AIXUV’s EUV-LAMPs

Additional Information for our Potential Customers and Preliminary short Product Description

Figure 1 AIXUV’s fully automatic turn-key EUV-LAMP System consisting of a control and operation rack (left with PLC control, HV and Vacuum supply) and the Lamp-head (on the table)

Figure 2 AIXUV’s EUV-LAMP for Research. Operation is semi-manual, i.e. vacuum, gas flow and discharge parameters have to be set manually.
1 Description of AIXUV’s EUV-LAMP

1.1 Standard features of AIXUV’s EUV-LAMP

AIXUV’s EUV-LAMPs are designed to give our customers flexible, fast, safe, reliable, easy and cost effective access to EUV-radiation. The EUV-LAMP head is designed to allow easy integration with customers’ metrological experiment or into their system solution planned to accomplish their research.

However, we all know, that the tasks in developing EUV-technology are as manifold as are approaches to fulfill the demands in EUV-metrology or to do research with EUV. Therefore we offer to our customers flexible adopting to their demands.

The philosophies of our standard EUV-LAMP systems are as follows:

- Wall plug, turnkey installation.
- Fully automatic push-bottom-controlled operation.
- Full control of all potential defects and hazardous factors by PLC-control. Guaranteed by the CE certifications and passed EMV tests.
- Permanent emission for at least 8 hours without any need of shift. In principal, “24 hours, 7day / week operation” is possible. Our longest test up to now was for 2 ½ weeks of permanent „on“.
- No need to control any parameter of the lamp. Thus trained operators without any special knowledge can easily operate the lamp.

Additionally we supply a “down-engineered” system for significant lower costs, to give research at universities or institutes budgetary access to EUV-Technology for early learning.
1.2 Principles of EUV-LAMPS

AIXUV’s EUV-LAMP are discharge produced plasma based EUV-sources. The basic discharge concept of the EUV-LAMPS is the “Hollow Cathode Triggered Pinch (HCTP)”. This concept is patented worldwide by Fraunhofer society. Patents are licensed to AIXUV for low power applications and to Philips EUV GmbH for the development of production sources.

Figure 3 Schematic of the patented the “Hollow Cathode Triggered Pinch (HCTP)” concept, which is used in the EUV-LAMPS and by Philips EUV for the development of high power, sources.

Figure 4 shows the spatial resolved emission spectrum of the EUV-LAMP as recorded with the E-SPEC from JENOPTIK Mikrotechnik using an “imaging slit in the tool-wheel”. EUV-Lamps emit a typical XENON EUV spectral distribution from a inband EUV source size of 400 µm FWHM. As seen from the image, source size might vary with wavelength.

Figure 4 Spatial resolved EUV-Spectrum of the EUV-LAMP as recorded with the E-SPEC from JENOPTIK Mikrotechnik using an “imaging slit in the tool-wheel”
Description of AIXUV’s EUV-LAMP

Figure 5  Spectrum of EUV-LAMP as recorded with the E-SPEC. EUV-flux of unresolved transition arrays and identified lines is emitted over the whole EUV range. *

Figure 6  Stability of source size, single pulse position and long-time emission in inband EUV (40 minutes scan through single spectra). *
All our power measurements are with respect to the E-MON which is a joint development of JENOPTIK Mikrotechnik and AIXUV. The E-Mon uses two (!) multilayer reflections and a zirconium coated siliconnitride window for spectral filtering of the EUV inband radiation. E-MONs have been primary calibrated at PTB at BESSY II. Each E-MON is calibrated by JENOPTIK Mikrotechnik by cross-calibration measurements at the EUV-LAMP they have bought from AIXUV.

1.3 Standard set of parameters

AIXUV’s standard EUV-LAMP system is optimized for working with Xenon at an electrical input power of 2 J per pulse at 50 Hz.

1.4 Operation with different gases

In principle, it is very simple to change the gas in our EUV-LAMP. The EUV-LAMP works with all gases and is able to find the right operation regime. However, for each given gas, some control parameters or/and components have to be adjusted to guarantee reliable operation and a given spectrum at maximum conversion efficiency.

The standard EUV-LAMP we sell at this time is designed to work with just one gas; i.e. the parameters are set for optimized operation with one gas, which is usually Xenon. The working
gas has to be supplied by the customer at a standard input port with a pressure of 1.2 to 2 bars.

In principle, switching to other gases is possible by just supplying the EUV-LAMP with your gas of choice. This change can either be accomplished if the lamp is switched off or if you install your own gas switch. However, it is recommended that you ask AIXUV for permission to use a special gas. On demand, AIXUV will test operation with your working gas of choice.

Various gases have been tested. There is no special difference if you want to use Nitrogen, air, Argon, Neon or Krypton.

Shorter maintenance intervals are expected for operation with pure Oxygen, therefore AIXUV might protest guarantee if operation with pure Oxygen is diagnosed in the case of failure.

Severe risks are expected when operating with carbon or metal containing gases for a longer period of time and when operating with fluorine. The risks are with faster electrode erosion or/and short switching of the discharge chamber. Short period operation with Methane, CO₂, and Fluorine have been tested successfully. Nevertheless, neither long-life guarantee can be given with these risky gases nor is low debris operation guaranteed.

AIXUV will be able to build a lamp which allows for operation with a mixture of up to three gases with adjustable mixing ratios at additional cost. If you wish to operate with mixed gas, small amounts of a probe gas added to a standard gas might not harm operation.

Figure 11 The EUV-LAMPS can be operated with various gases, allowing for tuning spectral distributions to special demand. While Xenon is an ideal emitter for high total flux and best “in-band” conversion, line emitters are of special interest, because they can be used to supply nearly monochromatic radiation (λ/Δλ typically > 1000) when filtered with multilayer mirrors.

AIXUV’s EUV-LAMPS can also be tuned to emit radiation in other spectral ranges outside typical EUV (10-20 nm). Even standard EUV-LAMP can be parameterized to emit water.
window radiation when operated with Argon as shown in figure. For the time being, little optimization has been done for this spectral range; hence significant increase of conversion efficiency is expected if a LAMP system is ordered for this spectral range.

Figure 12  Near water-window emission of standard EUV-LAMP when operated with nearly standard set-up. It is expected that EUV-LAMP systems can be specially tuned for high conversion efficiency in this spectral range.
1.5 **Beamline / vacuum vessel**

In principle optical components can be positioned as close as 100 mm from source point. However, our standard vacuum vessel is designed in a way that our customers can start building their application from the exit port flange which can be delivered as CF, KF or ISO with diameters ranging from 10 to 100 (Standard sizes).

If the integration of the EUV-LAMP has to start closer to the source, the CF-150 flange of the source's vacuum vessel can be used as the main interface. In such applications, source pumping and gas flow has to be specially designed. It has to be taken into account that the source needs pumping speeds in the range of 20 – 40 l/s. It is suggested to contact AIXUV for joint interface engineering.

1.6 **„Clean-EUV-Photon-Exit port“**

AIXUV’s EUV-LAMP emits very low amounts of debris. Any debris can be easily shielded by a LUXEL zirconium foil which is introduced anywhere in your application beamline. Long term operation of this filters directly attached to the exit port has shown very little erosion. However, such a window limits the accessible solid angle.

When larger solid angles are needed AIXUV offers - as additional options - „Clean EUV-Photon-Beamlines“. In these beamlines the discharge volume and application chamber are totally separated by a thin zirconium or siliconnitride window which is located within the lamps vacuum vessel. Due to the expected higher danger of erosion some means are added to reduce the danger of erosion.

Any thin window guarantees that no debris whatsoever from the source will reach your application. A typical LUXEL zirconium window reduces usable EUV-flux by about 50 %.

1.7 **Peripherals needed for operation**

All the needed peripherals for lamp operation and control are within the control rack or attached to the lamp head. All these components are needed. We think that this separation gives maximum flexibility to our customers. The turbo pump attached to the lamp head and the pedestal under the circular lamp head are essential for operation.

Little additional peripherals have to be supplied by the customer to operate the EUV-LAMP:

- For higher flexibility and security Xenon (4.0) supply is on customer’s side. That means that a bottle of Xenon 4.0 with pressure reduction to 1.5 to 3 bar is needed. Connection to the lamp is with gas hose of 6 / 4 inch diameter which is supplied by AIXUV [we use SWAGELOCK: order Nr. : SS-PB-14-TM6-TM6-118- YW]

- Current supply : 3*220 V 16, male connector is standard for customers in Europe but can be adopted to other country’s standards.

- Argon (5.3) supply with pressure reduction to 1.5 to 3 bar is needed if „Clean EUV-Photon Beamline“ is ordered.
1.8 Prices

Our standard EUV-LAMP is delivered for turn-key installation, supplied with vacuum system, high voltage power supply and fully automatic closed loop control and PLC operation rack.

The list price is for a standard EUV-LAMP of 50 Hz repetition rate. 100 Hz (double power) is available for about 20 % higher costs. Discount may apply for special R&D at universities and / or institutes. Burst operation of a few seconds with lower duty cycles may be supplied delivering EUV powers of up to a factor of 5 higher at little higher costs.

For OEM-applications - which has to be discussed in more detail - the "naked lamp plus power supply" can be down to about half the list price depending on specifications.

Operation costs are electrical consumption (about 4 times the electrical input power plus < 1 kW; e.g. around 1,5 kW for the 50 Hz, 2 J version plus gas consumption. Xenon and Argon consumption is below 10 sccm/min.

A typical lifetime of 250 hours (100 million pulses) of emission is guaranteed for the lamp head and one year of operation for the peripheral components. AIXUV will guarantee 500 hours, 1000, 1500 hour or 2000 hours for 5 % of the system price each step of lifetime. Replacement of a head after an unexpected fault with a regenerated substitute will be within less than two weeks.

Head replacement costs (after guaranteed lifetime) is around 15 % of the system price if a new head is chosen and below 10 % if a regenerated head is sufficient. The latter offer might be not available.

1.9 Terms

Typical time of delivery from the date of order is about 4 months. However, depending on order book longer periods might apply. Special features might need longer time for ordering and fabrication.

Discussion on how to meet your requirements best is welcome (Please sent back “Lamp selection form”). There are many chances to tune AIXUV’s EUV-LAMP to your demands.

Don’t hesitate to ask further questions. You are always welcome to arrange a visit at our site. On such occasions, we will prepare a presentation adapted to your list of questions and will demonstrate a lamp in operation. For a low daily charge we offer application tests at our site or might even arrange an in-house test at your site. If requested, we will send you an official quote or will ask our representatives to do so.
2 Dimensions of AIXUV’s EUV-LAMP

<table>
<thead>
<tr>
<th>Control-rack</th>
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<tbody>
<tr>
<td>Height</td>
<td>1800 mm</td>
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<tr>
<td>Width:</td>
<td></td>
</tr>
<tr>
<td>Without connectors</td>
<td>610 mm</td>
</tr>
<tr>
<td>With connectors</td>
<td>715 mm</td>
</tr>
<tr>
<td>Depth</td>
<td>800 mm</td>
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<table>
<thead>
<tr>
<th>Lamp-Head</th>
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<tbody>
<tr>
<td>Height (mounted on base plate)</td>
<td>430 mm</td>
</tr>
<tr>
<td>Diameter of Lamp-body</td>
<td>347 mm</td>
</tr>
<tr>
<td>Depth (depends on beamline vessel)</td>
<td>285 – 310 mm</td>
</tr>
<tr>
<td>Height of beam from bottom of base plate</td>
<td>255 mm</td>
</tr>
<tr>
<td>Minimum distance to source</td>
<td>as small as 50 mm; Distance to termination flange depends on beamline and vessel solution selected (typical 150 – 190 mm)</td>
</tr>
<tr>
<td>Weight</td>
<td>About 50 kg</td>
</tr>
</tbody>
</table>

Distance side of control rack to Lamp head

Standard: 1500 mm
Longer distances feasible.

Figure 13 Schematic dimensions of AIXUV’s EUV-LAMP and control rack.

A Table can be ordered to match your operation height.

The lamp can be mounted on any table or holder at the base plate. Orientation has to be specified for best positioning the turbomolecular pump.
EUV-LAMPS are – in principle – terminated by a CF-160 flange. Interfacing to customer’s application can start at this flange. Please supply us your preferred interface, AIXUV will check whether it can be supplied with no or little additional costs.

For each use, the lamp has to be supplied with a vacuum vessel with high vacuum pumping. Additionally it is suggested by AIXUV to use some „beamline“ between source and application such that a solid window totally separates the source volume from the application volume.

With respect to the vacuum vessel AIXUV offers – for the time being – two standards:

- Version 1 with minimum volume for best system integration (Figure 15).
- Version 2 with open with CF-160 flange which allows the customer on one hand to place components very close to the source, and – on the other hand – to offer maximum flexibility with respect to vacuum connection by using different termination plates. With this vessel all types of standard vacuum flanges can be supplied as connector (e.g. CF-40, CF-64, CF-100, KF-20 etc.). See Figure 16.

High vacuum pumping can be part of the application; hence either the sources vacuum pump can supply the application, if little pumping speed is required, or the source can be operated with the application’s vacuum pump.

For stable source operation the pumping power should be in the range of 10 – 30 l/min with base pressures below $10^{-4}$ mbar. Strong pumping might increase the gas consumption and increase the danger of contamination. Lower pumping speed may not be sufficient for good stability and lead to high transmission losses in the beamline.

Mechanically the EUV-lamp is mounted at the base plate as shown in Figure 17.
Figure 15 Dimensions of standard vacuum vessel I, which is suggested for best system integration.

Distance from medium source point (Quellpunkt) to flange terminal is 179.5 mm

Figure 16 Dimensions of standard vacuum vessel II that is suggested for best flexibility to place components close to the source.

Either the CF-160 or the terminal plate (here with the possibility to mount CF-40) can be used as the interface.

Distance from medium source point (Quellpunkt) to flange terminal is 170.5 mm in this example.
Figure 17 Schematic drawing of the base plate which is used for mounting of the LAMP-head. The same base plate is used with all vacuum vessels.
3 Some additional results on EUV-Lamp performance

Figure 18 EUV emission of HCT-Pinch observed from different angles with respect to the pinch axis. Observed from end-on position an EUV-emitting spot of about 500-micrometer diameter is seen. From arbitrary angles the pinch column is visible but partly obscured by the electrodes. (Courtesy FhG-ILT).

Figure 19 Side-on image of visible light emission of the HCT-pinchplasma located between the electrodes. The pinch is centered with respect to the boreholes in the electrodes.

Figure 20 Typical emission spectrum when operated with Xenon.

Variation of spectrum of EUV-lamp as function of operation temperature
AIXUV wants to develop our lamp for maximum customer’s use. Therefore we will try to adopt to your wishes as far as it is possible. We are open to adapt to any demand, knowing that – for the time being – there is no “standard” use or interface within EUV and XUV technology.
4  Options

1.10  Options

AIXUV’s EUV-LAMP are manufactured and tailored to our customer’s demands. Knowing about the different tasks in integrating EUV-Sources into applications, we can supply a wide variety of lamp-versions for the different demands. Typical parameters, which have to be decided upon, are:

- Emitting gas.
  Xenon is the standard, most flexible emitting gas, when “inband” EUV radiation flux is demanded or if emission in the whole EUV range from 10 to 20 nm is desired. However, other operating gases offer supplementing features like “free-standing emission lines” or center of spectrum at other wavelengths. AIXUV’s EUV-LAMP can be operated with nearly every gas; however optimizing the source for any gas requires tailored setting of parameters.

- Wavelength range
  AIXUV’s EUV sources are optimized for emission around 13.5 nm. However, they can also be optimized for wavelengths shorter than 4 nm or longer than 15 nm.

- Source Power
  EUV power of the EUV-LAMPs scale with repetition rate. Repetition rates of up to 250 Hz can be supplied as standard. Usually, higher power sources need additional cooling, which can be supplied at additional costs. If duty cycles are low and bursts are shorter than 10 seconds, higher power sources can be supplied without additional cooling.

- Vacuum interfaces
  AIXUV’s EUV-LAMPs are – as standard – supplied with a vacuum vessel (type I) with integrated turbomolecular pump and a CF-40 exit flange. Many other solutions can be realized using the standard CF-160 flange at lamp body. We adapt vacuum vessels, beamlines and interfaces to our customer’s demands.

- Beamlines
  Although AIXUV’s EUV-LAMP are of low debris, we suggest as good practice, to separate the application from the source plasma by a beamline for debris mitigation. AIXUV has integrated and tested a variety of beamlines. The most economic beamline solution can be tailored, taking into account the boundary conditions of your application.

- Source Orientation
  EUV-LAMPs can be mounted in any orientation. However, for best performance in your preferred orientation, the system should be set-up and checks specially for this orientation.
1.11 **Order Information**

Some standard solutions are available on order number. Special solutions have to be discussed.

<table>
<thead>
<tr>
<th>Order number</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>001-001-100</td>
<td>EUV-LAMP-system fully automatic push-button operation with 50 Hz repetition rate: &gt; 20 mW/sr in 2% bandwidth around 13.5 nm; air cooled; standard vacuum vessel Warranty for 100.000.000 pulses (i.e. &gt; 500 h @ 50 Hz of emission)</td>
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<tr>
<td>001-EW-500</td>
<td>500 additional hours of warranty on lamp head</td>
</tr>
<tr>
<td>001-BL-100</td>
<td>Clean-photon beamline: nearly total separation between source and application vacuum with large aperture</td>
</tr>
<tr>
<td>001-SH-VAT</td>
<td>Beamline-valve with zirconium window for choice of nearly total separation between source and application vacuum and limited aperture</td>
</tr>
<tr>
<td>001-VK0-COM</td>
<td>Compact vacuum vessel for minimizing distance source – application</td>
</tr>
<tr>
<td>001-VKM-3PT</td>
<td>Vacuum vessel and lamp-beamline configured to have 3 exit ports</td>
</tr>
<tr>
<td>001-01-U02</td>
<td>Upgrade to 100 Hz</td>
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<tr>
<td>001-01-U05</td>
<td>Upgrade to 250 Hz</td>
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<tr>
<td>001-000-OK</td>
<td>Oil cooler for temperature stabilization</td>
</tr>
<tr>
<td>001-RMS-010</td>
<td>Manually controlled stand-alone EUV-LAMP</td>
</tr>
<tr>
<td>001-RMV-010</td>
<td>Lamp-head with suggested HV-capacity charger and cable and suggested turbopump</td>
</tr>
<tr>
<td>001-RML-010</td>
<td>Lamp-head with suggested HV-capacity charger and cable.</td>
</tr>
<tr>
<td>001-RM0-010</td>
<td>Only lamp-head for customers OEM integration or for customers which want to use their own HV and vacuum supply and manually control gas flow sensors for temperature and oil pressure integrated specification document on the use of the system</td>
</tr>
</tbody>
</table>

Please mail to AIXUV GmbH, Steinbachstrasse 15, 52074 Aachen; Germany
Or FAX to +49 (0) 241 8906 121 or Mail to AIXUV@AIXUV.DE