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Fraunhofer Institut Lasertechnik

Lessons learnt on Sn DPP sources in Alpha tool and the road to HVM

October 30, 2007

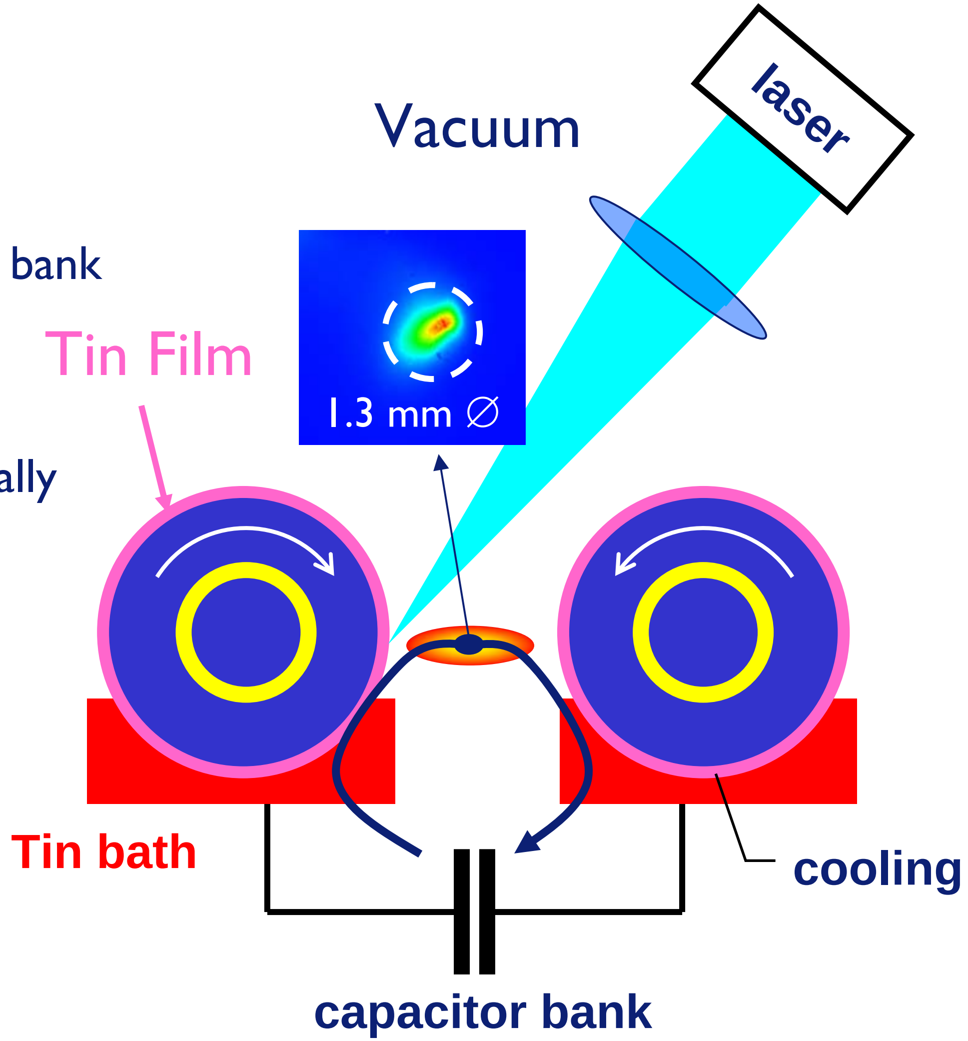
Marc Corthout and
the whole Philips Extreme UV team

Overview

- Status of Alpha sources
- Philips' debris mitigation system
- DPP Scalability
- Philips' SoCoMo roadmap

DPP scalable power concept: rotating electrodes

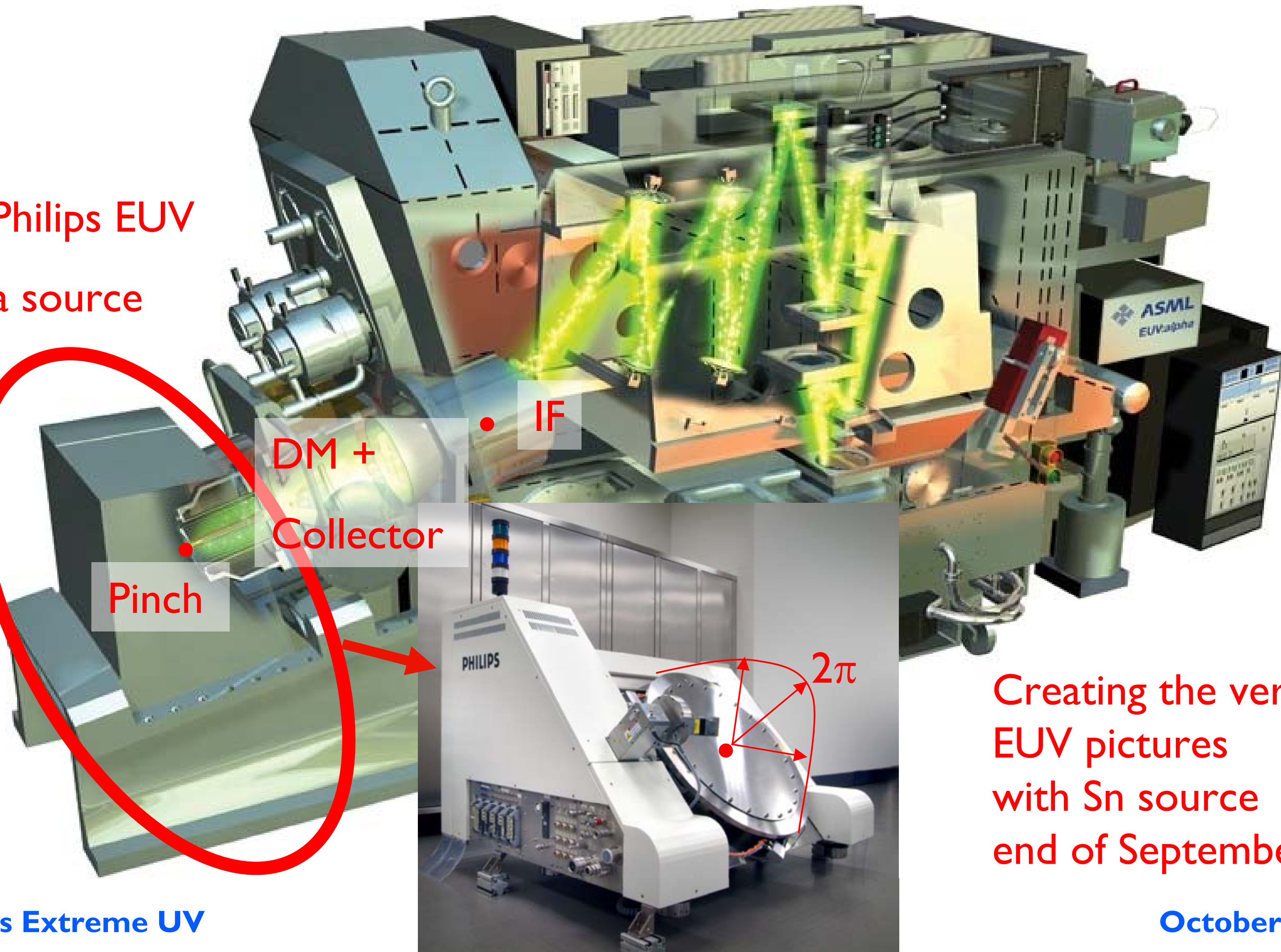
- Laser Triggered Vacuum Spark
- Electrical contact through Sn
  - Simple power supply to load capacitor bank
- Regenerating liquid tin surface
  - Electrode erosion problem fundamentally solved !
- Liquid metal cooling
  - Very efficient to remove excess heat: >>100kW input power



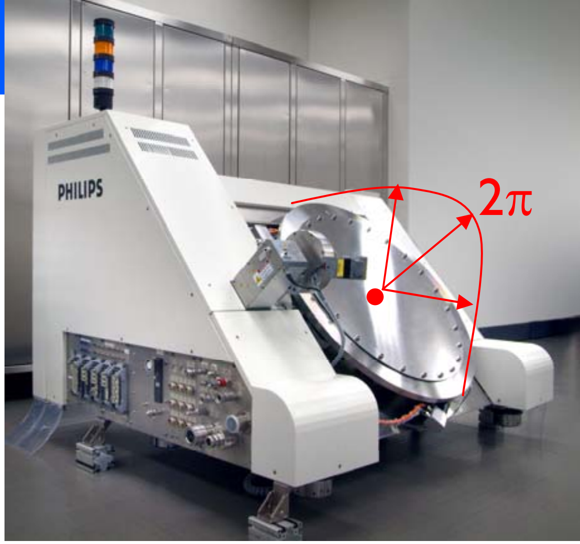
The ASML EUV Alpha Demo Tool

The Philips EUV

Alpha source

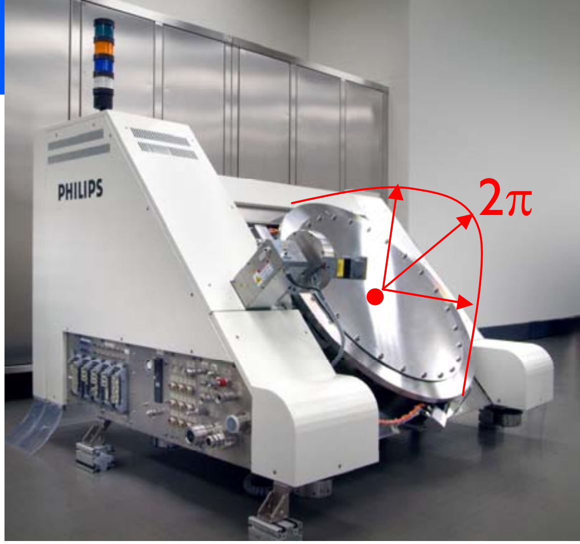


Creating the very first
EUV pictures
with Sn source
end of September 2007



Alpha source power levels in 2π

- Current ADT source is 70W in-band EUV
  - Power constrained to a fraction of this in current ADT due to actual debris mitigation (DM) implementation
- Upgrade to 120W delivered to our customer end of October 2007
- Upgrade to 170W delivered to our customer end of March 2008
- Experimental status: 195W



Reliability tests at 90W in 2π

Total experimental time of 30 h continuous operation with 100 % duty cycle
distributed over three experiments with 10 hours each.

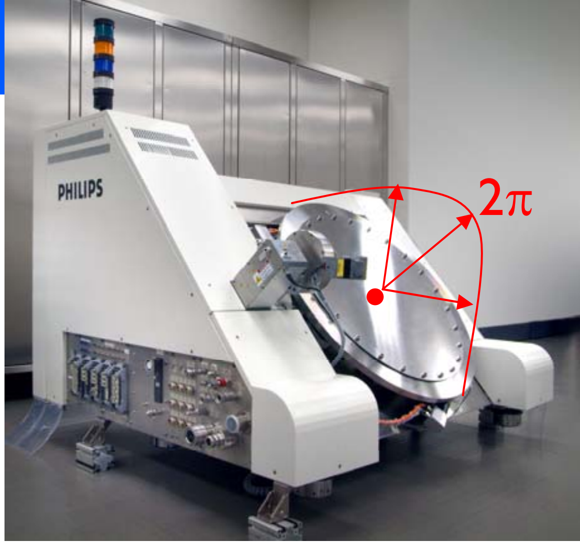
1 assist after 20.5 h
(after 6.6 MJ EUV in 2π)

10 h | 20 h | 30 h

10MJ EUV

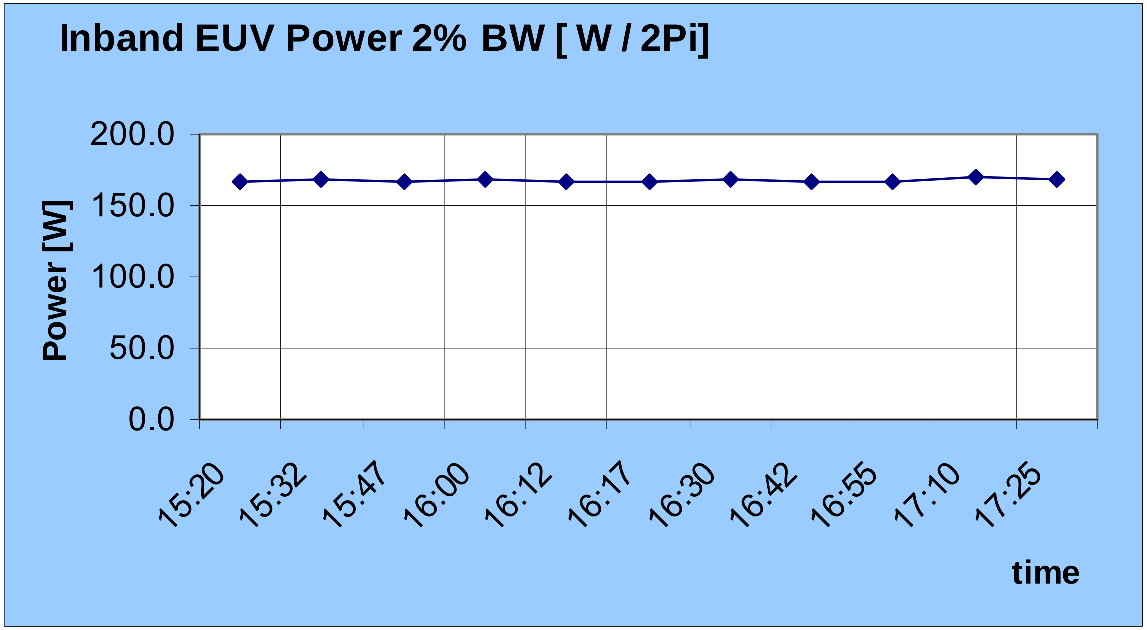
1 failure after 15.3 h
(after 5MJ EUV in 2π)

SEMATECH Report



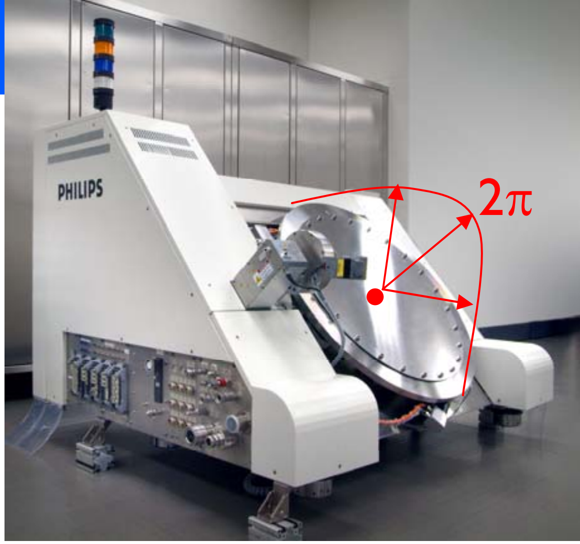
Further power scaling: 170W in 2π

- 170 W demonstrated over 2 hours:
  2 hours of continuous operation (100 % duty cycle) were shown.



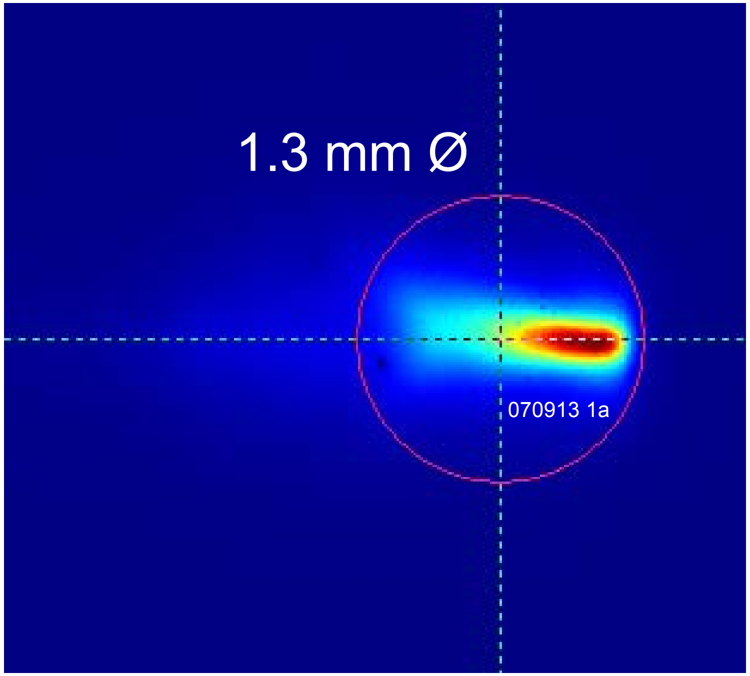
Experimental result: 195W in 2π

continuous operation (100% duty cycle)



Intrinsic CE = 2.6 %

EUV in 2π / energy delivered to electrode system



39 mJ EUV in 2π / pulse

(LPP: 1-2 mJ EUV in 2π / pulse)

So 1Gshot $\cong$ 40 MJ in 2π
or
25 Mshot $\cong$ 1 MJ in 2π

Tin consumption

- Tin consumption Philips EUV: **25 g / MJ EUV in 2π**

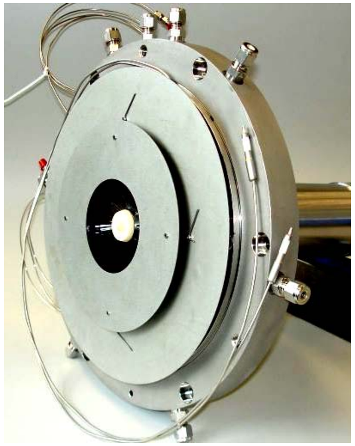
- Compare with LPP publications for SPIE 2007 and Baltimore 2007:
  assuming best case:
  50 micrometer droplets (~0.5 μg) @ 50 kHz (~24 mg/s)
  yielding 90 W EUV in 2π (= 90 J EUV / s) (if it would be continuous)
  $\Rightarrow$ **270 g / MJ EUV in 2π**

- **Thus one order of magnitude less Sn consumption compared to LPP**

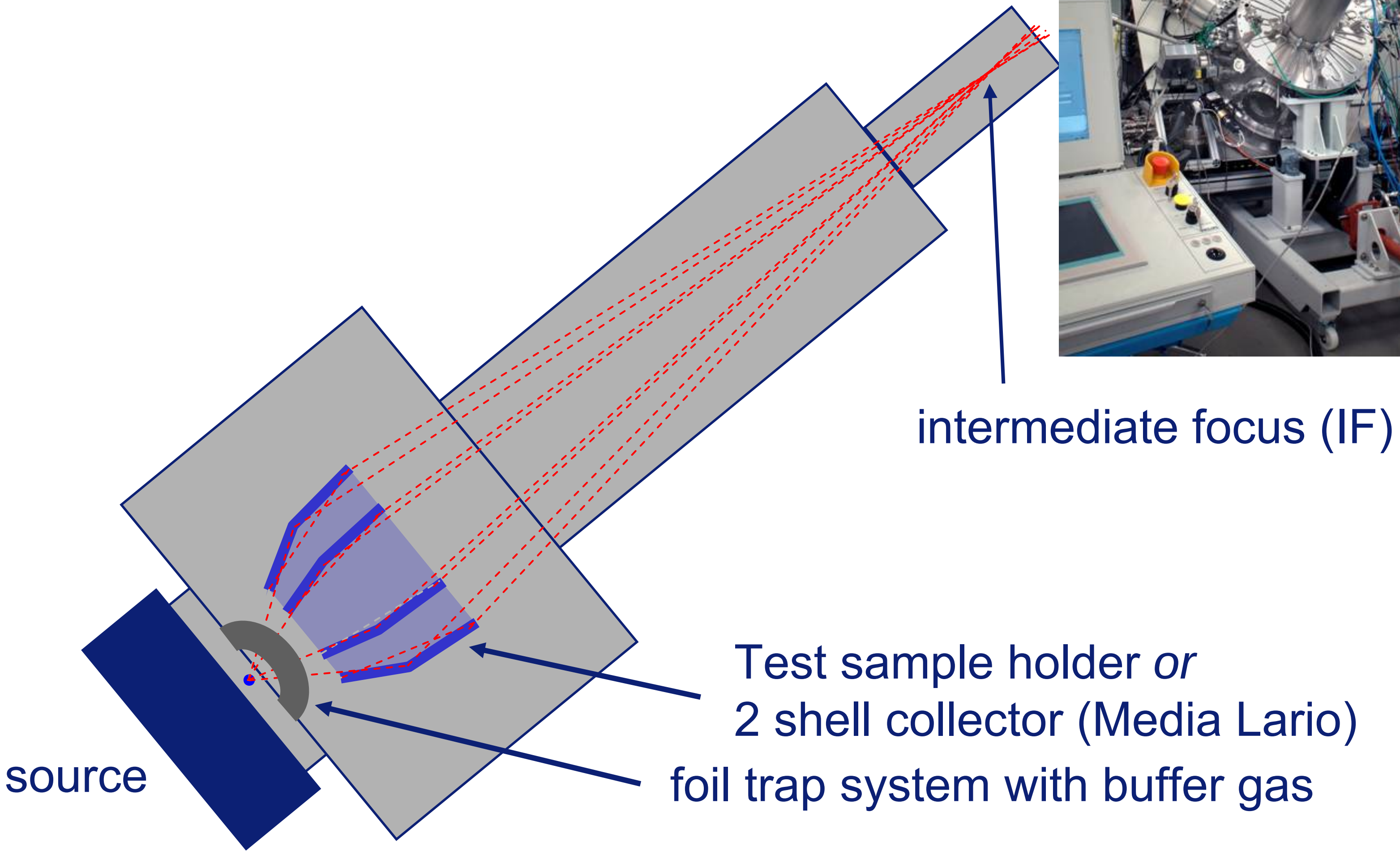
- For Philips EUV source:
  - All tin is being processed by the Philips' DM solution
  - No recycling necessary

Philips' Debris Mitigation Generations

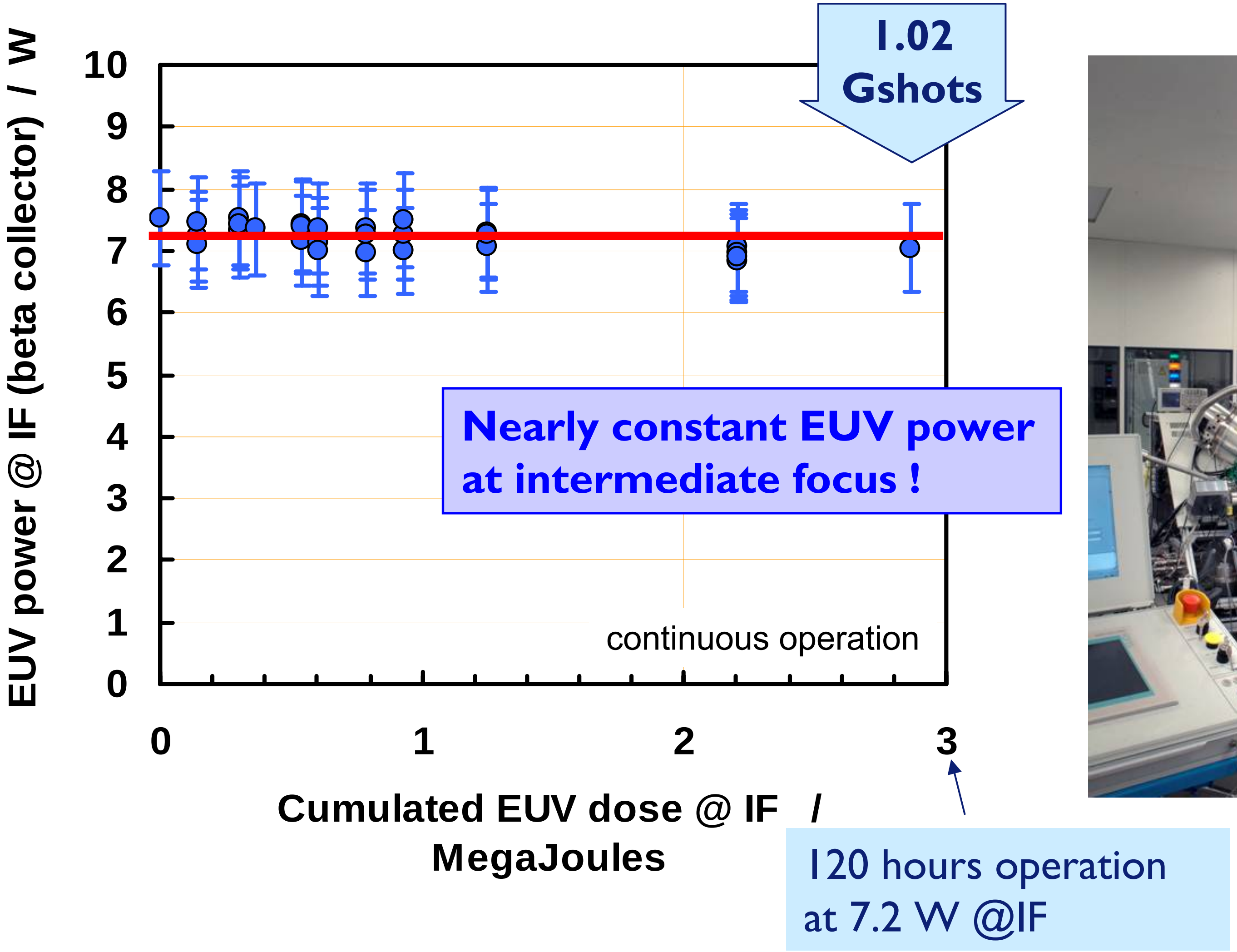
- 2004 V.0 DM experiment for proof of concept
- 2005 V.1 DM for ADMIRE tool
  - many basic experiments for debris mitigation
- 2006 V.2 DM system for Sn-Socomo
  - two-shell collector
  - intermediate focus diagnostics
- 2007 V.3 DM system for full ADT collection angle
  - advanced system for high power (>170 W source)
  - long life and high-tech water-cooling solution
  - compatible with ADT collector and vessel



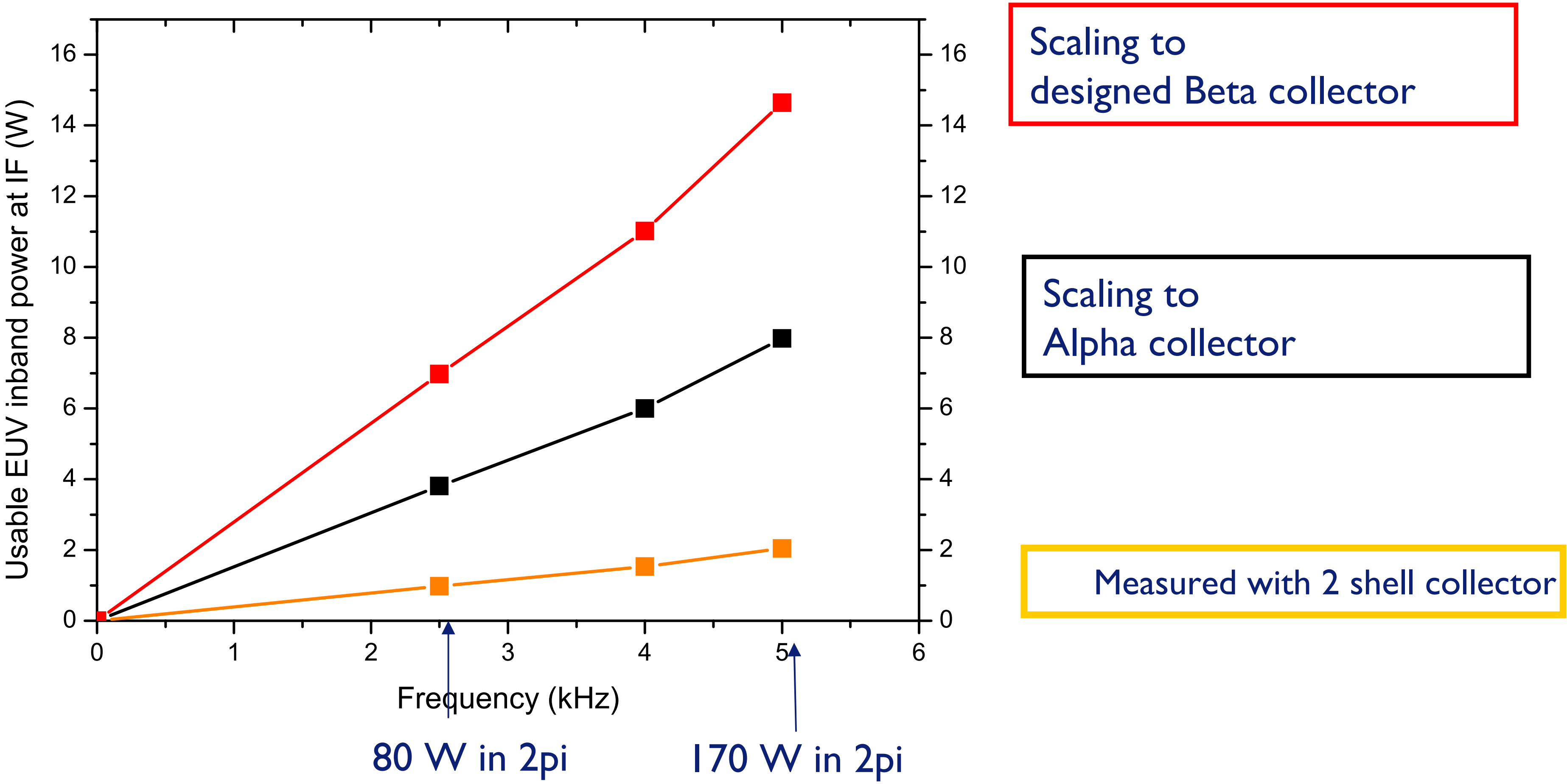
Philips Sn-SoCoMo Demonstrator



Mitigation Efficiency: **3 MJ EUV** @IF Collector Lifetime

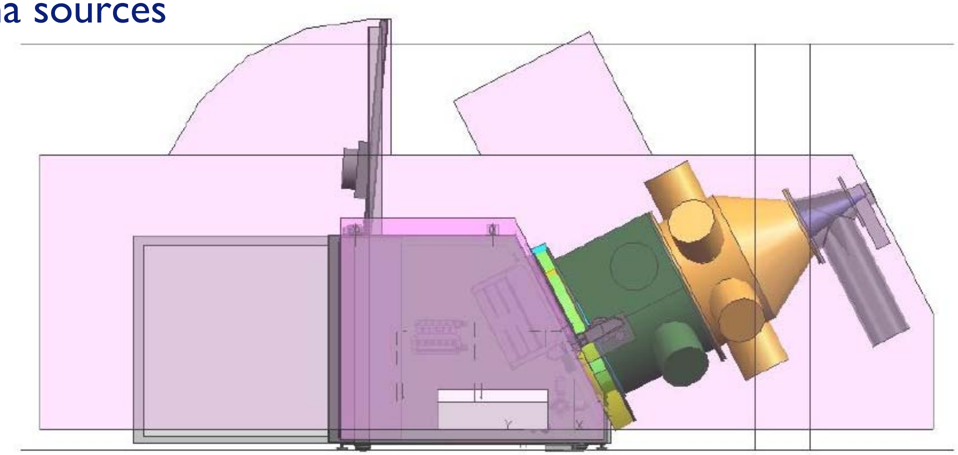


Usable IF power demonstrated in Philips SoCoMo (continuous mode measurements 100 % duty cycle)



Beta SoCoMo

- Designed for power ranges @IF from 50 to 200 Watt
- Sn DPP based, same concept as Alpha
- Power scaling mainly achieved via frequency scaling
  - Feasibility proven
- Engineering upgrade to higher power within current concept
  - Thermal management
  - Improved tin handling
  - Power supply
- MTBF is key focus area
  - Building on continued experience with Alpha sources
- Timeline
  - End 2007: First light from Beta Source
  - Mid 2008: start SoCoMo integration
  - Mid 2009 delivery



The way to HVM requires

- Constructive discussions with scanner manufacturers on specs, CoO (and scanner architecture)
- Continuous learning from Alpha and Beta tools to increase MTBF

- … and Socomo power scaling
  - collector
  - debris mitigation
  - source:
    - Laser
    - Power supply
    - Electrode system → improved cooling
    - High frequency plasma operation → scaling experiment

Cooling: fundamentally solved by using liquid Sn

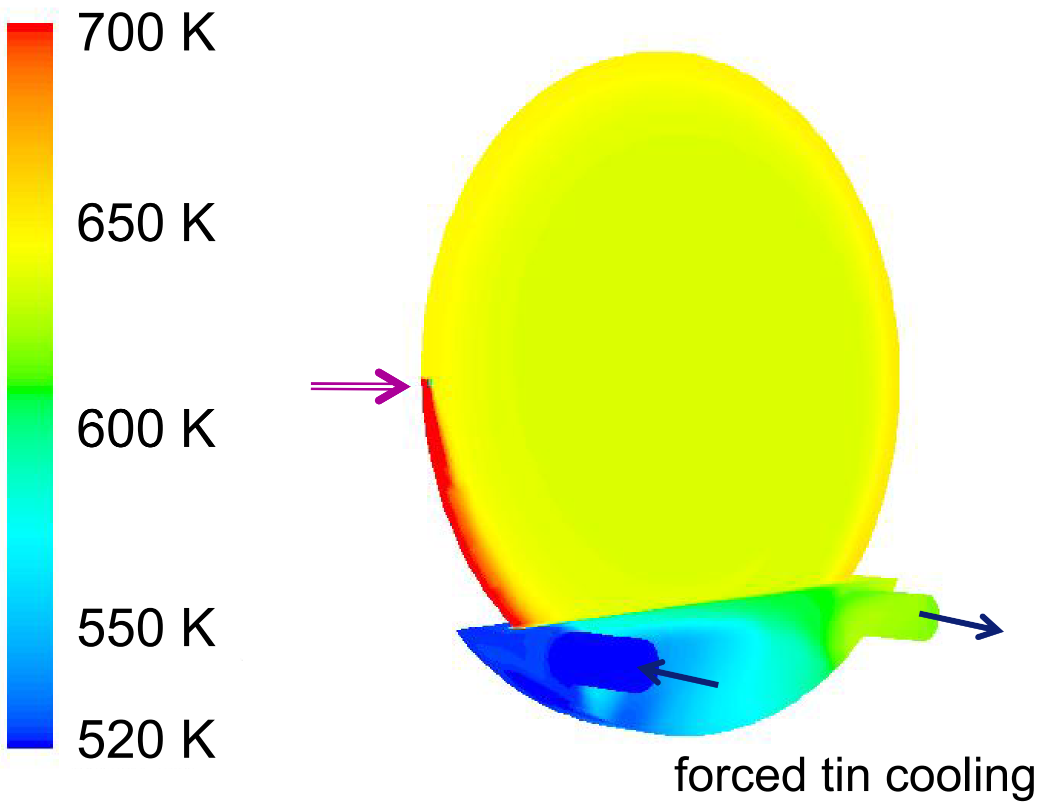
Wheel speed increases with repetition rate

→ dissipated energy per unit of circumference is constant

High rotation speeds improve the heat contact between wheel and tin

120 kW input power

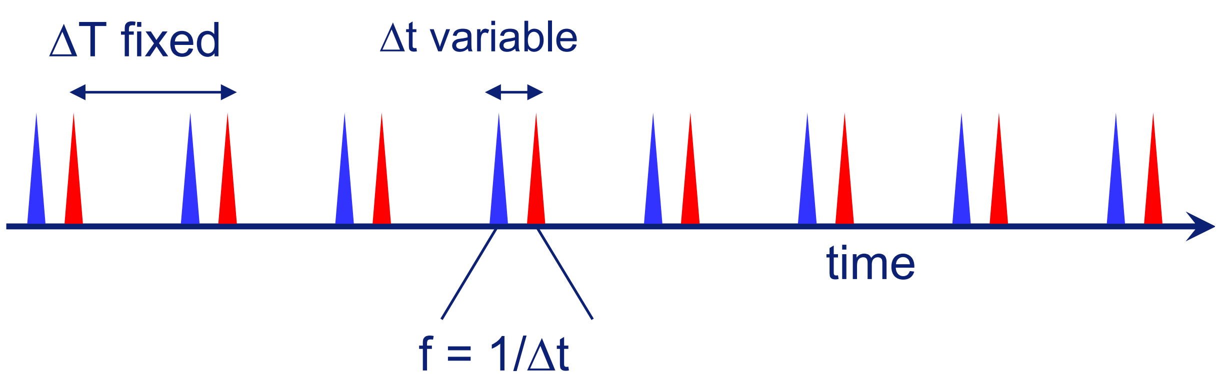
Resulting average wheel temperature about 640 K

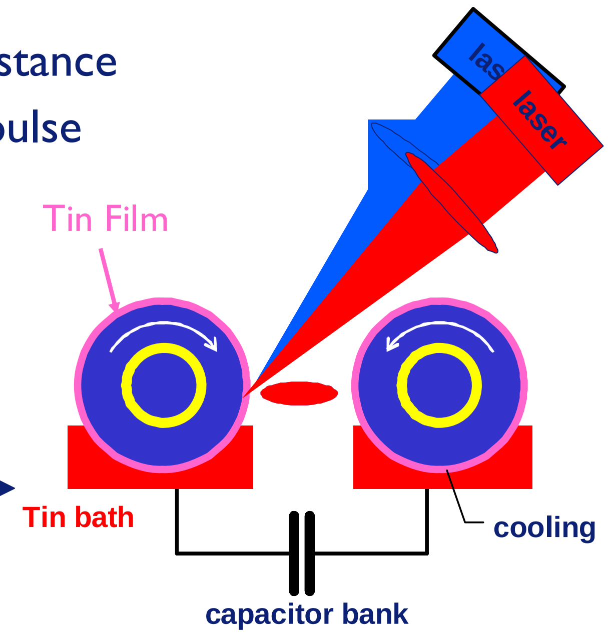


Power Scaling Experiment

- Aim: Explore limits of repetition frequency for Sn DPP
  - Limits of electrode system recovery time
  - Influence repetition frequency on source size and efficiency

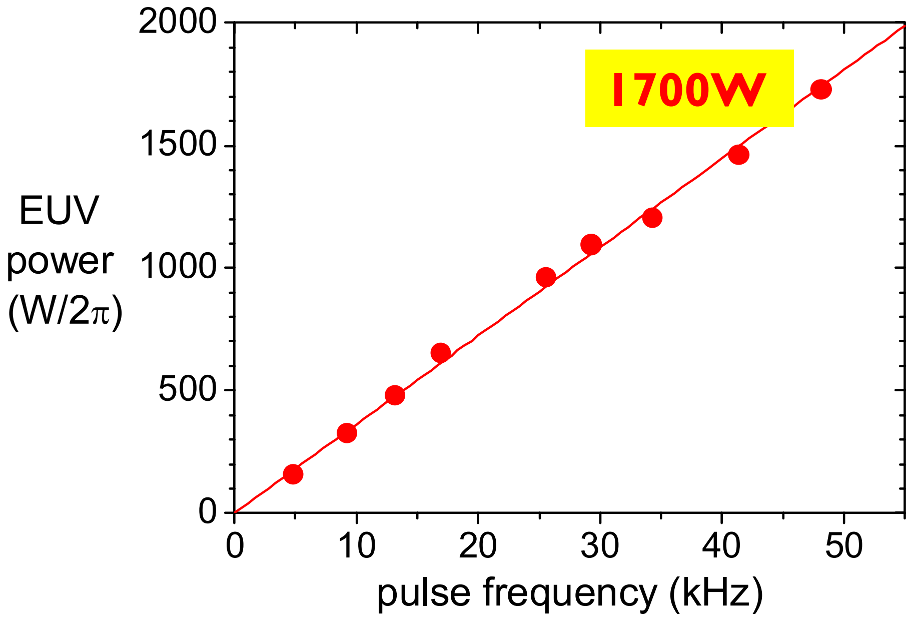
- Method:
  - Operate EUV-source with two pulse trains of variable distance
  - Thereby measure effect of short recovery time to next pulse
  - Mimicking high repetition rate laser *

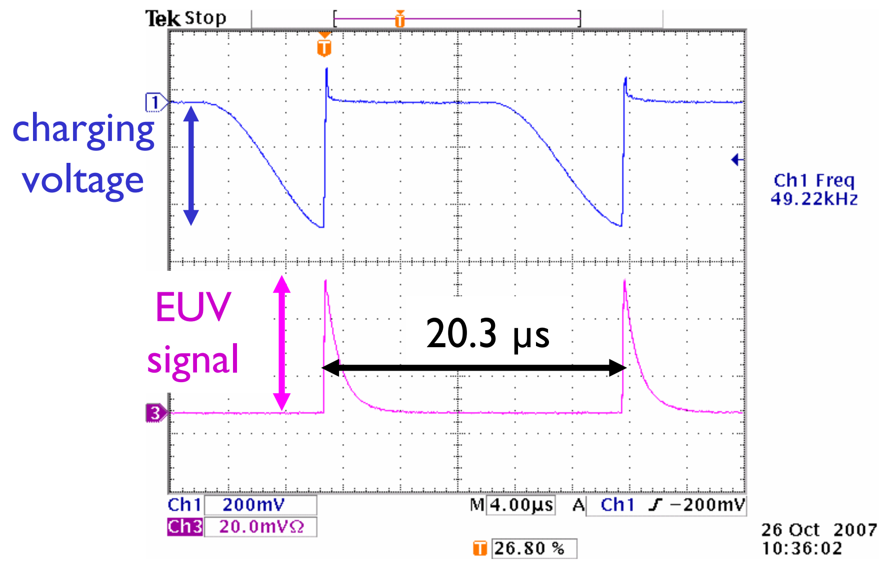


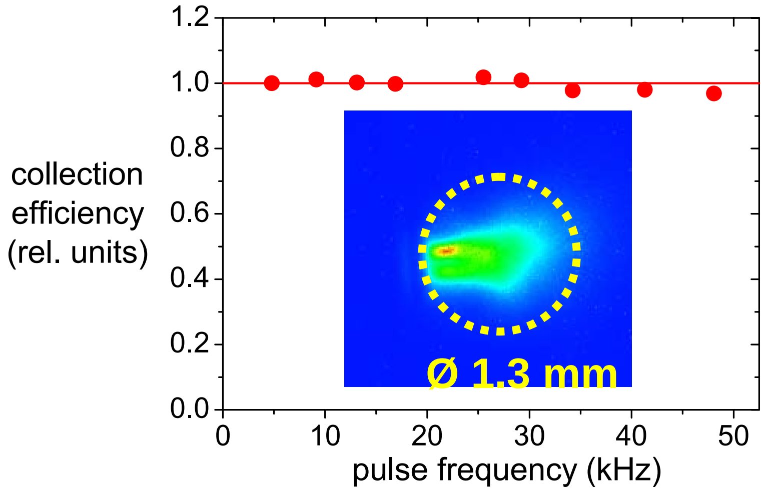


* Not a technical roadblock, but only to be made when needed

Power Scaling Results

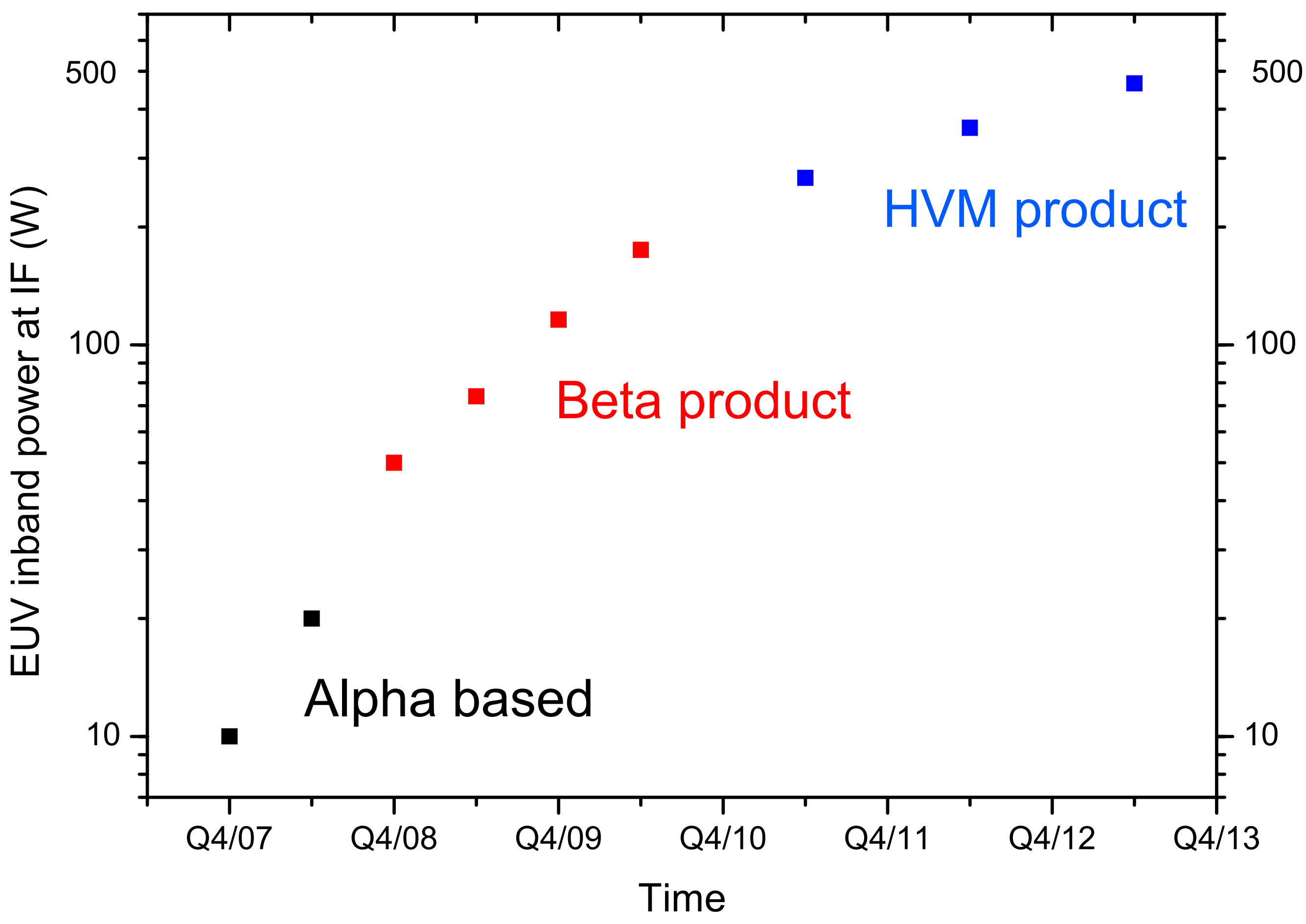






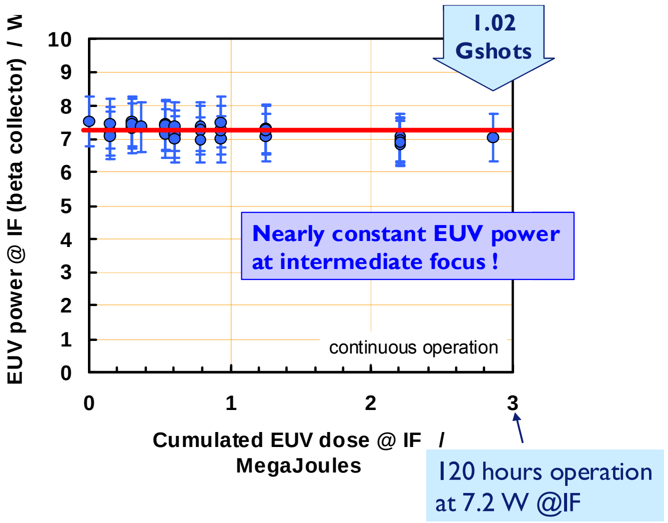
- Physics allows scaling above 50 kHz
- Record power of 1700 W/2π shown enabling 200W in IF
- Further scaling by frequency scaling and pulse energy

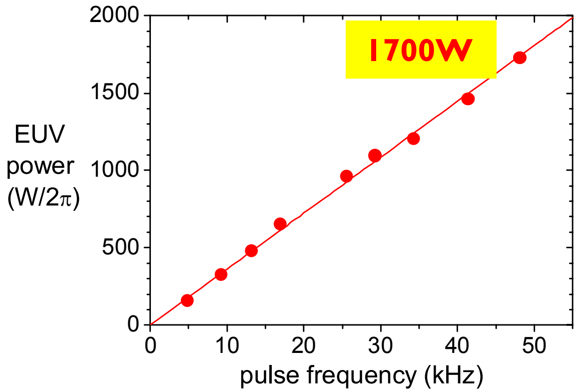
IF power roadmap for SoCoMo integration



Conclusions

- A simple and scalable concept
- Alpha source performance
  - Scaled to >170W in 2π
  - MTBF approx. 10MJ and improving
- Alpha SoCoMo
  - Source power > 170W in 2π
  - Philips DMT developed for full collector, working at this power level
- Beta SoCoMo
  - Scalability of IF power to range of 50-200W
  - Mainly engineering
    - MTBF key focus area: continuous learning required
  - First Source test end 2007. Delivery mid 2009
- HVM: further scaling of frequency and energy/pulse





Announcement

Philips Extreme UV and Xtreme Technologies,

supported by their stakeholders,

Philips Lighting, Ushio, and Jenoptik,

will join forces
and are committed

to deliver the first industrial Beta SoCoMo mid 2009

to enable the start up of EUV production

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sense and simplicity