

# Novel Compact Synchrotron Radiation Sources

Requirements and Development for Application in

**Mask Inspection in EUV Lithography**  
**Scientific and Applied Research**

Udo Klein

Advanced Accelerator Technologies AG (AAT), Villigen, CH

# Embedded in Federal Initiative

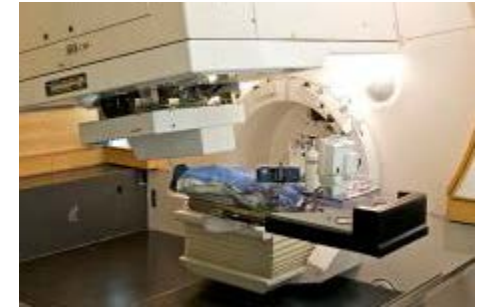


Swiss Free Electron Laser



Accelerator technologies

Human Health



Materials & processes



Energy



Swiss Light Source

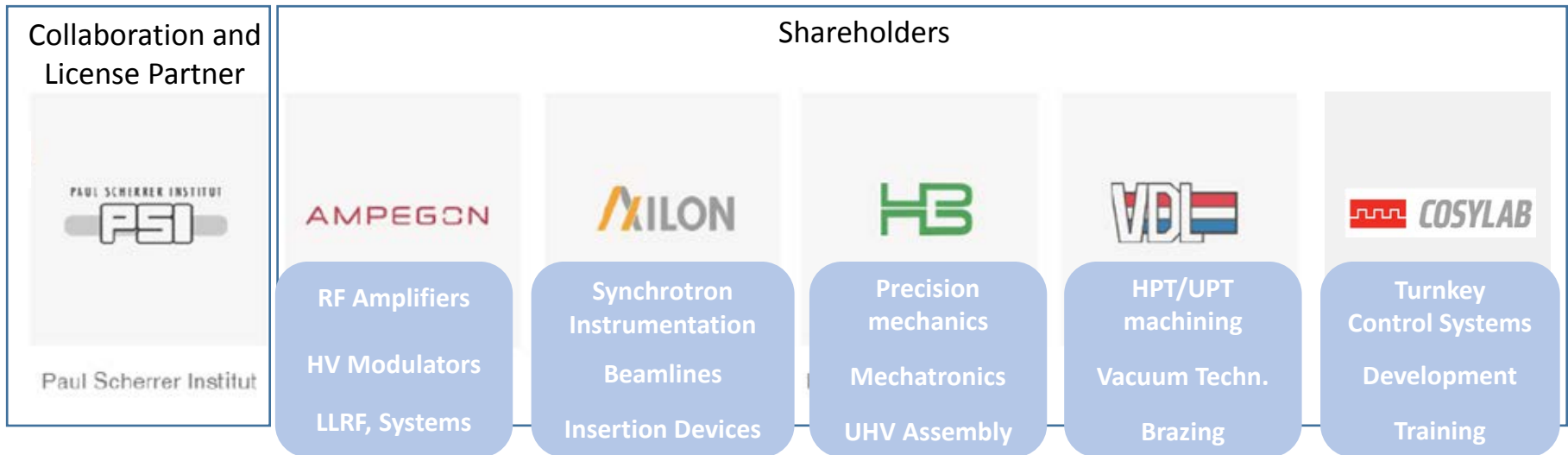
## **Leverage PSI/industry know-how to create new/additional business with advanced accelerator solutions and application for science, medicine and industry**

### New approach for Tech Transfer and Business Development

- Joint effort in business development of market leading high-tech suppliers
- Leverage the extended PSI know-how in accelerator technology, large science infrastructure and their scientific and industrial applications
- Combining business relevant IP with industrial and market/demand know how of leading high-tech suppliers.
- Develop business cases and operate them

# AAT and its Partners

AAT is a joint venture of industrial companies in research and high tech equipment



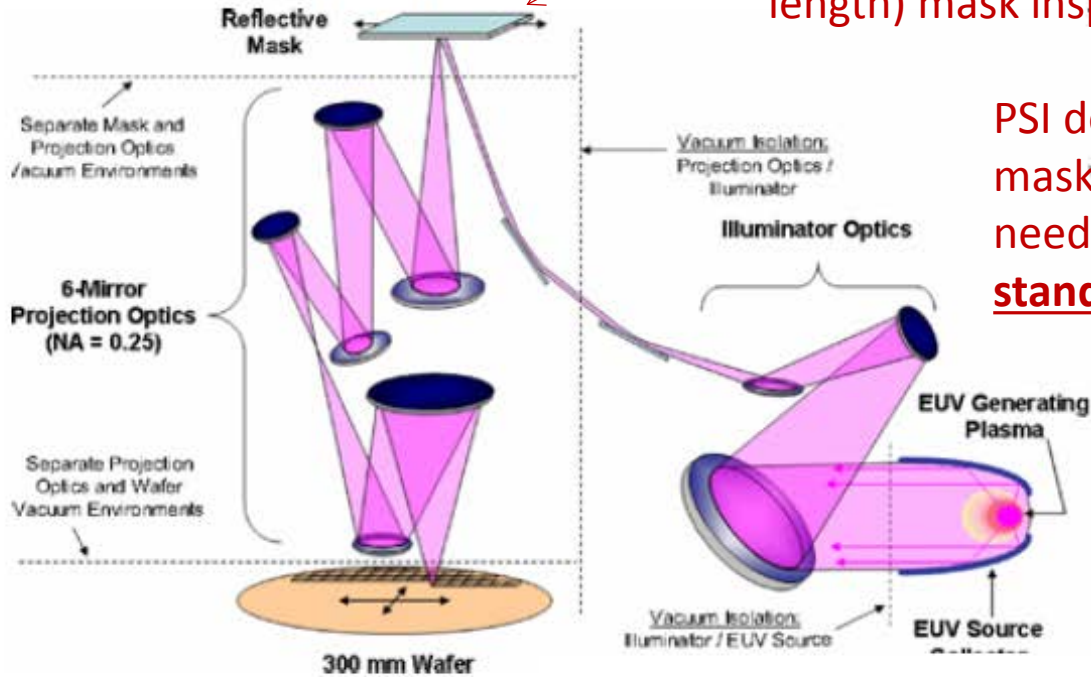
**Enhance economic impact of combined PSI and AAT Know How  
Create value beyond individual expertise**



# EUV Lithography

Mask

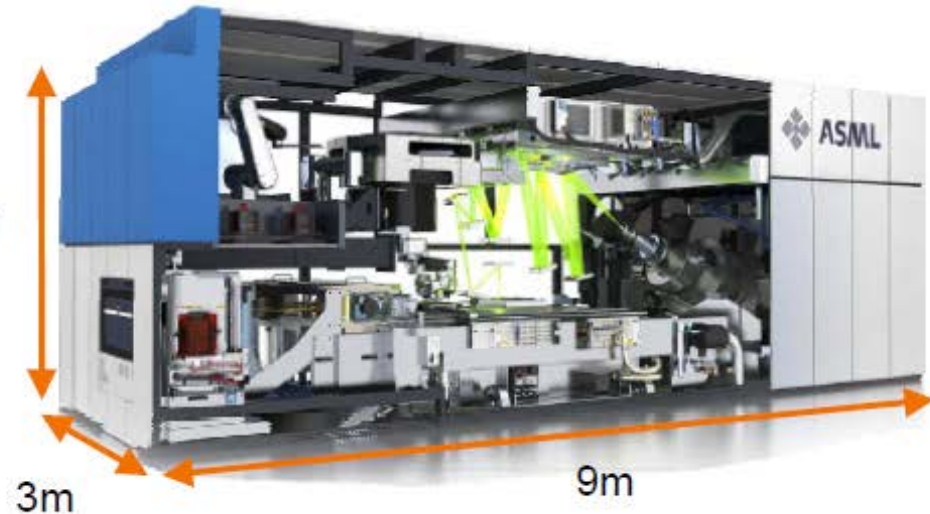
Topic here: Actinic (i.e. on wave-length) mask inspection in EUVL



PSI development of a mask inspection tool needs for a high quality stand alone EUV source

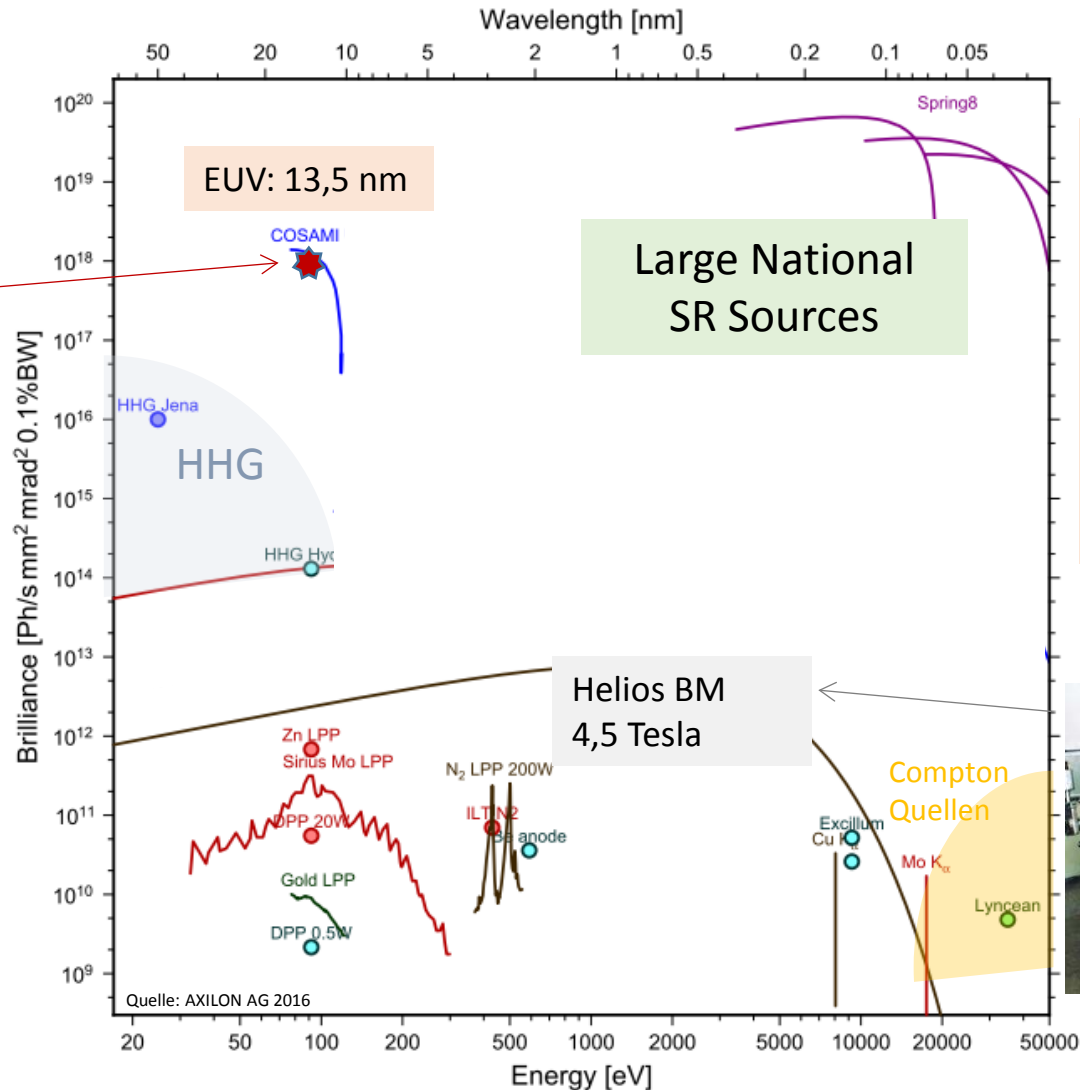
- EUV lithography: reflective optics and mask, plasma source
- EUV in high-volume production delays mainly due to source power
- Planned for HVM production in 2017

(Yasin Ekinci/PSI)





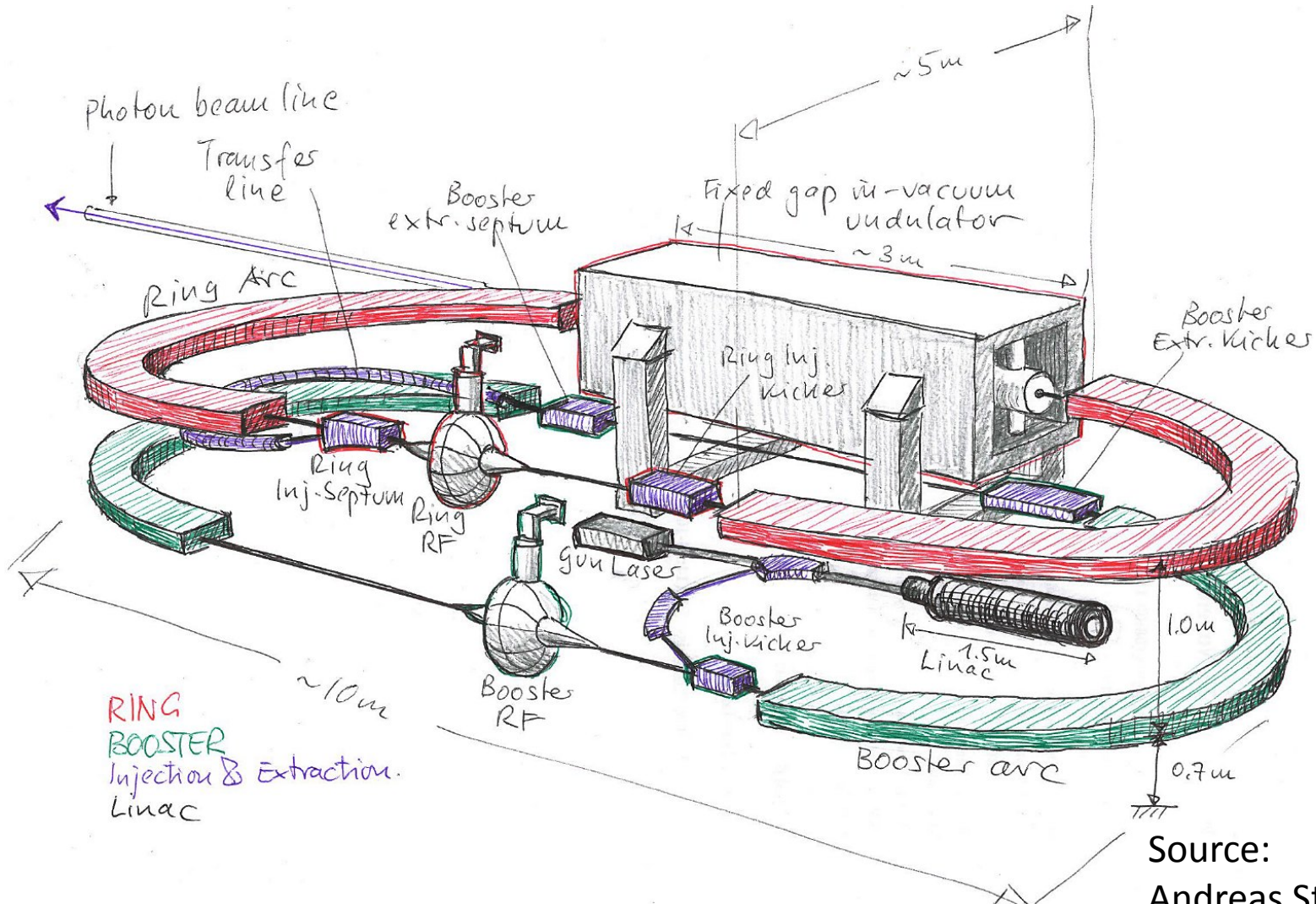
Compact Synchrotron for Actinic Mask Inspection; COSAMI



**COSAMI:**  
Mask inspection with EUV-light (Extreme Ultraviolet); requires „Compact Source“  
Potential demand for this application  
6+ systems, evtl. >10



# An artist's/physicist's impression



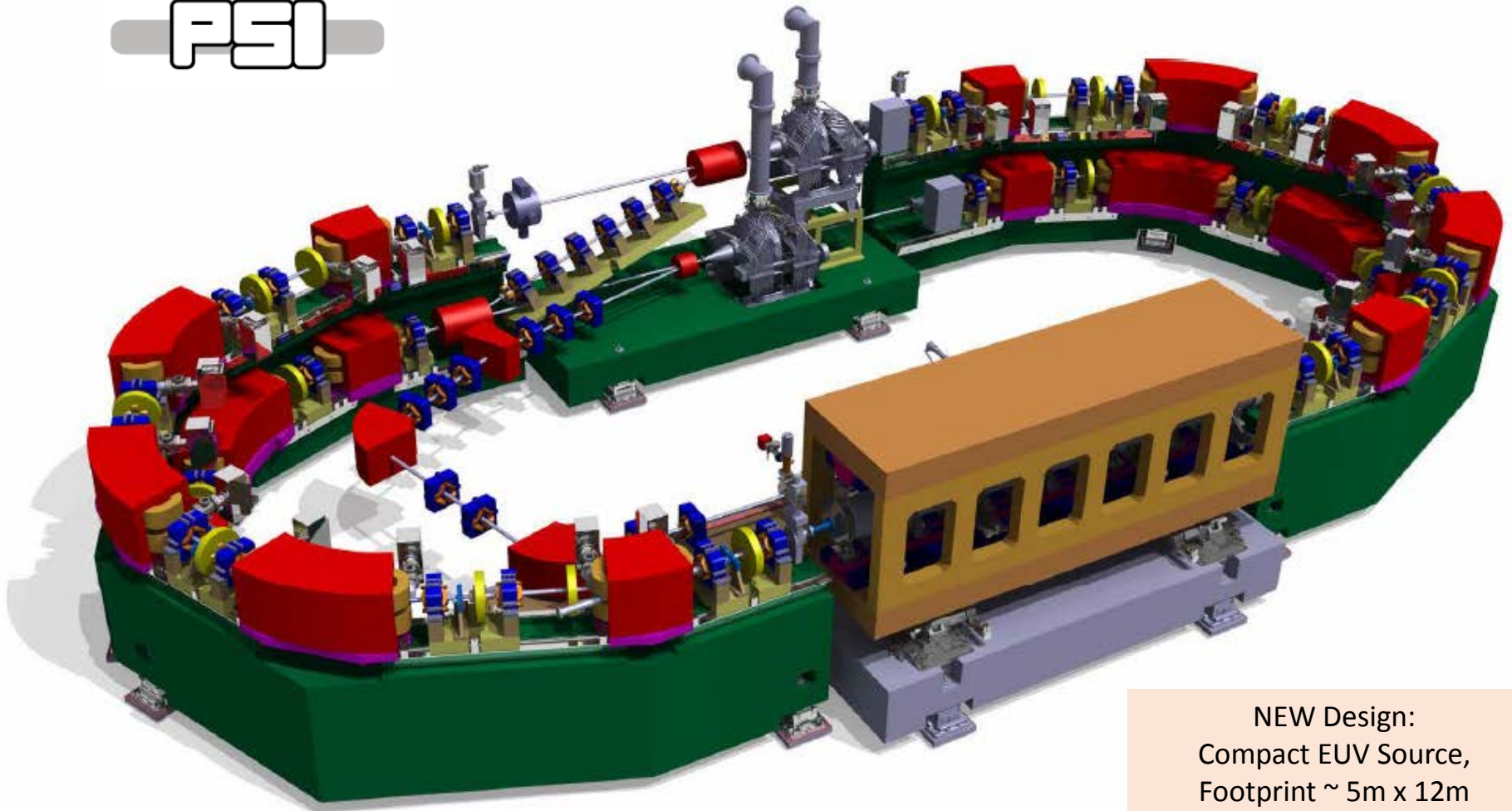
# COSAMI

Compact light source for actinic mask inspection



Advanced Accelerator  
Technologies

PAUL SCHERRER INSTITUT



NEW Design:  
Compact EUV Source,  
Footprint  $\sim 5\text{m} \times 12\text{m}$



## Compact EUV Metrology Source „COSAMI“

Highly coherent , extremely stable , compact EUV (13.5 nm) synchrotron radiation source

Undulator radiation wavelength	13.5 nm
Flux	$1.4 \cdot 10^{15}$ photons/s/0.1% BW
Brilliance	$1.8 \cdot 10^{18}$ photons/s/mm <sup>2</sup> /mrad <sup>2</sup> /0.1%BW
Coherent fraction	~ 6%
Intensity stability	$10^{-3}$
Beam energy/beam current	430 MeV/150 mA
Pulse structure	~ 50 psec spaced by 2 nsec
Injection system	Top-up mode
Magnet system	Conventional, normalconducting
Footprint	5 m x 12 m

# Synchrotron Radiation „Light“ Sources

Very attractive but large devices  
diameter typically 100 m and more

Light sources: > 50 producing synchrotron light

60'000 users world-wide



Source:

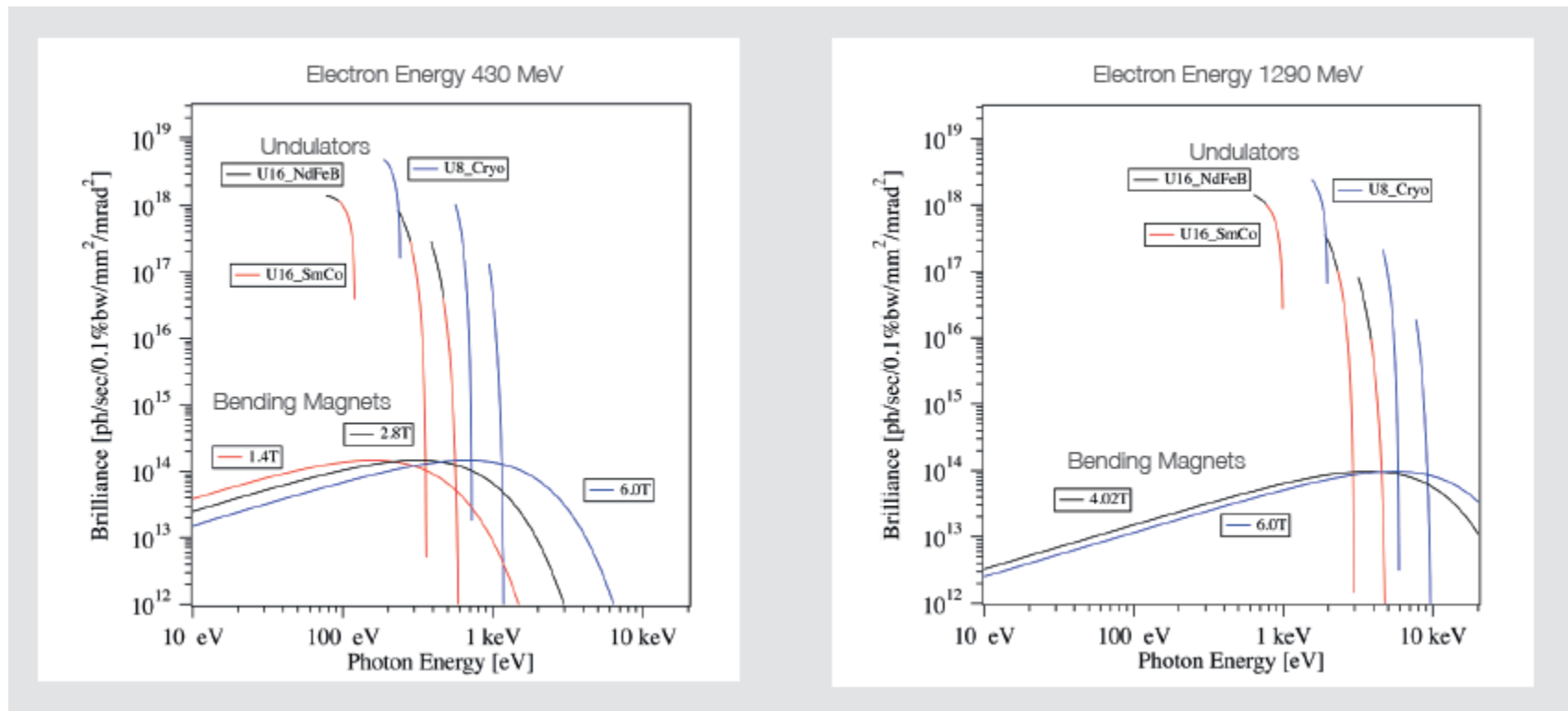


Electron Beam Dynamics, L. Rivkin, Introduction to Accelerator Physics, Budapest

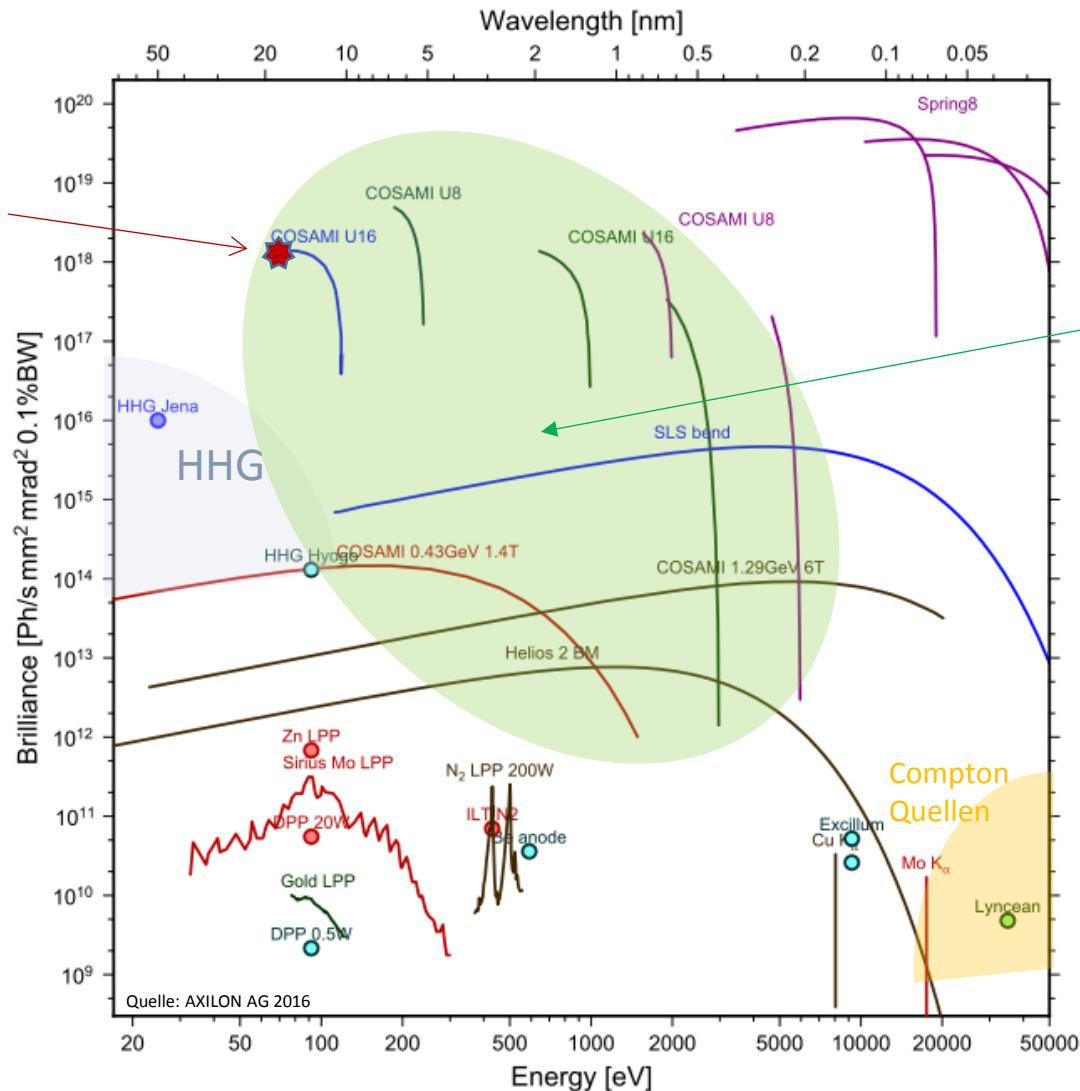


# Family of Compact Sources on one technology platform

Expand offer to larger user groups in Laboratory and Fabrication



Compact Synchrotron  
for Actinic Mask  
Inspection



Parameter regime of compact sources derived from COSAMI/PSI Technology. The different implementations essentially vary in electron energy, type/strength of bending magnets and insertion devices.

# „Bring Synchrotron X-Rays into your Factory and Laboratory“



## Advanced Accelerator Technologies



**Advanced Accelerator Technologies**

### Compact Synchrotron Radiation Sources

Advanced Accelerator Technologies (AAT), a joint venture of industry leaders in the large science and high-tech enterprise supply markets, in cooperation with the Paul Scherrer Institute (PSI), is commercializing innovative accelerator solutions and applications to industry processes and scientific investigations. Key novelty: Compact synchrotron radiation sources that are based on the cumulative know-how, exper-

ience and innovation of PSI from developing, building and operating the Swiss Light Source SLS and the Swiss Free Electron X-Ray Laser SWsFEL. A family of compact synchrotron radiation sources with similar beam optics has been designed for a broad spectrum of wavelengths and energies opening a new era of access to synchrotron X-rays.

Bring Synchrotron X-rays into your Factory and Laboratory



According to your specific application and the respective design performance requirements we develop the optimum configuration for your compact synchrotron radiation source of choice. Our suite of accelerators comprise: electron accelerators with energies ranging

from 0.5 to 1.8 GeV and up to 250 mA beam current. Top-up injection is an integral feature in the low-energy regime. The compact source for 450 MeV is fully developed while detailed design work for higher energy solutions will follow specific customer requests.

#### Key Features and User Benefits

- Multi-point synchrotron light accessible for production floor and research labs
- Optimized for customer's space
- Technology based on PSI know-how & innovation
- Commercialized by industry leaders through their joint venture AAT
- Stable, reliable and low cost operation
- Delivery, commissioning and service innovation

### Compact Synchrotron Radiation Sources

Bring Synchrotron X-Rays into your Factory and Laboratory

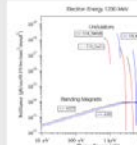
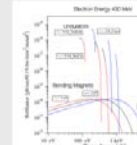
Paul Scherrer Institute technology scaled for your needs and space

#### Compact X-ray Sources in the keV-regime

keV-radiation available by selecting electron energy, special injection devices and superbend magnets

	Undulator radiation range	Bending magnet radiation range
Photon energy range	100 keV - few keV	10 keV to <math>\sim 200</math> keV
Flux	up to $2 \cdot 10^{19}$ photons/s/0.1% BW	up to $4 \cdot 10^{18}$ photons/s/0.1% BW
Brilliance	up to $10^{19}$ photons/s/mrad <sup>2</sup> /0.1% BW	up to $10^{18}$ photons/s/mrad <sup>2</sup> /0.1% BW

Layout with 400 MeV electron energy delivers considerable photon flux up to several keV depending on the choice of specific bending magnets and undulator types. Approximate accelerator footprint is 10-12 m x 8 m depending on the length of the injection device.



#### Compact EUV Metrology Source „COSAMI“

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Flux	$1.4 \cdot 10^{19}$ photons/s/0.1% BW
Brilliance	$1.8 \cdot 10^{19}$ photons/s/mrad <sup>2</sup> /0.1% BW
Coherent fraction	~ 6%
Intensity stability	<math>10^{-3}</math>
Beam energy/beam current	450 MeV/160 mA
Pulse structure	~ 80 psec spaced by 2 nsec
Injection system	Top-up mode
Magnet system	Conventional, normalconducting
Footprint	8 m x 12 m



Paul Scherrer Institute PSI

AAT offices, PATH INCUBATOR, Dornbirn, Austria

#### About AAT

Advanced Accelerator Technologies AG (AAT) has been founded on an initiative of the Paul Scherrer Institute (PSI) in 2015 in order to identify the commercialization of its experience and know-how in accelerators and large scientific infrastructure development and operation as well as the broad spectrum of their applications. As part of the national initiative Swit-

zer and Innovation, AAT is located in PARK INNOVARE at PSI in Villigen. Switzerland. AAT is set up as a joint venture of industry leaders in the large science and high-tech enterprise supply markets, joining their specific industrial skills, experience and strengths in order to create higher customer value by combining with PSI's vast R&D expertise.



Based on a broad cooperation and license agreement with PSI AAT commercializes innovative and custom designed high and intermediate energy systems for research institutions and high-tech industries. AAT is member of Switzerland Innovation Week (CIW).

#### About PSI



PSI is the largest national research institute in Switzerland with excellence in a wide spectrum of scientific fields and nuclear technology developments. PSI has been ordered in building and operating worldwide outstanding accelerators and other large science infrastructure for numerous scientific experiments. Furthermore, it has

generalized applications with social and economic mission such as cancer therapy, energy solutions, industrial processes among others. Technologies developed for the Swiss Light Source SLS and the Free Electron X-Ray Laser SWsFEL are key for AAT's compact synchrotron radiation sources offering

SWsFEL 2010

Free Electron X-Ray Laser SWsFEL



#### Contact

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This concept can cover a wide area of photon energies below 10 keV with high brilliance

**Challenge for the community:**

**Find compact, high brilliance accelerator solution for hard X-rays in the 10 keV+ regime !**

Identification and development of a suitable application and the respective accelerator based solution requires broad technological skills and – if commercialisation is envisaged - a business development process

COSAMI: Example for focused product development with wider application space below 10 keV photon energy.

Compact SR sources may be interesting as „home/local source“ for research institutions/universities or countries w/o national source but interested to enter SR science

**Challenge for the community: High brilliance compact sources for 10 keV+. They would find wide application !**

**Thank you for your attention**