EUV Light Source – The Path to HVM

Scalability in Practice

Marc Corthout et al. *(all people at XTREME)*

International Symposium on Extreme Ultraviolet Lithography

Miami

Oct. 2011

XTREME technologies

Taking light to new dimensions…

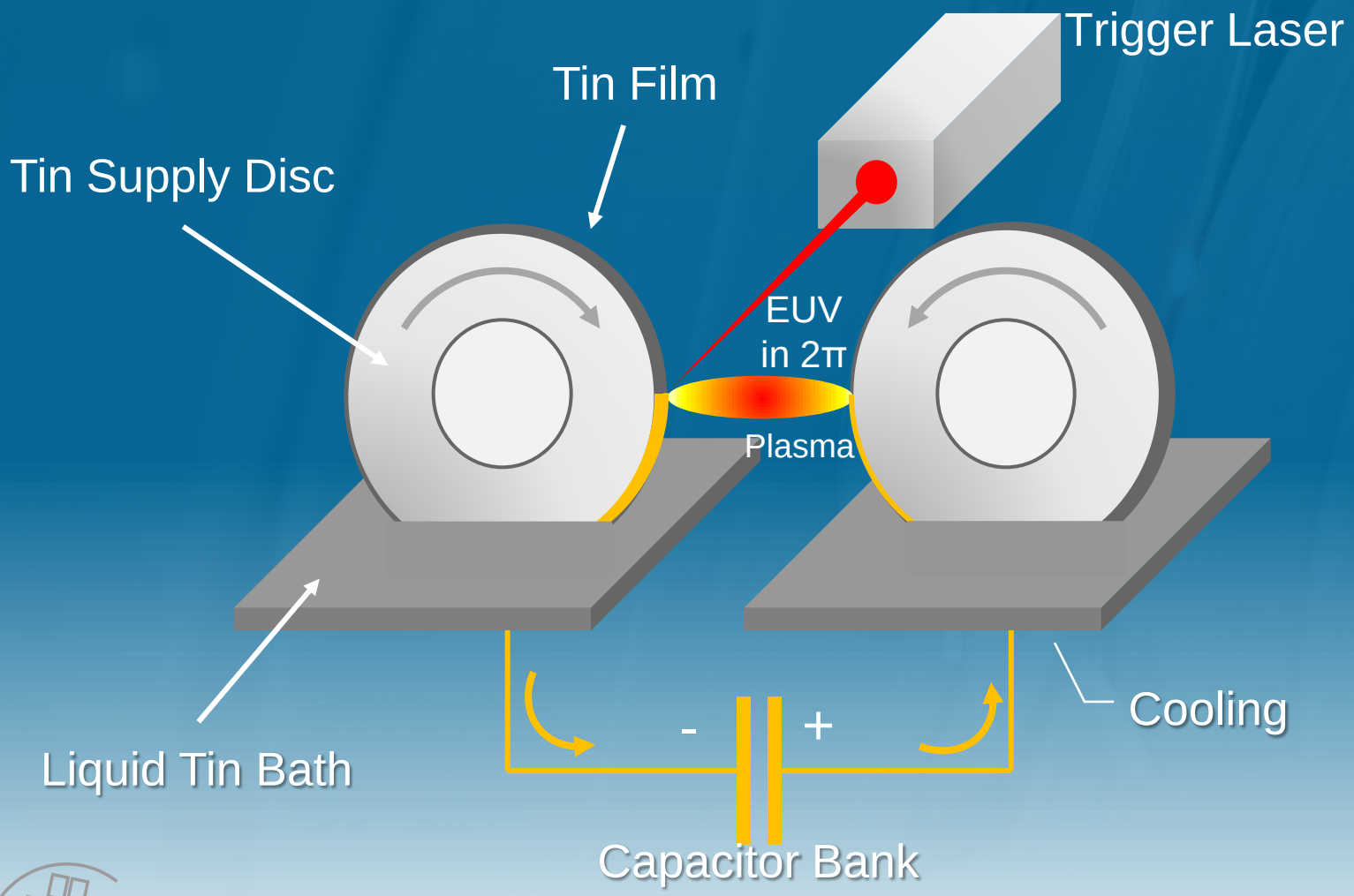
USHIO GROUP

Today's Talk

- LDP Technology – A Quick Refresher
- Why LDP Technology ?
- Where Are We Now ?
- What's Next ?
- Conclusions

LDP* Technology Concept – A Quick Refresher

***Laser assisted Discharge Plasma**



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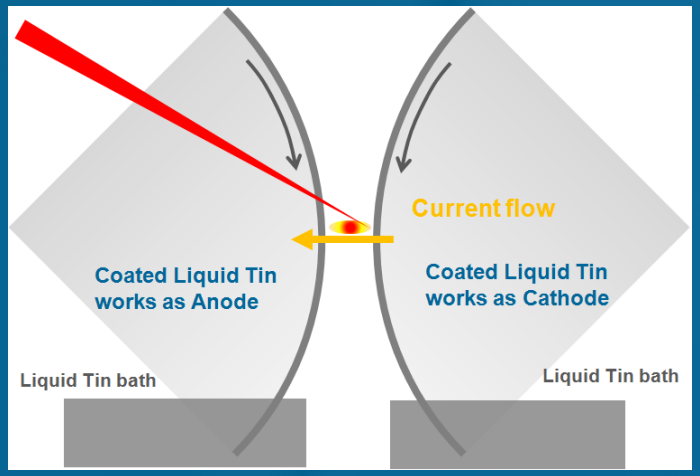
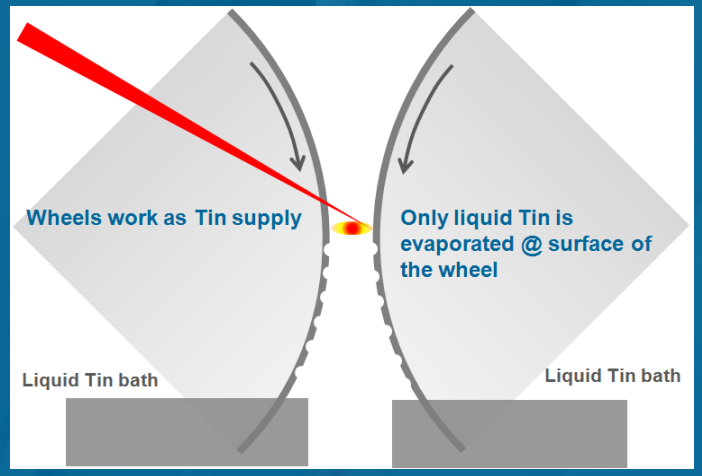
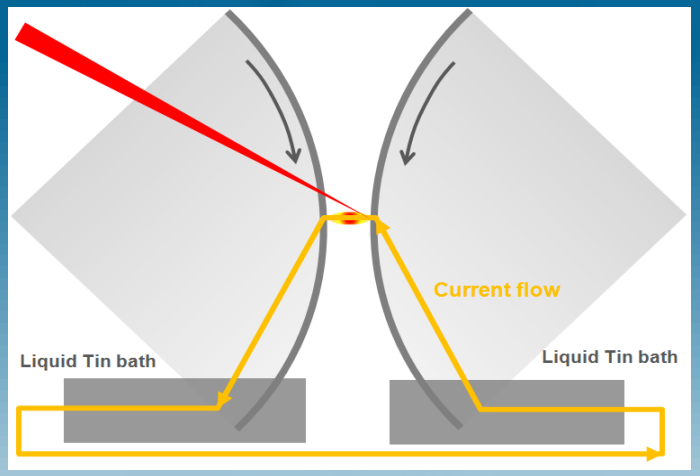
LDP Technology – Tin Fulfills Multiple Roles



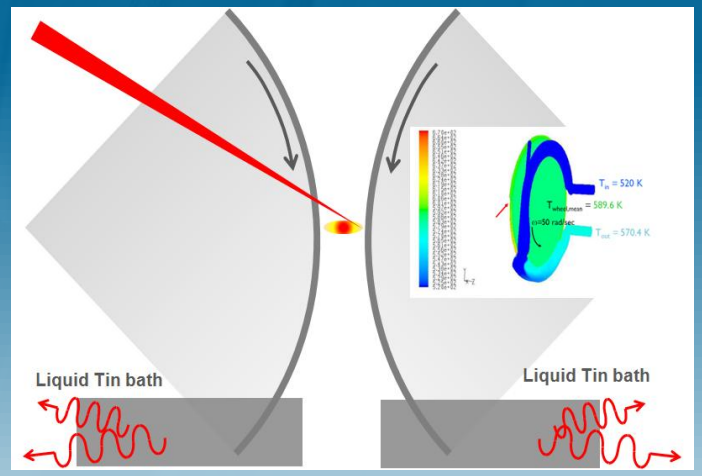
Tin as electrodes



Tin as wheel protection

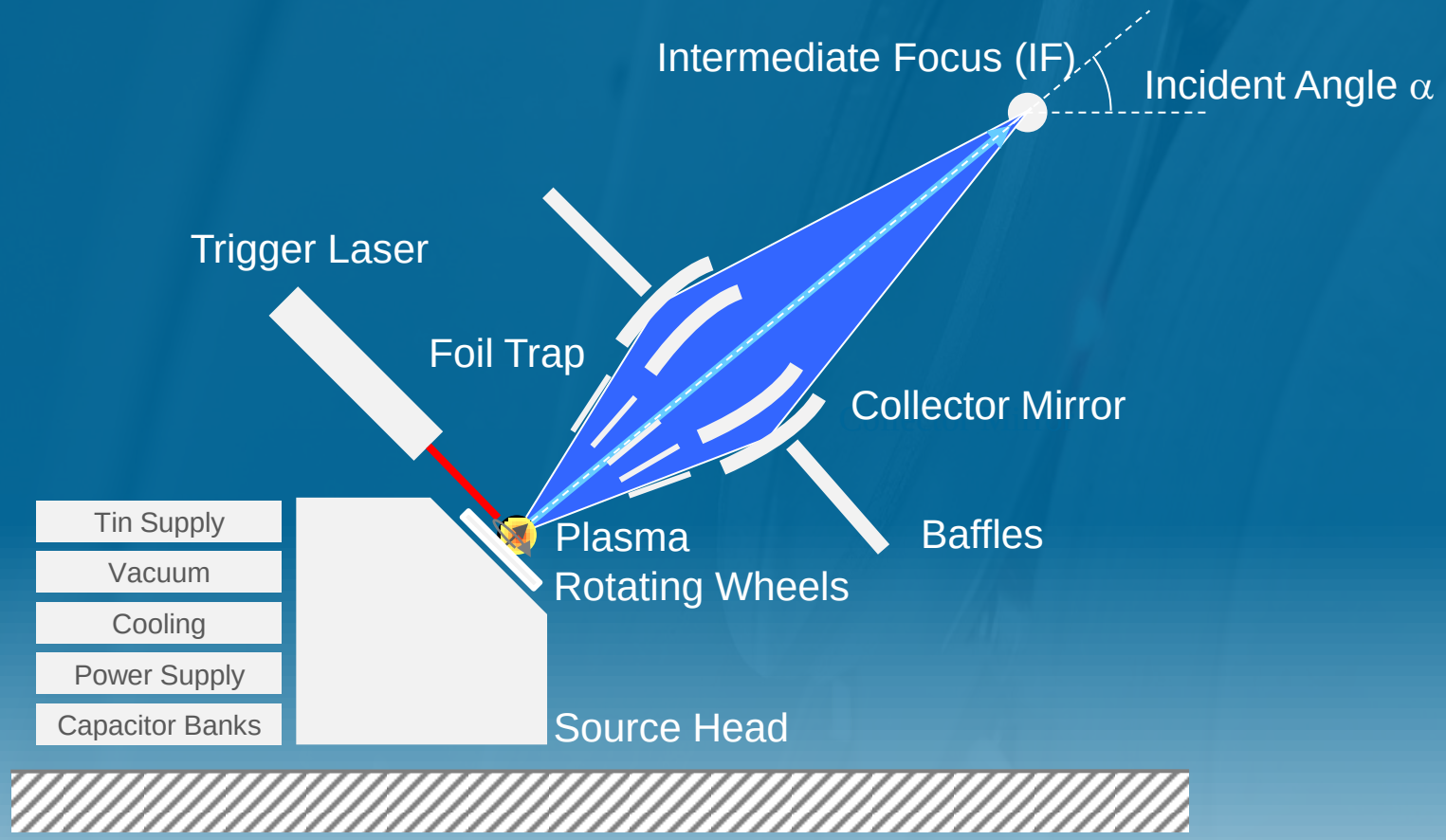


Tin as conductor



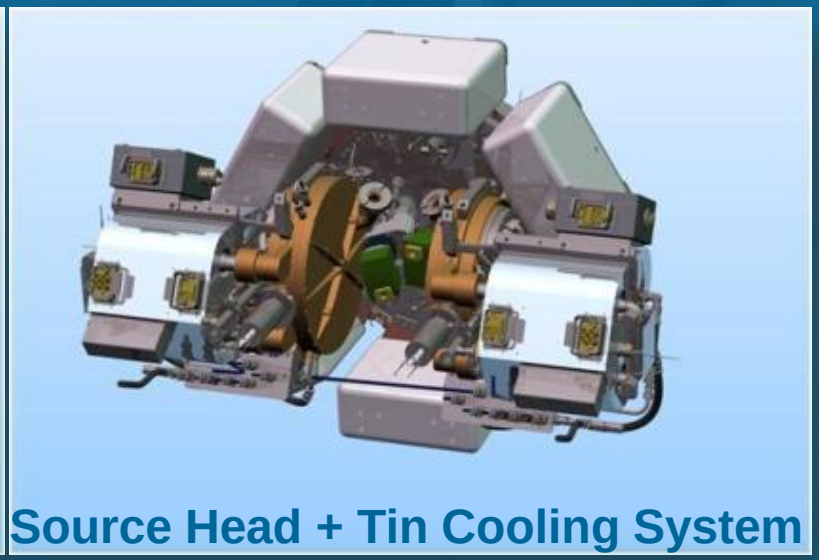
Tin as dynamic coolant

LDP Technology – Producing, Collecting & Directing EUV

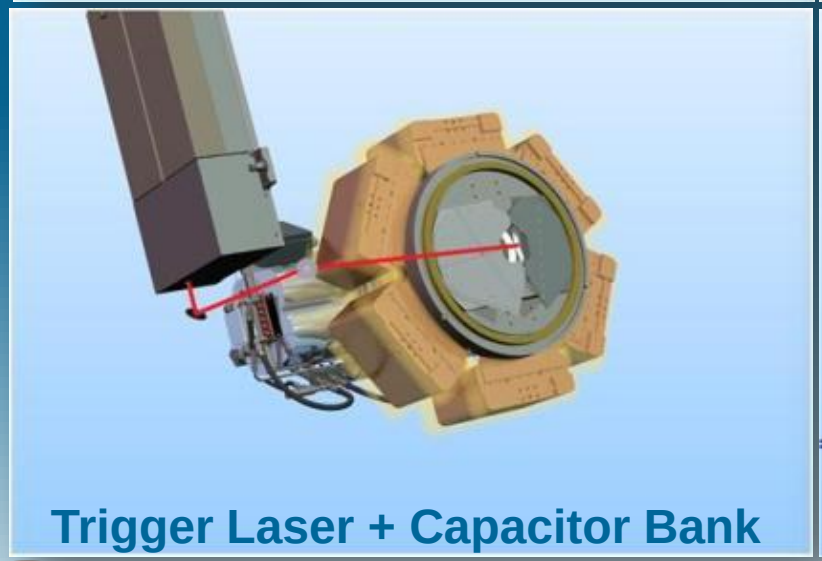


LDP Technology – Modular Architecture

Rotating Wheels



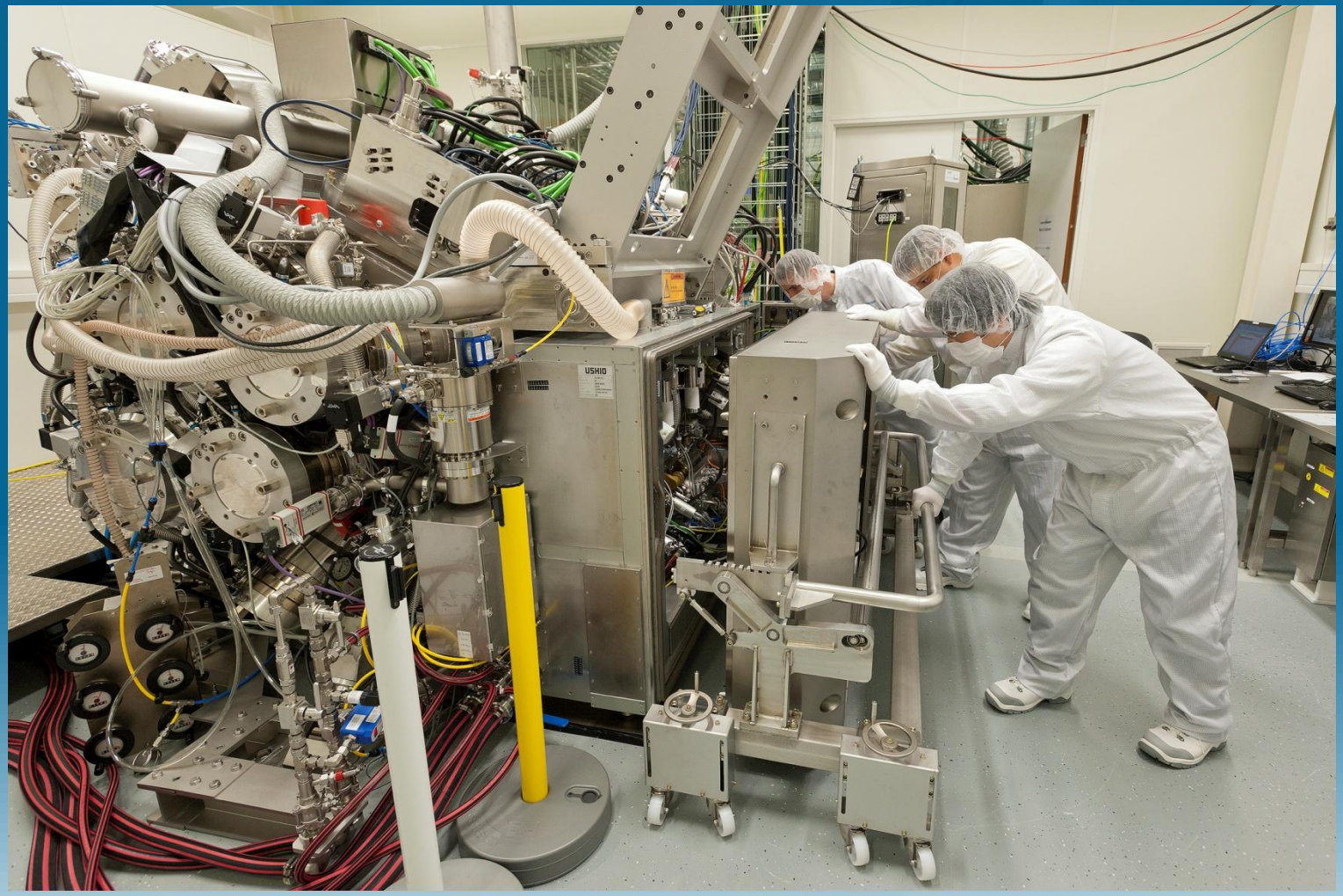
Source Head + Tin Cooling System



Trigger Laser + Capacitor Bank

Foil Trap + Collector Mirror

LDP Technology – A Reality



Why LDP – The Rationale

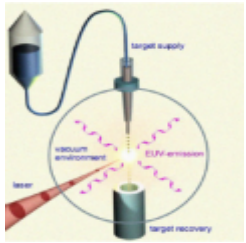
Enabling EUV Lithography

EUV SCANNER		EUV Source
Imaging	→	Clean Photon (& Spectral purity)
Yield CD uniformity Iso-Dense Bias	→	Stability (Dose, Timing …)
Maximum Throughput	→	Power
Effective Throughput	→	Duty Cycle

Why LDP - The Best Of Both Worlds

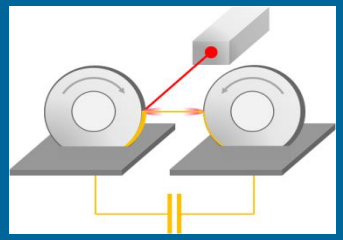
Laser-assisted Discharge Plasma

Traditional LPP



Scalable

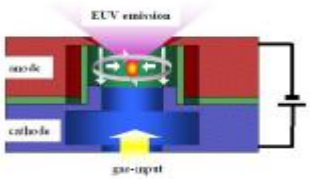
LDP



Stable

Scalable

Traditional DPP



Stable

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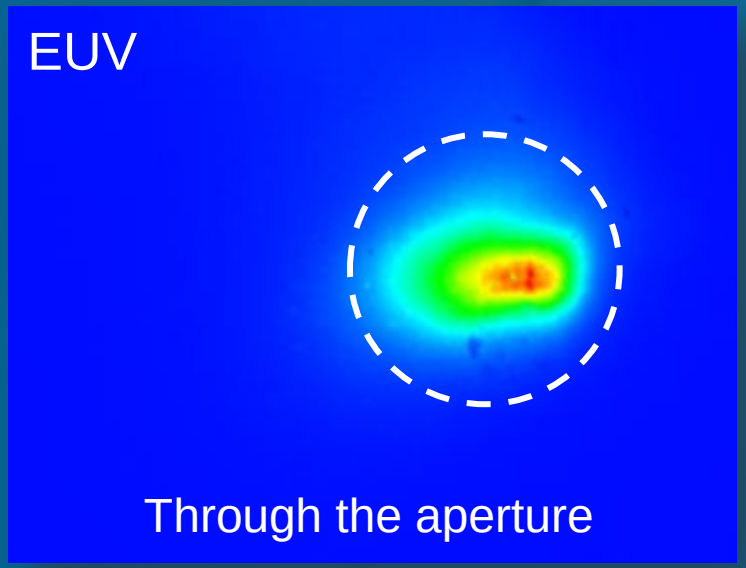
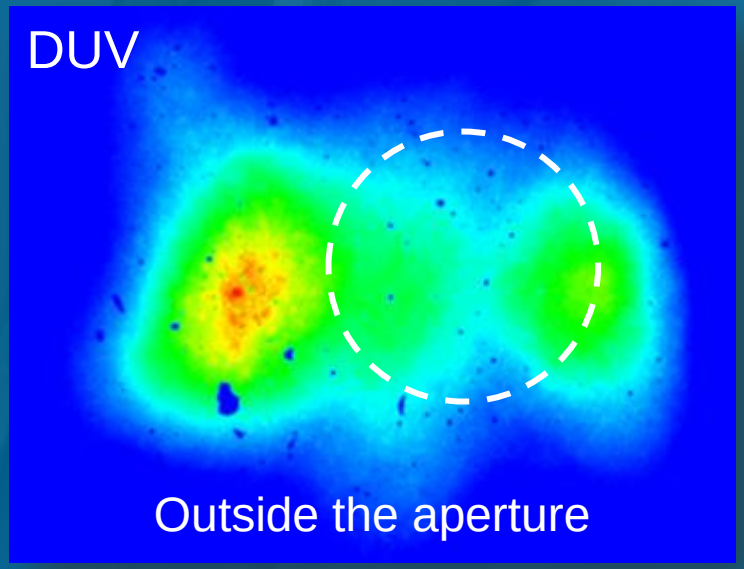
OOB DUV – LDP Photons Are Clean

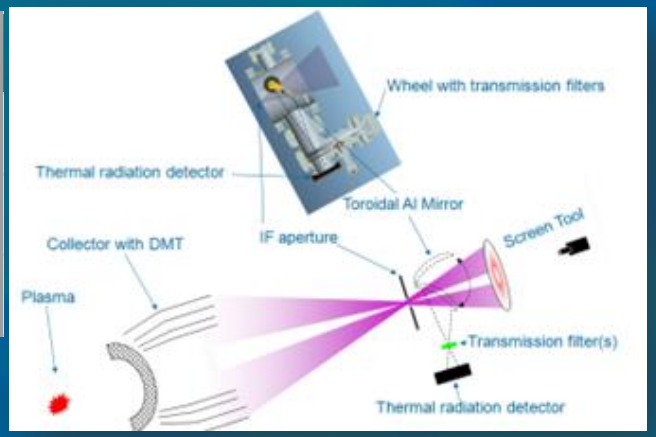


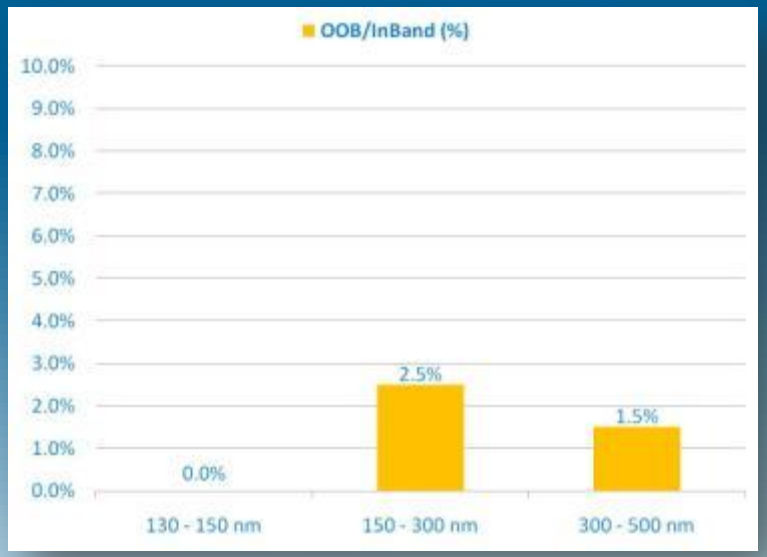


- LDP IF aperture spatially filters out DUV radiations
- DUV is imaged outside the IF aperture and is thus mechanically blocked
- Mostly, only EUV photons go through the IF aperture

OOB DUV – LDP Photons Are Clean

LDP - NXE:3100	OOB/InBand (%)
130 - 150 nm	0.0%
150 - 300 nm	2.5%
300 - 500 nm	1.5%





Measurements:

Output inband EUV power: 5 W

Filters:

CaF2	130 – 12000 nm
Suprasil 300	150 – 4000 nm
WG295	300 – 2800 nm
GG495	500 – 2800 nm
Suprasil 300 + Si	1500 – 4000 nm
WG295 + Si	1500 – 2800 nm

LDP photons are clean

No need for SPF

No impact upon wafers

Proven @ ADT

Now being validated @ IMEC

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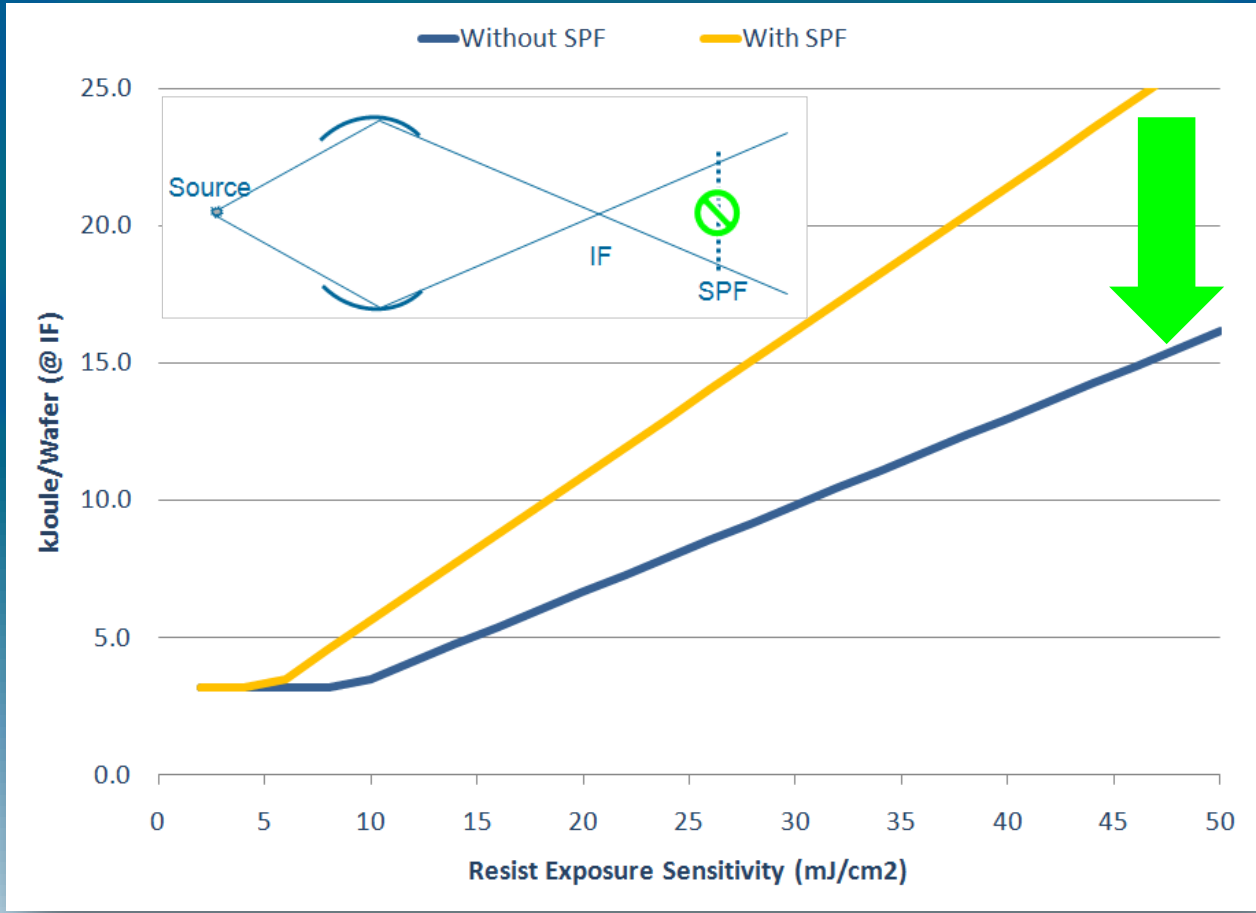
OOB DUV – LDP Photons Are Clean

- NXE:3100 with LDP technology does not require a Spectral Purity Filter (SPF)



LDP photons are clean

No SPF

No loss of In-Band EUV power

Lower kJoule/Wafer

More wafers/year

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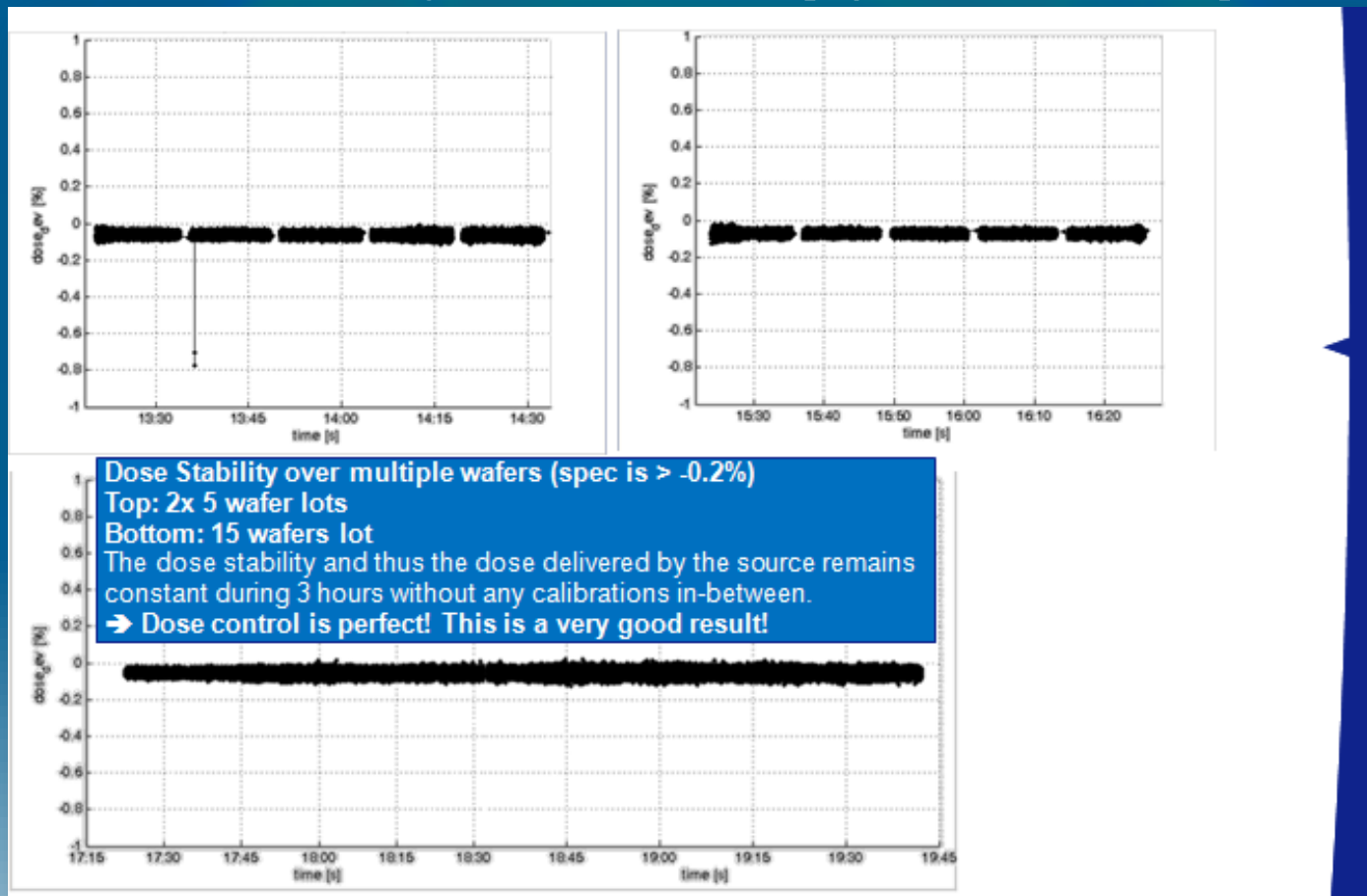
Dose Stability Means CD Uniformity

- Dose stability is 3 σ < 0.1 % [Spec. 3 σ < 0.2%]



Conditions:

IMEC's NXE:3100

0.25NA/ 0.81s

14.5mJ/cm2

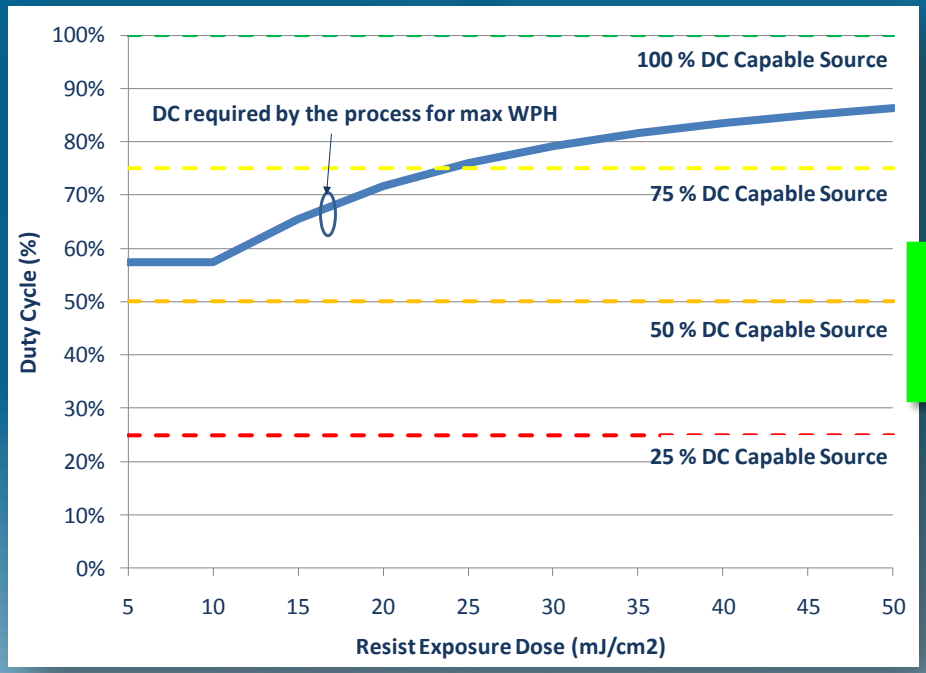
27nm LS

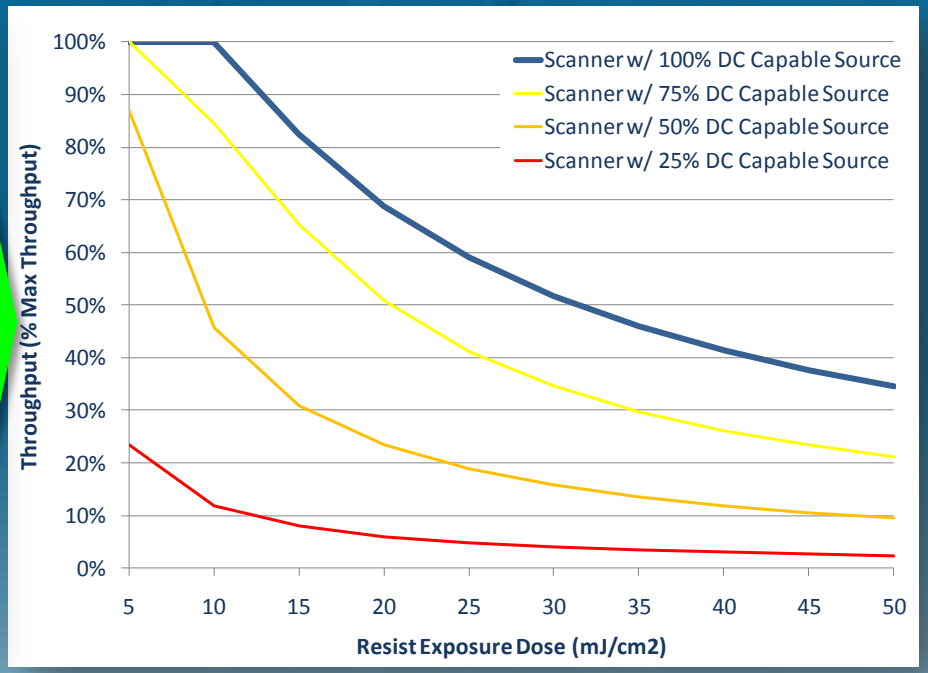
Exposure time was 1hr. 11min. for 5-wafer lot full field, full wafer coverage

Exposure time 3hr. 10min. for 15-wafer lot full field, full wafer coverage

Duty Cycle Means Productivity

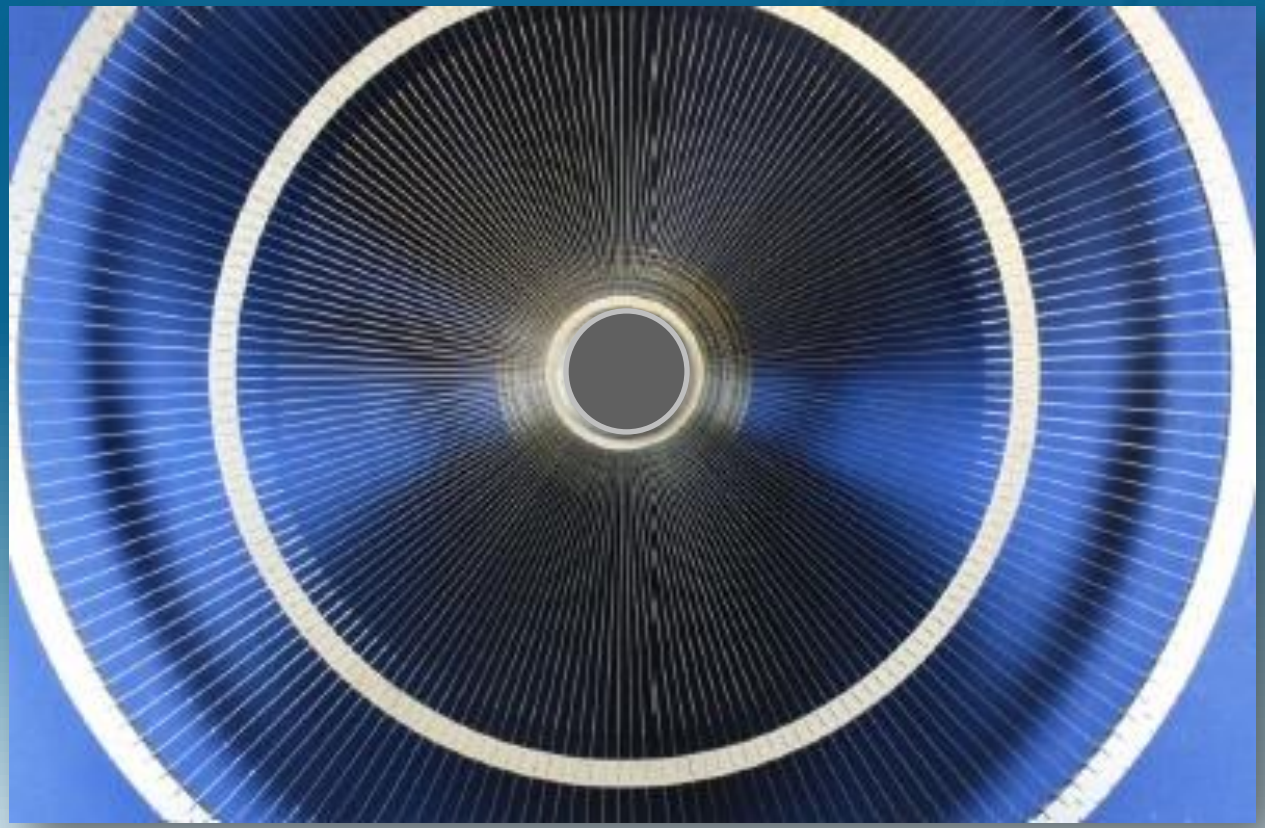
- High Source Duty Cycle is required to enable maximal throughput





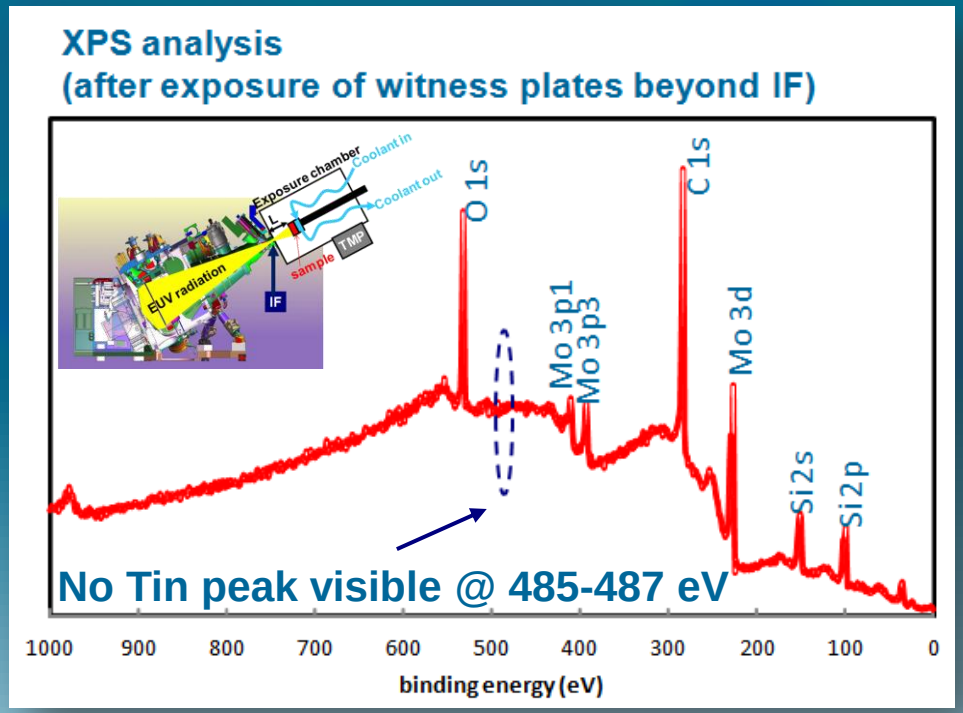
Debris & Contamination Management

- XTREME's unique Foil Trap module is designed:
  - To protect the collector mirror from Tin deposition and erosion (debris)
  - To prevent Tin transport towards the scanner and the pellicle-less mask
    - Tin contaminants on mask → Yield loss



No Tin Contaminant Beyond IF

- Mechanical baffles and Foil Trap prevent Tin contaminants to transport - through the IF aperture - towards the scanner and the pellicle-less mask



The "dirty" area physically isolated

No Tin transport

No scanner contamination

No Tin printing defects

No yield loss

Confirmed by ASML: over 1 year of utilization w/ ADT

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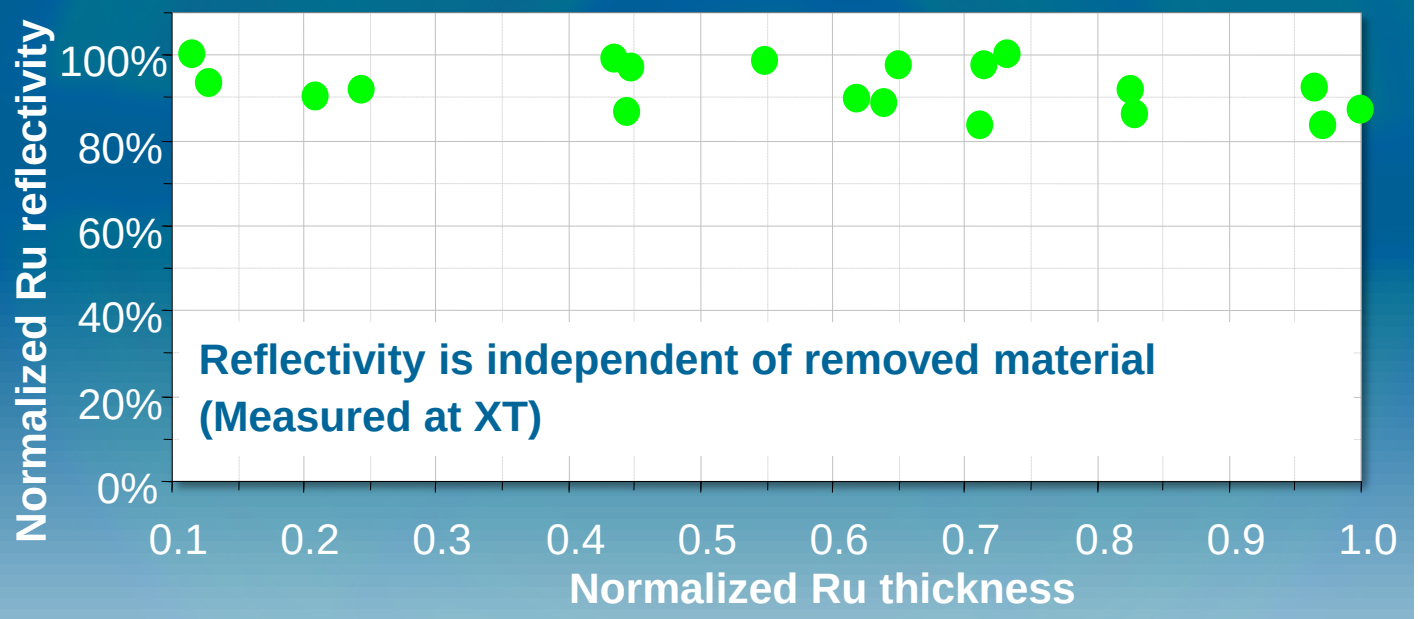
Long Collector Mirror Lifetime Is Proven

- The FT protects the collector mirror
- Ruthenium (Ru) coating can also be used as sacrificial material with constant optical performance of the collector

LDP collector lifetime ~ 1 year



* Confirmed by ASML: over 1 year of utilization w/ ADT

Sacrificial Ru layer

Self-cleaning collector

Stable power & stable Far Field image over lifetime

Stable scanner imaging quality

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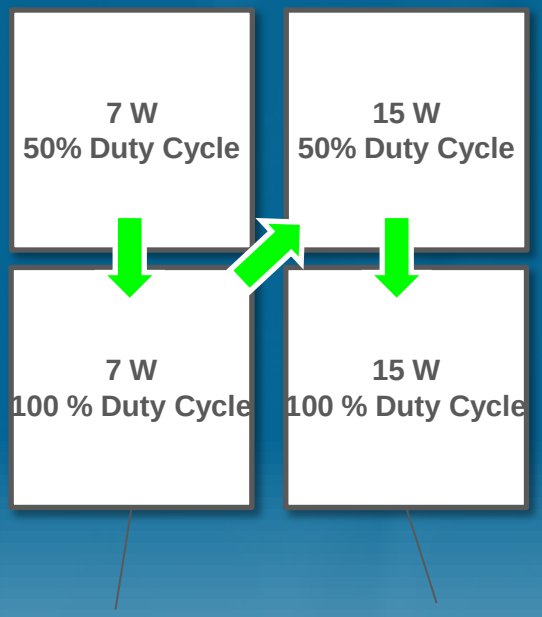
Where Are We Now ?

Where Were We Earlier This Year – SPIE Lithography 2011



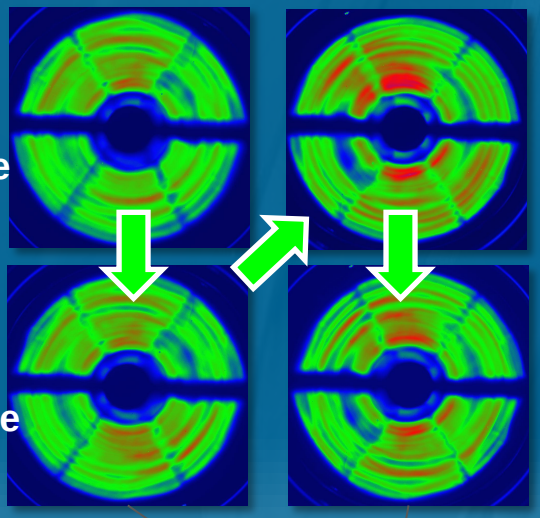
2010			2011												2012		
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.

Where Are We Today

7 W
50% Duty Cycle

15 W
50% Duty Cycle

33 W
50 % Duty Cycle



37 W
50 % Duty Cycle

7 W
100 % Duty Cycle

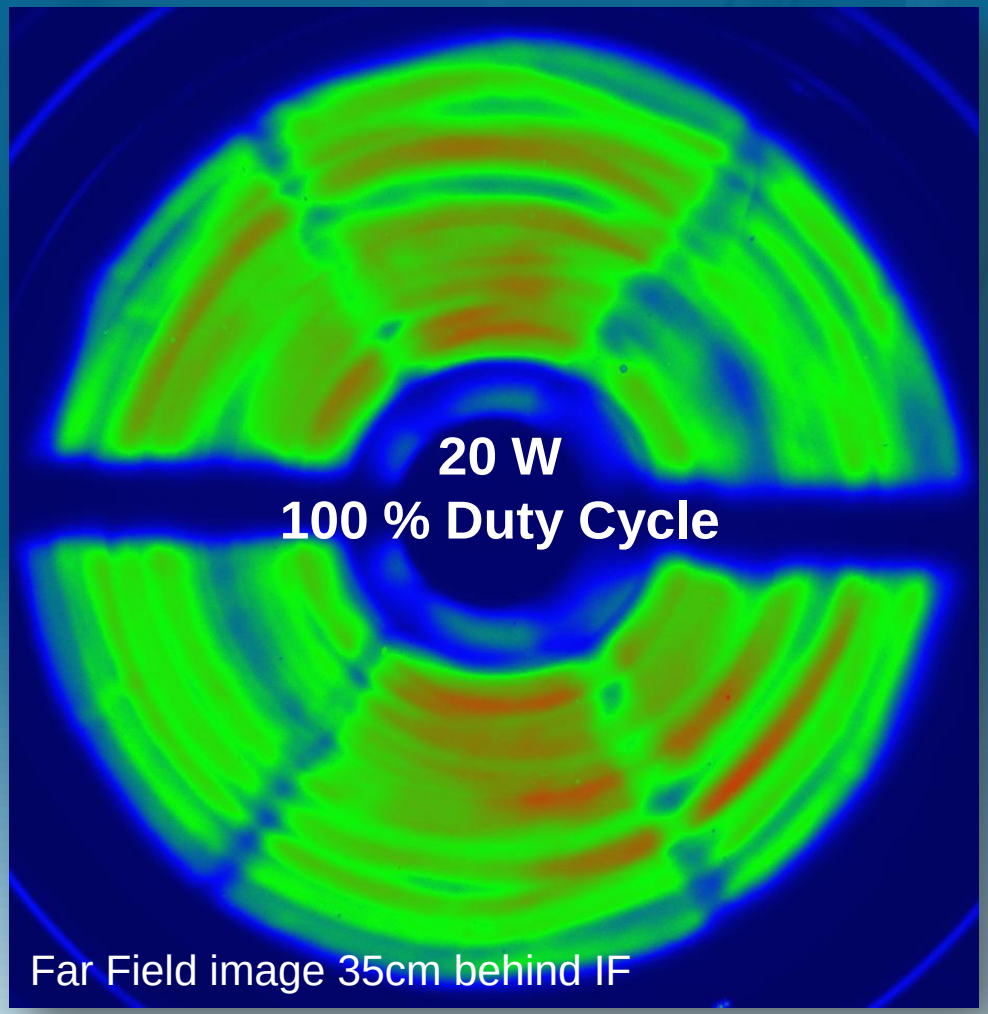
15 W
100 % Duty Cycle

20 W
100 % Duty Cycle

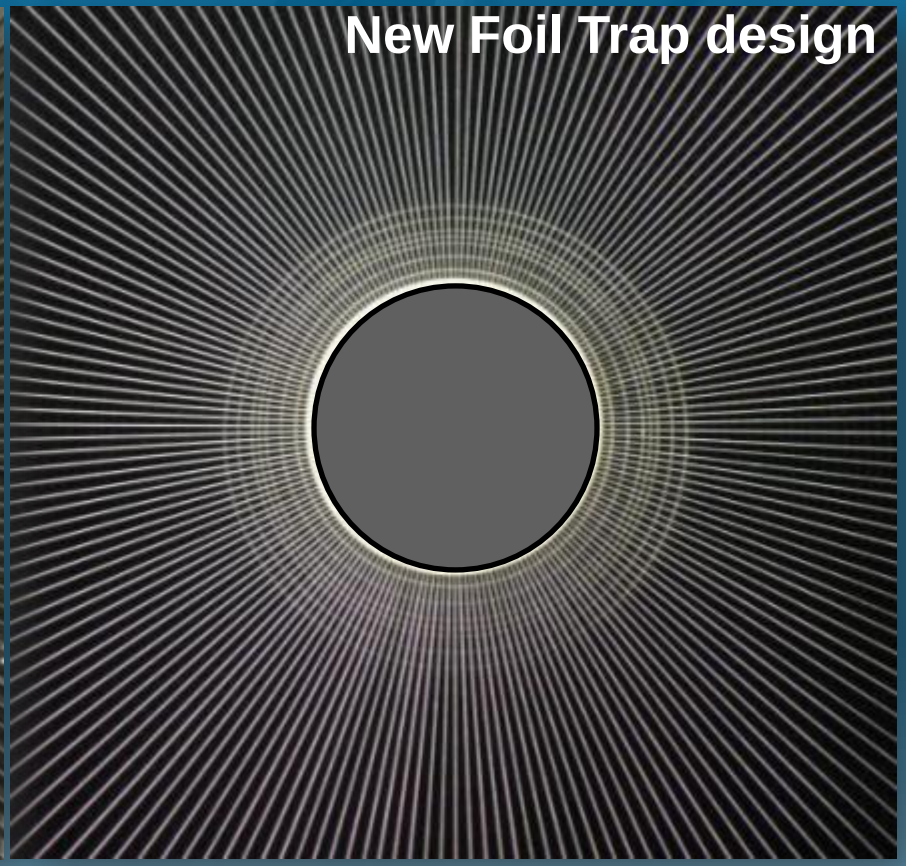
30 W
100 % Duty Cycle

2010			2011												2012		
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.

The Initial Breakthrough



Removing The Bottleneck – Design For Manufacturing



- Bended blades
- Irregular spacing

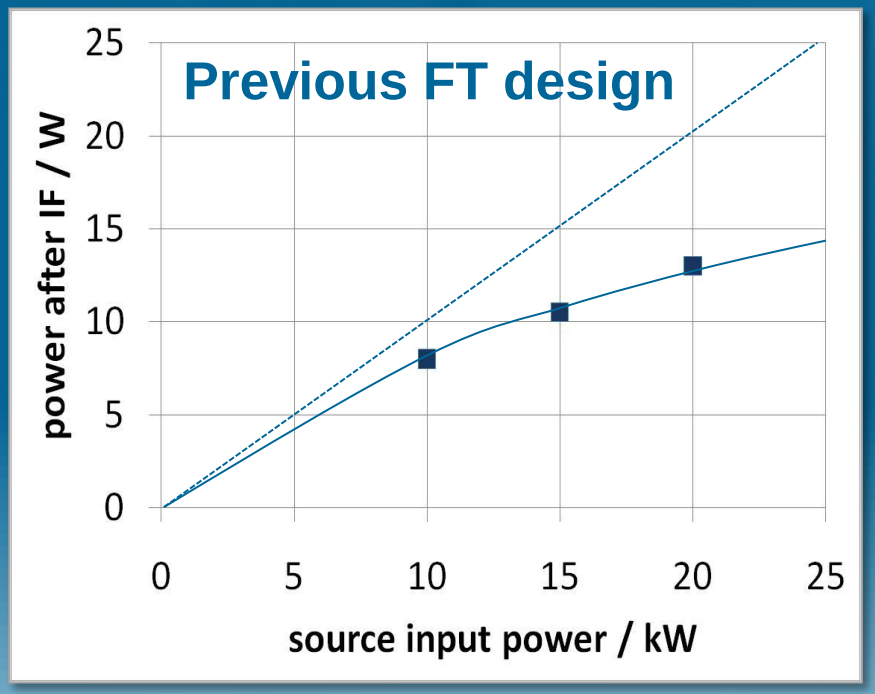
→Low optical transmission < 60%
→Higher heat load

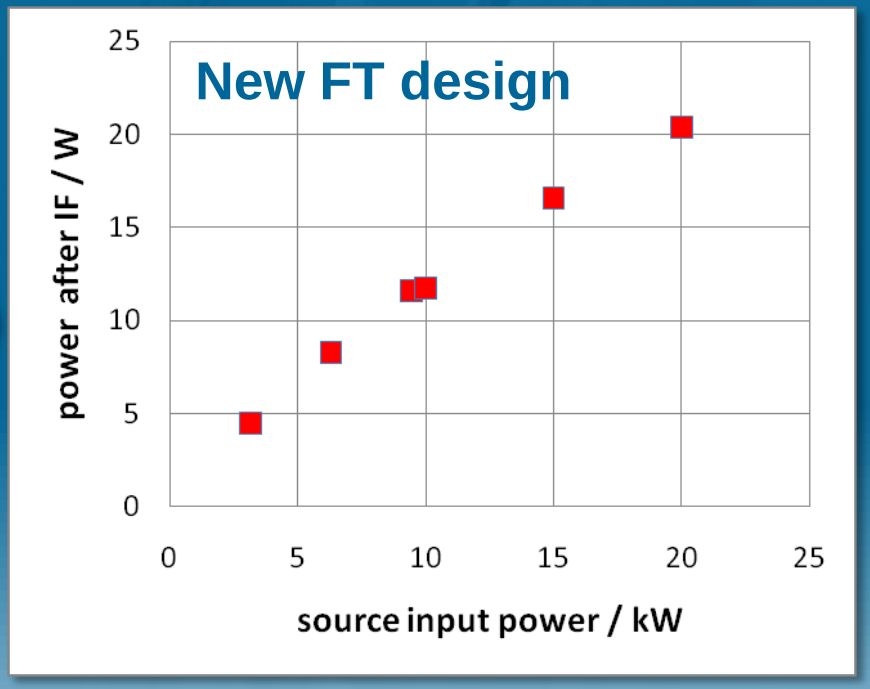
- Straight blades
- Regular spacing

→High optical transmission > 76%
→Reproduced on 5 newly manufactured FTs

The Initial Breakthrough

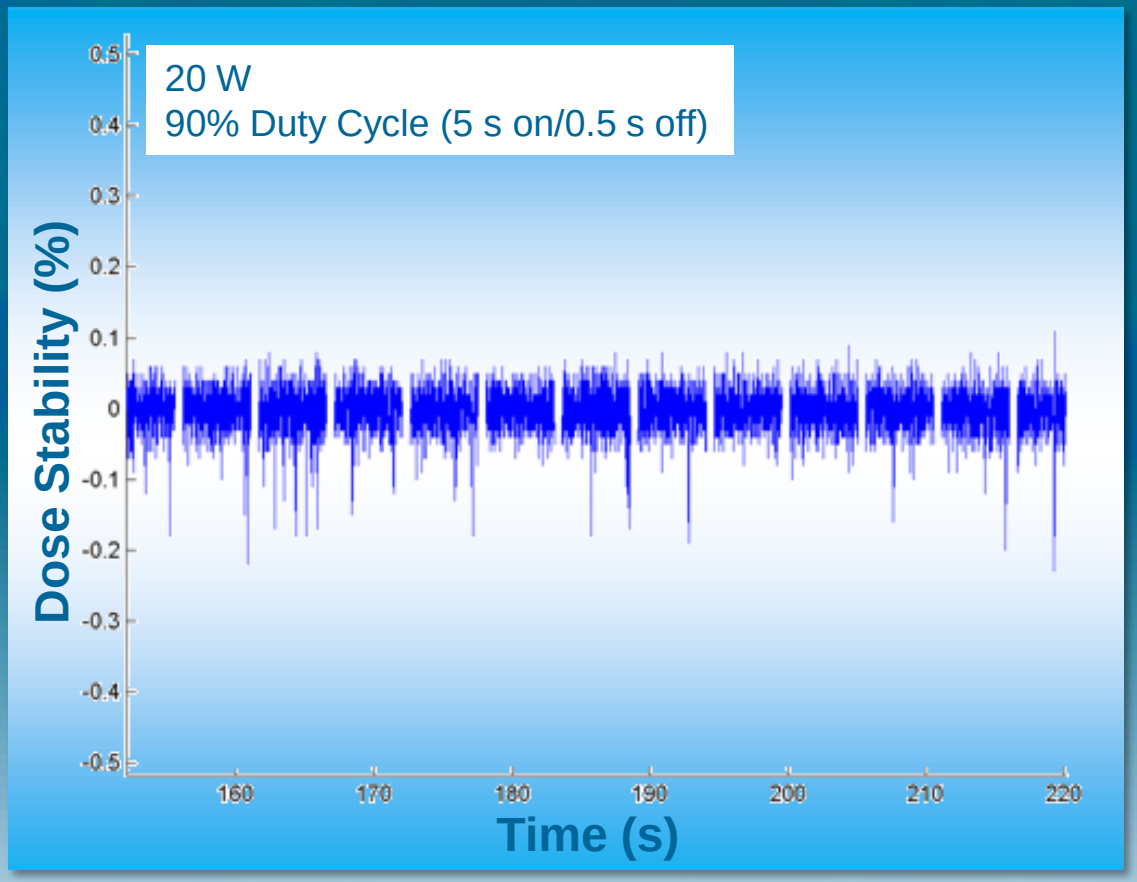
- New Foil Trap design → output power now scales linearly





Dose Stability Is Also Within Specifications

- NXE:3100 Specification: 3 σ ≤ ± 0.2 %



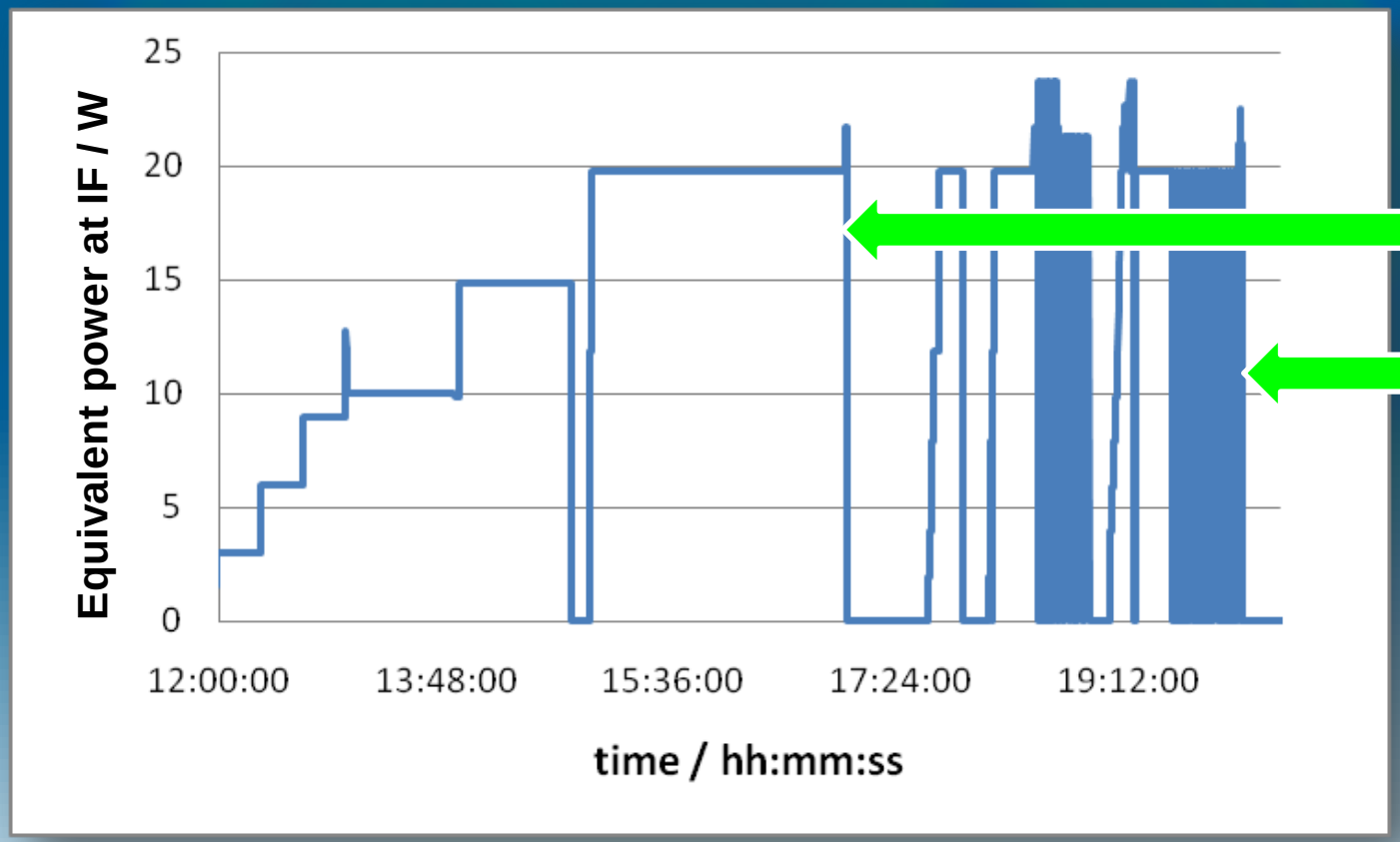
Automated feedback implemented since ADT

Continuous Tin delivery ensures timing stability

LDP dose control independent of the power level

The Breakthrough Is Sustainable

- Cumulative 9 hours @ 20W over 3 days proven

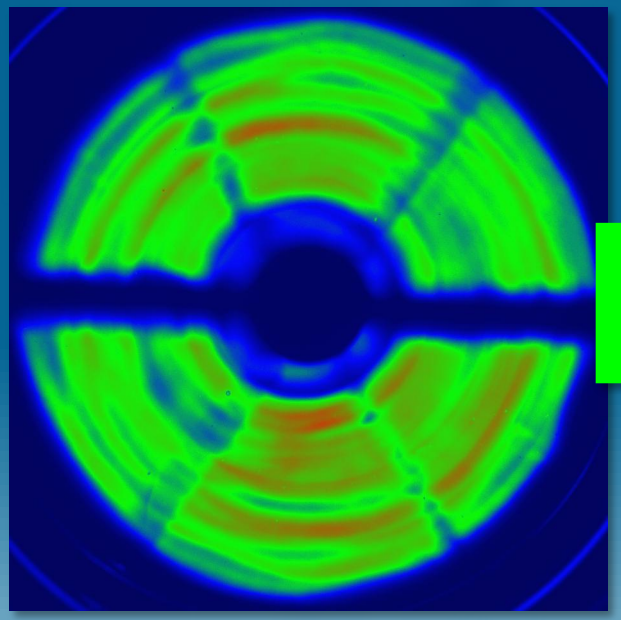


20 W output power
20 kW input power
100 % DC

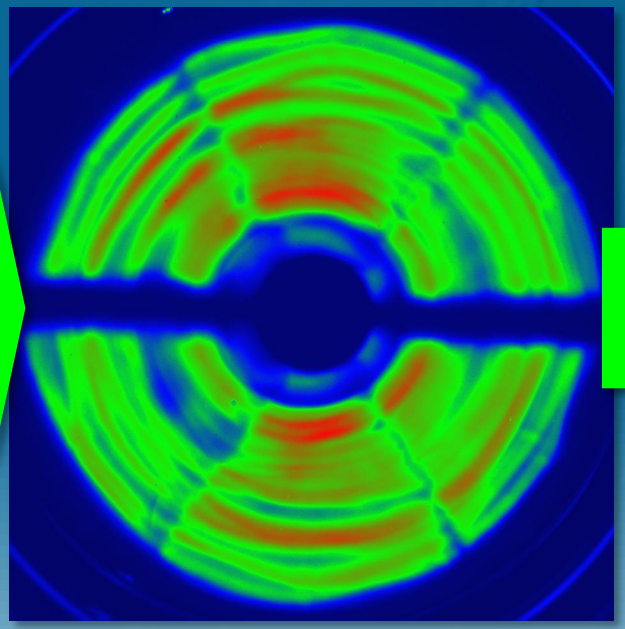
20 W output power
20 kW input power
Variable DC
(to simulate scanner actual operations)

Since Then, Progress Is Steady

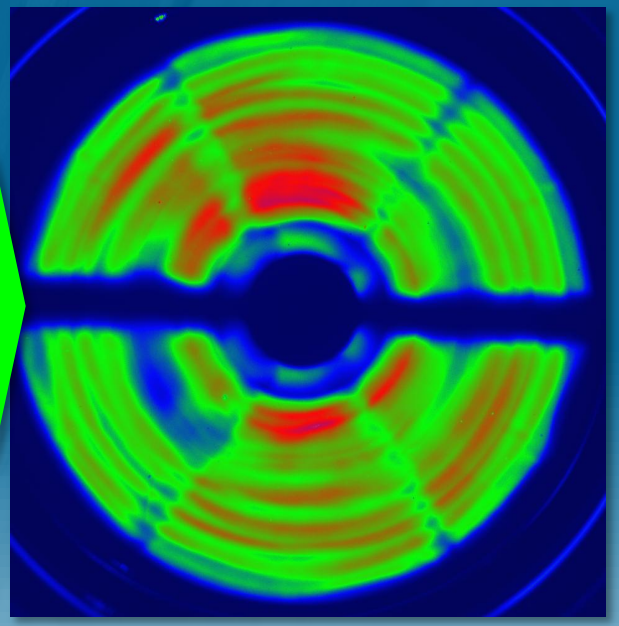
33 W
50 % Duty Cycle



30 W
100 % Duty Cycle



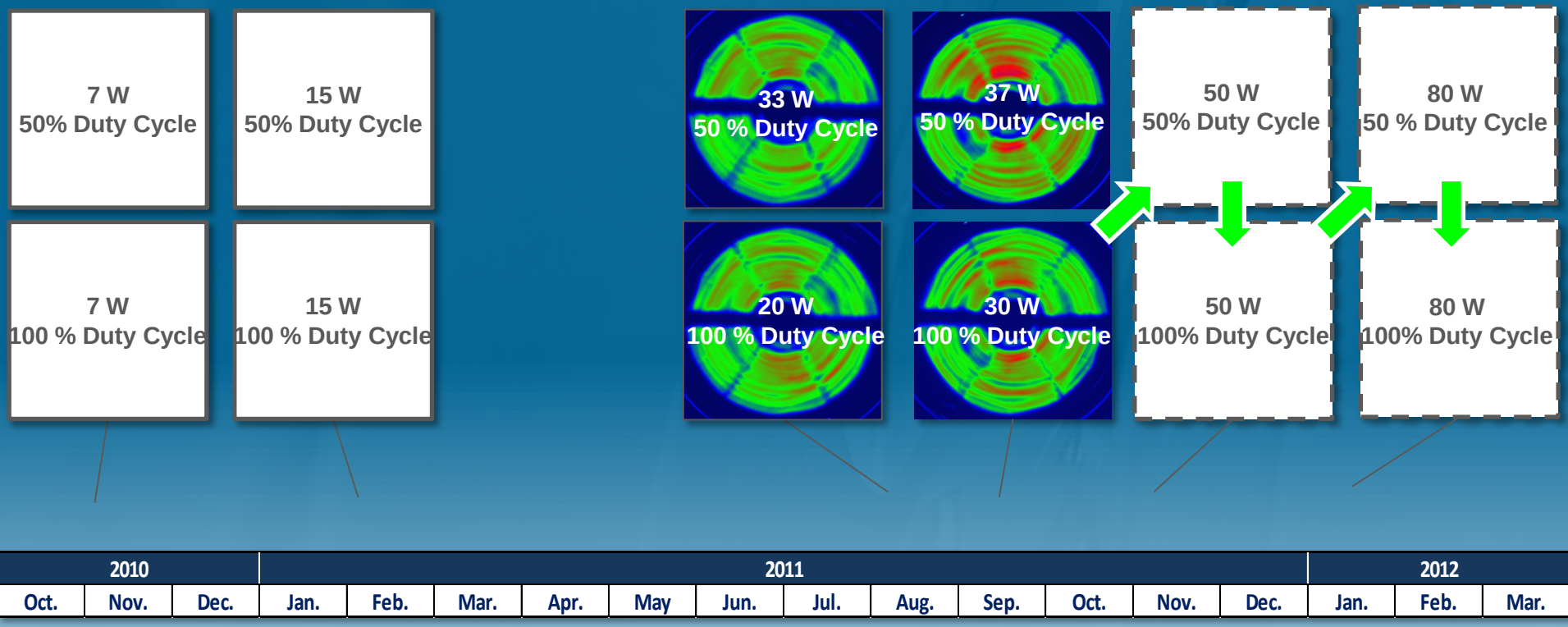
37 W
50% Duty Cycle



Far Field images 35cm behind IF

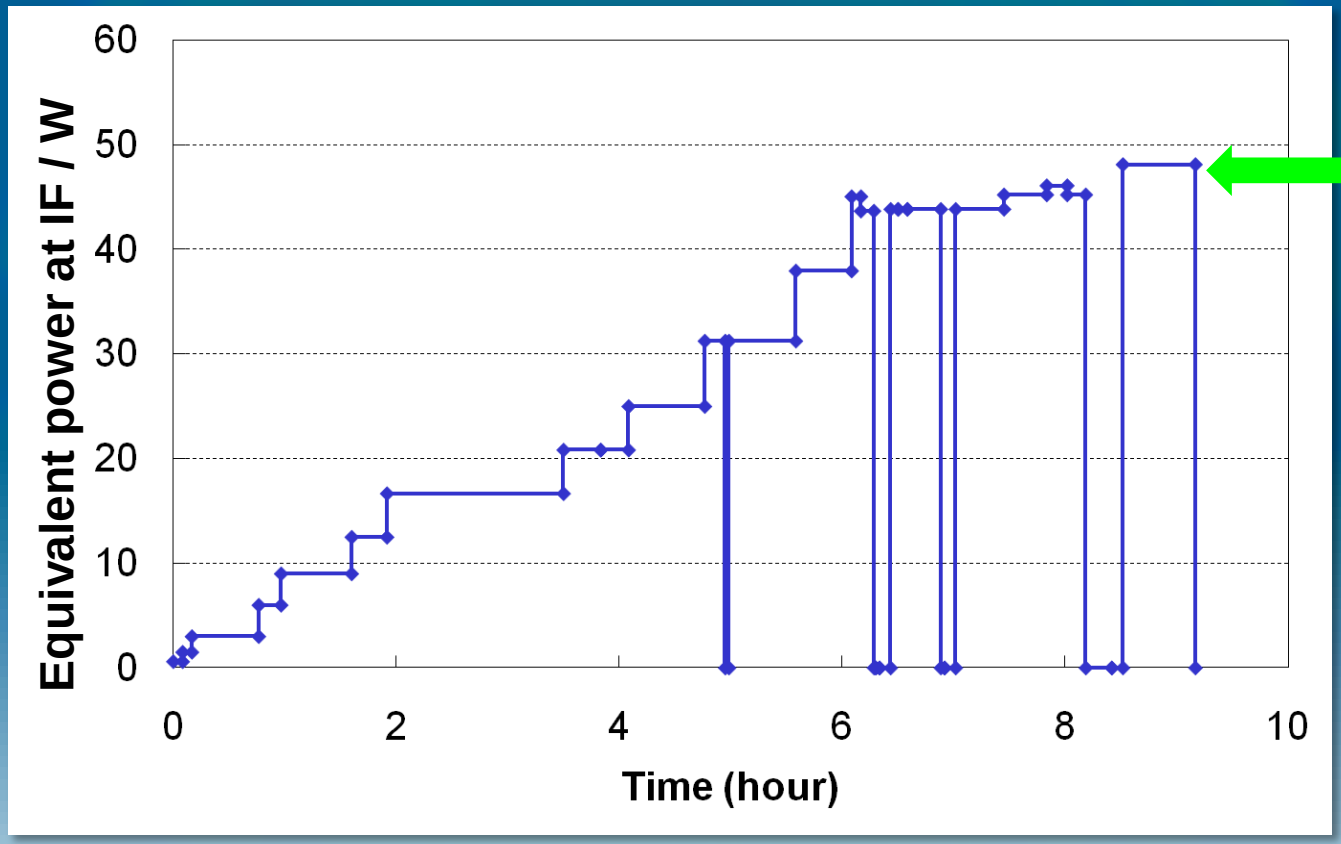
What's Next ?

Higher Power Is Around The Corner



48 kW Source Head Will Soon Deliver 50 W

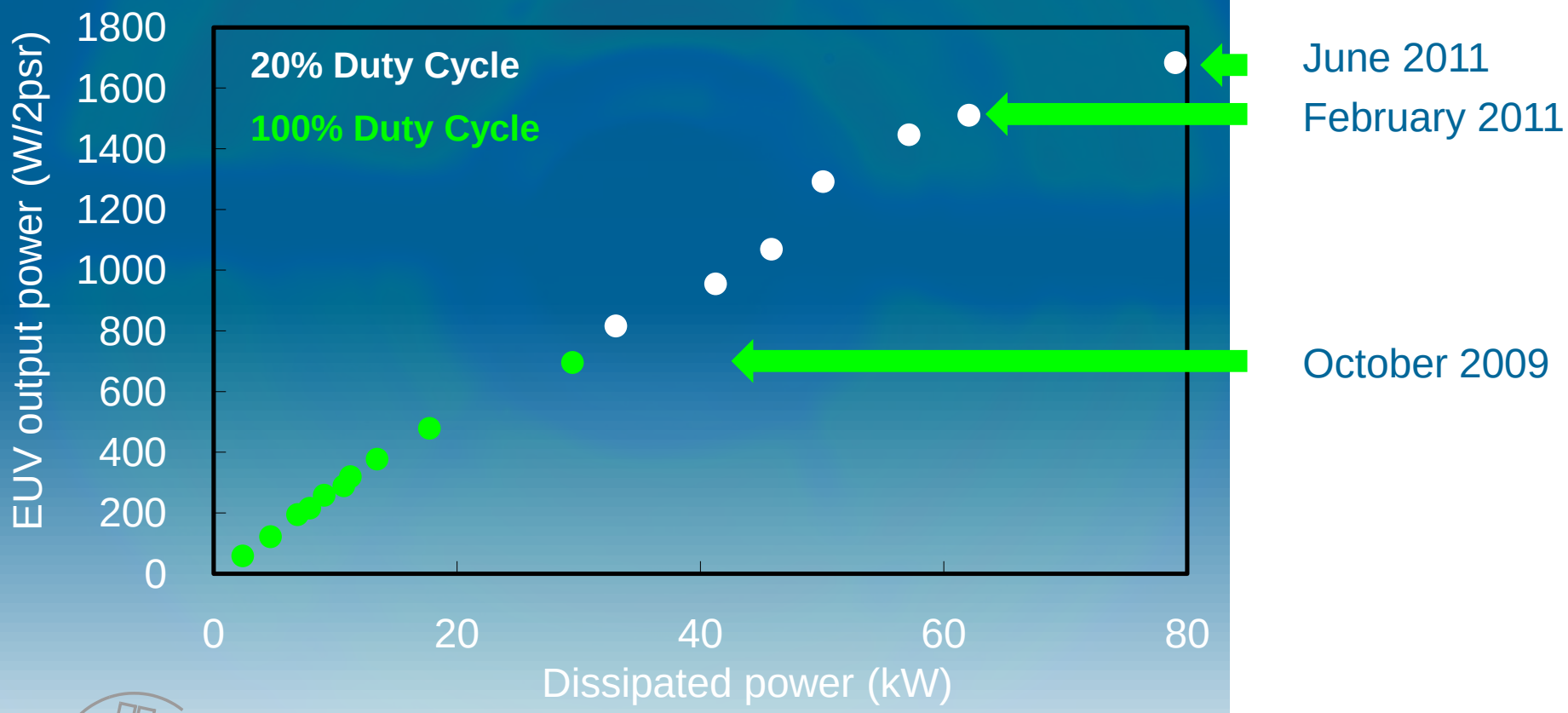
- Next generation Source Heads are now tested as stand alone module



48 W output power
48 kW input power
100% DC
40 minutes

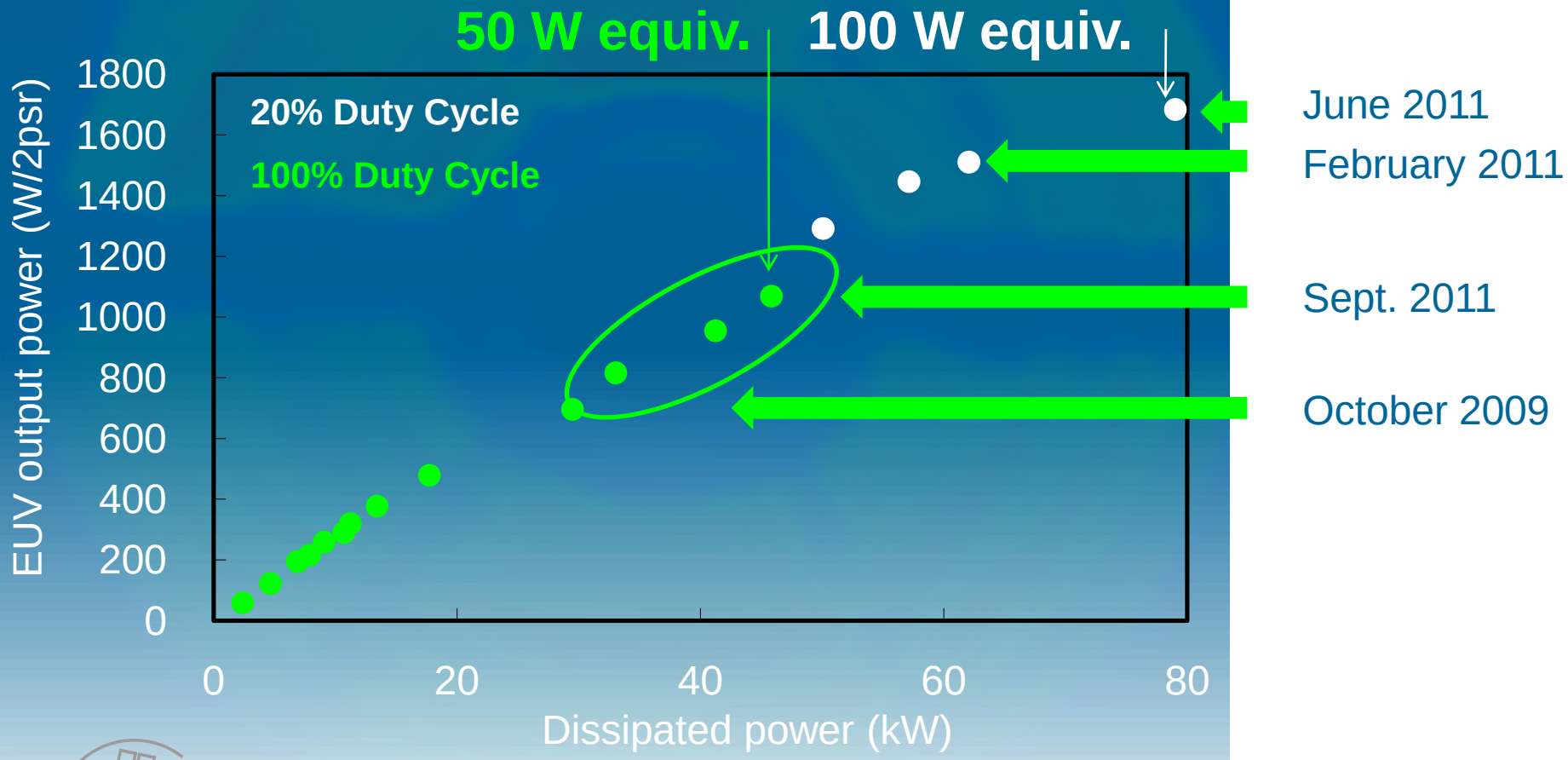
Higher Power Is Around The Corner

- To achieve 100 W EUV power, higher input power Source Heads is required
  - The 100W enabling 76 kW Source Head is being tested



Equiv. 50W Proven At Module Level

- 76 kW Source Head will be used to generate 100 W EUV output power
  - 1700 W/2psr / 76kW → ~ 2.3% CE



Towards HVM

- The path towards HVM high power is clear

250 W Source

48 kW Source Head → 300 kW Source Head

Increase electrical input power by increasing repetition rate

Increase the rotation speed of Source Head wheel

Increase Tin cooling capacity

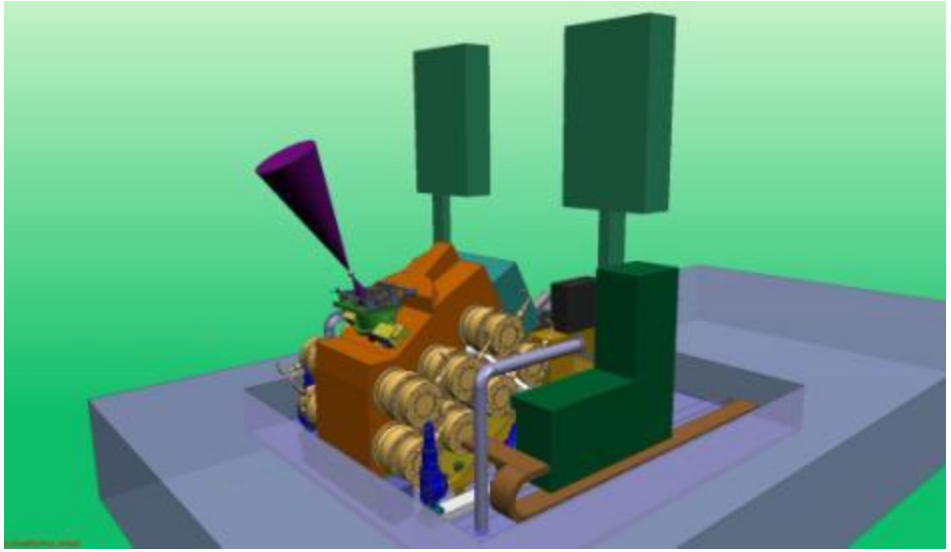
50 W Foil Trap → 250 W Foil Trap

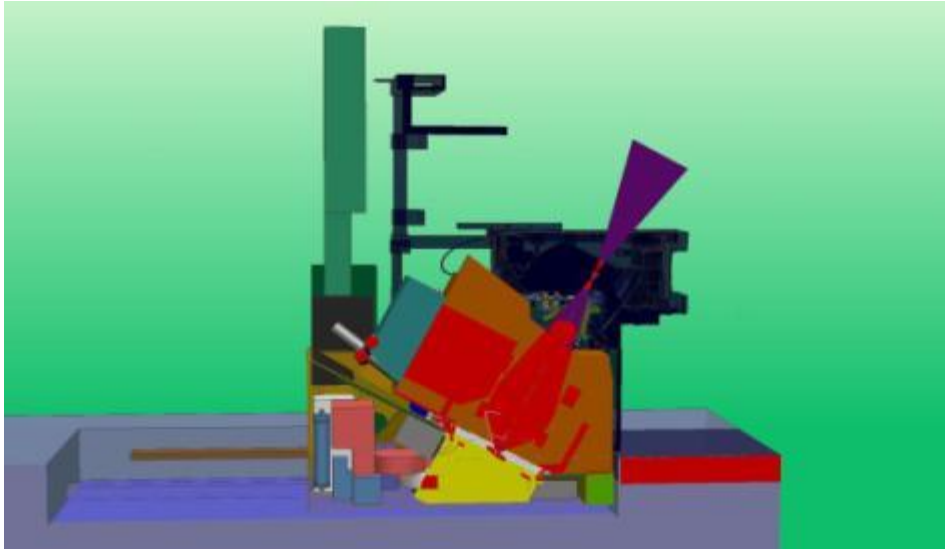
Increase distance to plasma

Increase cooling efficiency

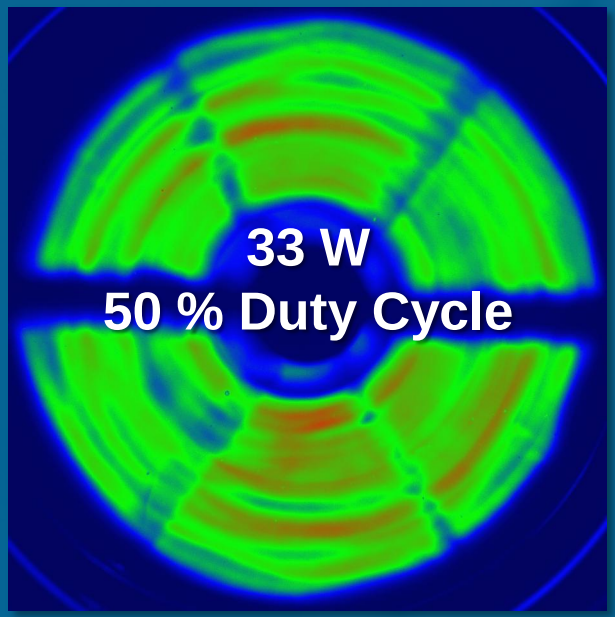
The Design Is Underway

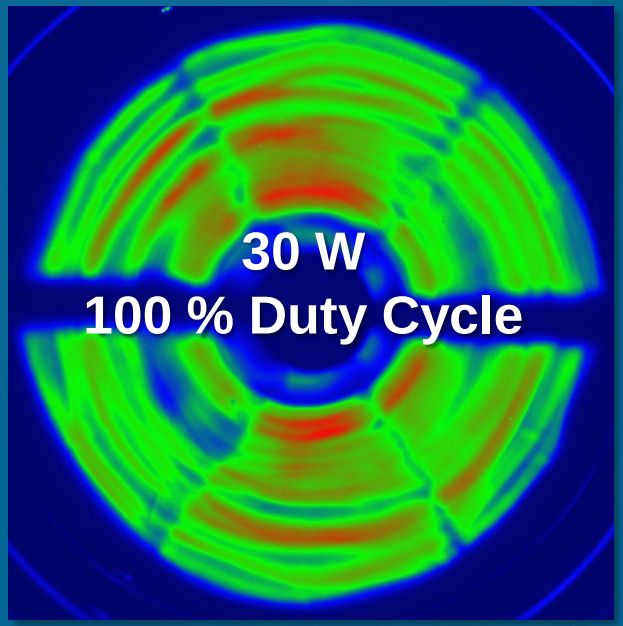
- Design boundaries:
  - Higher reliability
  - Higher power
  - Better serviceability
  - Ease of maintenance (e.g. less connections)
  - No Tin cross contamination in the Fab during maintenance
  - Stand-alone operations
- Geometric boundaries
  - Tighter space
  - Higher source angle

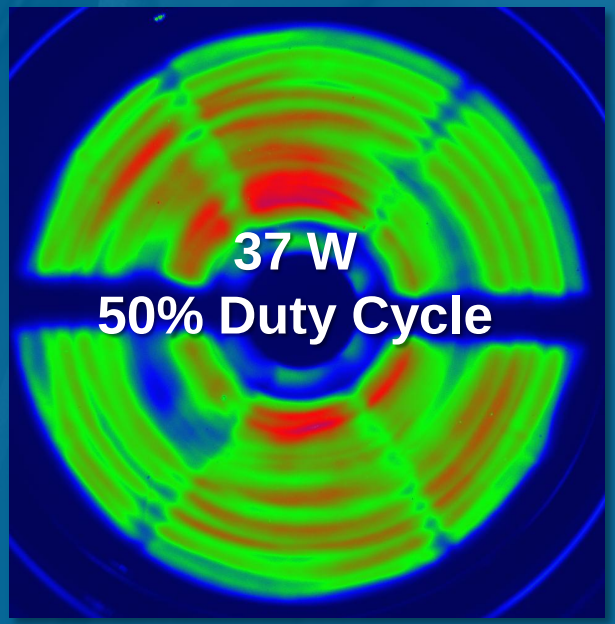




Conclusions

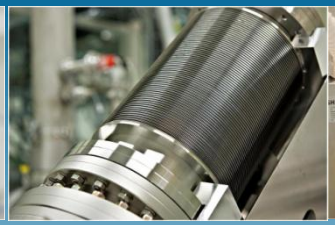






- 30 W / 100% DC has been achieved at system level
- 37 W / 50 % DC has been achieved at system level
- 50 W / 100% DC has been achieved at the module level (SH)
- Higher power is around the corner
- LDP is scalable to higher power. The path to 250 W is identified

THANK YOU VERY MUCH FOR YOUR ATTENTION



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