Development Status of High Power Tin Gas Discharge Produced Plasma Sources For Next Generation EUV Lithography

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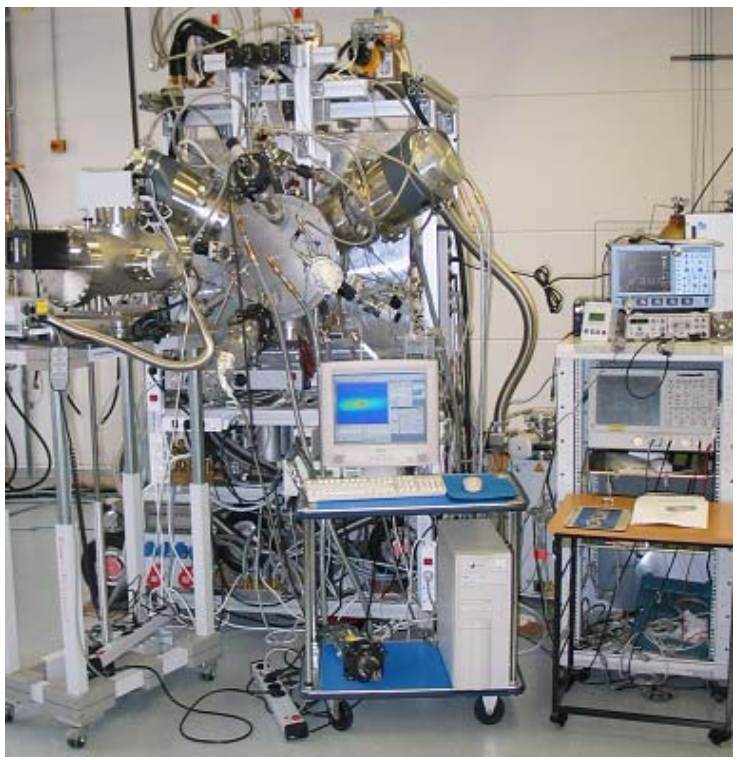
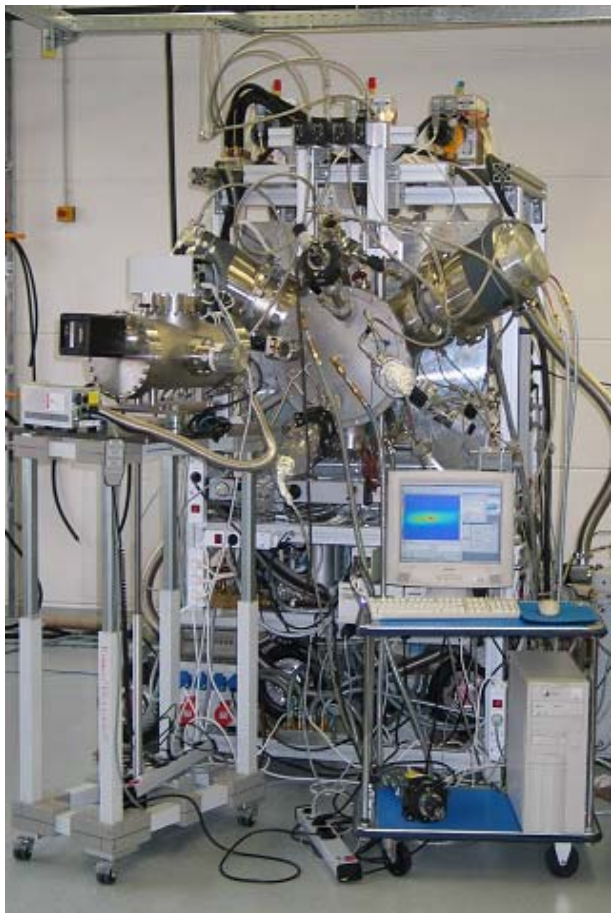


3rd Intl. Symposium on EUVL

Miyazaki, JP, 02 November 2004

Outline

- HVM Power requirements
- Gas Discharge Produced Plasma EUV Sources with tin
    - Spectral distribution
    - Conversion efficiency
    - Power scaling
    - Pinch size
    - Stability
    - Debris
    - Power status and roadmap



HVM Power Requirements: estimations

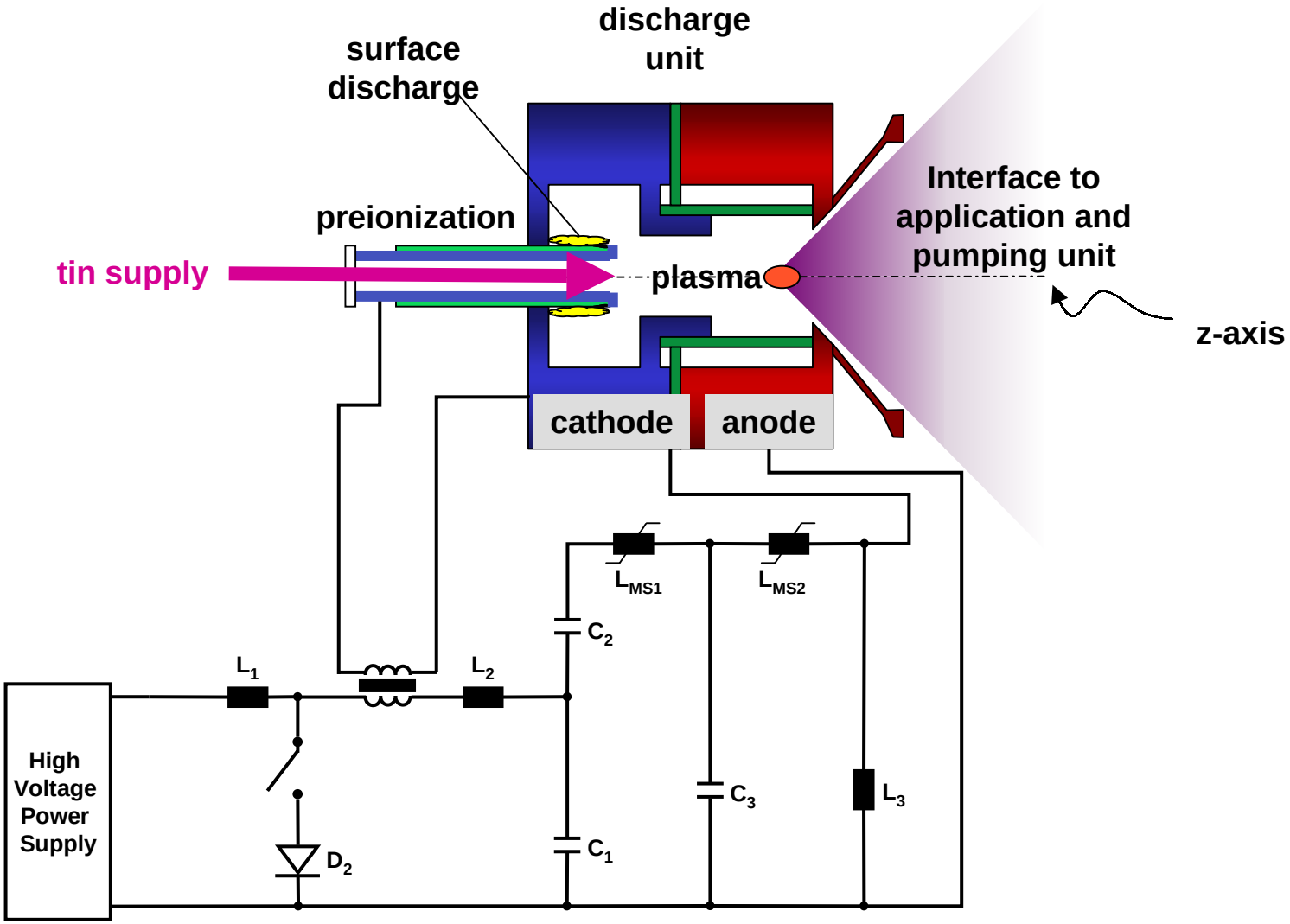
Required power at intermediate focus (2% bandwidth, 13.5 nm) for HVM

115 W

Etendue acceptance factor:	0.5 – 1.0
Debris filter transmission:	0.8
Gas transmission:	0.85
Required source power in collection angle:	169 - 338 W
Geometrical collection efficiency / 2p sr:	0.5
Angular averaged collector reflectivity:	0.55
Required source power into 2p sr:	615 – 1230 W

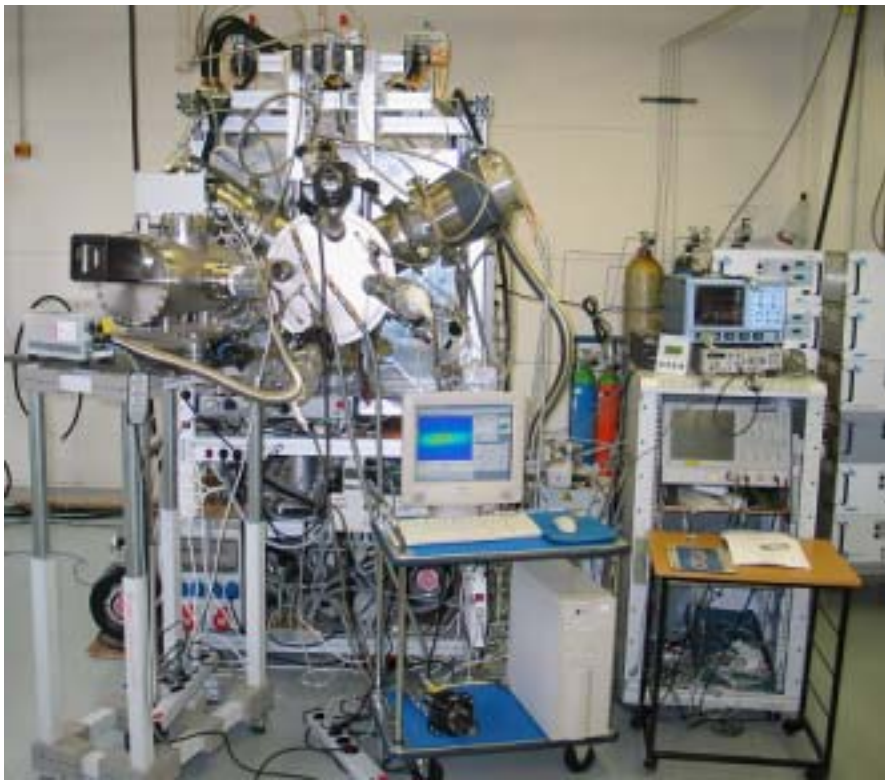
GDPP EUV Sources with Tin: source setup

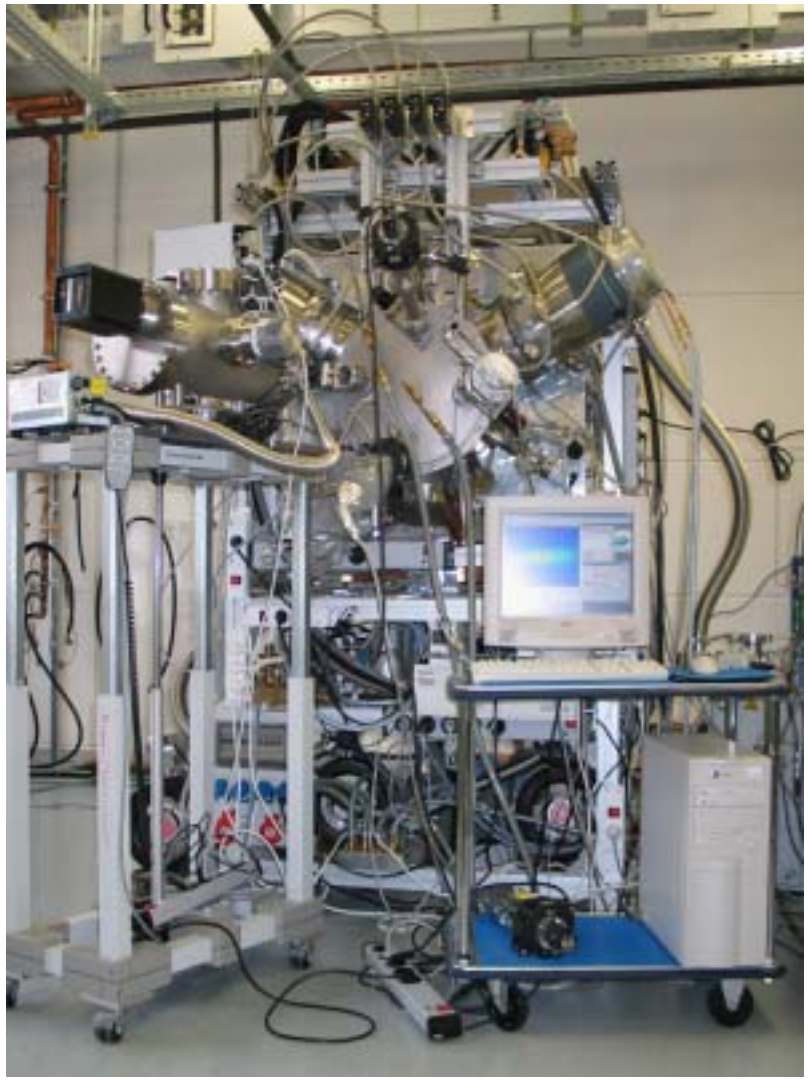
Z-Pinch tin EUV source



GDPP EUV Sources with Tin: source setup

High power tin source



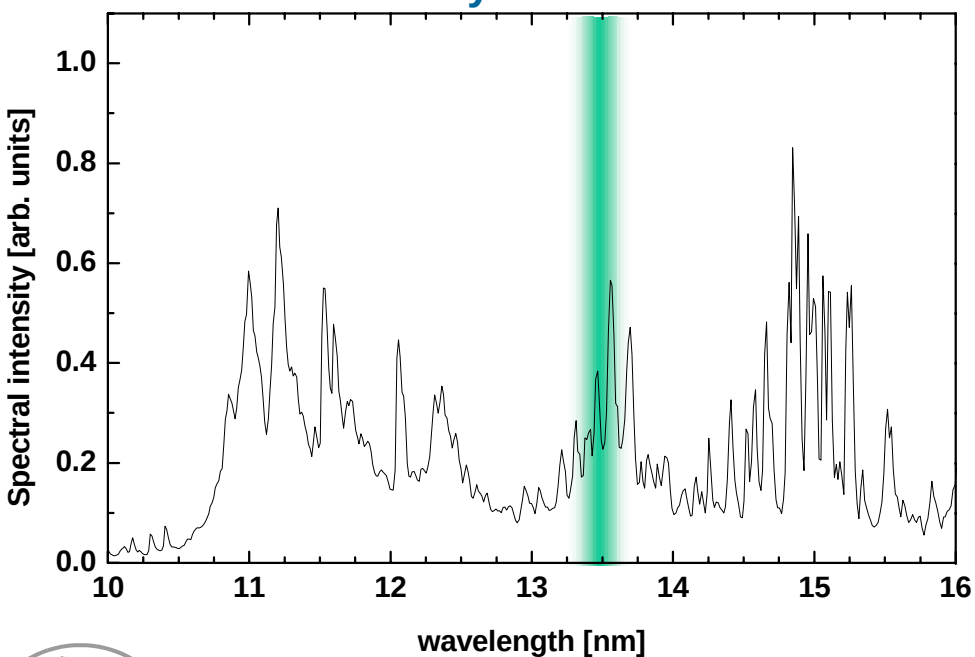


GDPP EUV Sources with Tin: spectral distribution

Why tin?
- Shifting the peak emission to 13.5 nm
- better spectral purity / lower out-of-band contribution
- tin approx. twice as efficient as xenon

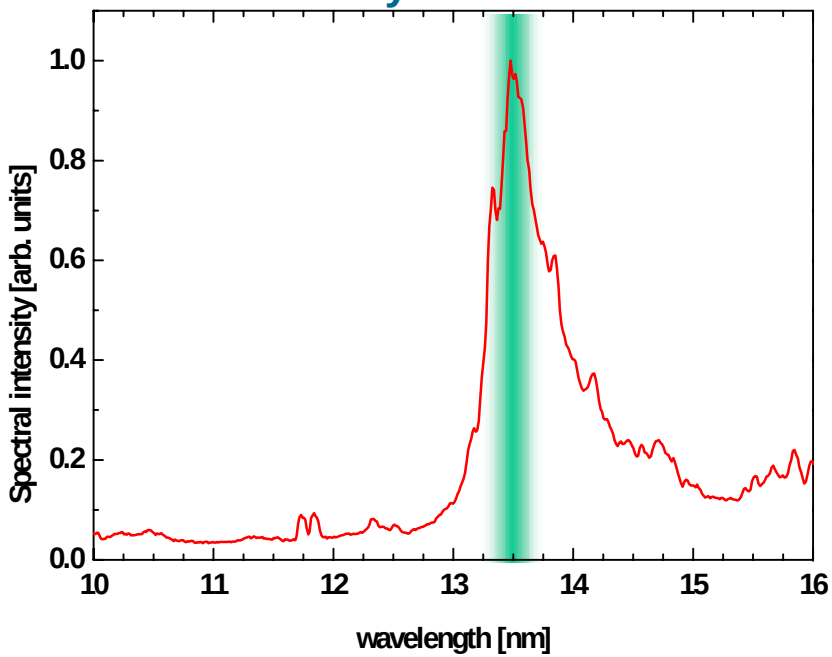
Xenon

Efficiency 1.0...1.6 %



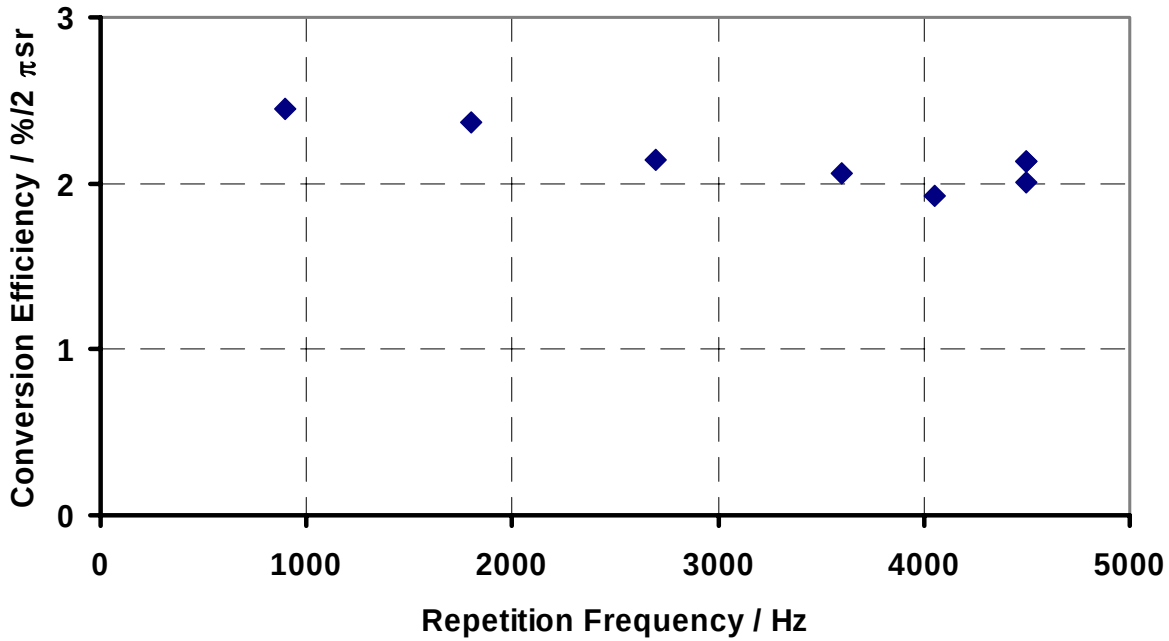
Tin

Efficiency 2.0...2.9 %



GDPP EUV Sources with Tin: conversion efficiency

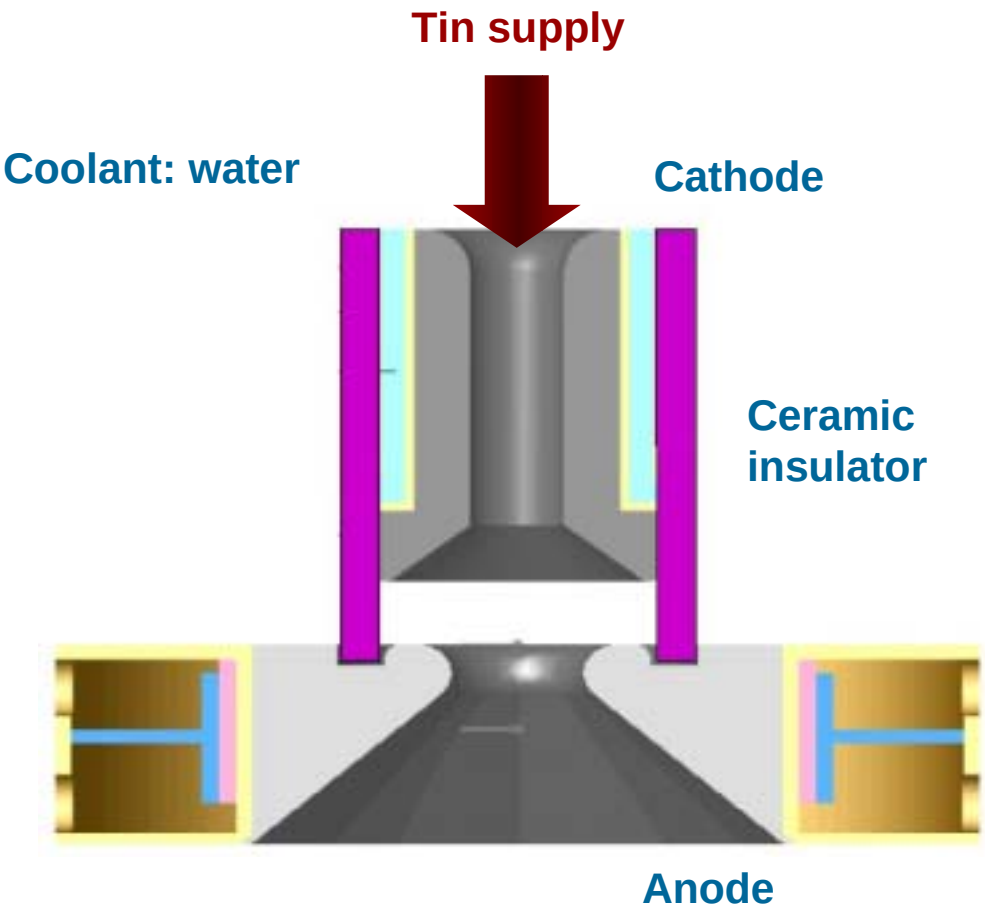
Max CE 2.9%/2π sr achieved



Higher values possible with optimized electrical circuit

About 2 times higher CE for tin compared to xenon!

GDPP EUV Sources with Tin: cooling improvement for Z-Pinch



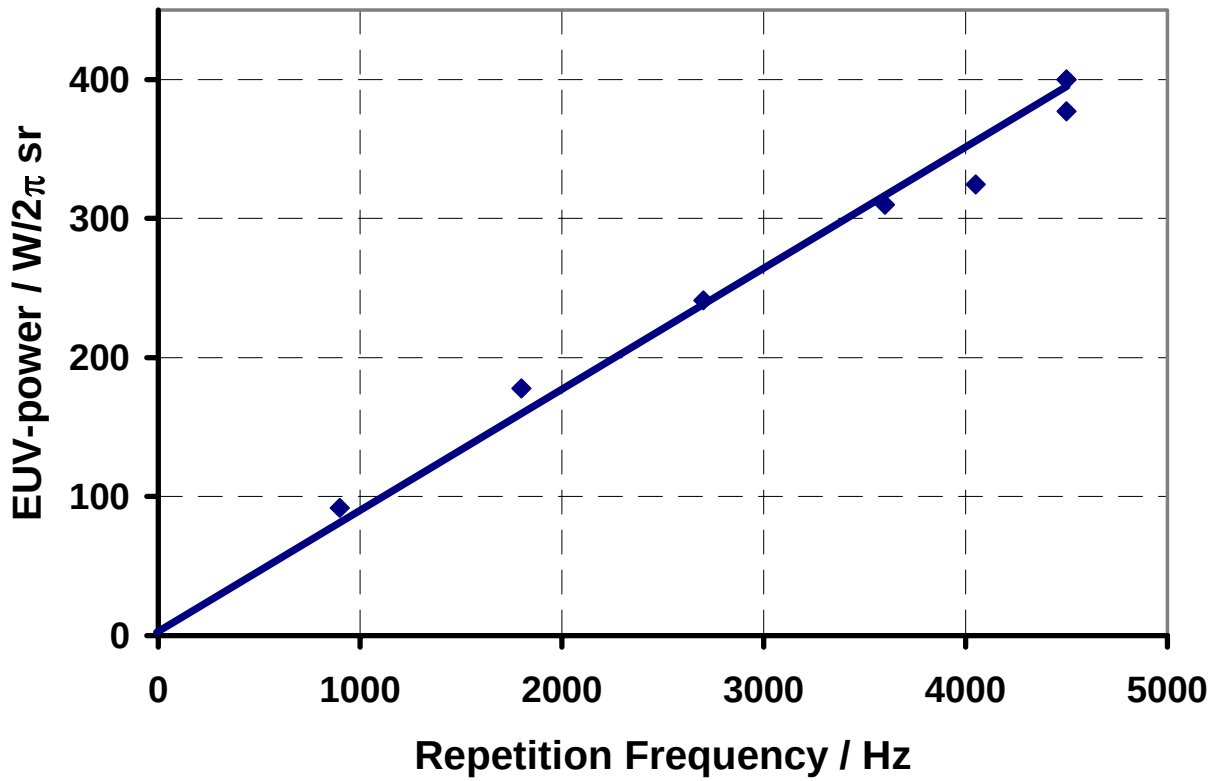
Cooling capability

Maximum cooling power ≥20 kW

Porous metal cooling technology

GDPP EUV Sources with Tin: power scaling

Highest power from tin GDPP source



400 W/2π sr EUV in-band power achieved

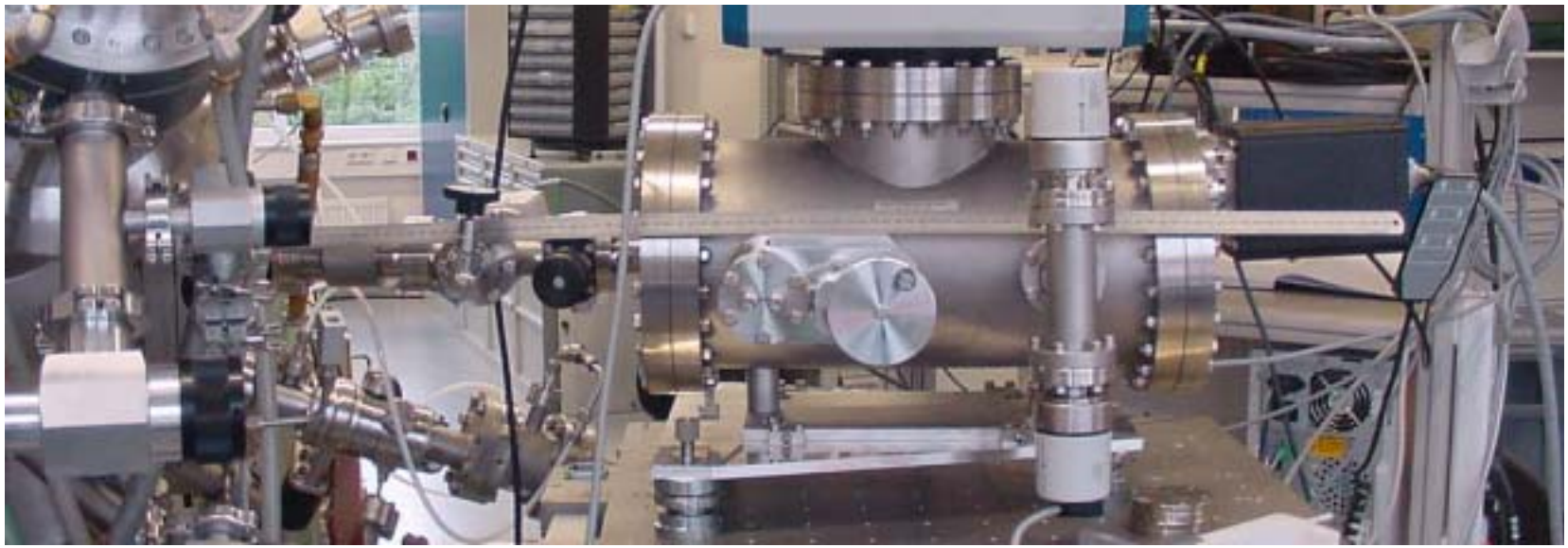
Repetition rate:

Up to 4500 Hz continuous mode

Scalable to higher power by higher pulse energies and repetition rates

GDPP EUV Sources with Tin: pinch size

pinch size determines usable IF power



EUV spectrograph with additional slit for spatial resolution

Determination of the pinch size at individual wavelengths

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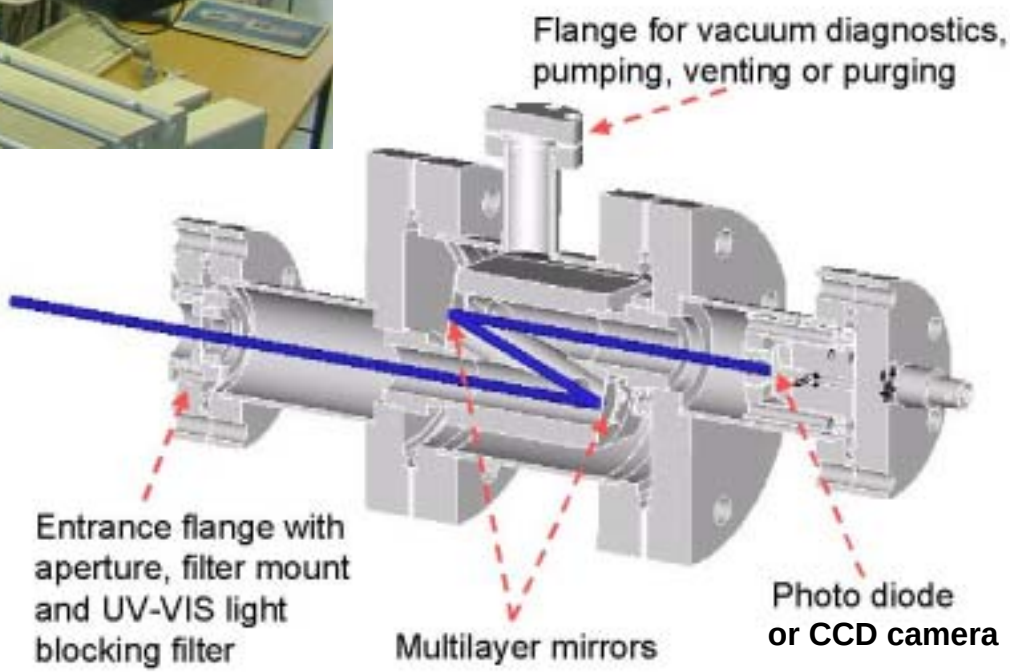
Taking light to new dimensions…

GDPP EUV Sources with Tin: pinch size

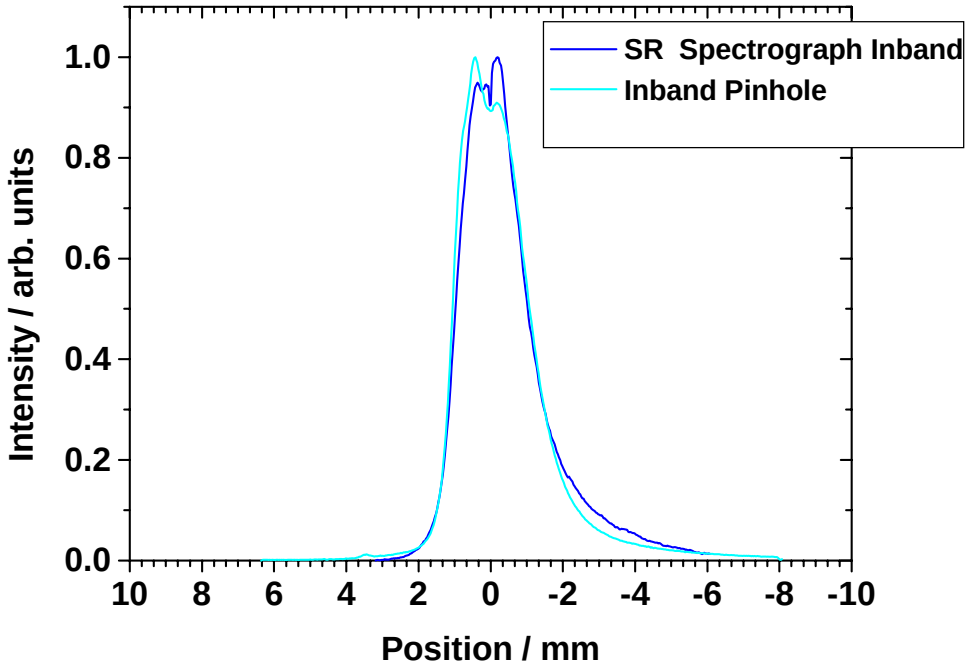
JENOPTIK JENA Mikrotechnik

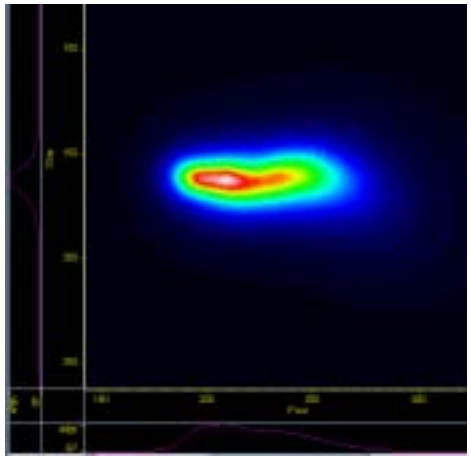
Sketch



EUV in-band camera setup

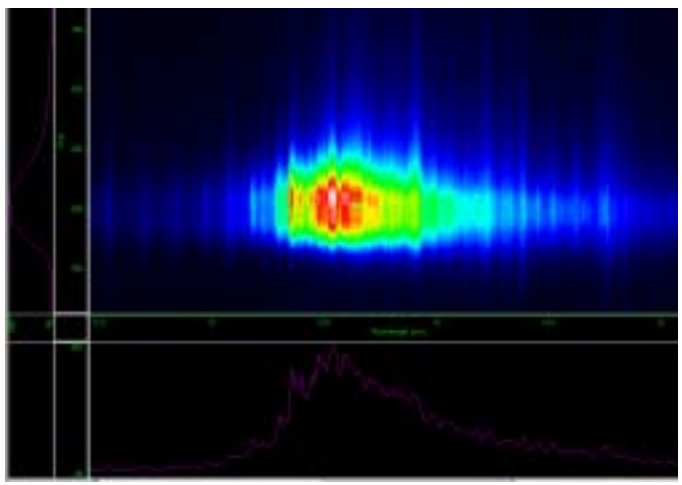
GDPP EUV Sources with Tin: pinch sizes





Pinhole camera image

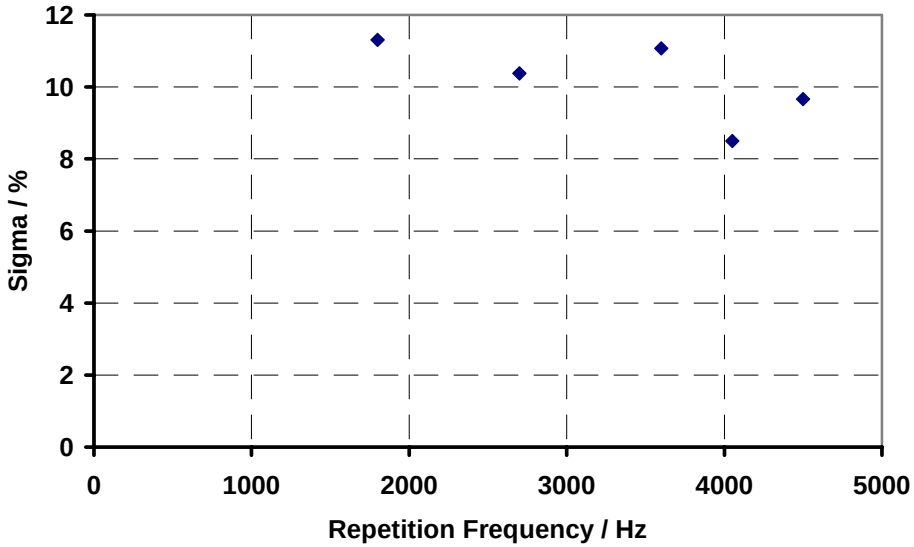
- **Plasma size 1.0 ... 4.0 mm depending on excitation conditions**
- **Small background compared to xenon image**
- **Excellent agreement between both measurements**



Spatially resolved Sn spectrum

GDPP EUV Sources with Tin: stability

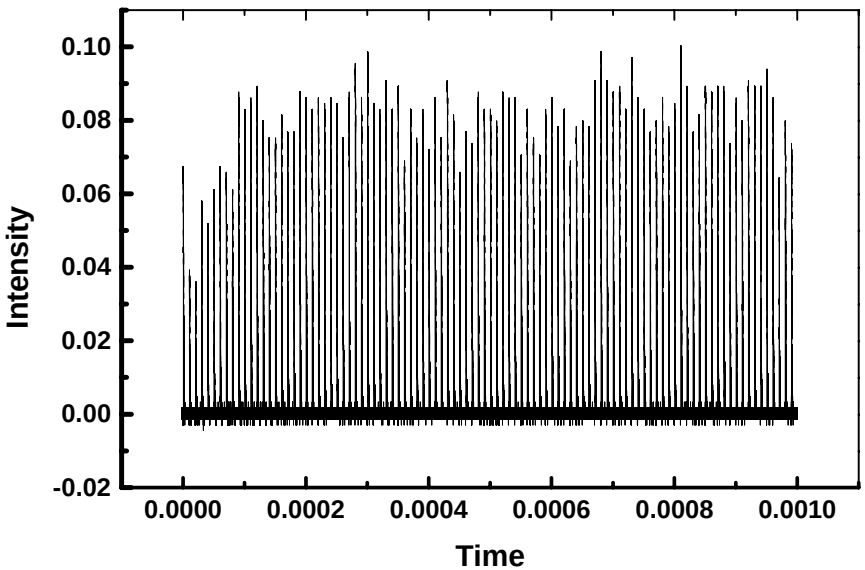
High-Power Source



Measured value σ ≈ 10 % including undershoot

Optional improvement by optimization of:

- tin supply
- electrode system and circuit
- cooling system

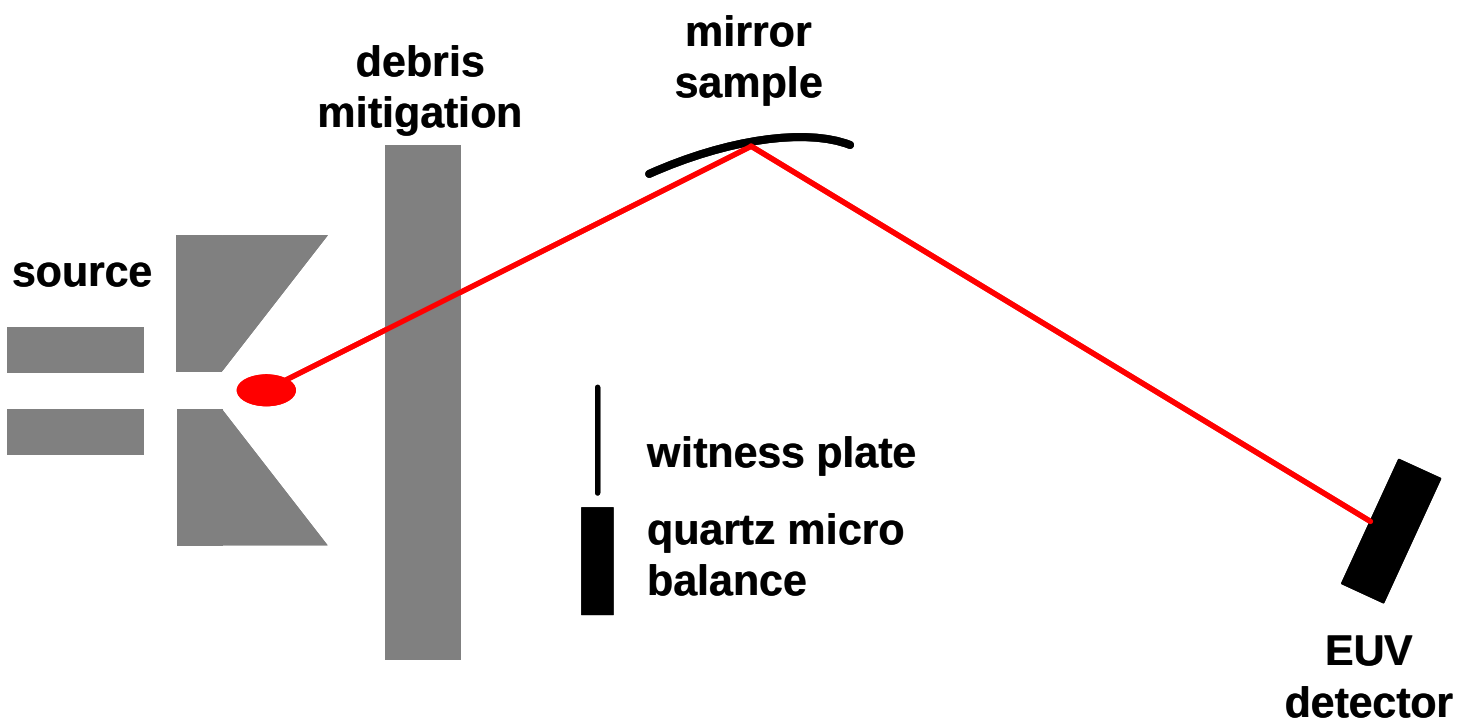


Expectation:

Comparable stability values for tin and xenon sources

GDPP EUV Sources with Tin: debris

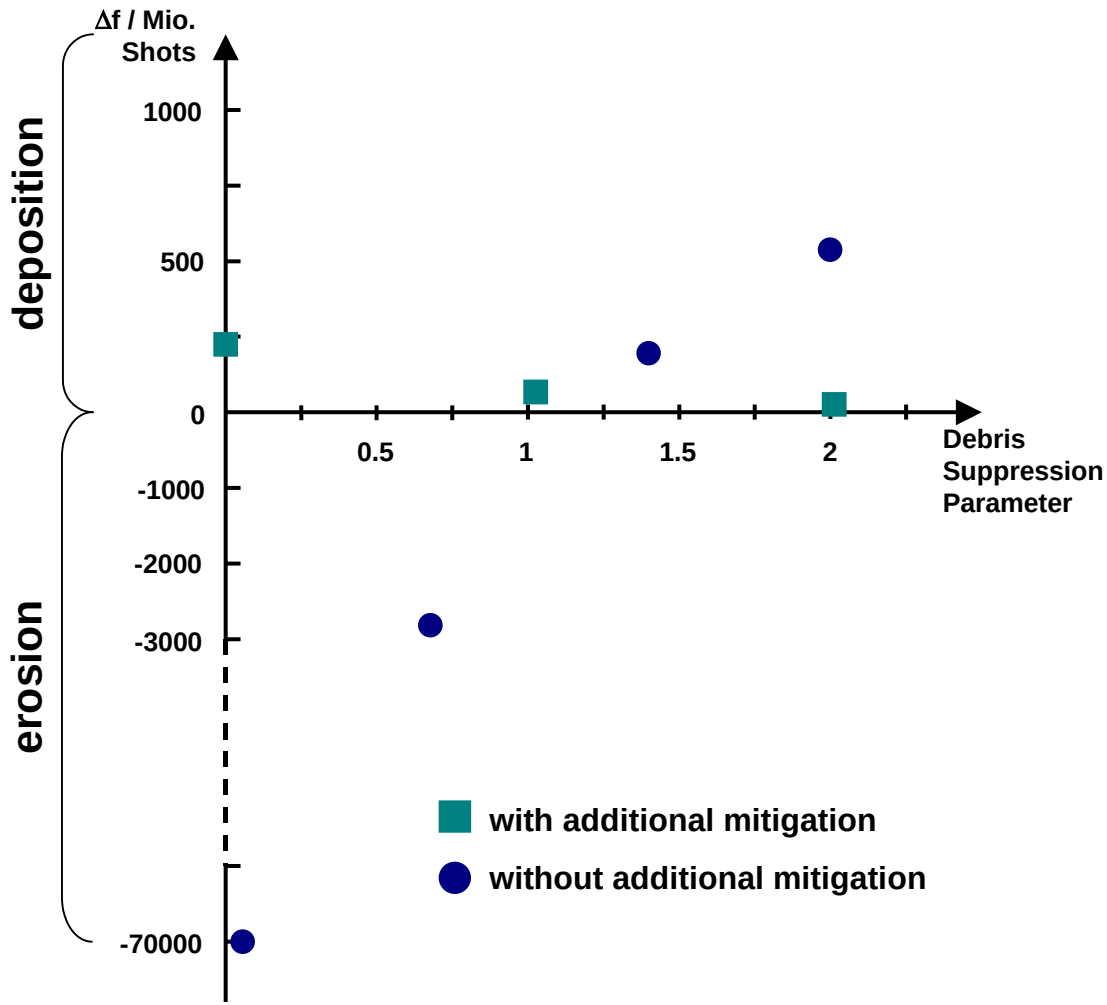
Experimental setup for debris measurements



Analysis:

- Reflectivity of mirror samples
- Analysis with QMB
- SEM, XPS, TOF-SIMS
- Transmission of quartz witness plates

GDPP EUV Sources with Tin: contamination debris



- QMB measurement
- Balance between erosion and deposition adjustable
- Minimum optics lifetime >5 million pulses

GDPP EUV Sources: power status and roadmap

Fuel	tin status 11/2004	tin on the roadmap with collector of today	tin on the roadmap with improved collector
Heat removal from discharge (kW)	20	40	40
Conversion efficiency (%)	2.0	3.0	3.0
EUV power (W/2π sr)	400	1200	1200
Transmission of debris mitigation	0.8	0.8	0.8
Collection solid angle (sr / 2π sr)	0.3	0.3	0.5
Average reflectivity of collector	0.63	0.63	0.55
Gas transmission in collector module	0.85	0.85	0.85
Available IF power (W)	**51.4**	**154.2**	**224.4**
Etendue acceptance factor	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0
Usable IF power (W)	**25.7 - 51.4**	**77.1 - 154.2**	**112.2 - 224.4**

Thank you for your attention !!!

XTREME technologies GmbH, Germany

Acknowledgement

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