KLA-Tencor

Accelerating Yield

Status of Actinic Patterned Mask Inspection at KLA-Tencor

Oleg Khodykin

Outline

- **Introduction**
  - Bridge solution
  - Status of prior research investigations
- **Xe LPP source**
  - Requirements
  - Choice of architecture
  - Current status
- **Conclusions**

Latest reticle inspection solution

- EUV patterned masks and blanks
- Optical, Complex OPC, Quartz etch reticles
- For ≥ 10nm Generation
- *Practical sensitivity limited by edge roughness*

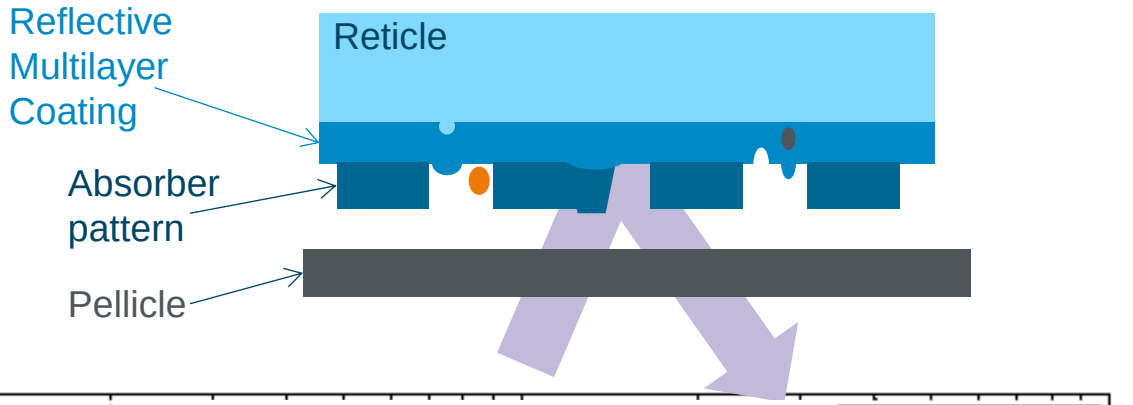
Teron 6xx platform

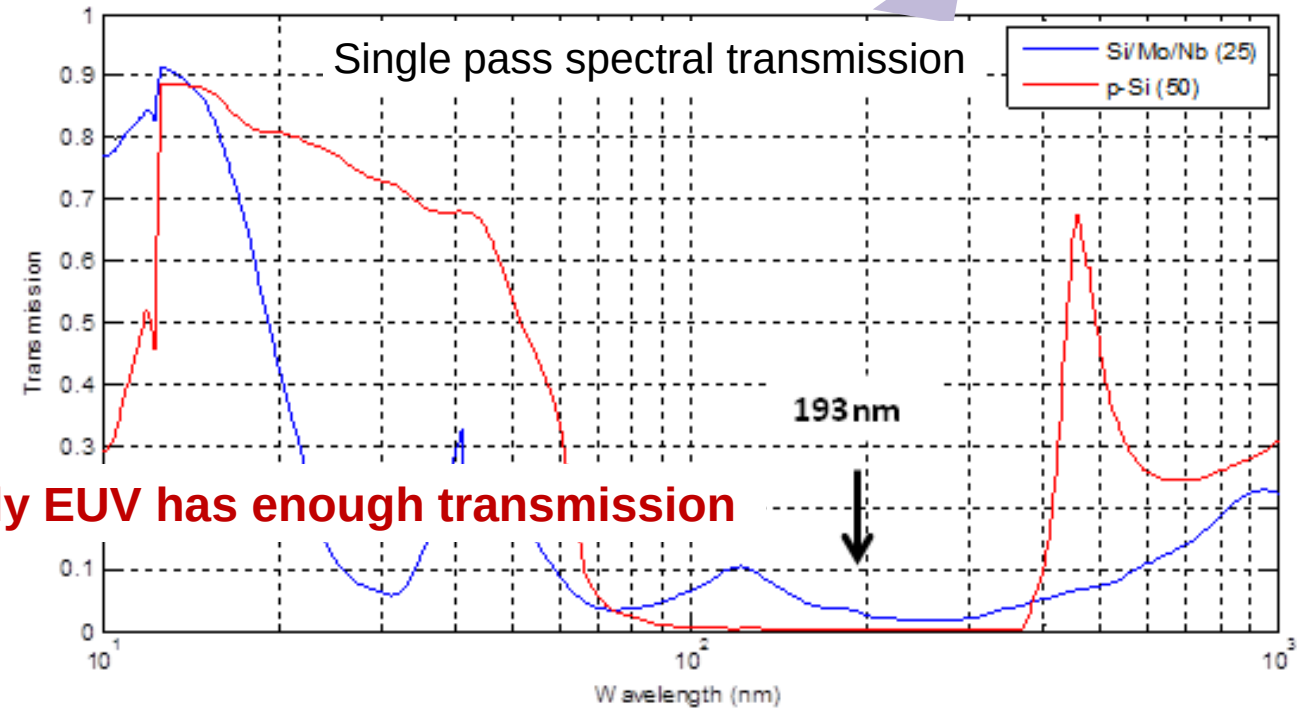
Industry proven sensitivity for advanced optical and EUV Mask applications

2016 International Workshop on EUV and Soft X-Ray Sources, Amsterdam

EUV reticle defect and inspection challenges

Pellicle transmission effects will narrow the wavelength choices





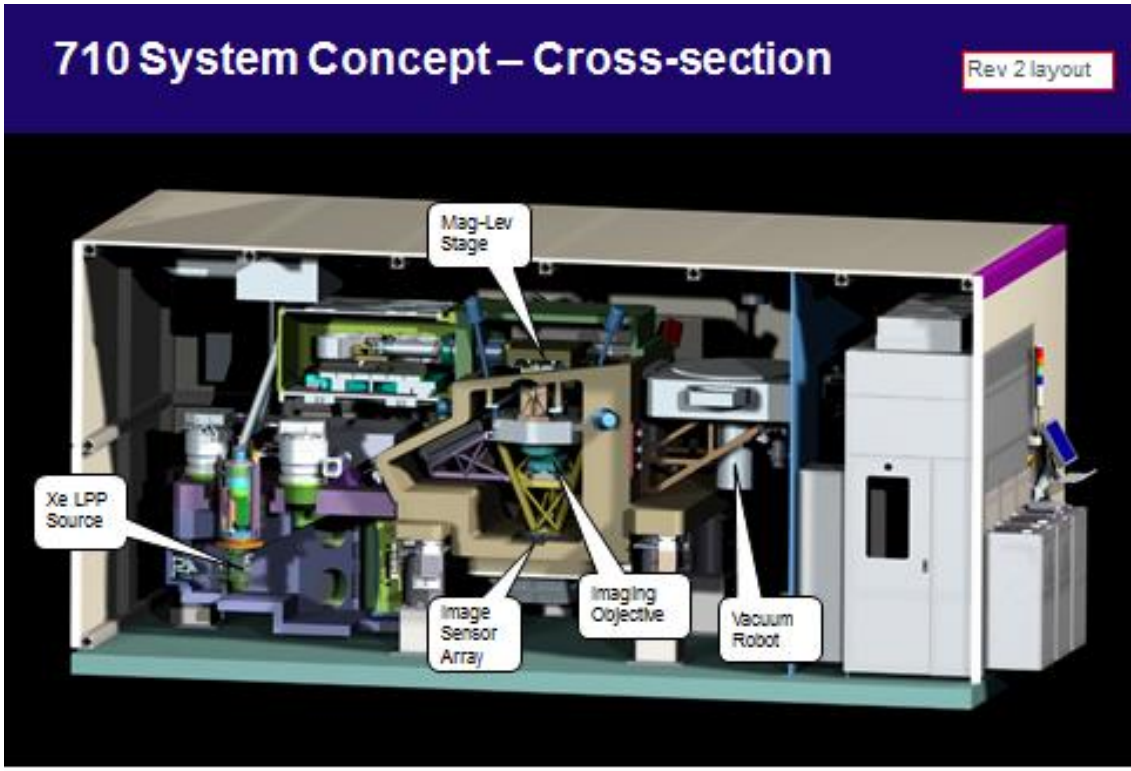
Only EUV has enough transmission

2016 International Workshop on EUV and Soft X-Ray Sources, Amsterdam

7xx program summary

EUV actinic patterned mask inspection

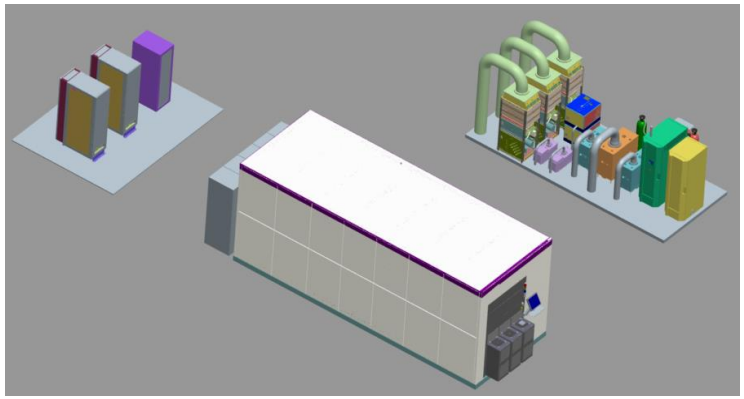
- System architecture defined
- EUV-specific image sensor designed and tested
- Optics concepts provide large field and high transmission
- Xe LPP source prototype shows required lifetime
- Ultra-clean vacuum prototypes tested
- Pilot production facility ready for build-out



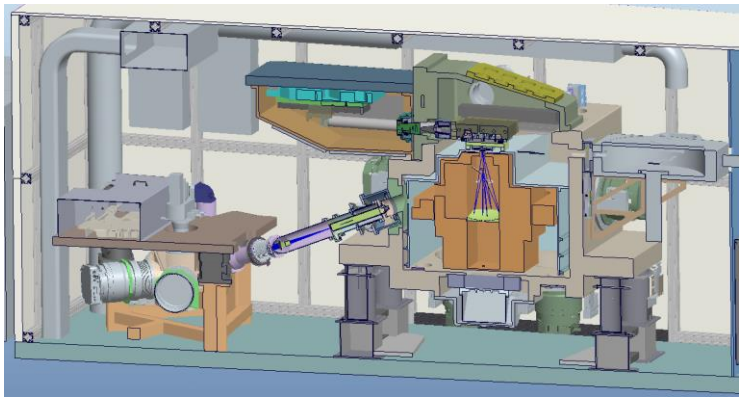
Program ready for full-scale development

APMI Concept Phase → Technical "Go"

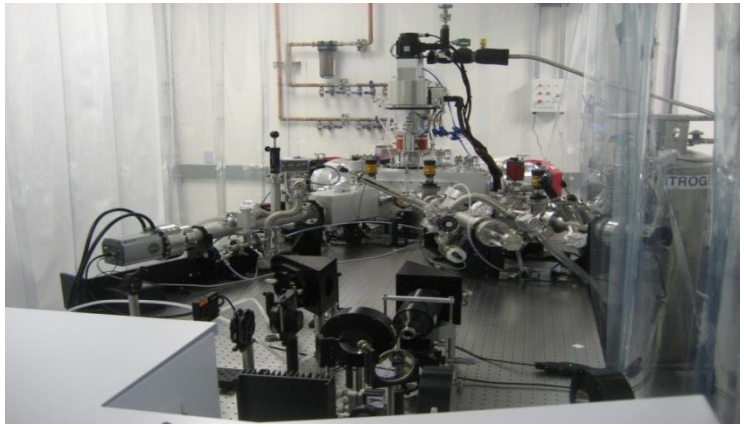
Overall System Layout



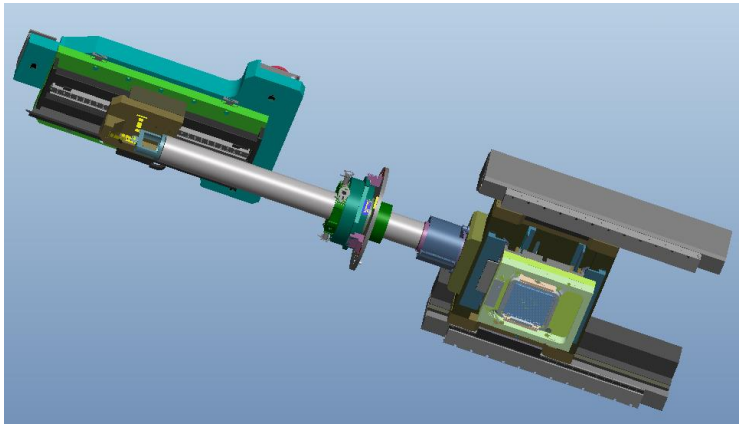
Optics Design



Source Prototype Test Bench



Stage Design



K-T's comprehensive multi-year investigation addressed and solved all significant technical risks

Contamination Control Technology developed at KT

To optimize Particle Performance of Wafer and Reticle Inspection Tools

Collect Particles

VPTS

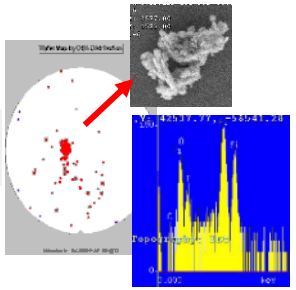
Quantity, Location & Size

SP3 & 5

Materials

eDR-7100

7-Step



Analysis and Mitigation

<u>All</u> vacuum component suppliers have significant challenges with particle and molecular contamination

We have Repeatedly Demonstrated Zero-PWP

Both in Atmosphere and Vacuum in Dedicated Particle Test Stand

K-T's infrastructure investments enable shortest time-to-success

KLA-Tencor

Accelerating Yield

Xe –based LPP source

Actinic patterned mask inspection: source requirements

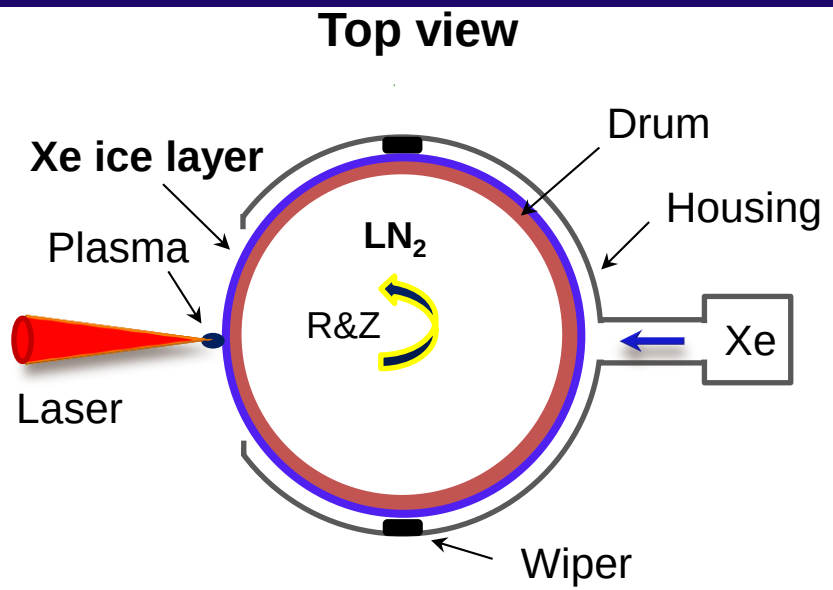
Property/parameter	Target Value	Units
Wavelength	13.5	nm, centroid
Pulse repetition rate	> 10	kHz
Pulse duration	> 10	ns, FWHM
Duty Cycle	> 95%	- minimum burst > 15 sec
Etendue	1.0 x 10^{-2}	mm^2-sr
Radiance at IF	> 20	W/mm^2-sr
(Averaged over etendue, lifetime)		2.2% band, pre-SPF
Footprint (m)	2.8W x 2.8D x 2.8H	
Availability	> 95%	
Cost of Service (annual)	< 10%	Relative to CoGs / Price
Cost of Operation (annual)	< 5%	

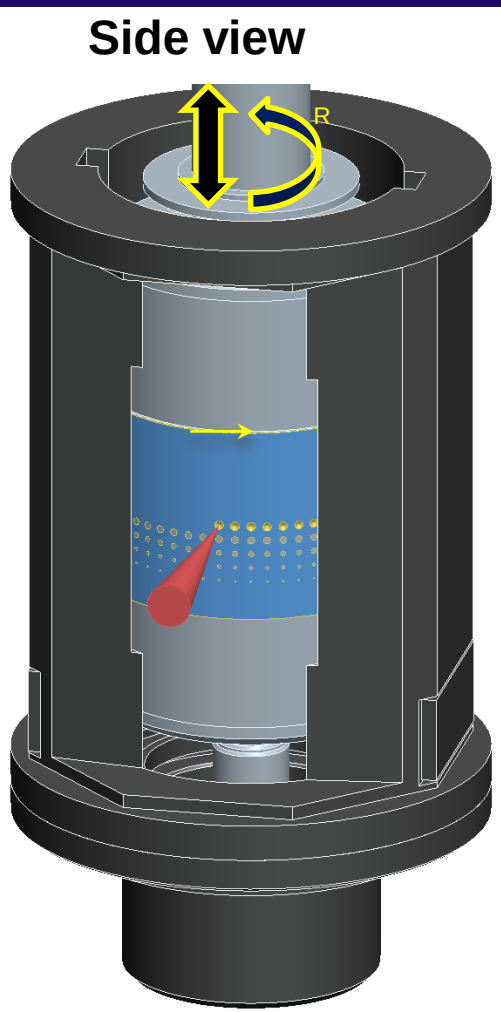
Options

Method	DPP/LDP	LPP
Advantages	Simple (DPP)	Clean (mass limited targets) Small plasma size Scaling though repetition rate
Disadvantages	Erosion of near-plasma elements Large plasma volume Long plasma	Target –laser interaction (droplets)

Target	Xe	Sn
Advantages	Noble gas No deposition Off-shell vacuum pumps	High CE (>3%)
Disadvantages	High cost	Deposition (collector lifetime) High temperature operation Reacts with Ru to form alloys

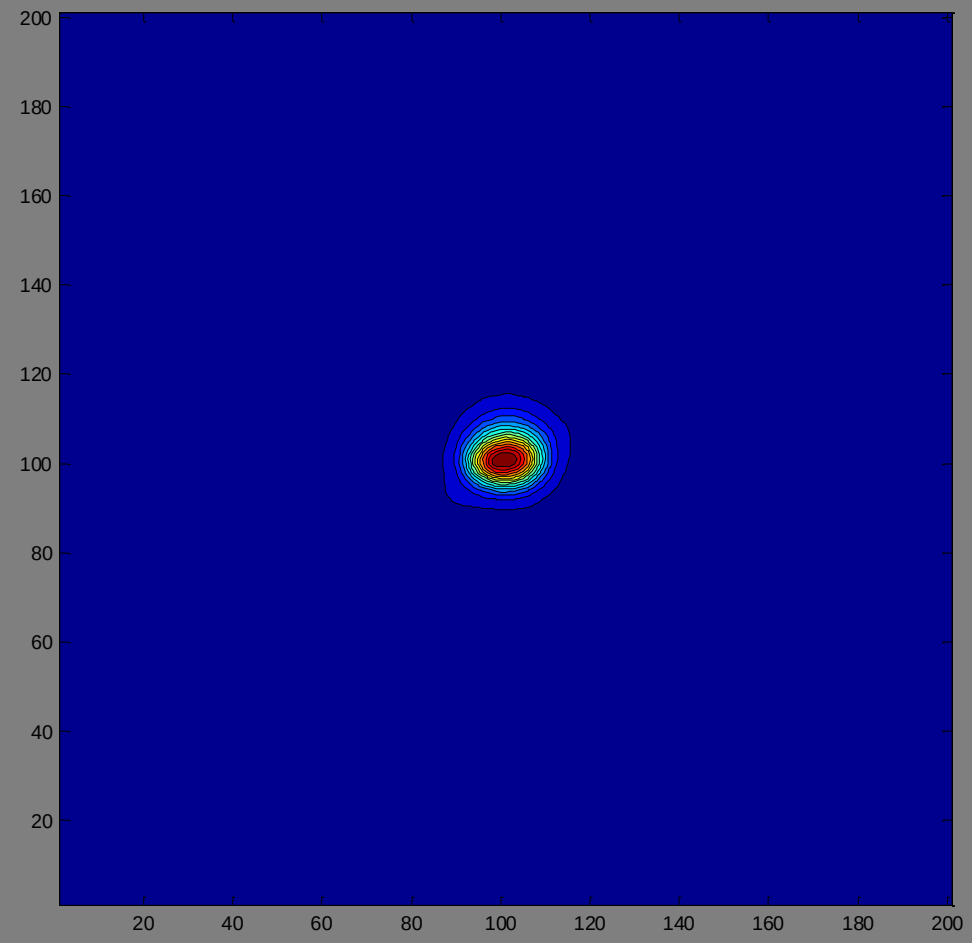
Solid Xenon Drum Target

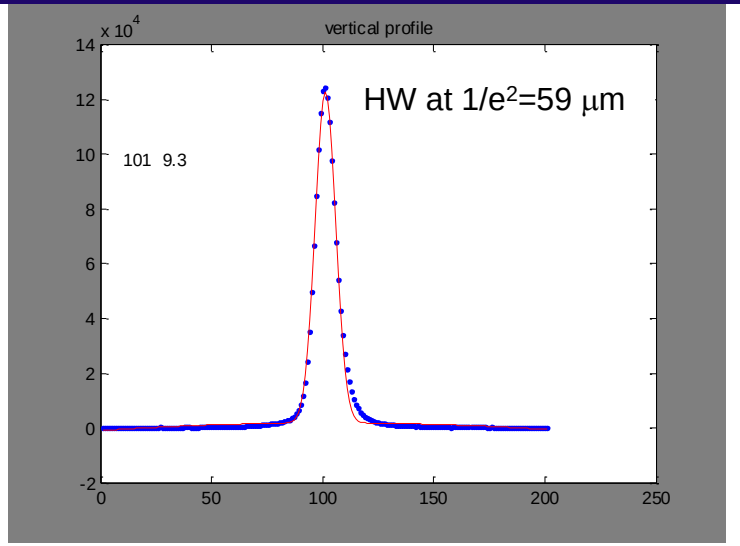


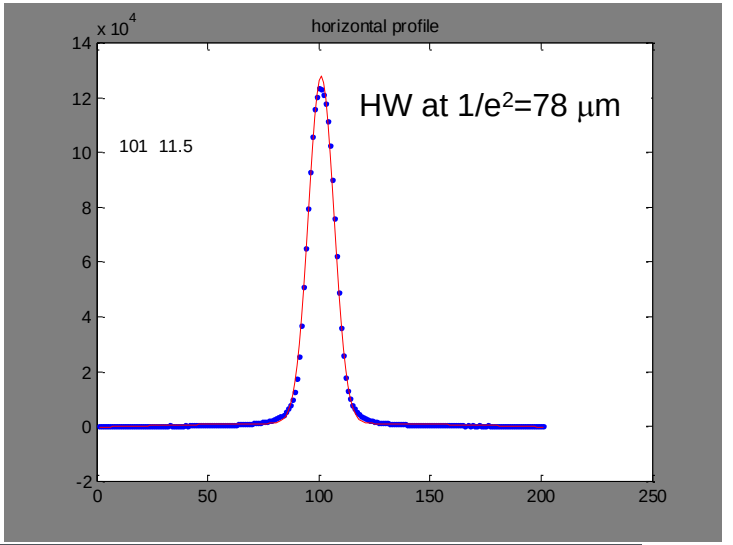


- Key features of the drum target:
  - LN cooled to form solid Xe film
  - Continuous Xe film growth
  - Laser hits fresh spot every time

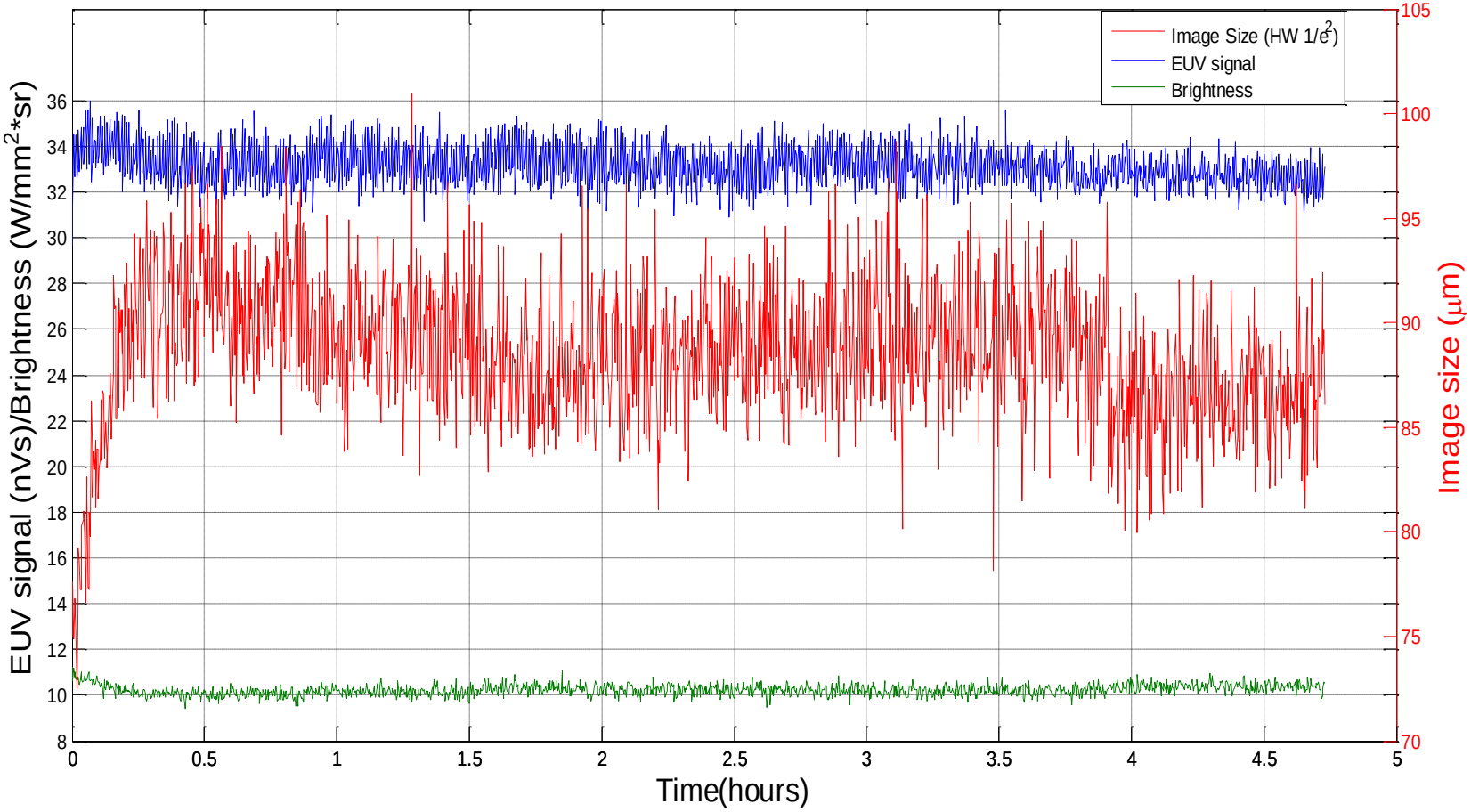
EUV plasma image



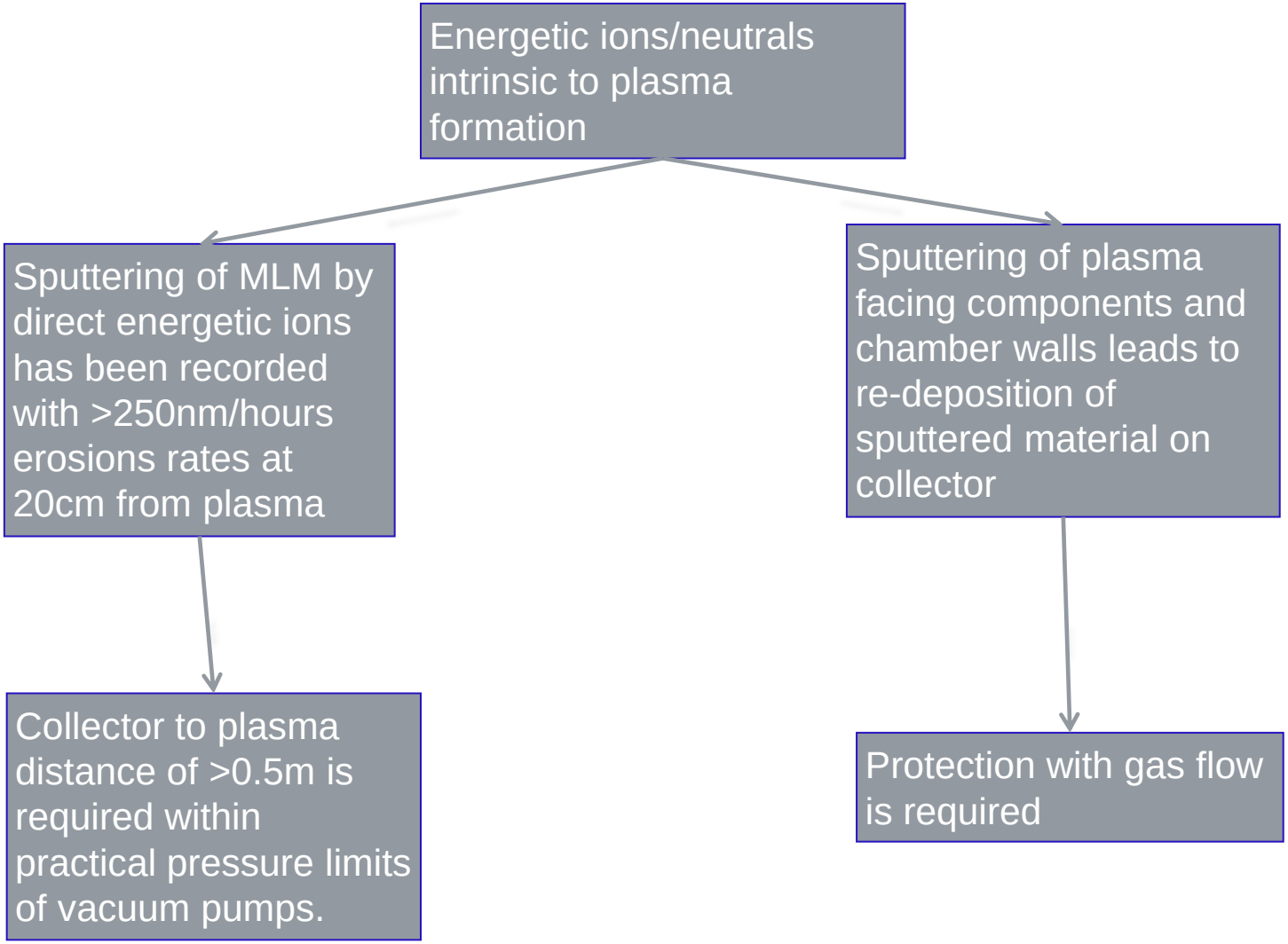




EUV signal, plasma size, and radiance



Primary collector damage mechanisms



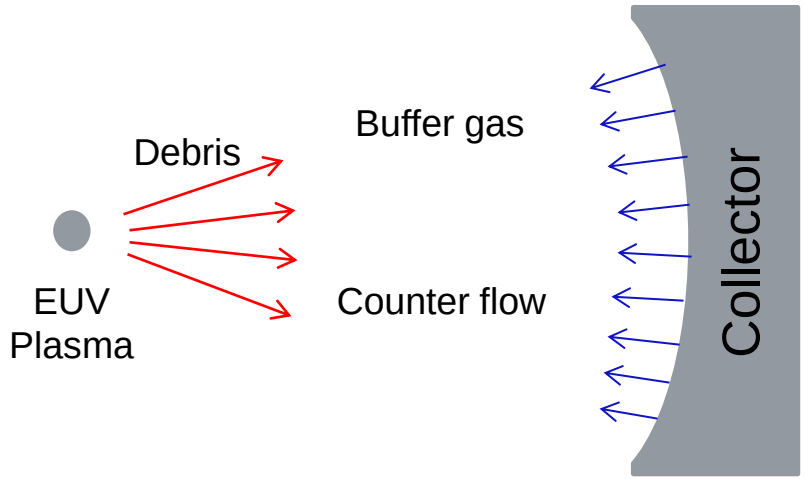
Collector lifetime : re-deposition mitigation

Collector Damage Mechanisms

Energetic ions from plasma

Sputtering of plasma facing components leads re-deposition on collector

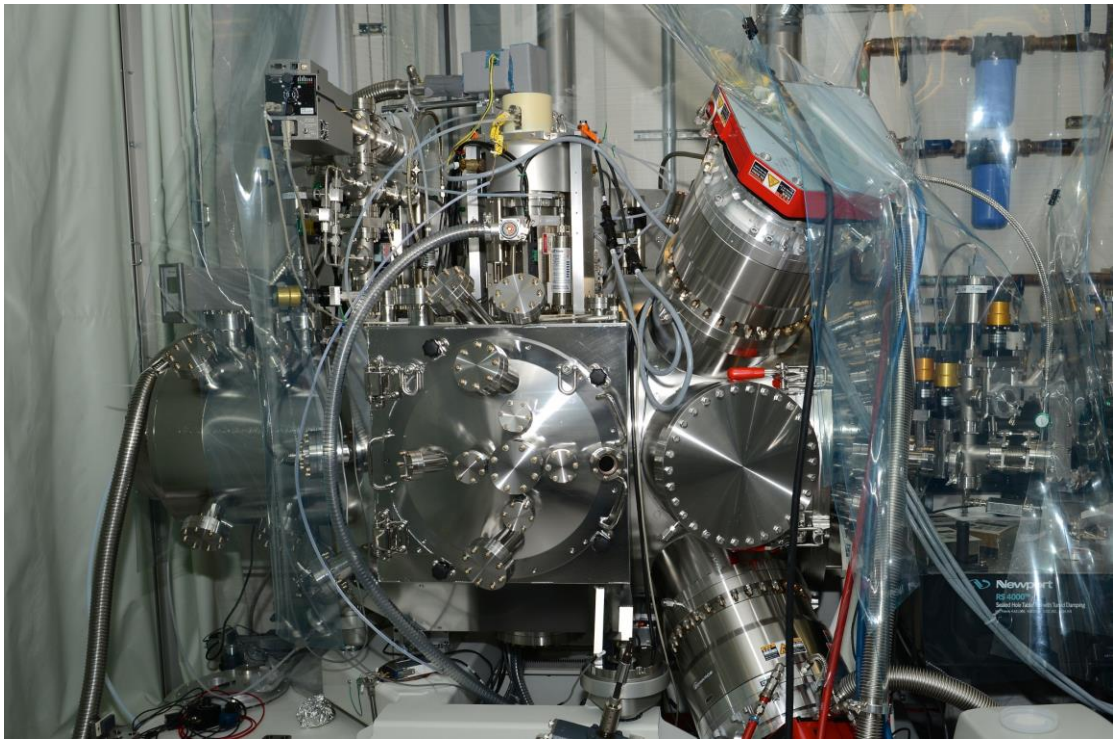
Protect collector with buffer gas and counter gas flow



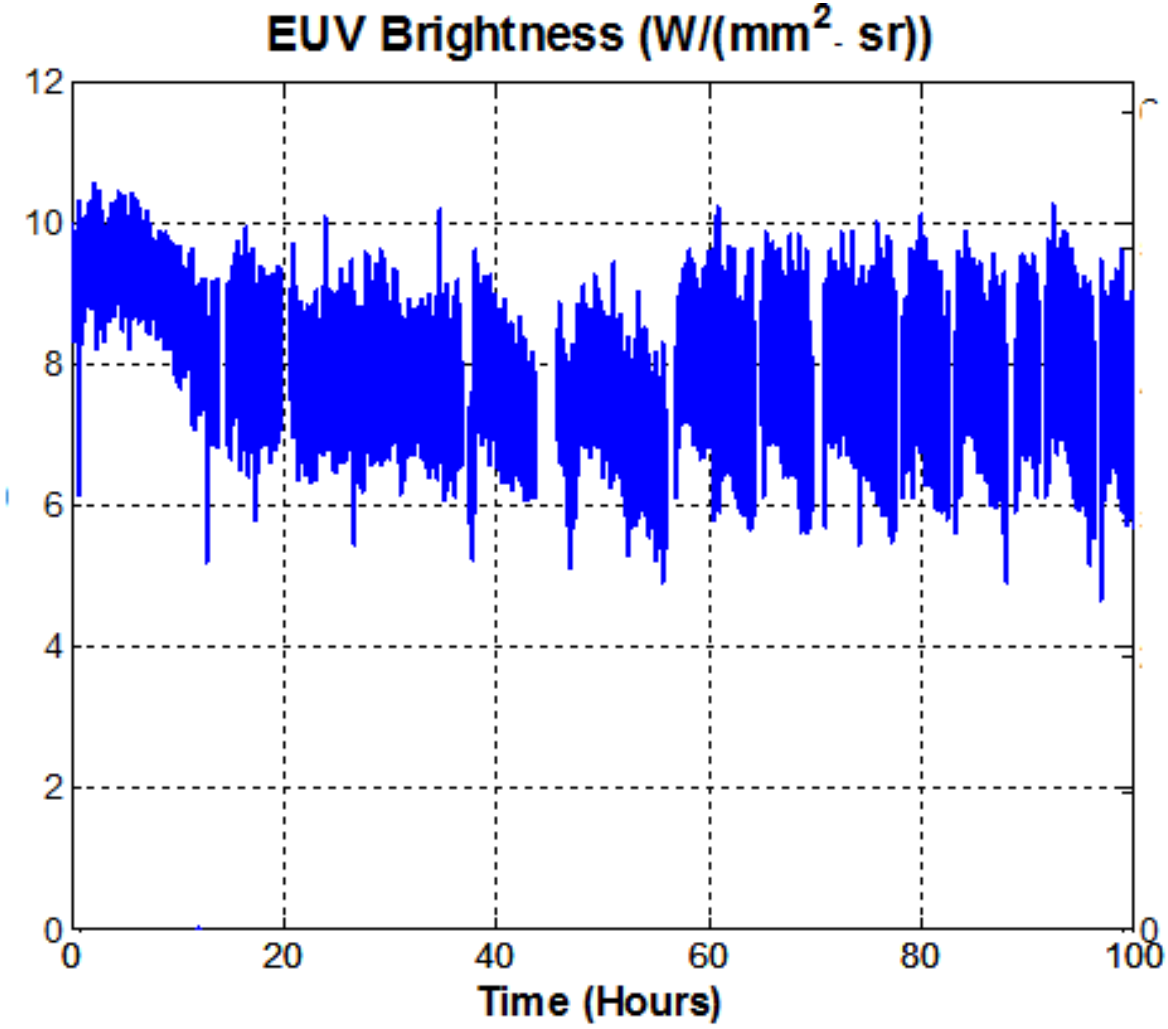
Argon buffer gas stops energetic Xe ions/neutrals and provides efficient (>90%) EUV transmission

EUV source prototype

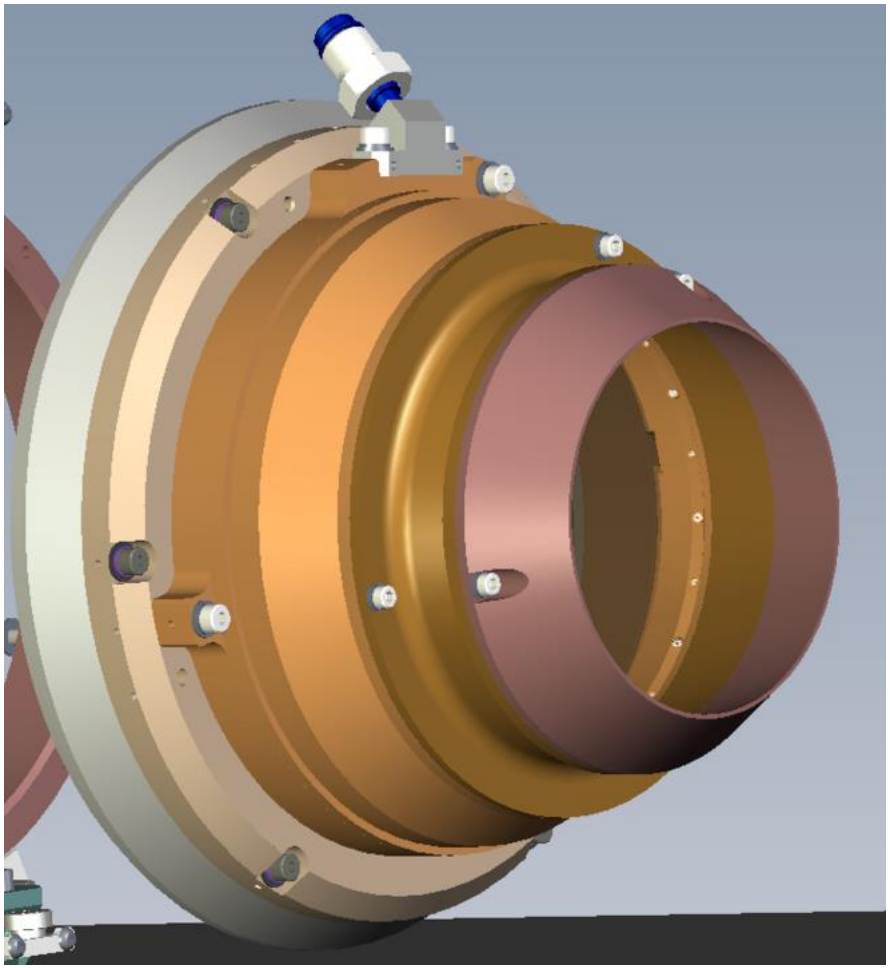
- Long collector lifetime achieved with :
  - Large plasma to collector distance -> Zero erosion of vacuum vessel
  - Advanced protection of collector and laser optic
  - Distributed buffer gas flow
  - Clean chamber: base pressure < $2*10^{-8}$torr.

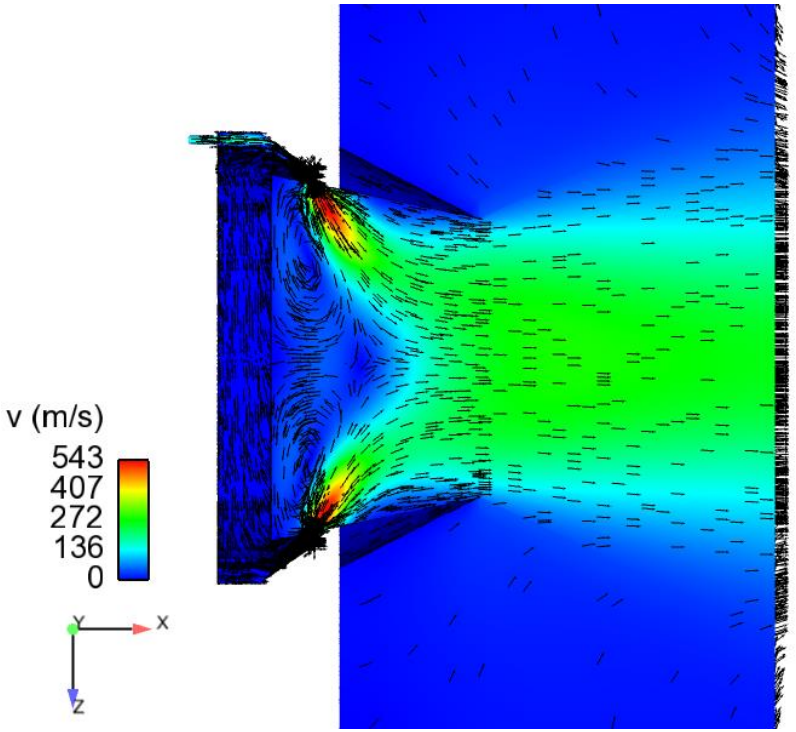


Long term source brightness in free run

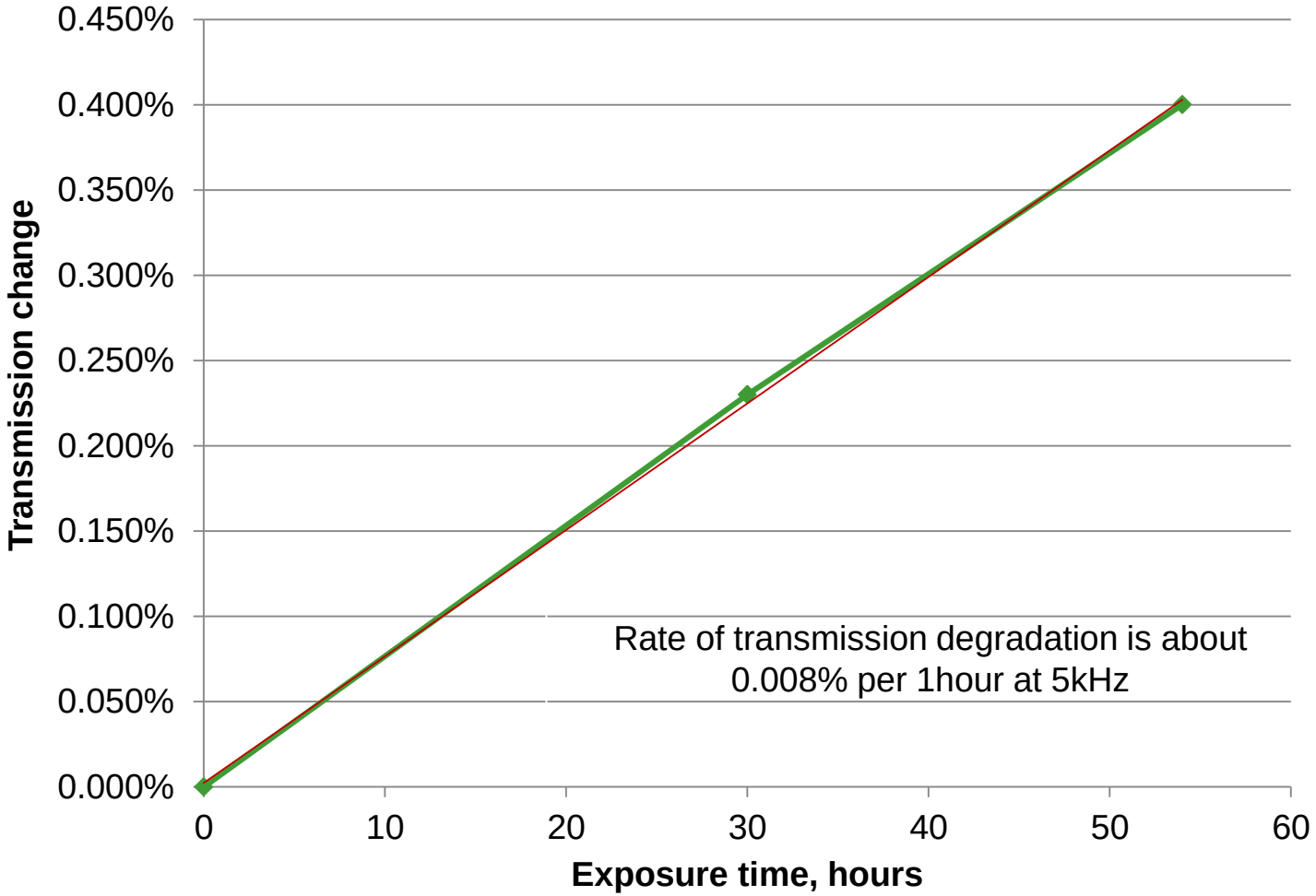


Laser optics protection design

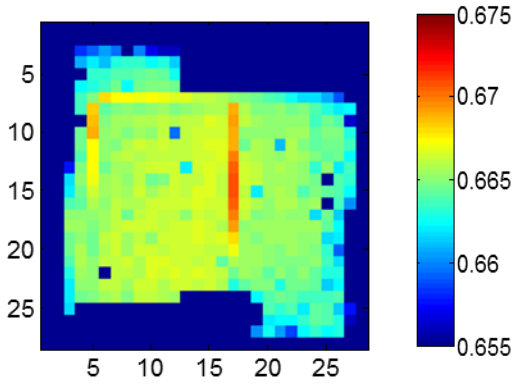


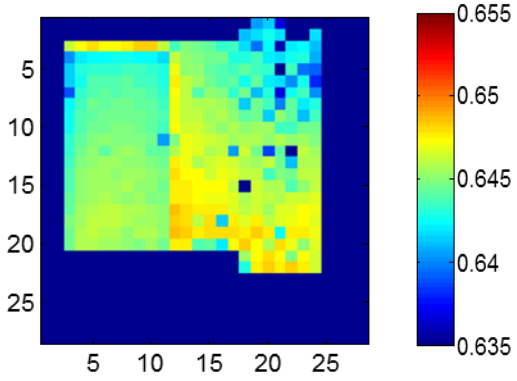


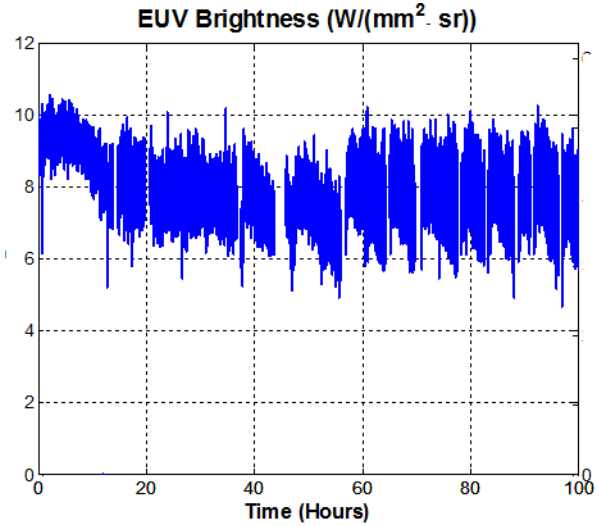
Performance of laser optics protection



Demonstrated prototype performance







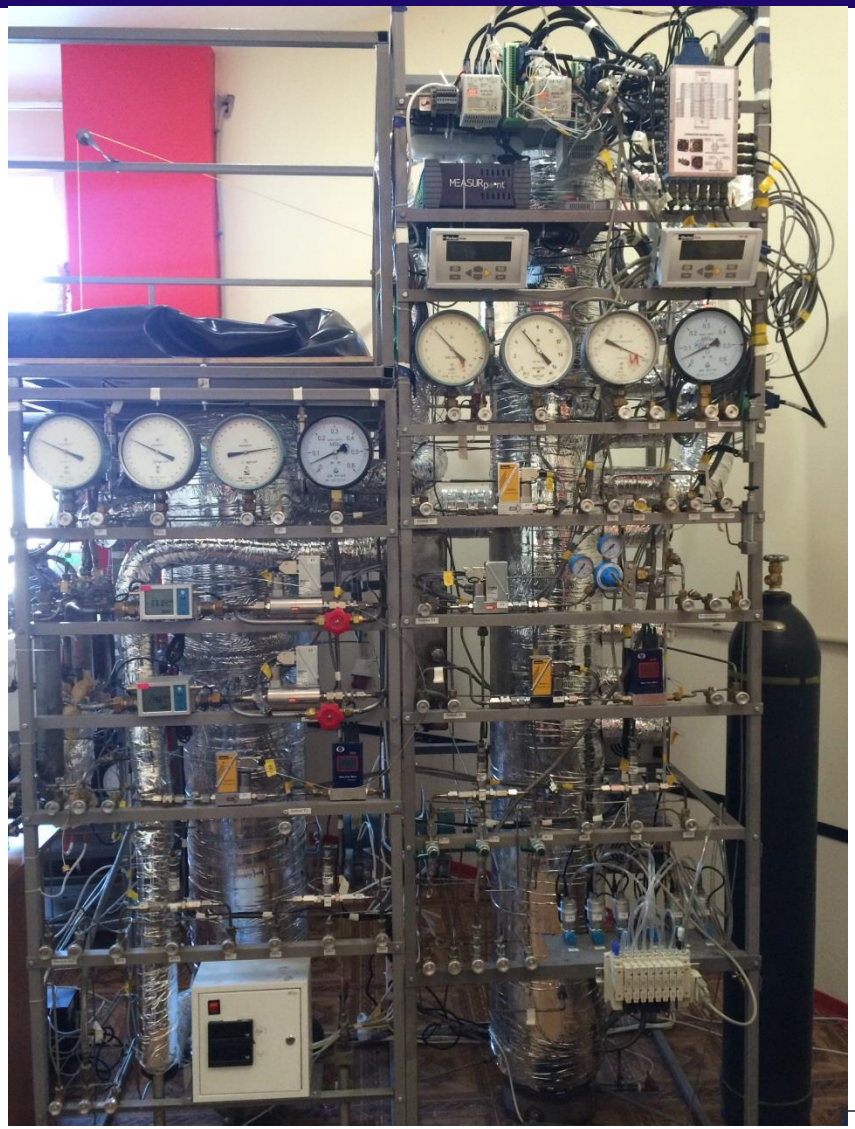
Duration -120 hours

Effective duty cycle - 80%

Radiance is >8W/mm ^{2}sr @5kHz in free run mode

No reflectivity degradation (within 0.5% accuracy)

Xenon costs controlled through recycling



Demonstrated >98% Xe gas recovery with 99.999% purity of Xe.

Full scale proto-unit has been built and tested.

Long term (days) operation in steady state regime.

Automated start-up/shut-down proof-of-principle experiments performed.

Conclusions

- Comprehensive multi-year investigation addressed and solved all significant technical risks.

- Xe LPP EUV source provides unique advantages:

  - Xenon-based source and high-transmission illuminator design provide architectural advantages in cost and CoO.
  - Achieved >5000 hrs collector lifetime at 8-10 W/mm^{2}sr^2, and demonstrated >98% Xe gas recovery in closed-loop operation.
  - Scalability – created path to 40 W/mm^{2}sr^2.
  - Xenon costs controlled through recycling.

Thank You