GDSII editor and viewer	• View and design structures, e.g. rectangles, polygons, circles, ellipsoids, lines, dots, paths in one or more process levels and hierarchical layers. • The GDSII format has been extended to allow for dose information and further special structure types, e.g. single pixel lines, bitmaps and text formats. • Externally prepared CAD files in GDSII-, AutoCAD DXF-, ASCII-, and CIF-format data can be converted to the GDSII

format.

- Creation of text pattern and related functions, i.e. exposure time and date for documentation.
- Mathematical function generator for arrays of curved lines.
- Generation of hierarchical structures with elementary cell repetition to realize complex repetitive pattern with a minimal amount of data.
- Creating, moving, zooming, deleting, adding, repeating and referencing structures.
- Undo function.
- Post-processing tools, e.g. shrink, frame, overlap removal, etc.
- Image overlay options on design for CAD layout navigation.
- The proximity effect correction automatically divides a pattern into substructures and assigns the correct dose to each.
- Divides a pattern by framing routines prior to running the proximity effect correction.
- Integrated simulation for inspecting patterns with respect to proximity effects. The simulation incorporates thickness and contrast of the resist. Results are displayed in a color map.
- Calculates proximity parameters α, β, and η from a database which the users can modify according to their needs. The calculations take into account the acceleration voltage, resist thickness and substrate material.

Stage and column control

- Control of column parameters, like magnification, focus, beam alignments, lens settings, beam voltage, and current settings.
- Absolute and relative addressing, two coordinate transformations between stage and sample, display of current stage position, storage of positions.

Proximity effect correction

- Software for correction of proximity effect.
- Data post-processing features, like grow, shrink, frame, overlap removal, etc.
- Proximity effect parameter determination using lookup table for standard substrates.

Image acquisition	• Noise reduction: Pixel averaging and frame averaging. • Displayed on 19" high resolution flat panel. • Hardcopy: any printer type can be used. • Archiving as files on hard disk or over network. • Comprehensive suite of functions to enable high resolution images and data handling thereof.
Wafer and CAD layout navigation	• Overlay of CAD layout into all windows like images. • Generation or import of wafer maps with definition of notch, flat, and chip numbering. Several chips can be saved and given a common property, e.g. 'must be inspected'.
Metrology	• Line width, position, and pitch measurements based on real-time line scans or from acquired images. • Pattern placement control across single write fields, single chips/dies or across the whole wafer in conjunction with laser interferometer stage. • Threshold algorithm, cross-correlation, or manual assignment of edge locations.
Surface Editor	• Definition of milling elements directly in images. • Available elements boxes, polygons, lines, dots and wedges under all angles. • Dwell time, step size, number of loops, repetition of lines can be selected.
Protocol and error handling	• Operator and system actions in a rolling protocol. • Error and debug information in a separate file.
Help functions	• Complete reference manual presented context sensitive.

4 Acceptance specifications

The acceptance testing procedure verifies that the tool is performing within the bounds set in the Technical Specifications section. The testing procedure is conducted twice, first at the factory as a pre-shipment performance check and then again at the customer's site to verify that the tool has been installed properly. The customer is strongly invited to attend both of the testing sessions.

4.1 Qualification test criteria

Beam size	≤ 4 nm at 1 kV (1,3)
	≤ 2 nm at 20 kV (1,3)
Beam current drift	≤ 0.5% in 8 hours (2,3)
Beam position drift	≤ 300 nm/hour (2,3)
Minimum grating periodicity	≤ 100 nm
Minimum feature size	≤ 20 nm
Field stitching	≤ 40 nm (|mean| + 3 · sigma)
Overlay accuracy (alignment)	≤ 40 nm (|mean| + 3 · sigma)
Height sensing reproducibility	≤ 1 µm

(1) The beam size is not necessarily a guarantee of lithography resolution or image resolution, each of which is dependent on a variety of factors, e.g. the user's process or environmental disturbances, e.g. vibration and acoustic.

(2) If the room temperature drift is kept within ±0.5 °C.

(3) The test criteria can only be demonstrated at the customer's site when all environmental conditions are in agreement with the conditions described in the section "Installation requirements". If for some reasons which are the responsibility of the customer these test criteria cannot be met in a reasonable time, Raith GmbH can decide at their discretion that the

system passes the test and the values recorded during factory acceptance will be used.

4.2 Qualification test procedures

Raith GmbH or their accredit representative provides the samples, chemicals, and test pattern required to perform these procedures. The test patterns are available from Raith GmbH on request.

4.2.1 Beam size

The measurements are taken on samples of Gold clusters on Carbon at high magnification. The edge sharpness at a selected site is determined by measuring the 20% to 80% rise of the secondary-electron intensity (American Society for Testing and Materials (ASTM) standard practice, Designation: E986 - 97) assuming a Gaussian distribution. In addition the common edge effect is taken into account. This distance measurement must be less than or equal to 4 nm at 1 keV and 2 nm at 20 keV. For these measurements the environmental floor vibrations, acoustic noise, and magnetic fields must be less than or equal to the specifications as stated in section "Installation requirements".

4.2.2 Beam current drift and beam position drift

Both tests are performed using 10-kV acceleration voltage and 30 µm aperture size. Either the beam current or the beam position is recorded every 15 minutes or less, over a period of time of 8 hours minimum.

The measurement for beam current drift is conducted using an internally mounted Faraday cup and the system's pico-Ammeter. The long-term maximum beam current drift shall be less than or equal to ±0.25% for any 8-hour period of time with respect to the mean value in the same period of time.

In a separate measurement, the stage is held in a constant position with respect to the stage-mounted laser interferometer. At the beginning of the beam position drift test the system will be calibrated, but during the test no further calibrations are carried out. The position of the mark is determined using the system's edge detection software routines. The position drift of the mark will be less than or equal to 300 nm/hour within any 1-hour time period.

Please note for both current drift and beam drift the environmental temperature stability of the room must be less than or equal to ±0.5 degrees Celsius. Under this condition the short-term beam current drift shall be less than or equal to 0.3% for any 1 hour time period. Since it is necessary to establish stable working conditions for the whole system, the instrument should be allowed to stabilize for at least 4 hours prior to testing. A measuring noise may occur not exceeding 1 pA.

4.2.3 Minimum guaranteed grating periodicity

A grating consisting of straight lines will be exposed using a 100 µm writing field. After developing, the sample is returned to the system. The periodicity is determined by measuring the distance between two successive lines with the best suited exposure dose. This periodicity must be less than or equal to 100 nm. In the same way, the line width and the space between the lines are determined. The width of the lines as well as the spaces will be demonstrated to be less than or equal to 50 nm.

4.2.4 Minimum guaranteed feature size

Isolated straight lines will be exposed using a 50 µm writing field. After developing, the sample is returned to the system. The line width is determined by measuring the width of a line with the best suited exposure dose. The width will be demonstrated to be less than or equal to 20 nm.

4.2.5 Stitching and overlay (mix & match) accuracy

A special test pattern is exposed in multiple exposure steps using a positive resist. In general, between each exposure step the sample is removed from the system, developed, and returned to the system. All alignment procedures and dimension measurements are performed upon the features written in previous exposure steps. The fidelity of the electron optics and collection electronics allows the system to image the "bare" features in the resist. No further metallization or processing is necessary to perform the mark detection and registration routines.

The test pattern is stitched together in a 6 by 6 array using a 100 µm by 100 µm writing field. The sample is returned to the chamber after development of the first "blind" stitching step. After the standard alignment routine, the complement, i.e. overlay, to the initial pattern is exposed. For each exposed field, a full write field correction and alignment is performed automatically using marks that were written in the first exposure step. After development the sample is returned for the third step, i.e. the overlay and accuracy measurements.

In the third step, scans are generated to measure the field stitching offsets and overlay accuracies obtained in the first and second exposure steps. Using metrology features within the software, scans are generated and saved to disk in a "correlated" manner. Scans of marks are matched or paired, so determining the center-to-center distance x_i between the marks is done automatically.

The results are later processed, evaluated, and graphically presented within the software using the metrology functionality. The mean value m and the standard deviation σ are defined by

$$m = \frac{1}{n}\sum_i x_i, \quad \sigma = \sqrt{\frac{1}{n}\sum_i (x_i - m)^2}$$

The (|mean| + 3 · sigma) value of the stitching accuracy will be demonstrated to be less than or equal to 40 nm.

The (|mean| + 3 · sigma) value of the overlay accuracy will be demonstrated to be less than or equal to 40 nm.

4.2.6 Height sensing reproducibility

An un-patterned sample is loaded into the system. In the following, the sample is tilted by an angle of approximately 0.1 deg.

The corresponding height variation is then detected by means of the height sensing at 500 positions along one line. The measured height h_i is then compared to the calculated height c_i by calculating the difference $h_i - c_i$. Using this difference one determines the standard deviation by

$$\sigma = \sqrt{\frac{1}{n}\sum_i (h_i - c_i)^2} \ .$$

This standard deviation value of the height sensing reproducibility will be demonstrated to be less than or equal to 1 µm.

The test procedure will be performed only, if the corresponding option has been ordered.

5 Installation requirements

This section is meant to aid in preparing the laboratory room for installation of the instrument. Advancements and improvements to the instrument and available options are an ongoing process. As a result, some specifications are subject to change or modification. If additional information is necessary, a separate document is available on request. It describes in more detail the installation requirements.

The environmental and utility requirements shall be the responsibility of the customer and shall be provided at the time of installation. Failure to comply with these conditions may adversely affect the performance figures quoted in this document. The optimum results can only be guaranteed if the specified environmental requirements are fulfilled.

One visit of an engineer is part of an order. During this visit a site survey is done including measurements of floor vibrations, magnetic fields, and acoustic noise. A report gives recommendations and detailed information about the expected influence.

5.1 Electrical services

Main power line

- Twice 230 V ±10%, 50/60 Hz, single phase, neutral ground.
- 2.5 kVA power consumption.

Note: If a system is purchased together with an uninterrupted power supply, the values are different. Please consult the Site Preparation Guide and with Raith directly.

Note: Recommendation for U.S. customers; if 230 V cannot be met, inquire about a transformer to boost 208 V input to 230 V.

Uninterrupted Power Supply (UPS)

If power failures are likely, we recommend an UPS which can be purchased through Raith (4-0R-UPS).

- Power 6000VA/4200W, battery voltage 240V.
- Autonomy time about 30 min at typical load, 15 min minimum.

Note: Depending on the purchased UPS, special power line requirements are mandatory. Please consult the corresponding Site Preparation Guide and with Raith directly.

Emergency stop

A special circuit should be provided for an EPO (Emergency Power Off) switch. A power switch for the instrument should be within easy reach, preferably next to the door.

Protective ground

The *e_LiNE* system is subject to regulations for high-voltage installations. Therefore, it must have a second safety ground connection or an equipotential connection via a separate line of at least > 16 mm² cross section and < 0.2 Ω resistance. From the customer this supply is normally realized as a conductor rail. Other local provisions may also be in effect.

5.2 Gas services

Nitrogen

Required for venting.

- Dry nitrogen, purity about 99.996%.
- 2 liter/minute at 0.2 bar over atmospheric, 0.3 bar maximum, pressure regulator required.

Compressed air

Required for pneumatic bellows used to support the main chamber. Compressor unit can be purchased through Raith (4-0R-COMP).

- 6 bar static pressure over atmospheric, 8 bar maximum, pressure regulator required.

5.3 Cooling requirements

Internal cooling systems

The system comes with an air-cooled water chiller producing an additional heat output of 1.5 kW. It is strongly recommended to set up the unit outside the lab room. A water-cooled chiller is available as an option (4-0R-CHILL-W). For long-term or critical exposures, i.e. lasting over 30 minutes or Mix & Match applications over the area of a wafer, an optional objective lens thermostat (4-0R1x0-THM) can be purchased to maintain the temperature of the final lens to within ±0.01 °C. The objective lens thermostat requires a separate supply of 16 A at 230 V, 50 Hz.

5.4 Room conditions

Room size

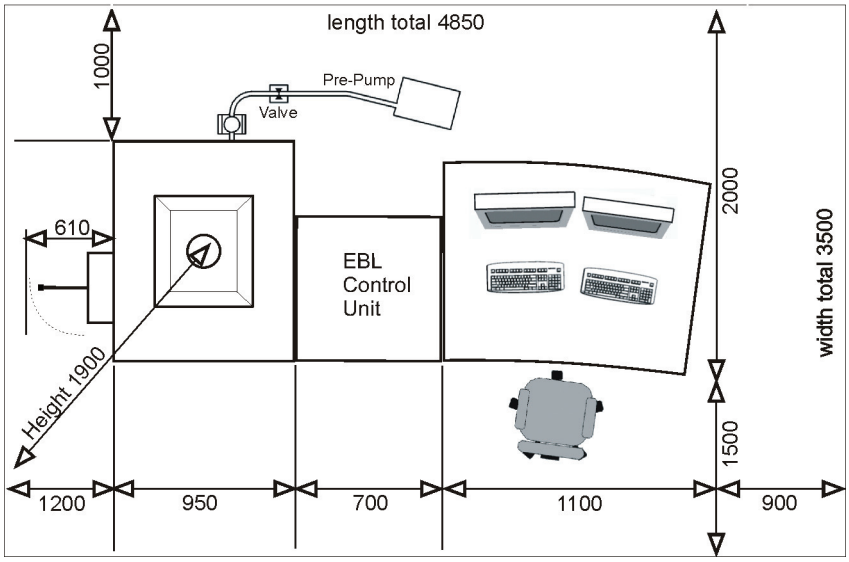
- 3.5 m by 4.85 m with a minimum ceiling height of 2.3 m. This is regarded as a minimum, suitable only for the instrument and

	one operator. • Recommended to have a 1 m space between system and surrounding walls to aid installation and servicing.
Way into the lab	• All door clearances from loading deck into the room should be wider or equal to 0.9 m and higher or equal to 2.0 m. • If the lab level differs from loading deck level, a transportation lift > 1400 kg is required.
Temperature	The heat output of the complete system is about 2.5 kVA and should be removed by circulating the air. The allowed temperature range for the room is from 20 °C to 25 °C controlled to ± 0.5°. For critical exposures, an optional objective lens thermostat can be purchased to maintain the temperature of the final lens to within ± 0.01 °C.
Exhaust	The *e_LiNE* uses an oil-free vacuum system. The exhaust during the evacuation of the chamber can be drawn off into air directly. An exhaust line is required only by customer's provisions. An exhaust filter might be mandatory.
Relative air moisture	Less than 65 %.
Floor vibrations [1]	The velocity of floor vibrations measured in a 1/3-octave RMS amplitude spectrum has to be less than 0.8 µm/sec for frequencies between the 1.6-Hz band and the 16-Hz band (including them). For frequencies above the 16-Hz band the maximum velocity should not exceed 1.0 µm/sec.
Magnetic fields [1,2]	The RMS value of the magnetic flux density over the entire frequency span from 0 to 625 Hz has to be less than 1 mG. Also avoid locations subject to varying fields, e.g. near an elevator or trains.
Acoustic noise [1,2]	The sound pressure level measured in a 1/3-octave RMS amplitude spectrum should not exceed 70 dBC for frequencies between the 31.5-Hz band and the 100-Hz band (including them). For frequencies above the 100-Hz band the sound pressure level has to be less than 60 dBC. The dB_C values are referenced to the standardized 20µPa.

(1) Special note concerning vibration, magnetic, and acoustic specifications. The performance of the system can be adversely affected if these limits are exceeded. In this case, special equipment may need to be added, e.g. anti-vibration platform. In addition special equipment may also be needed, if the measurement results get close to the specifications in more than one band but does not exceed them. See the document "Site Survey Rules" for detailed information about measuring these quantities.

(2) The specifications apply for the third octave amplitudes inside the stated frequency bands avoiding different results due to different spectrum analyzers.

5.5 Room layout



e_LiNE top view, all dimensions are in mm. Suggested layout, other layouts possible, please inquire.

5.6 Transport and packing

Overall system weight is approximately 1400 kg and will arrive on several shipping pallets. All components are packed into special transport boxes and are secured with plastic foil. Small components, wires, tools, etc., will be packed into paper boxes with foil and are likewise fixed on a pallet.

Critical crates are equipped with tilt/tip/shock indicators. Please make note of condition of pallets and crates when shipment arrives.

5.7 Summary of utility and environmental requirements

Main power	Twice 230 V (U.S. option of 208 V with boost transformer); second protective ground with < 0.2 Ω and >16 mm². 2.5 kVA consumption dependant on accessories.
Nitrogen	2 liter/minute at 0.2 bar, 0.3 bar maximum, regulator required.
Compressed air	6 bar static, 8 bar maximum, regulator required.
Ambient temperature	20-25 °C, controlled to ± 0.5°, heat output of system 2.5 kW.
Relative humidity	Less than 65 %.
Floor vibration	In 1/3-octave RMS amplitude spectrum less than 0.8 µm/sec at frequencies between the 1.6-Hz band and the 16-Hz band (including them), less than 1.0 µm/sec at frequencies above the 16 Hz band.
Magnetic fields	The RMS value of the magnetic flux density over the entire frequency span from 0 to 625 Hz has to be less than 1 mG.
Acoustic noise	In 1/3-octave RMS amplitude spectrum less than 70 dBC at frequencies between the 31.5-Hz band and the 100-Hz band (including them, less than 60 dBC at frequencies above the 100-Hz band.