Requirements and prospects of next generation Extreme Ultraviolet Sources for Lithography Applications

Vadim Banine, Harm-Jan Voorma et al

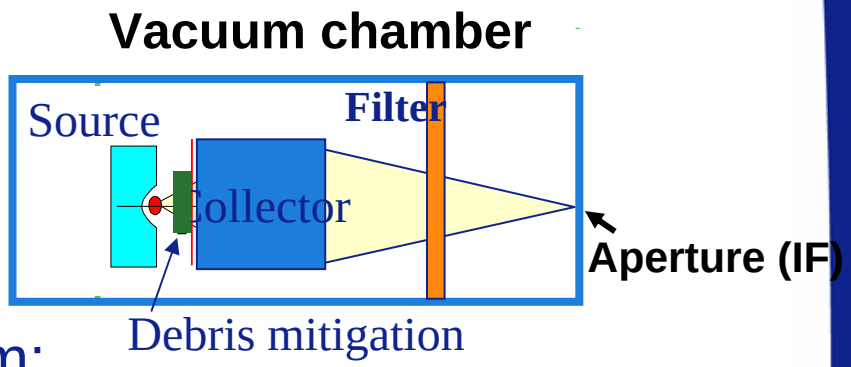
ASML EUV team presentations at this conference

- Other presentations:
  - Meiling et al. *Progress in the realisation of EUV lithography*
  - Groeneveld et al. *Full field imaging by the ASML EUV alpha demo tool*
  - M. van den Brink: keynote speech
  - Kürz et al. (Zeiss) *Optics for EUV lithography*
  - Corthout et al. (Philips Extreme UV): *the Philips Extreme UV source: recent progress in power, lifetime, and collector lifetime*
- Posters
  - Maarten van Herpen *Sn cleaning of multi-layer mirrors with hydrogen radicals*
  - A.E. Yakshin et al. *Interface engineering of Mo/Si multilayers for enhanced reflectance in EUVL applications*
- Other (Workshops, TWG meetings,…)
  - TNO/Bas W.: optics lifetime workshop

Contents

- Power at intermediate focus
  - Power production (Discharge or Laser Produced Plasma)
  - Power collection
  - Spectral purity
- Endurance of subsystems
- Conclusions

Power at intermediate focus dependence



- Power of the source
- Optical efficiency of the system:
  - Collection efficiency of the collector
  - Spectral purity filter transparency
  - Debris mitigation transparency (not covered here)

SOURCE CHARACTERISTIC	REQUIREMENT
Wavelength	13.5 [nm]
EUV Power (in-band) in IF	180 [W] (for 100 wph in tool etendue)

See Presentation of M. van den Brink

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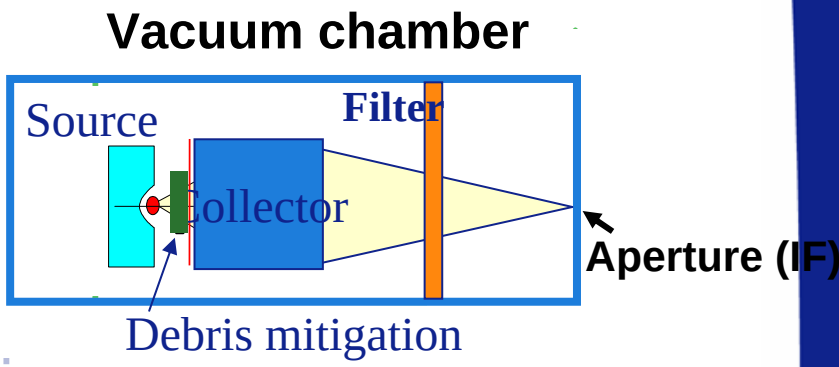
Power at intermediate focus dependence



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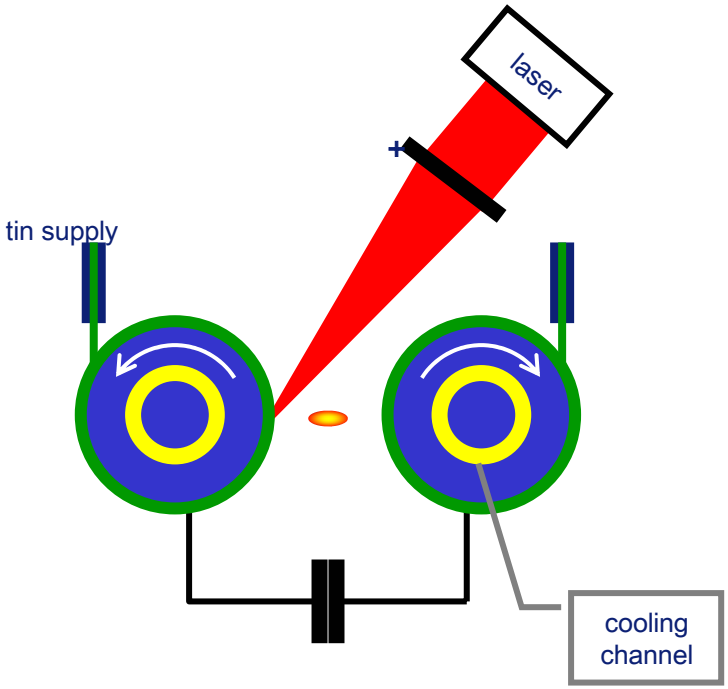
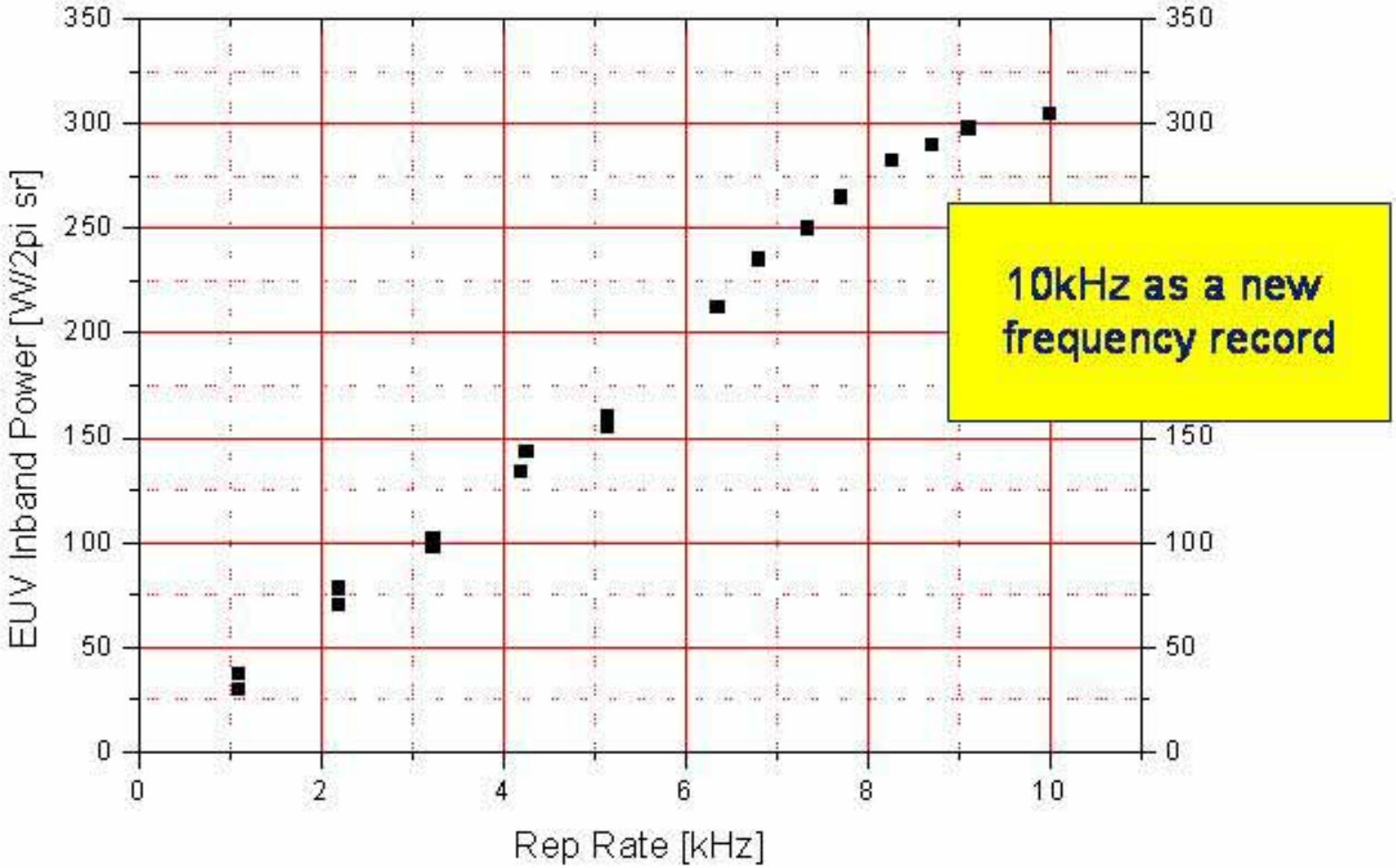
Philips‘ EUV Lamp: Sn-based rotating electrodes



- 200W/2π continuous operation (scalable to >600W /2π)
- very small pinch (<1mm)
- >>1 bln shots electrode life
- commercial product

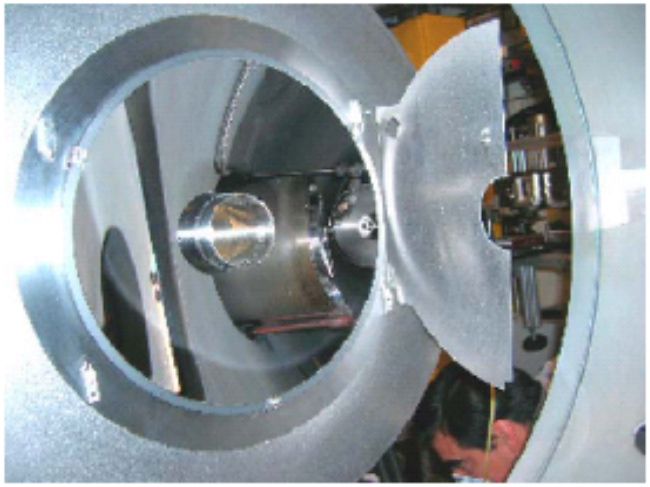
Turning the rep rate scalability "button"



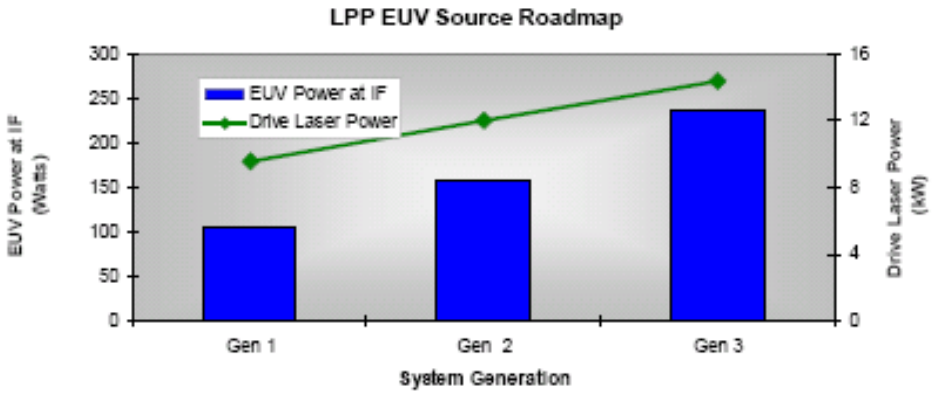
Cymer LPP EUV Source Development

Key System Results

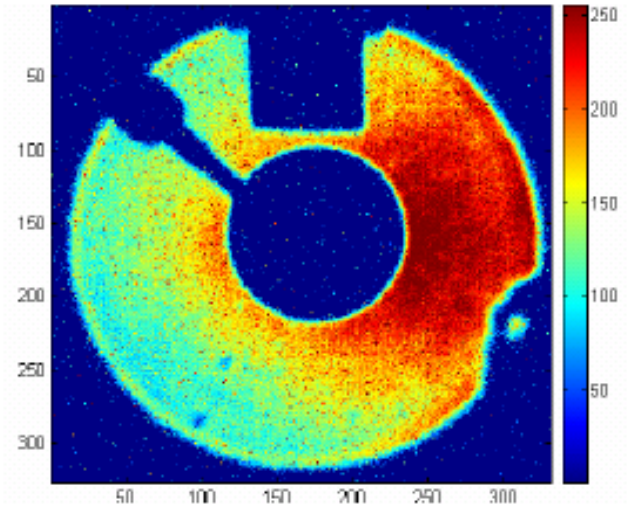
- Up to 45W in 2π at Plasma
  - Equivalent to ~15W at IF
- CO_2 Laser on Sn Targets
  - 24,000 – 30,000 Hz Rep Rate
- Normal Incidence Collector Manufacturing Infrastructure



• 320mm Diameter 1.6 sr NI Collector



• LPP EUV Source Power Roadmap



• Fluorescence Converter Image of EUV at IF

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DPP EUV Sources: Status and roadmap

Xenon-fueled DPP sources
EUV power in IF demonstrated: > 10 W

Tin-fueled DPP sources
Novel excitation scheme with rotating disk electrodes
EUV power in 2π sr demonstrated: > 200 W at 1.5 kHz with plasma size < 1 mm

	Status 10/2006	1st generation HVM	2nd generation HVM	3rd generation HVM
Repetition frequency (kHz)	1.5	7	7	10
Power into plasma (kW)	10 (1)	31	29.4	49.0
Plasma Diameter ∅ (mm)	< 1	<1	< 1	< 1
EUV power (W/2π sr)	**> 200**	**780**	**880**	**1470**
Intermediate focus power (W)	**28.9 (2)**	**100**	**180**	**300**

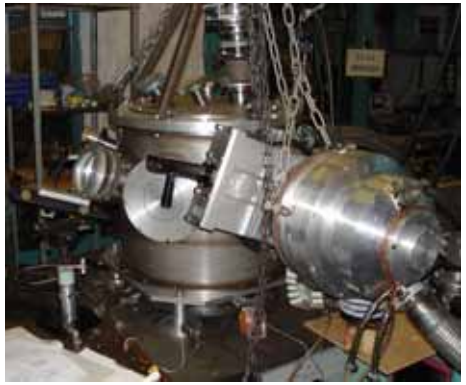
Prototype of commercial 10 W EUV source XTS 13-150-IF with integrated collector mirror

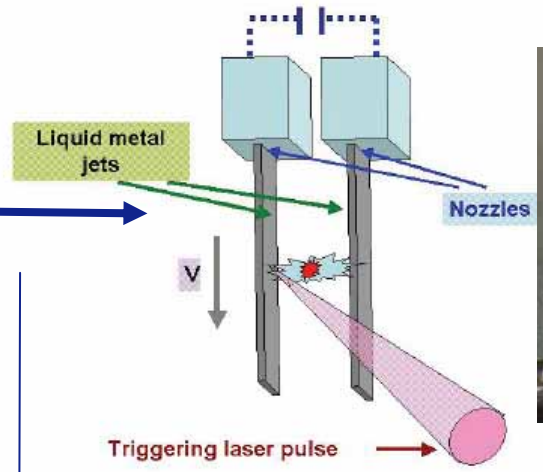
(1) in burst operation
(2) calculated for existing collector mirror

Laser triggered multiplexed Sn source evolution

Laser triggered multiplexed pseudo spark

2000-2005





2006

Achieved:

- 2 % CE
- 18 kW (Continuous)

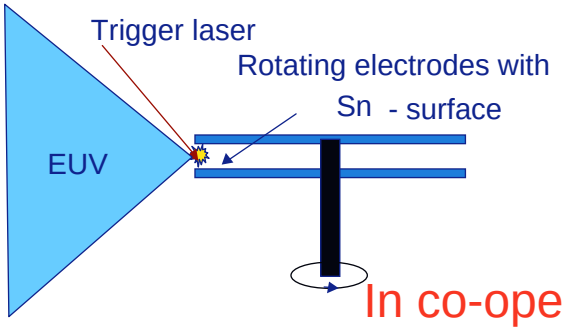
360 W in 2π in-band (about 18-36 W IF)

CE

Measurements Estimation	Conventional vacuum spark	Jet electrode system
Low melting temp tin alloy	1.5 %	1.4-1.5 %
tin	2.5 %	2.5 % (estimated)

Characteristics:

- Sustains High heat load
- Built-in debris mitigation
- Large opening angle
- No electrode erosion



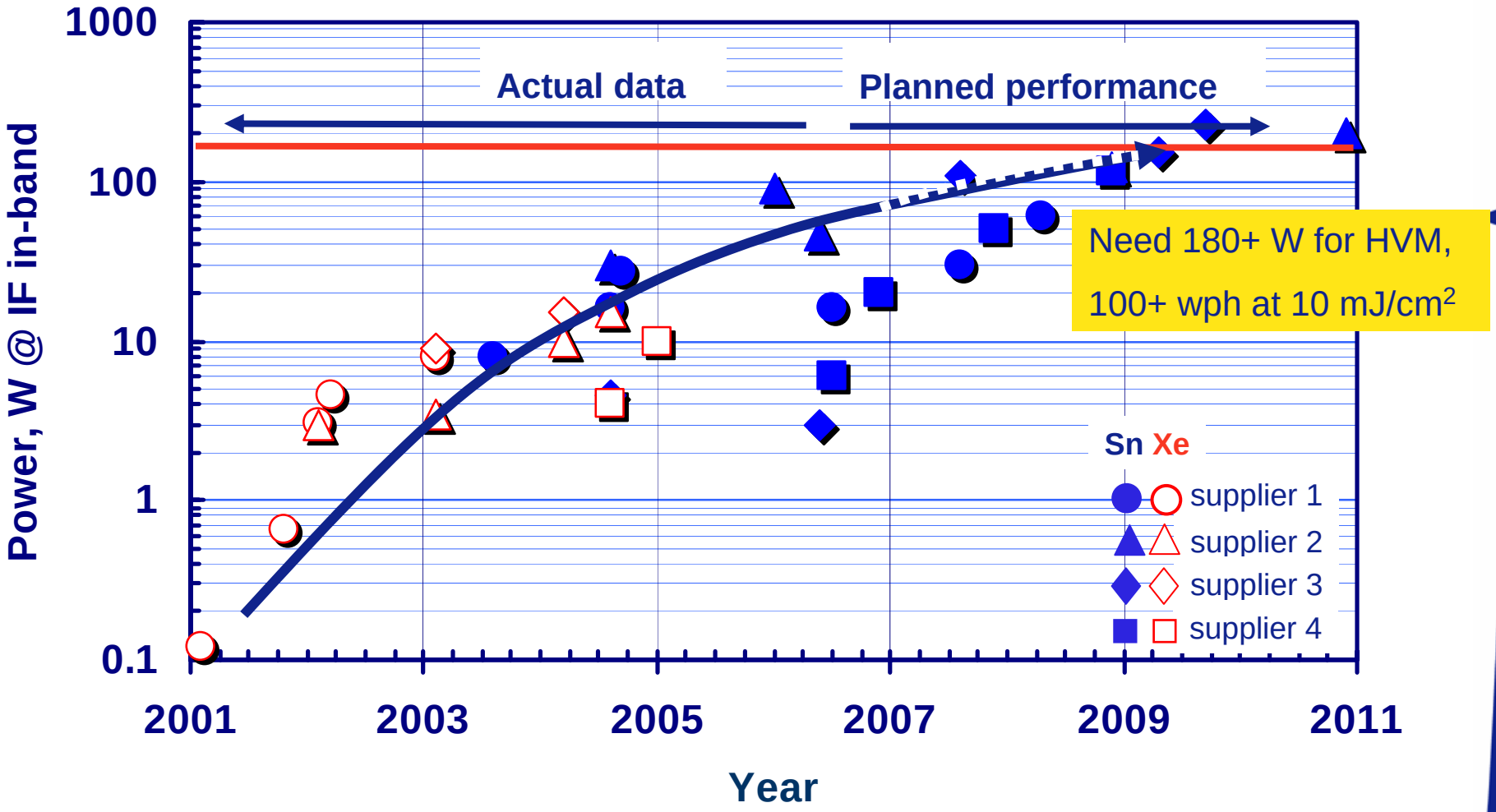
Distributed heat load:
Theoretically 120 kW for rotating wheels
And
> 200 kW for jets

* See presentation of Koshelev at SWS

In co-operation between ISAN and ASML

ASML

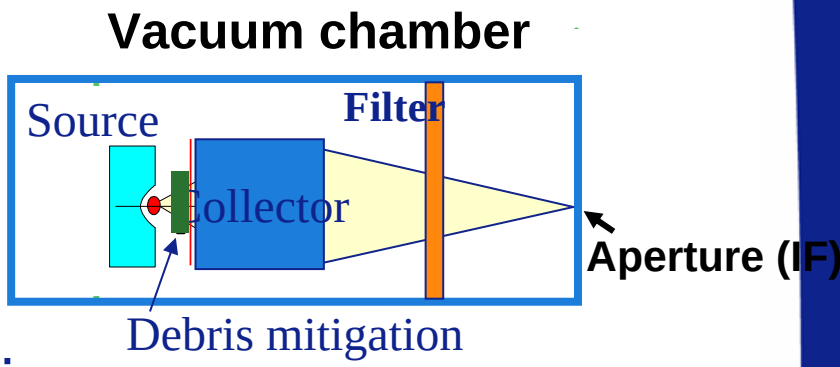
Source power progress has been increasing



Roadmaps conform to requirements

ASML

Power at intermediate focus dependence



- Power of the source
- Optical efficiency of the system:
  - Collection efficiency of the collector
  - Spectral purity filter transparency

SOURCE CHARACTERISTIC	REQUIREMENT
Wavelength	13.5 [nm]
EUV Power (in-band) in IF	180 [W]

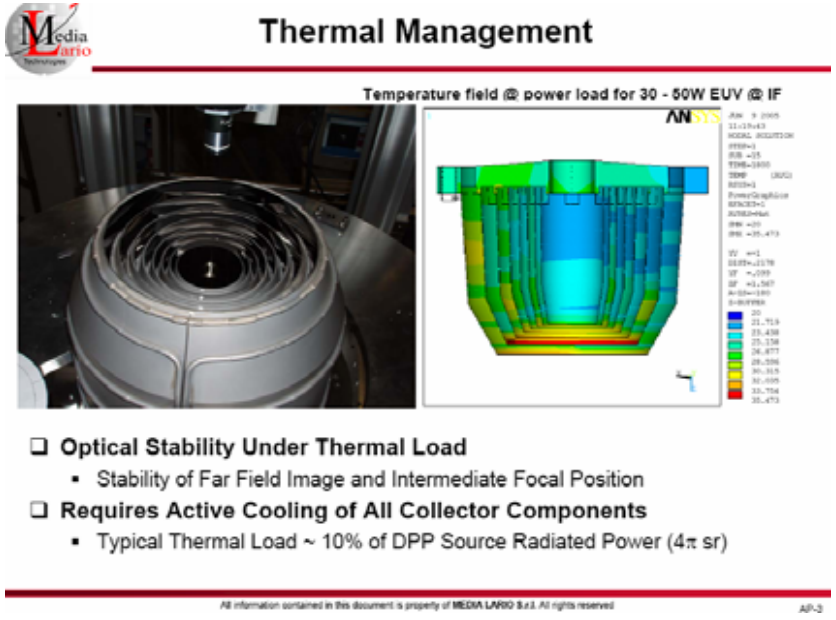
Collector status

Two approaches to collector design:

- Grazing incidence
- Normal incidence multilayer collector

Challenges:

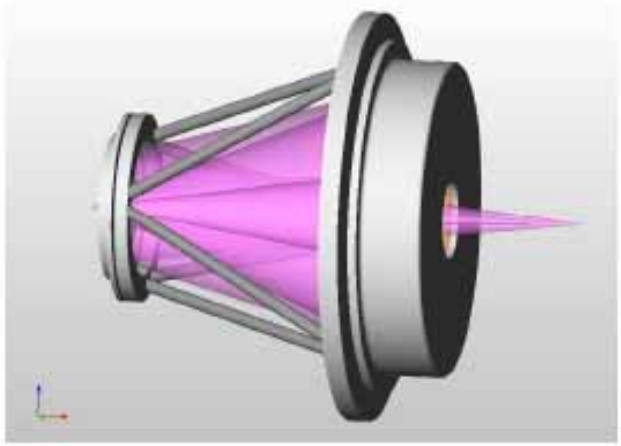
- High collection efficiency
- Heat load control

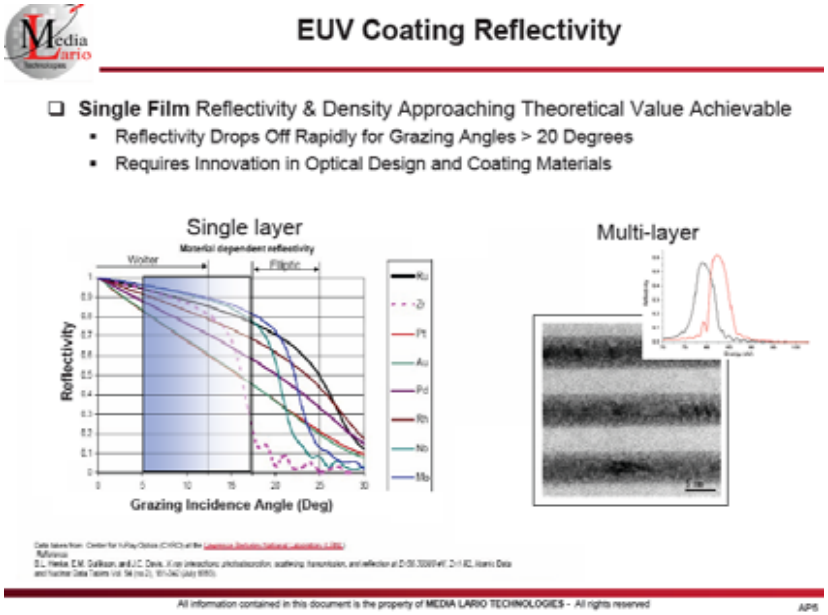


ASML

Collector development

Sagem

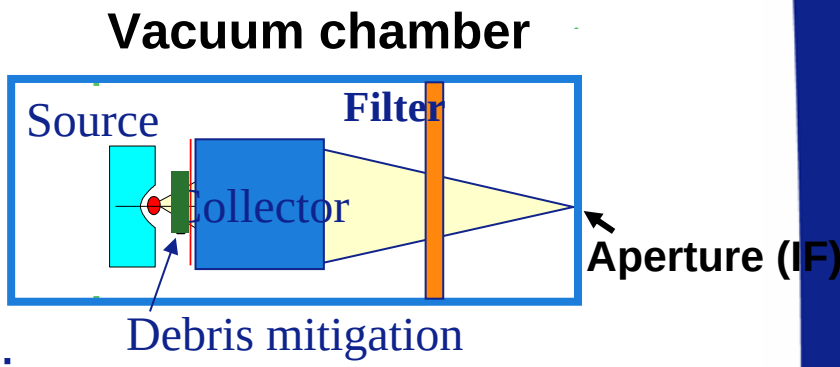




- **Optimized Throughput is up to 30% of 2π**

Improvement of 2x-3x in collection efficiency in comparison to the current is foreseen

Power at intermediate focus dependence



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Spectral purity (DUV)

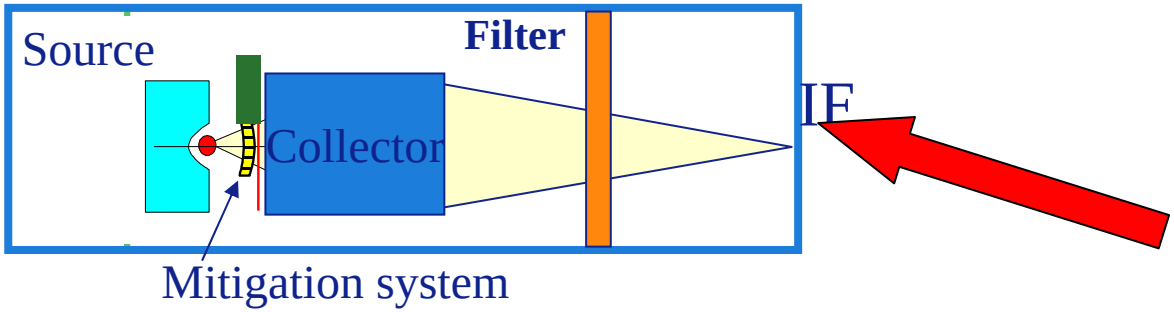
- DUV is defined here as non-EUV resist sensitive radiation
- Factors which influence the spectral purity specification :
  - non-EUV resist sensitive radiation @ at wafer (not well known and different for different resists)
  - non-EUV ML reflectivity (depends on wavelength, 11 mirrors!)
  - non-EUV source output (different per source

Joint spec: 1% DUV relative to in-band EUV @ wafer

$R_{DUV} \sim 0.5$

$N_{MLM} = 11$

<3-7% DUV @ IF



If Spectral Purity Filter will be needed for HVM we should be prepared

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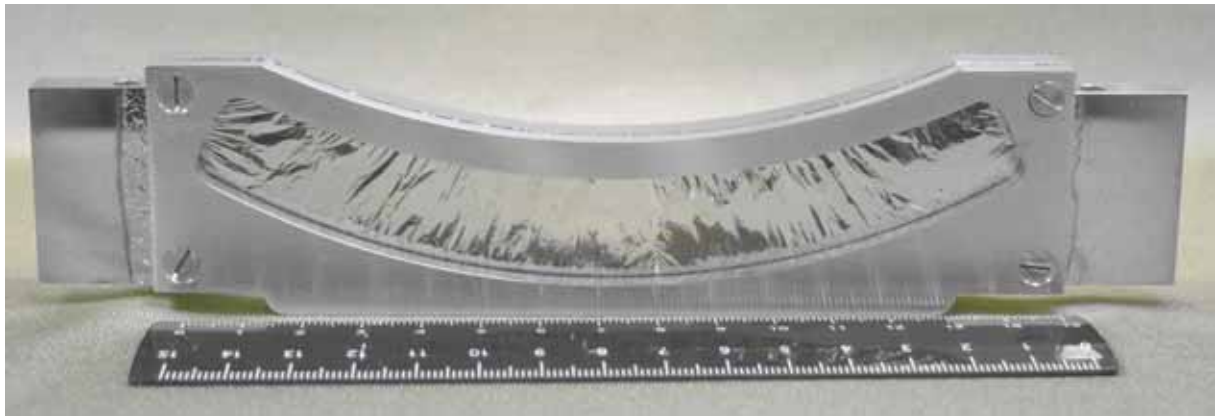
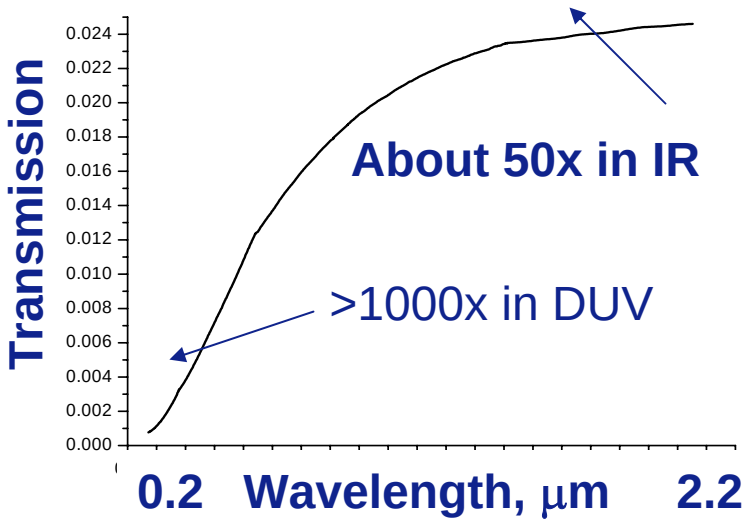
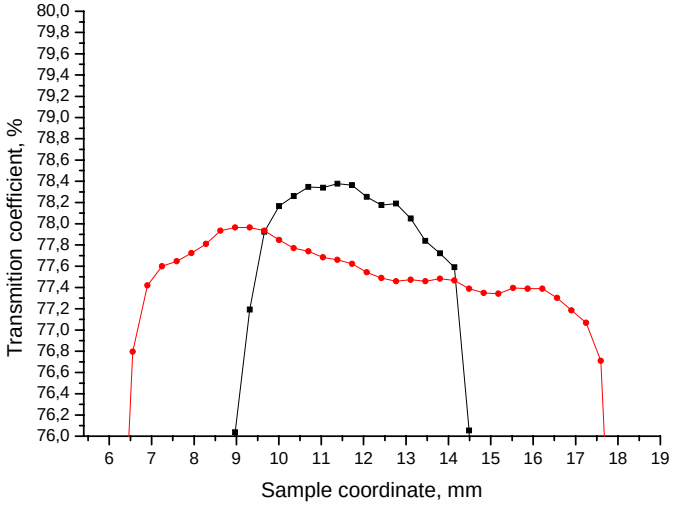
Results of the mechanical filter fabrication, solution once and for all (Transmission @13.5 nm 78%)



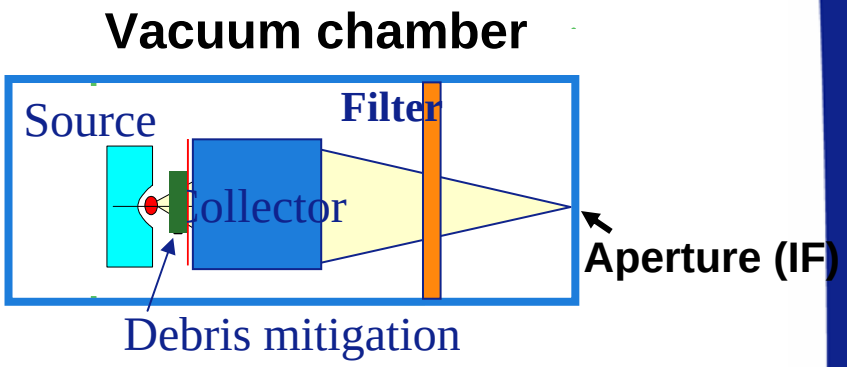
Typical transmission in DUV and IR



Uniformity about 0.5%



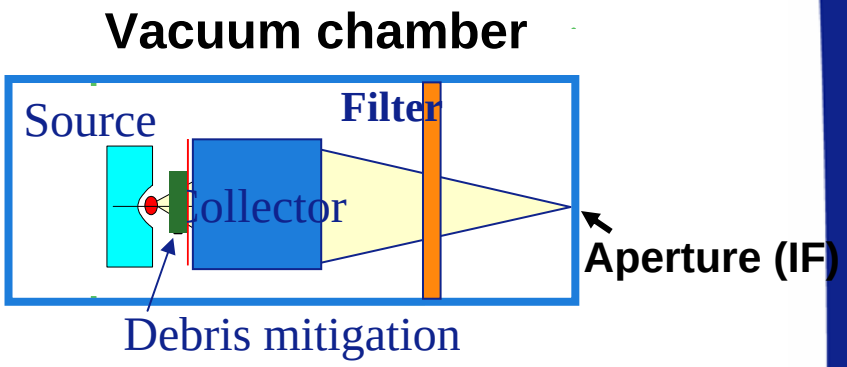
Endurance of the subsystems



- Lifetime of the source components
- Lifetime of optical components:
  - Collector lifetime and debris mitigation
  - Spectral purity endurance

Lifetime of components (HVM)	Target
Non-consumables	15000 exp. hours
Consumables	3000 exp. hours

Endurance of the subsystems



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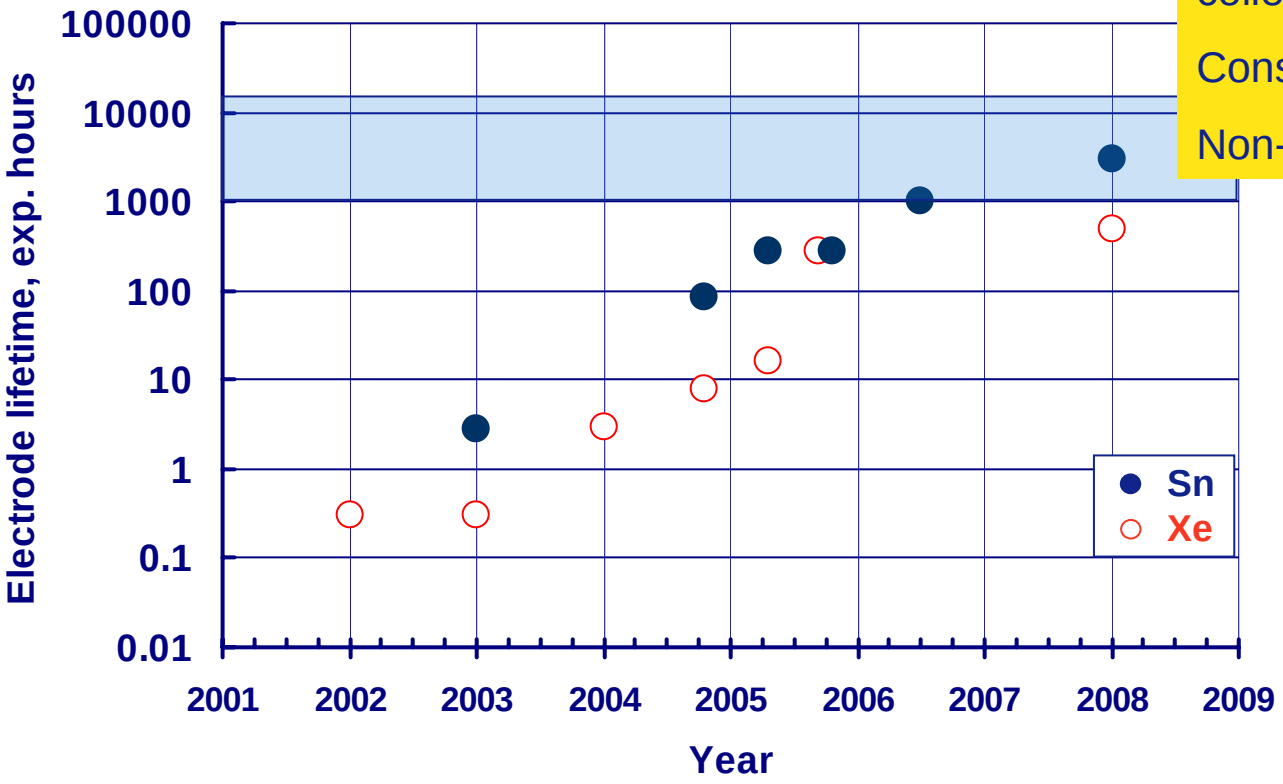
Lifetime of the source components (DPP example)



Target for production if collector is:

Consumables 3000 hr

Non-consumable 15000 hr

Introduction of the Sn recoverable electrodes brings the source electrodes lifetime within the target values

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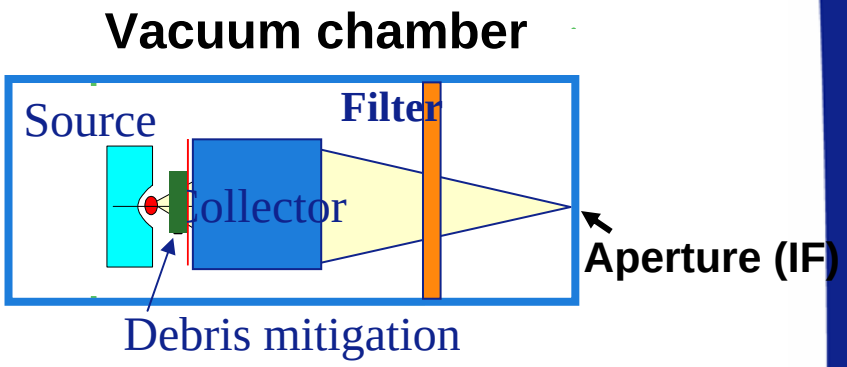
Endurance of the subsystems



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Lifetime of components	Target
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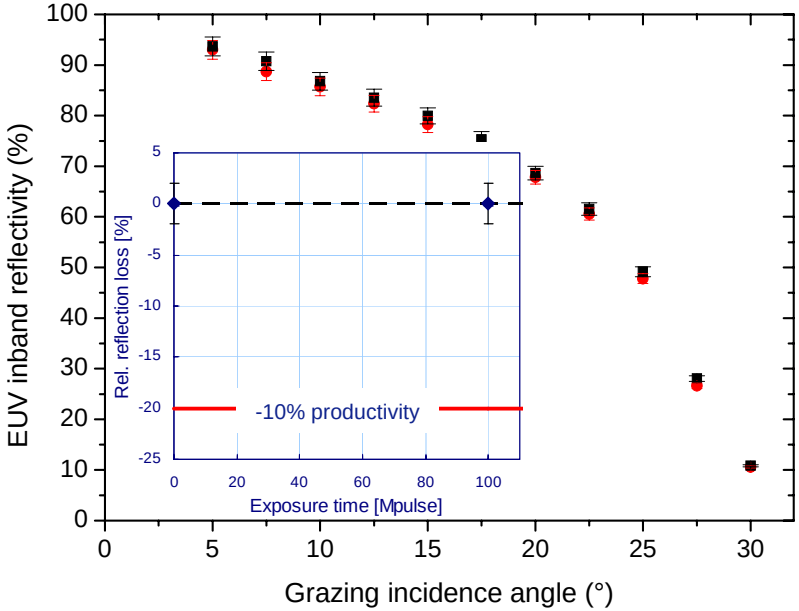
Endurance of the collector

Prevent the reflection loss during exposure

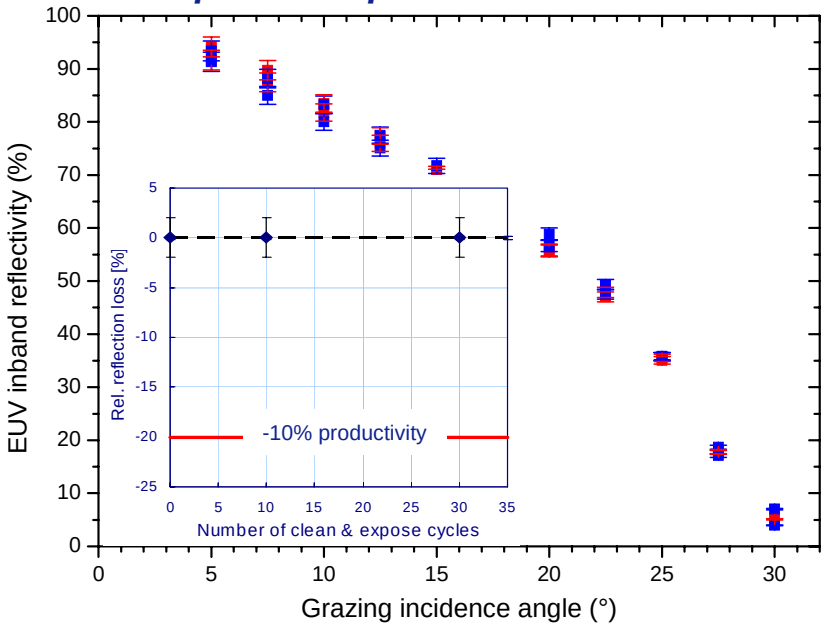
No productivity degradation after exposure to 100E6 pulses



Black: reference sample before exposure
Red: result after 100Mpulse exposure

Clean if necessary between exposures

No productivity degradation after repeated deposit & clean



Blue: reference sample before deposition/cleaning
Red: result after 30 Sn deposition and cleaning cycles

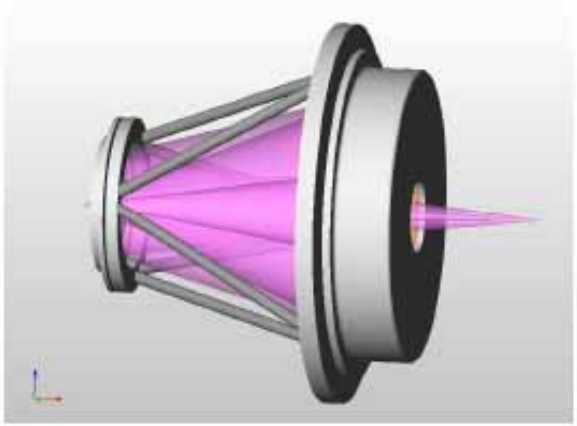
Projected lifetime of 1-2 years

PHILIPS ASML

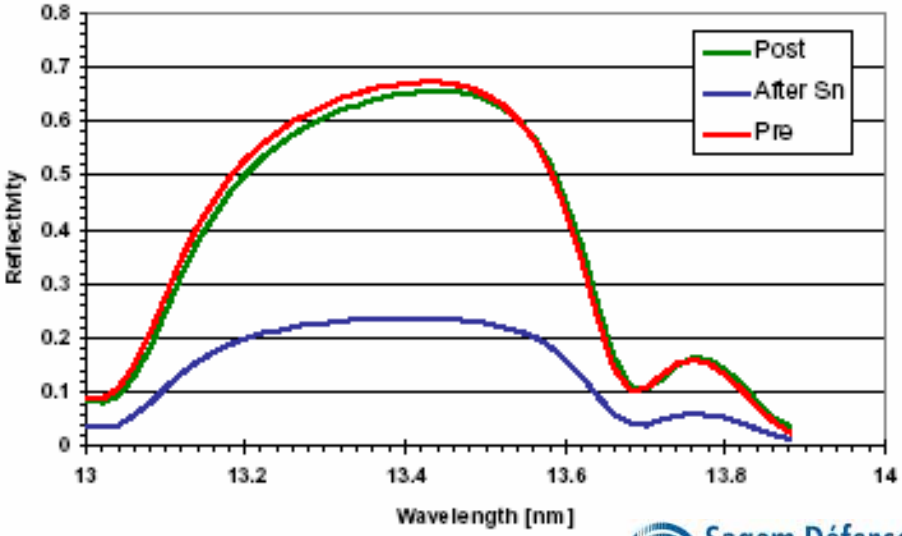
Sn deposition and cleaning of ML mirror

Cold cleaning (<100 C) procedure has been Introduced also for ML mirrors.
It proved to be working in the experiments performed within More Moore Program with:

- ASML
- IPM
- Sagem
- Philips Research



ML manufactured (Pre) – ML covered with Sn (After Sn) – ML cleaned (Post)

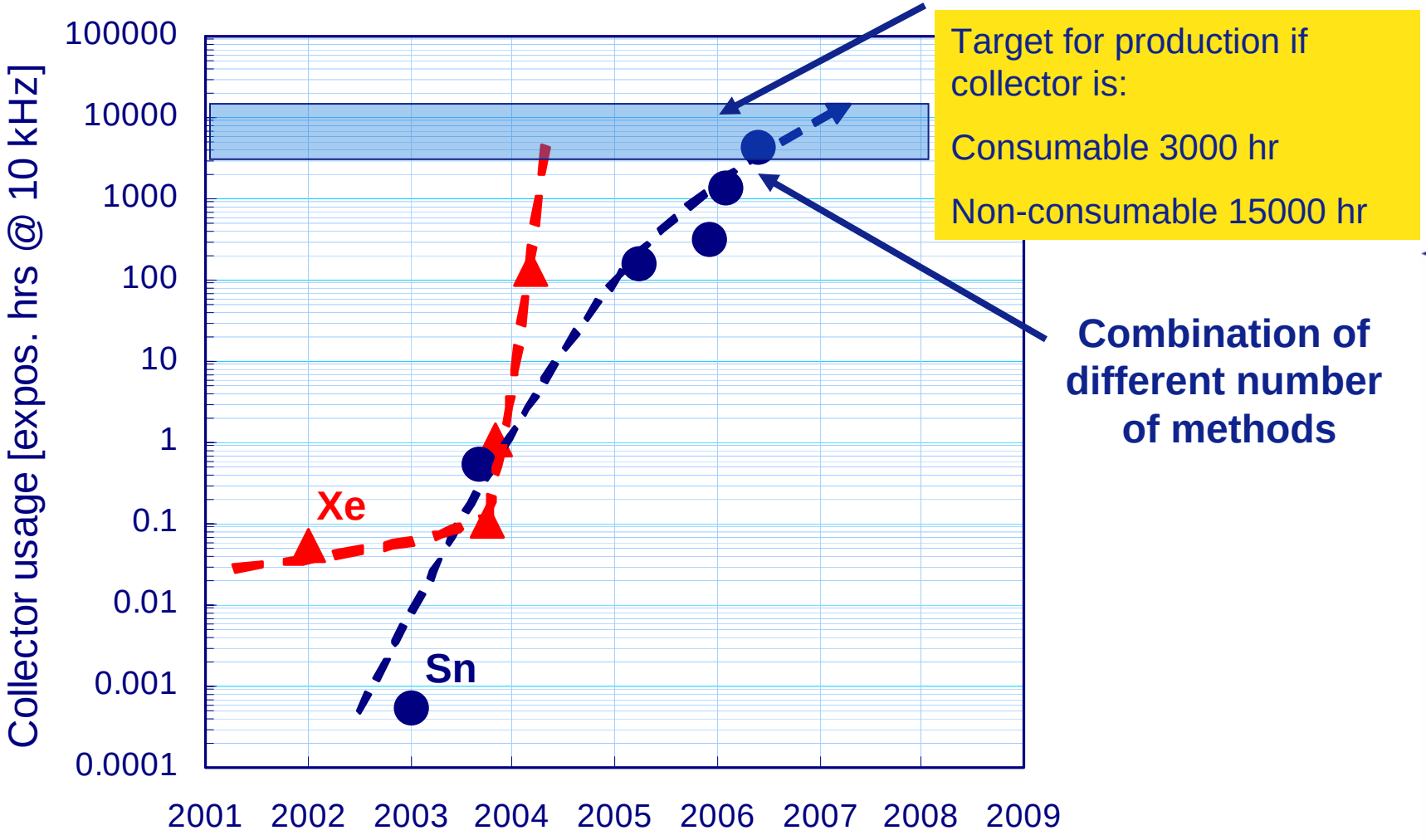


	Post	After Sn	PRE	ΔR/R
Rmax	65.56	23.64	67.08	-2.3%

See poster of M. van Herpen

PHILIPS

Collector lifetime combining a number of methods



Combination of methods demonstrate projected lifetime of 1-2 years

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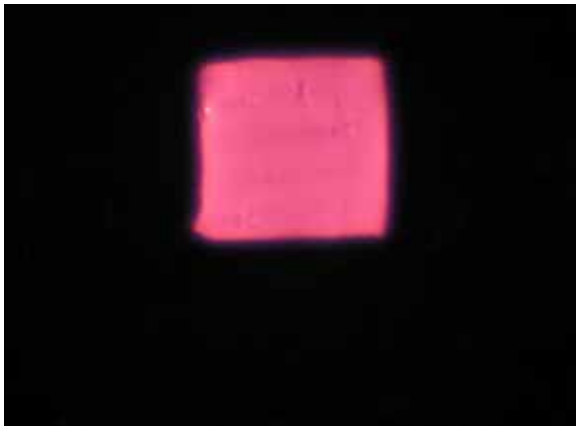
SPF transmission and endurance



A film sample emitting light at q = 5.7 W/cm^2, seen with and without external illumination; t ≈ 700º C

Recent results of 25 day exposures at 0.3 W/cm2,

Inband transmission variation: (76.53 ± 0.11) % → (76.0.4 ± 0.5) %

Out-of-EUV (633 nm) transmission variation: 2.54% → 2.8%

Concluding remarks

- The source power requirement remains >180 W EUV source to support 100+ wph throughput tool is needed
- Sources working with alternative materials and/or multiplexing show that power scaling (20-50 W already now) is feasible and roadmaps is conform required power level
- The work on collectors show a significant increase in the collection efficiencies (2-3x) to be possible
- Combination of a number of debris mitigation methods results in the projected collector lifetime of ~1-2 year
- Full field spectral purity filter has been manufactrured and withstood endurance testing (up to1000 x DUV suppression for 22% EUV loss)

People contributed to the presentation

- ASML: J. Benschop, N. Harned, H. Meiling, H. Meijer
- ISAN: K. Koshelev and team
- TUE: K. Gielessen
- Philips Research: M. van Herpen, W. Soer

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- Xtreme Technologies
- Cymer
- Phystex
- Sagem
- Media Lario

- …and many others

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