LPP EUV Source Performance and Prospects for NGL in Mass Production of sub-20nm Devices

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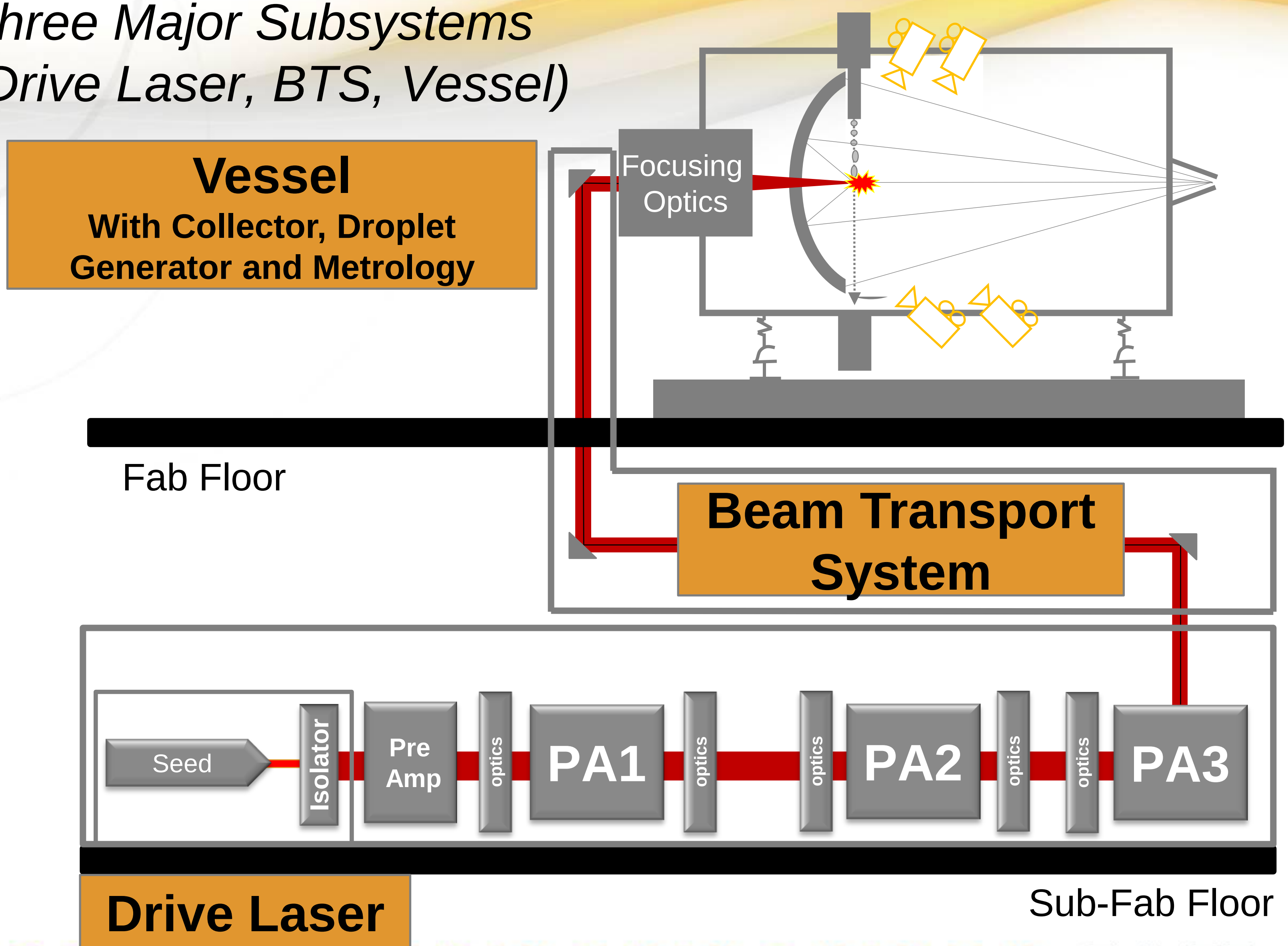
Introduction

Progress Summary

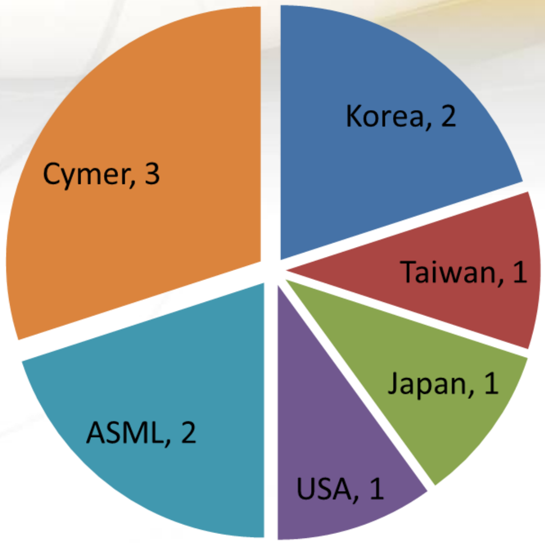
- Total of 10 HVM I sources are installed and operational
  - 5 sources installed and exposing wafers at development fabs
  - 3 HVM I sources in San Diego for upgrade development , reliability enhancements, and for technology transfer to HVM II
  - 2 HVM I sources installed and operational at ASML
  - Collector lifetime of 45 billion (~4 months) reached in the field
  - SEMI E10 availability of sources in field approximately 60%
  - Field teams in place to support 24x7 operation globally
- HVM I power upgrade development in San Diego
  - Demonstrated 50W expose power at 40% duty cycle on HVM I source using pre-pulse, with full closed loop operation
    - 90% of dies <1% dose stability
- HVM II source program
  - First delivery to ASML completed
  - 4 sources in integration in San Diego
  - HVM II Drive Laser production ramping, 2 delivered, several more in build, with scheduled deliveries planned

Laser Produced Plasma Source Architecture

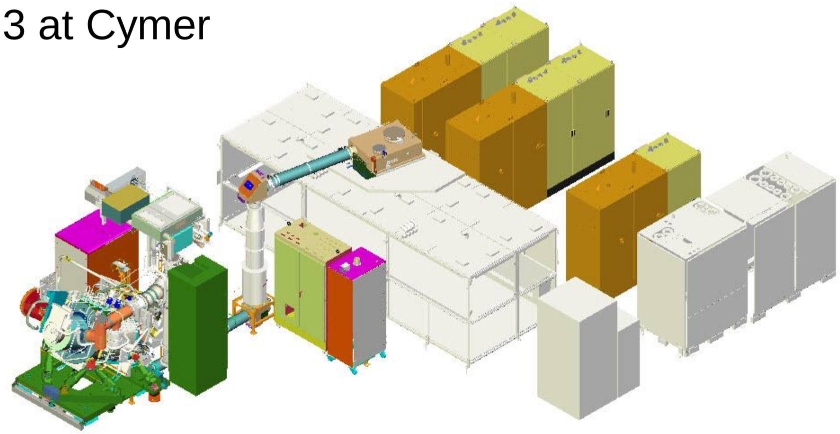
Three Major Subsystems
(Drive Laser, BTS, Vessel)

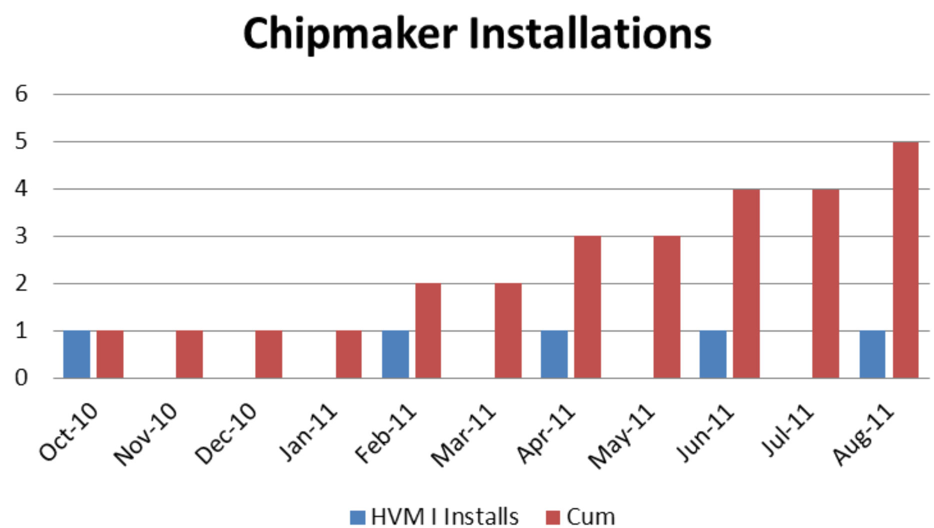


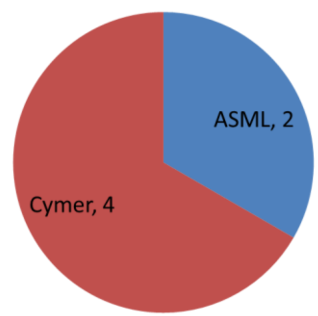
Cymer Worldwide LPP Source Installed Base



- **10 HVM I Sources installed and operational**
  - 5 at Chipmaker Fabs
  - 2 at ASML
  - 3 at Cymer



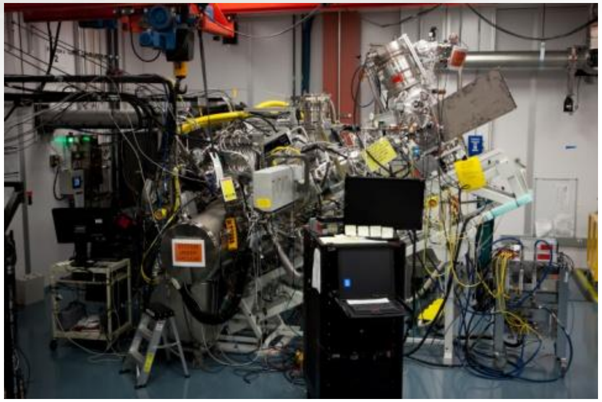




- **First 6 HVM II Sources in progress**

HVM I Sources for Prepulse Development

Internal Test Sources to Accelerate Power Roadmap



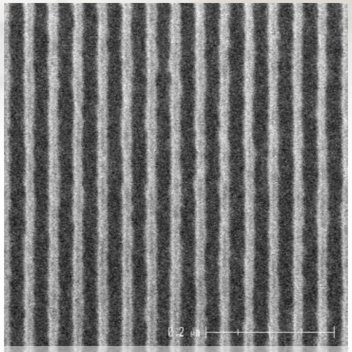
- Pilot 7, Dedicated R&D test source for Advanced Prepulse Development

- Pilot 8, Marathon runs using a scanner simulator to drive sequencing as if it were exposing wafers
- Collector life-testing
- Reliability testing
- Upgrade to Prepulse in Q4

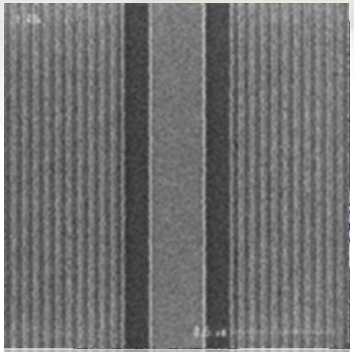
- Pilot 9, Dedicated Engineering test source for Prepulse deployment to the field and technology transfer to HVM II

Imaging Performance with LPP Sources on NXE:3100

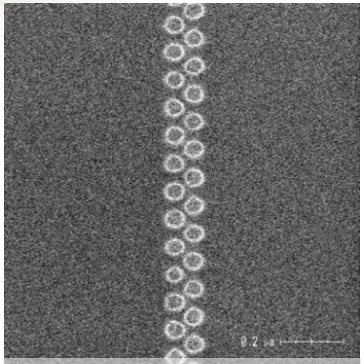
Enabling EUV Lithography



19 nm dense lines

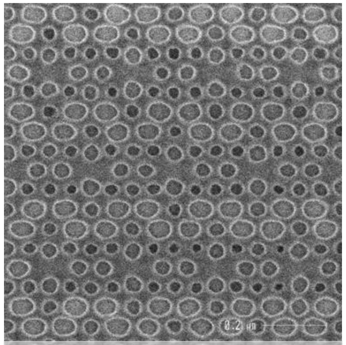


27 nm Gate Layer Flash



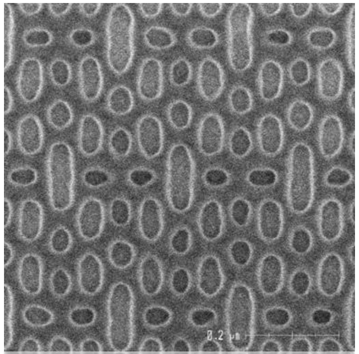
Flash staggered contact layer

Bitline pitch = 44 nm (1:1.2)
CH pitch = 74.4 nm



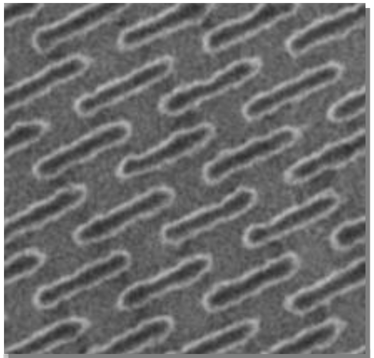
Sub 16 nm node SRAM Contact Hole

0.038µm2 bit cell-size, hp 30/32 nm



Sub 16 nm node SRAM metal-1

0.038µm2 bit cell-size, hp 30/32 nm

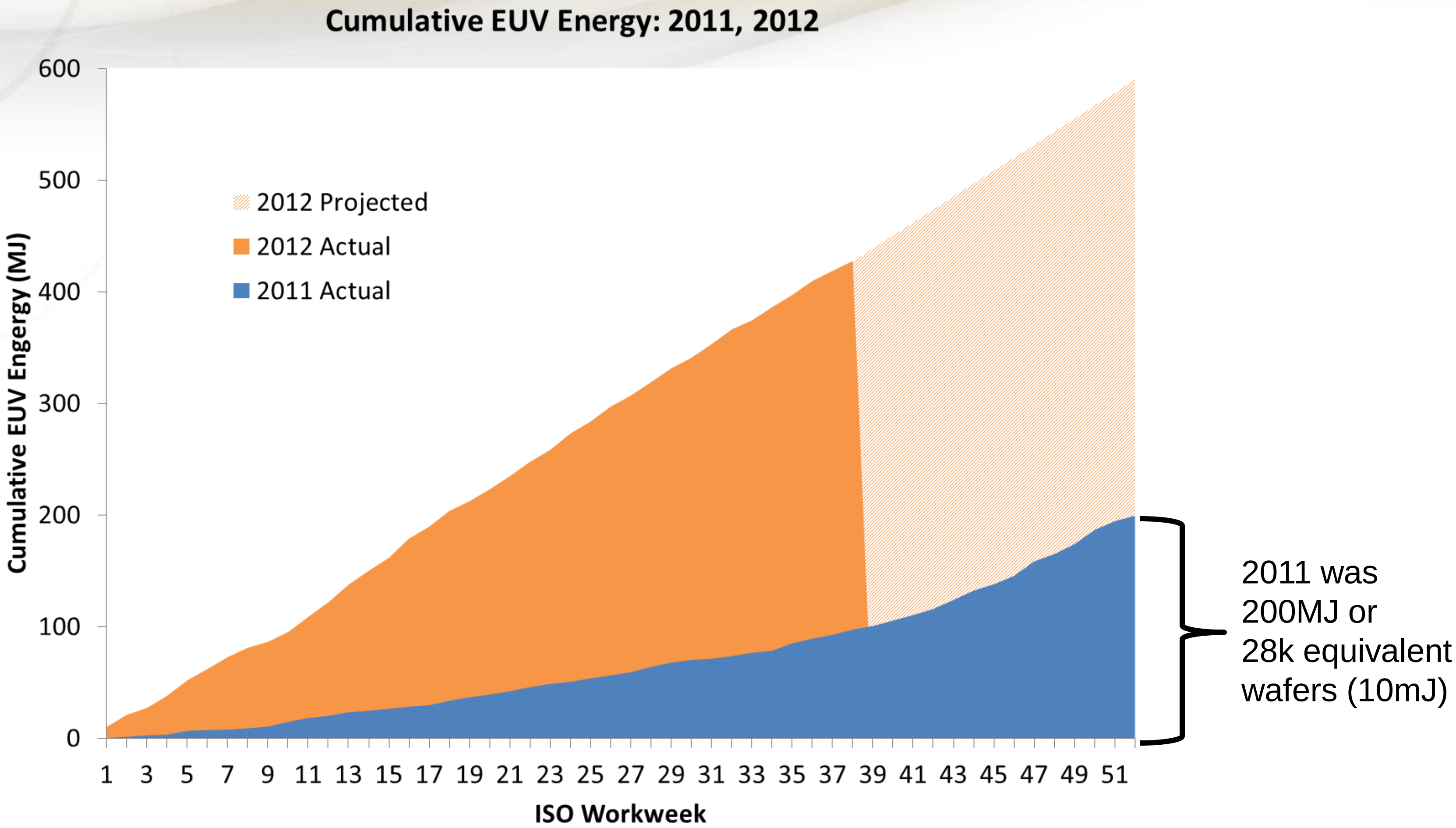


30 nm Brickwall DRAM

Courtesy of ASML

Total EUV Energy Produced: 2011, 2012

Cycles of Learning are Increasing Significantly



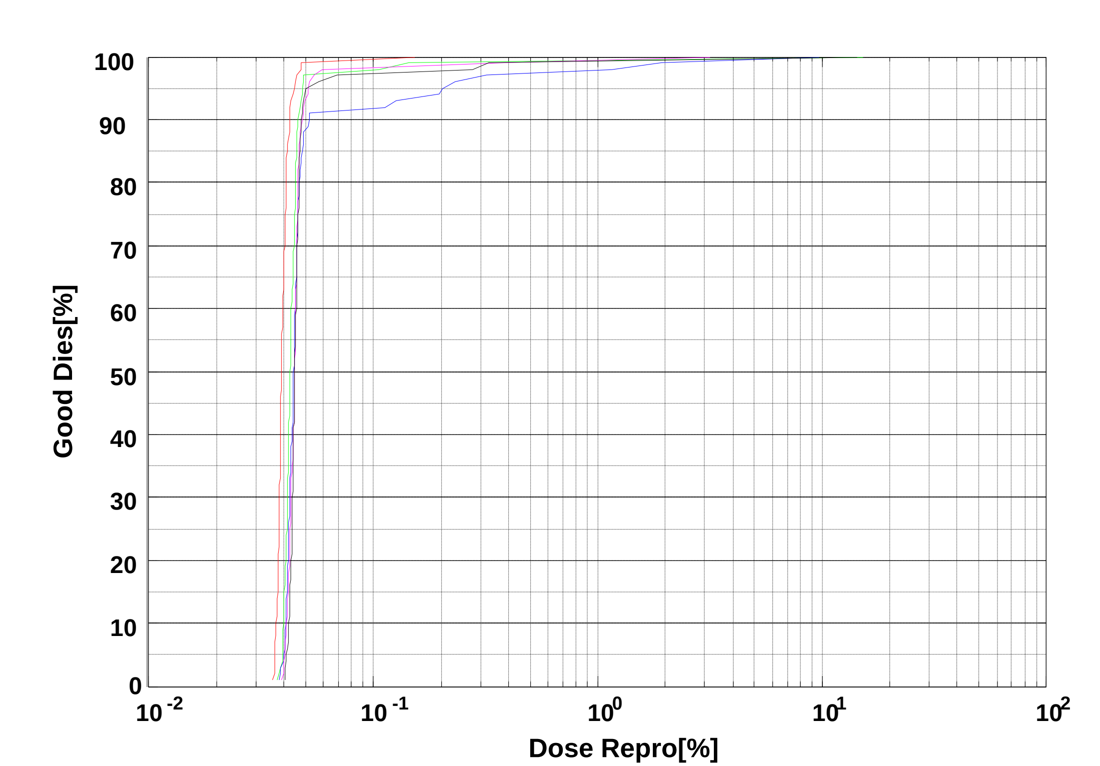
2012 YTD: ~430 MJ or 60,000 equivalent wafers (10mJ resist)

HVM I

Current HVM I Performance in the Field

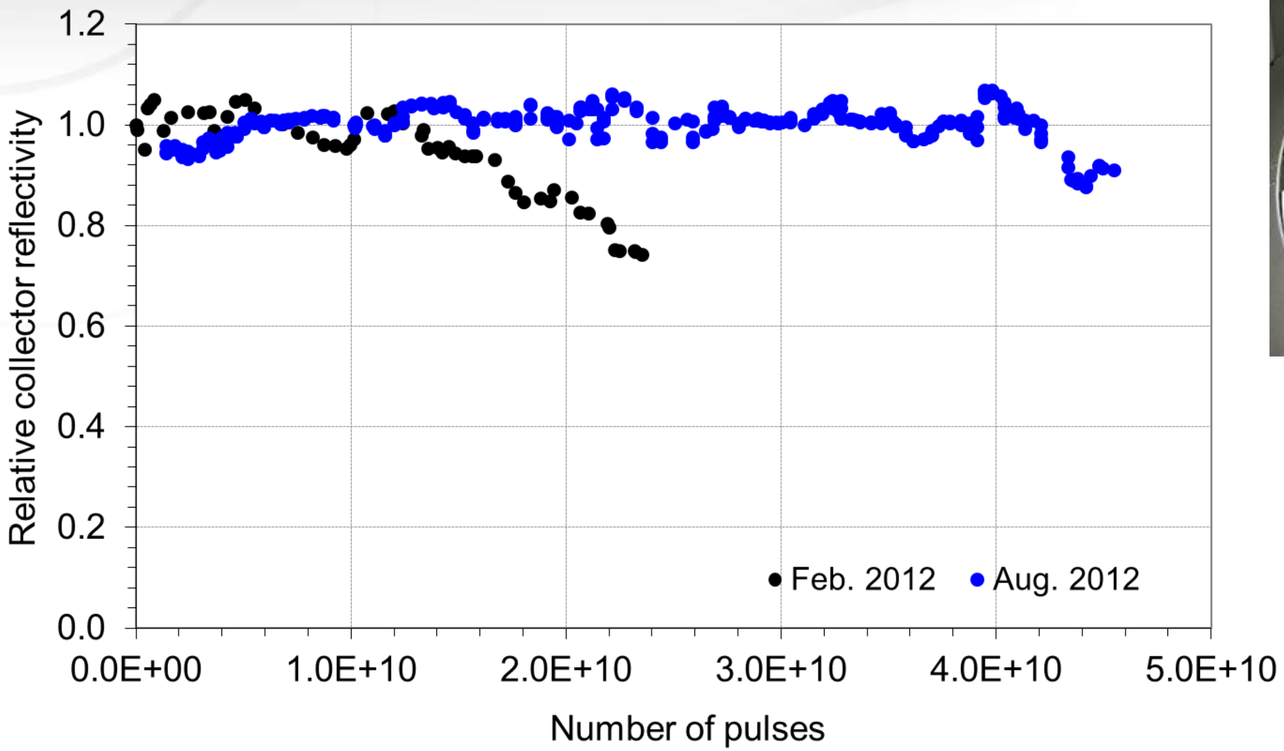
- **~9-13** W average exposure power is operational in the field
  - Capability for >100 wafers per day throughput
  - Better than ±0.5% dose stability on >99.7% of fields
- **60**% Source Availability (SEMI E10 Definition)
  - Down from 70% in previous quarters of 2012

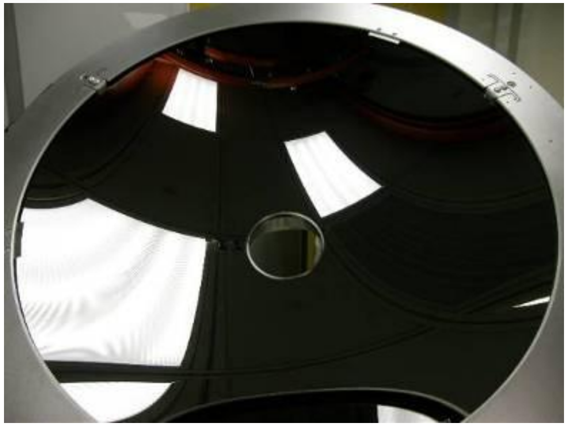
Typical Dose Stability in Field



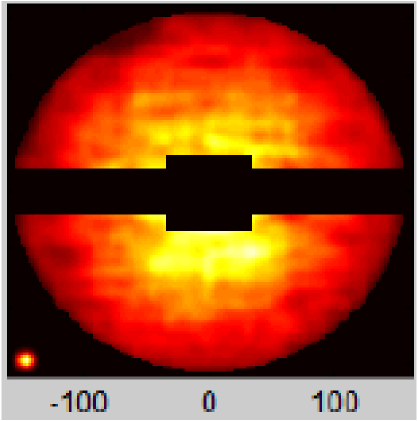
- Controls: Closed loop operation for dose and plasma position control in three dimensions (e, x, y, z)
- Machine software: reduction of overhead time provided increased productivity

Improved Collector Lifetime in the Field: 45 x 10^9 Pulses over 4 months of Operation





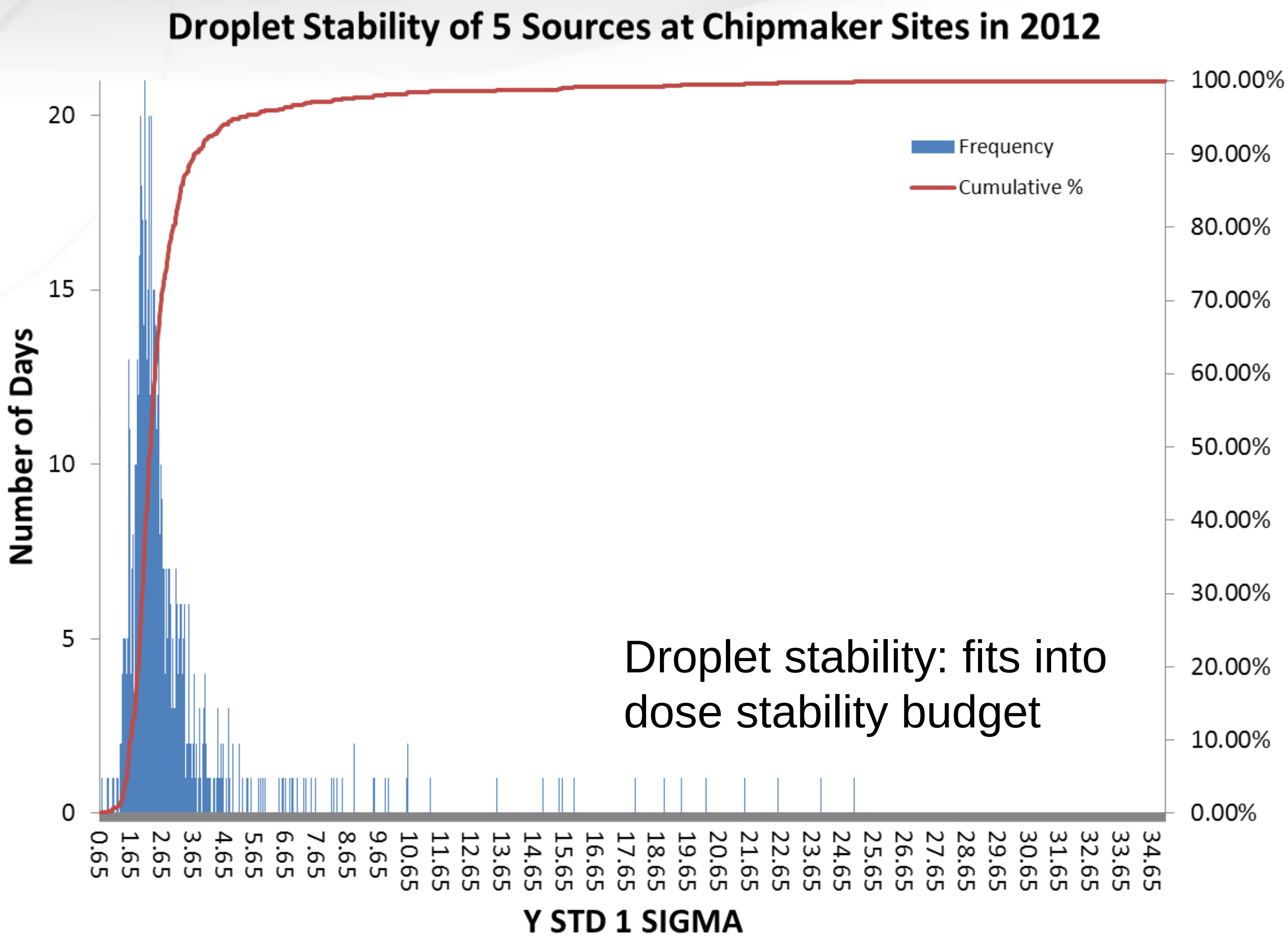
Far field image after 45 x 10^9 pulses still looks good



EUV Image at
45 Billion Pulses

Droplet Position Stability of Five Sources Installed at Chipmaker Sites in 2012

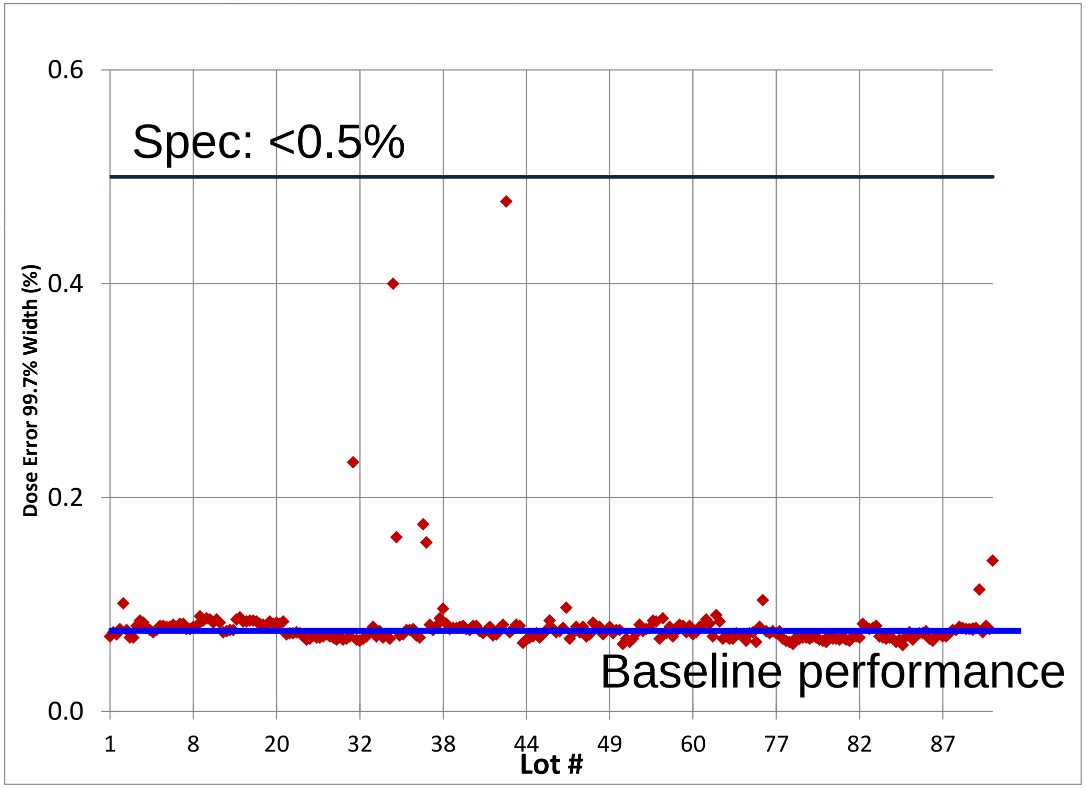
Typical performance 80% <3.0µm



2012 year to date

HVM I Dose Stability: Current Field Configuration

- **Simulated exposure of ~500 wafers at ~13W**
  - All meet wafer average dose error target
    - Only 1% of all wafers have individual fields above target



Each data point is one wafer

- Baseline dose stability performance is much better than specification
- Excursions can be eliminated by improving intrinsic stability or by applying controls

Prepulse

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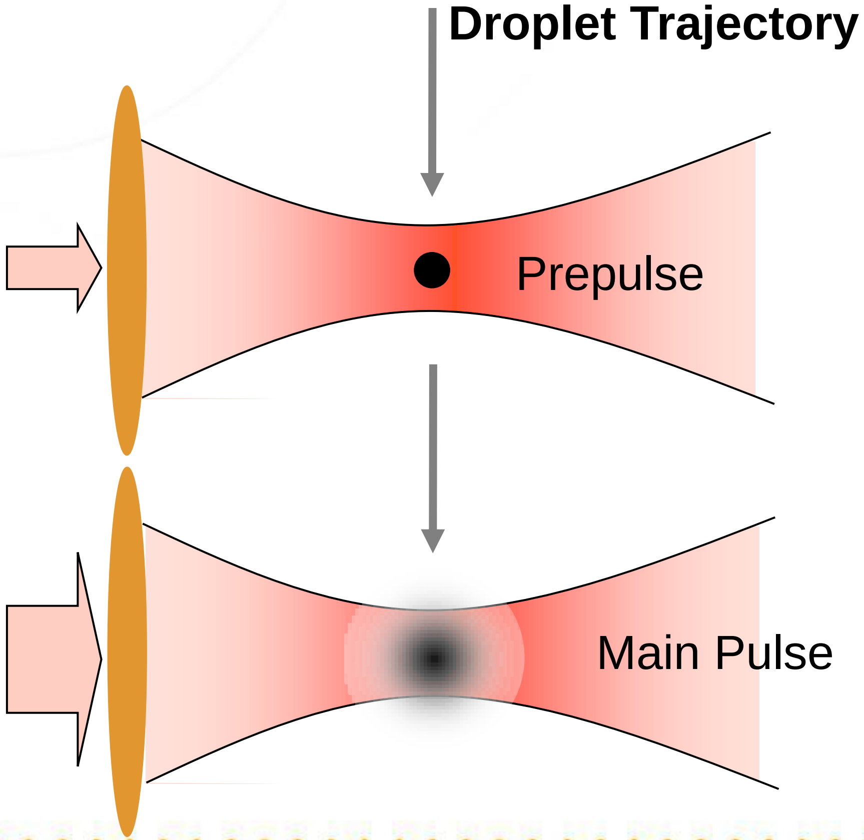
Prepulse (Target Conditioning)

Conversion Efficiency Technology Improvement

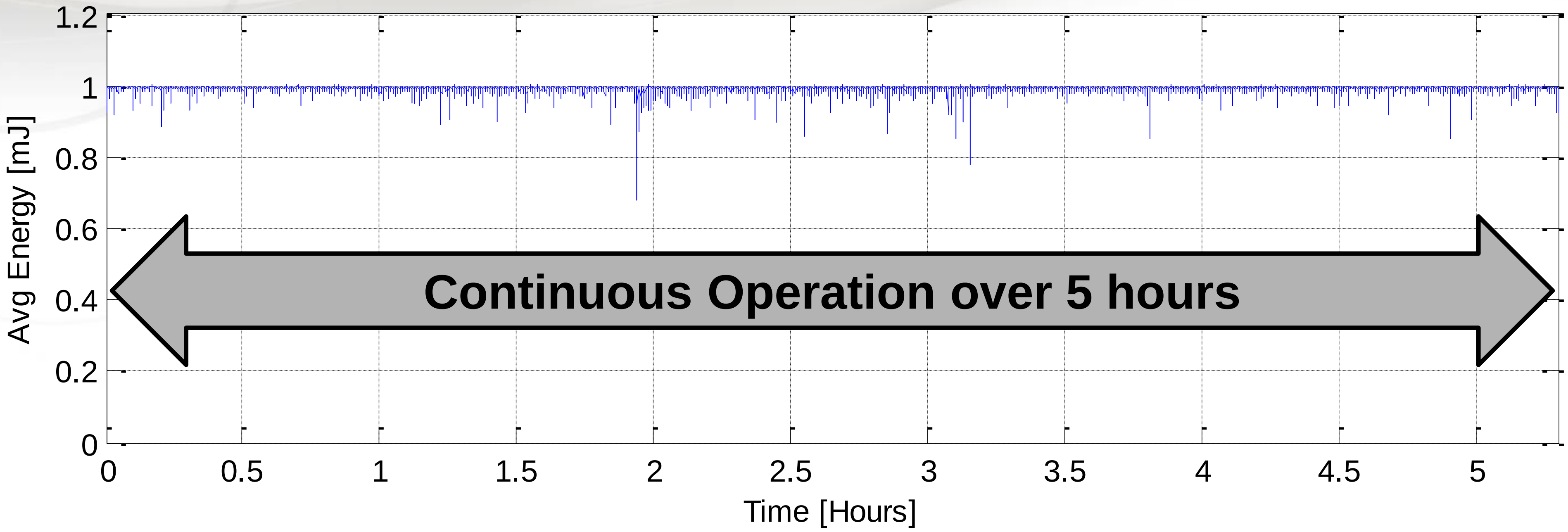
Scaling of EUV power requires increase in Conversion Efficiency (CE) – Prepulse has demonstrated this capability



Pre-pulse

- Pre-conditioning the droplet target by a pre-pulse is a demonstrated approach for CE scaling
  - Provides better matching of target size with focal region dimensions
- Preparing for deployment as an upgrade for HVM I and as the base configuration on HVM II

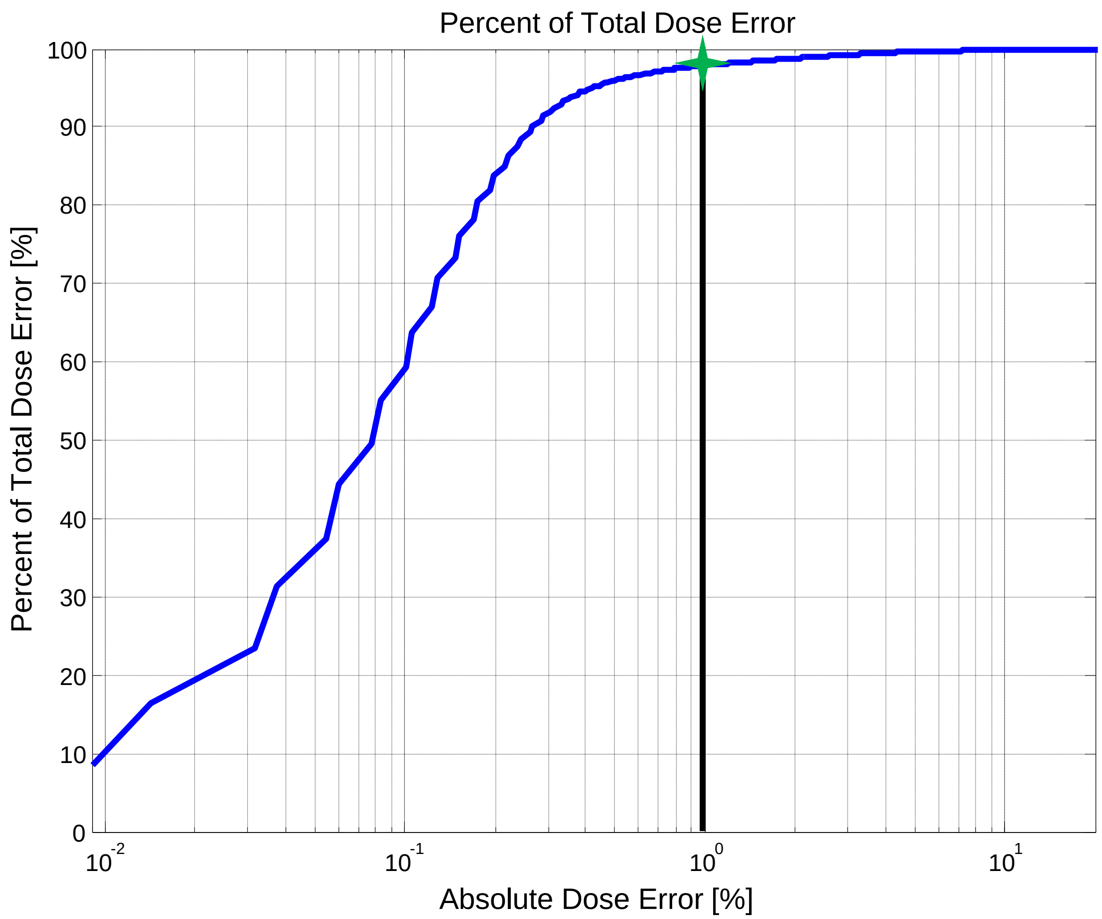
PrePulse Demonstrated with Closed Loop Control over 5 hours of Continuous Operation



- 50W in-burst dose-controlled power at 40% duty cycle
- Energy, timing, and plasma position in three dimensions under closed loop control (e, **t**, x, y, z)

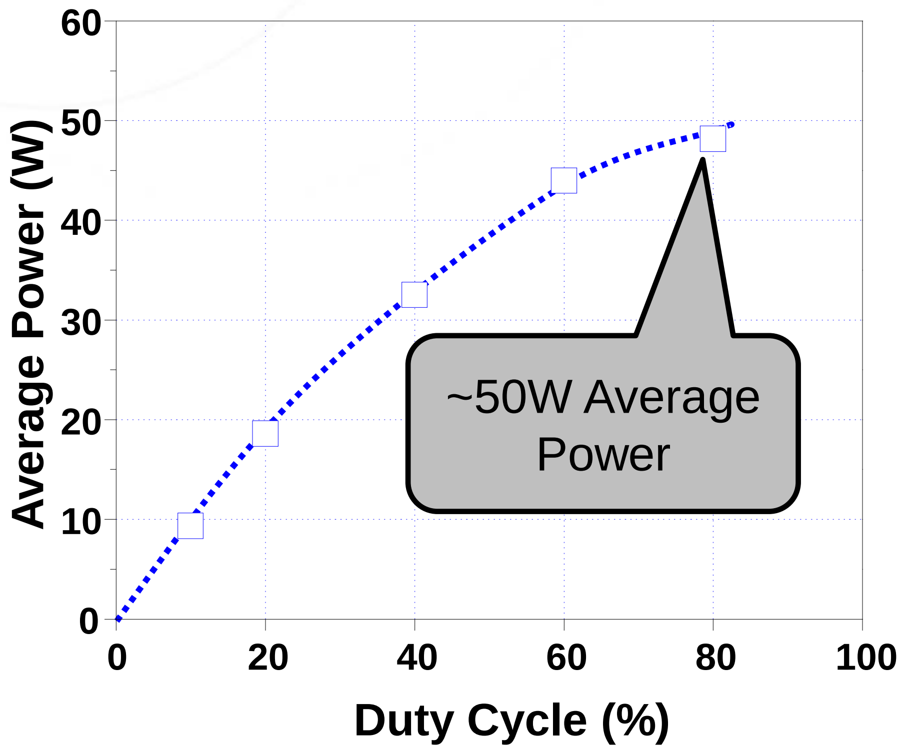
Dose Stability with Prepulse Demonstrated to Better than 90% of Dies <1% 3σ

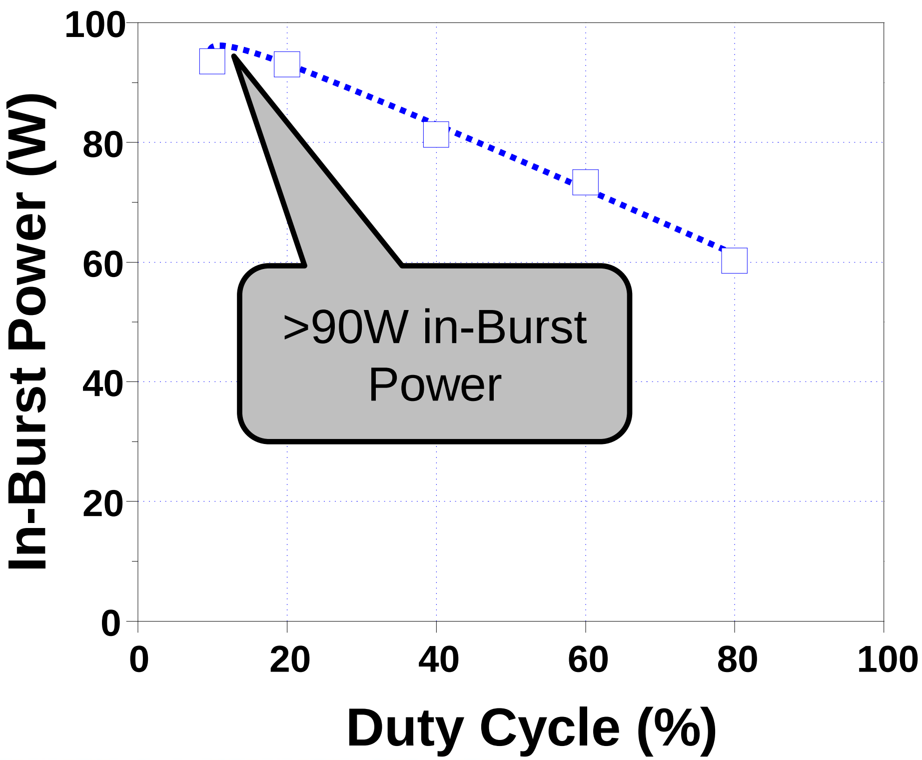
- Dose stability is currently limited by dynamics of Prepulse targeting and motion control; improvements in both are planned



LPP with Prepulse: Capability up to ~50W Average Power at High Duty Cycle Demonstrated

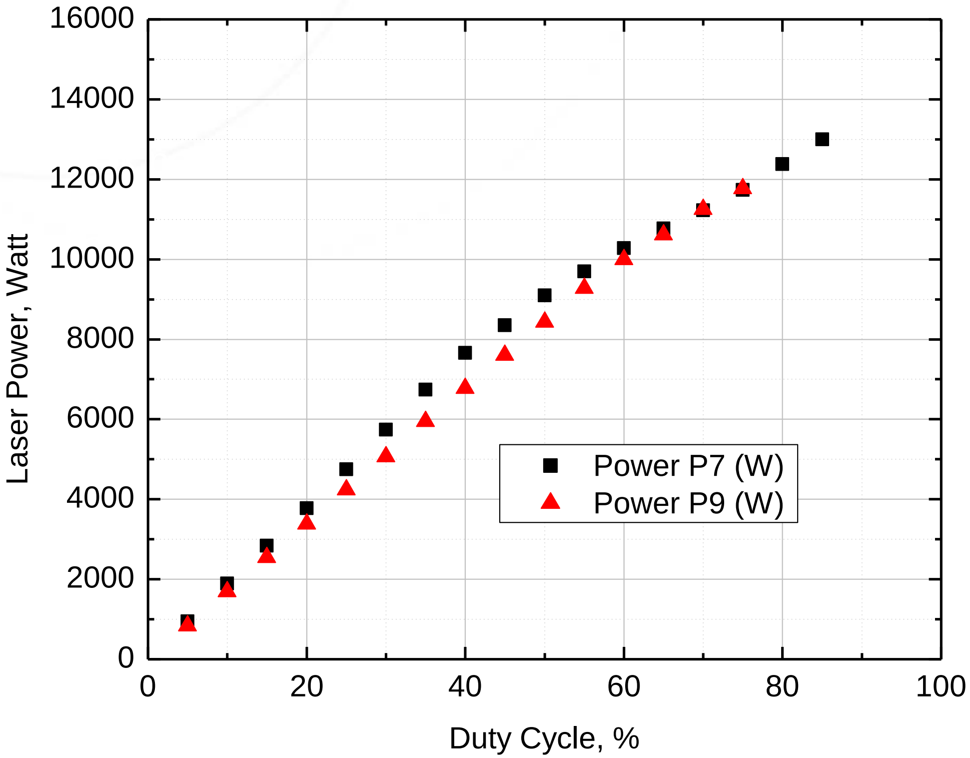
- Prepulse technology demonstrated up to 90W in the burst at low duty cycle
- Power roll off remains a challenge

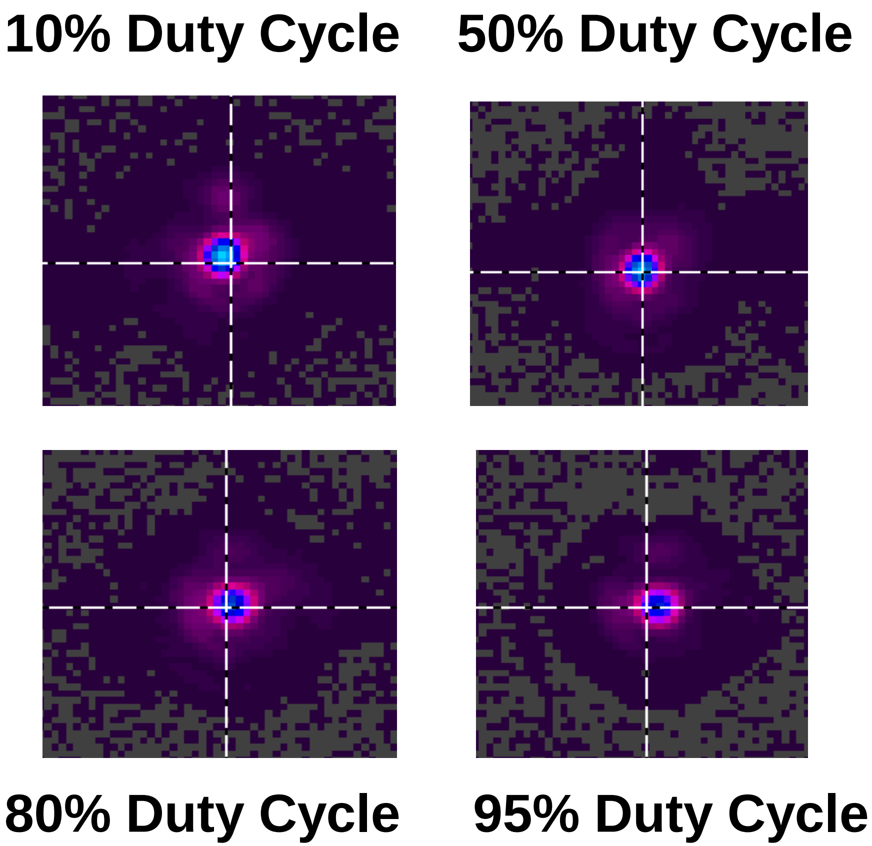




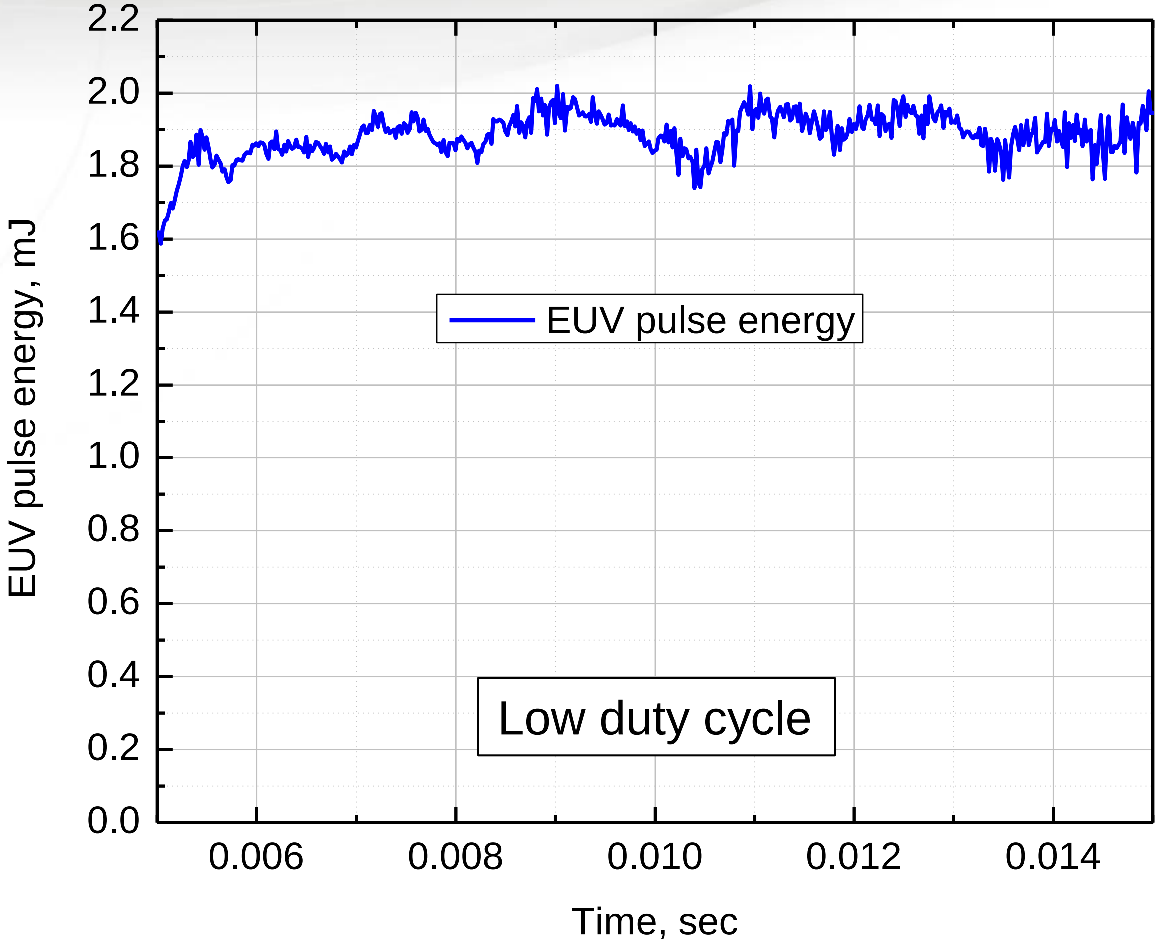
CO_2 Laser Power at High Duty Cycle Maintains Good Beam Quality

- Far-field beam quality remains relatively undistorted





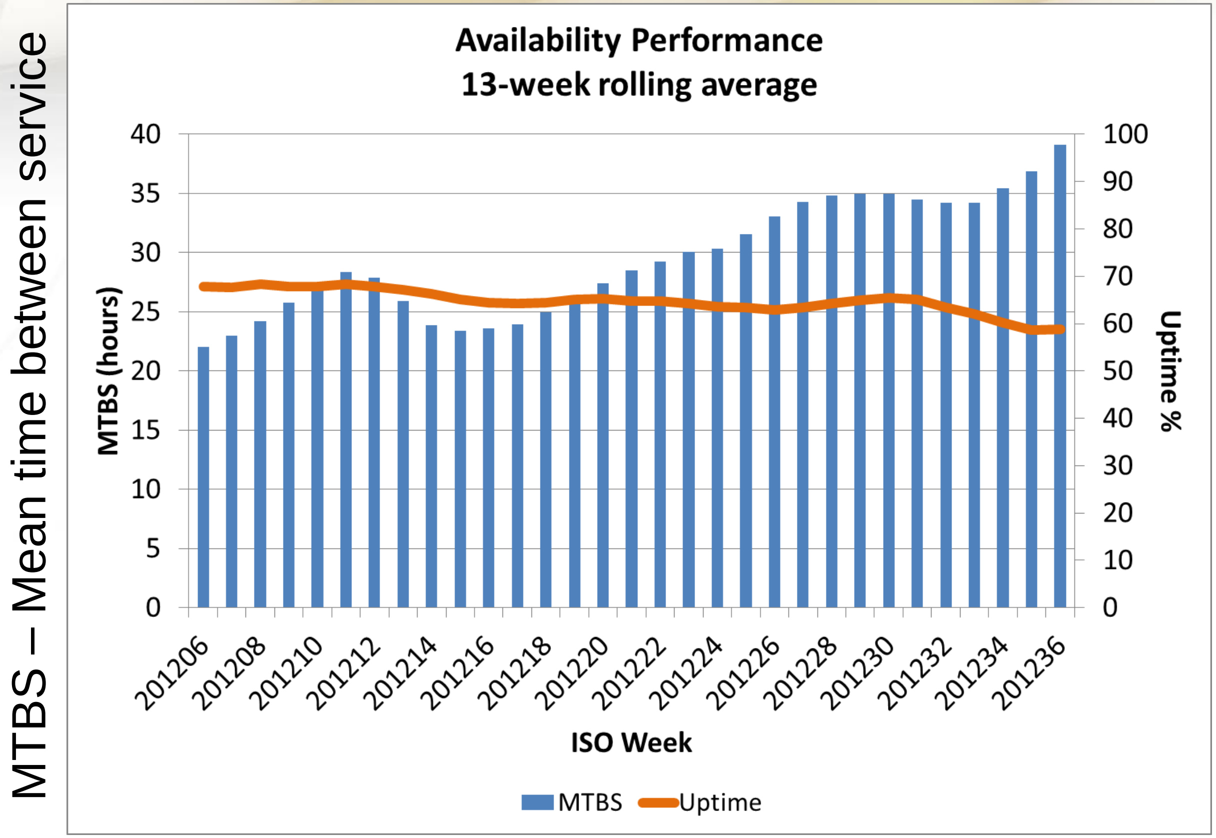
90W EUV Pulse Energy with Prepulse at 50 kHz Demonstrated on Internal Pilot Source



Prepulse development on internal pilot sources in San Diego making good progress

Availability

Availability of HVM I Sources in Field (SEMI E10)



- Scheduled downtime primarily on three modules; Collector, Droplet Generator and Focusing System
- Uptime maintained above 60%, down from 70%; Recent dip in uptime due to two long down events

Scheduled Downtime Budget for HVM I:
Improvements Planned for both HVM I & HVM II

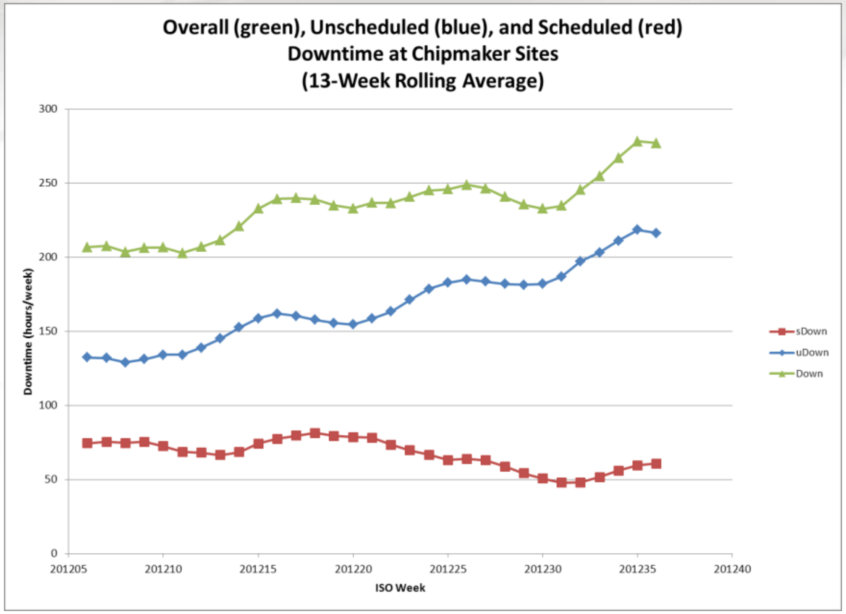
- Scheduled downtime increased with addition of Final Focus maintenance after upgrade to 60% duty cycle (10.6%)
- Improvements to all three modules prepared for HVM II
- Upgrades for HVM II will address both droplet generator and focusing system downtime

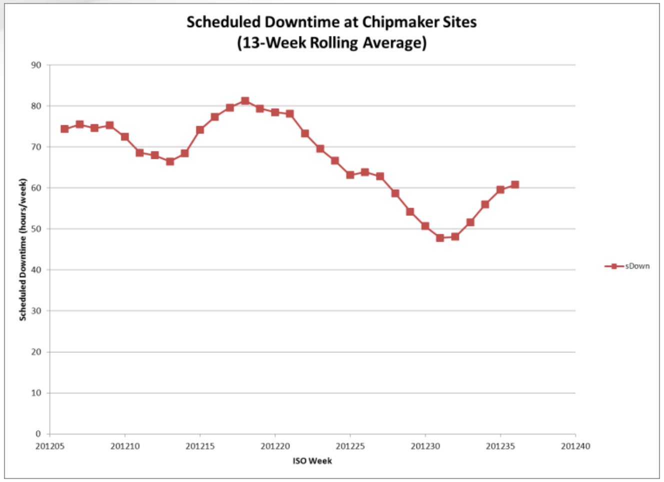
Scheduled Downtime

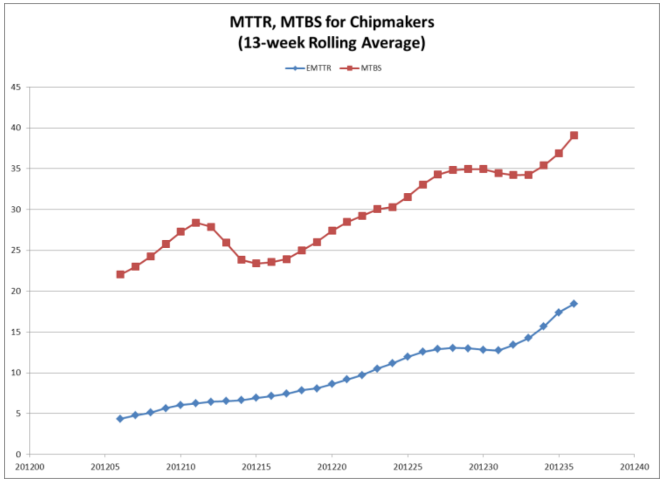
HVM I	MTBE (days)	MTTS (hours)	Downtime
Collector	60	115	7.5%
Droplet Generator	8.3	13	8.1%
Focus System	20	75	10.6%
Maintenance/Setup			4.2%
Other			6.0%
NET AVAILABILITY: 63.7%			

HVM II	MTBE (days)	MTTS (hours)	Downtime
Collector	67	12	0.7%
Droplet Generator	27	6	4.7%
Focus System	-	-	-%
Maintenance/Setup			4.2%
Other			6.0%
NET AVAILABILITY: 84.4%			

RAM Statistics for HVM I Sources at Chipmakers Sites (5 sites cumulative, 13 wk rolling average)

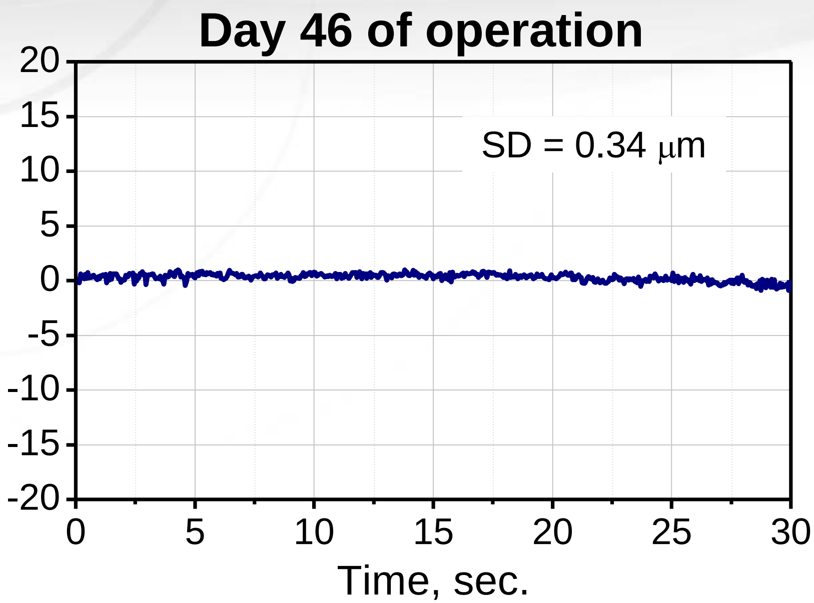


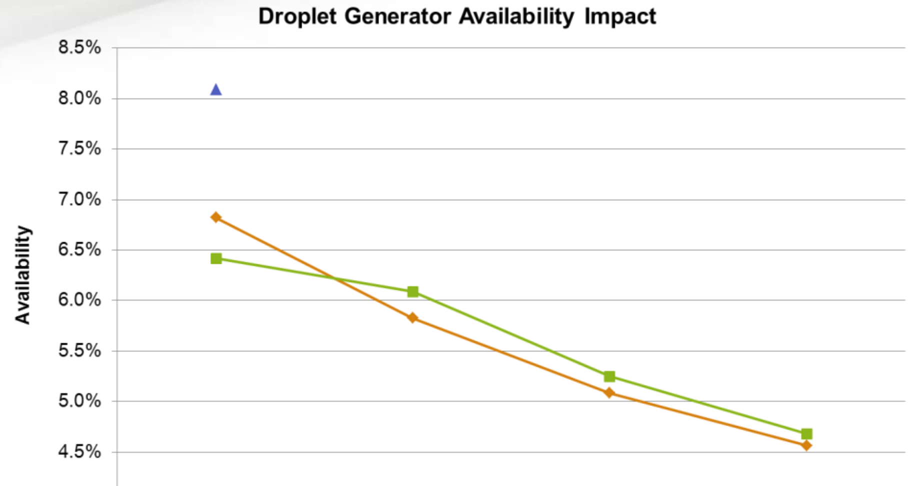




- Cymer Tactical Operations (TacOps) and Reliability Engineering track RAM and performance daily
- Customer data drives priority for continuous improvement projects

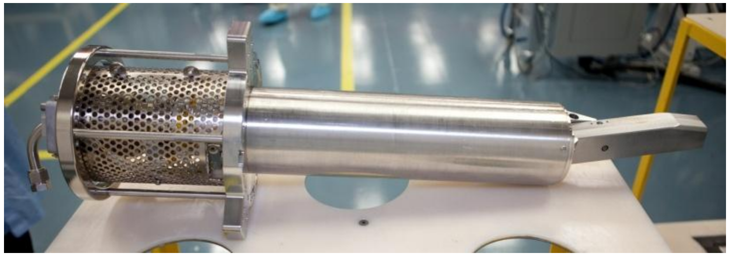
1100 Hrs Droplet Generator Operation with Refills Demonstrated (Reduced Scheduled Downtime)





	0 Refills	1 Refill	3 Refills	5 Refills
3100	6.8%	5.8%	5.1%	4.6%
3300	6.4%	6.1%	5.2%	4.7%
Current	8.1%			

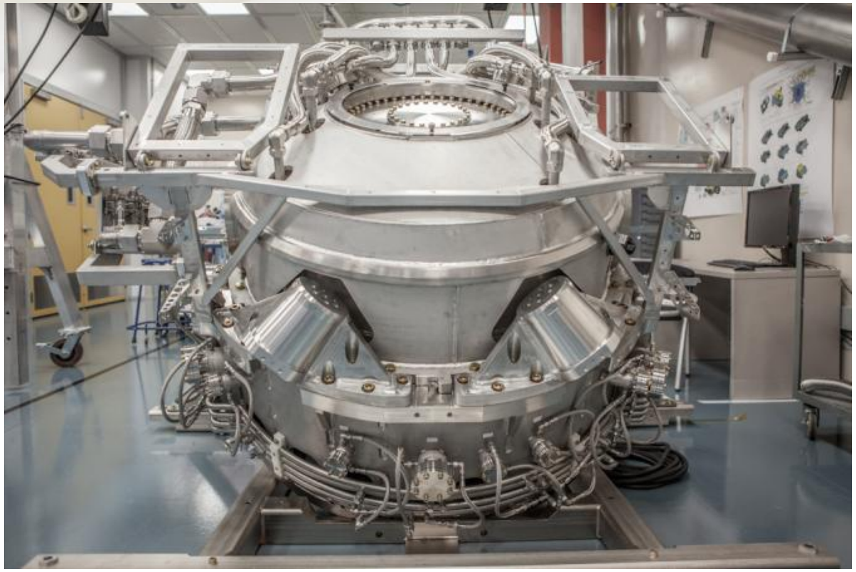
- Extended operational lifetime using refill is being deployed to the field on HVM I sources
- Positive impact to availability increases with the number of refills



HVM II

HVM II Source Integration in Process

- **First HVM II sources are being integrated in San Diego and in Veldhoven**



First HVM II Source Vessel

- The next 4 HVM II vessels are being prepared for test
- First 2 HVM II drive lasers are installed at ASML
- The next 3 HVM II drive lasers are in build at the supplier.

Manufacturing Capacity Expansion for HVM II Sources at Cymer and Suppliers

- Additional manufacturing space for integration and test of sources complete at Cymer and at suppliers

Path to Higher Power

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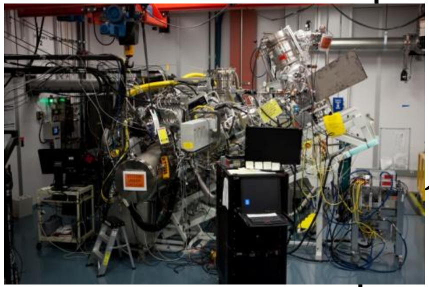
HVM I Source – 2012/2013 Power Upgrade Roadmap

Dedicated test source for prepulse

40-60 W Average Expose Power
- **<±0.5% Dose Stability**
- **Continuous mode with pre-pulse**

20W Average Expose Power
- **<±0.5% Dose Stability**
- **Burst mode, 90% duty cycle**

9-13 W Average Expose Power
- **<±0.5% Dose Stability**
- **Burst mode, 60% duty cycle**



Dedicated test source for 20W power

Now — Q4 — Q2

available for the chipmaker

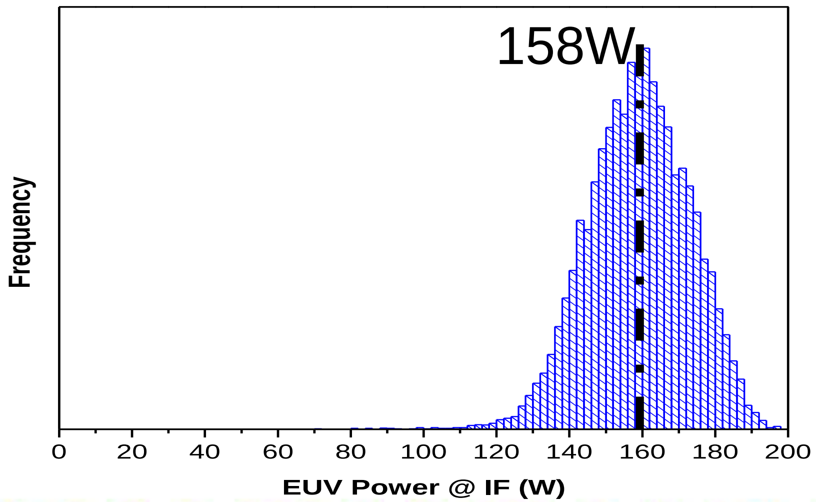
EUV Power Scaling Baseline

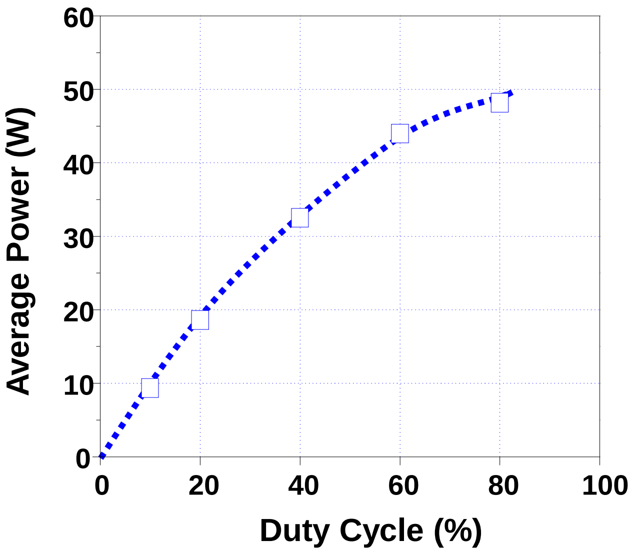
Low-Duty-Cycle Demonstration Status (LT1)

Expose power (calc.)	140W
Raw power (mean)	158W
Raw power	190W
CO_2 power	24kW
Test length	>15min
Duty Cycle	3%

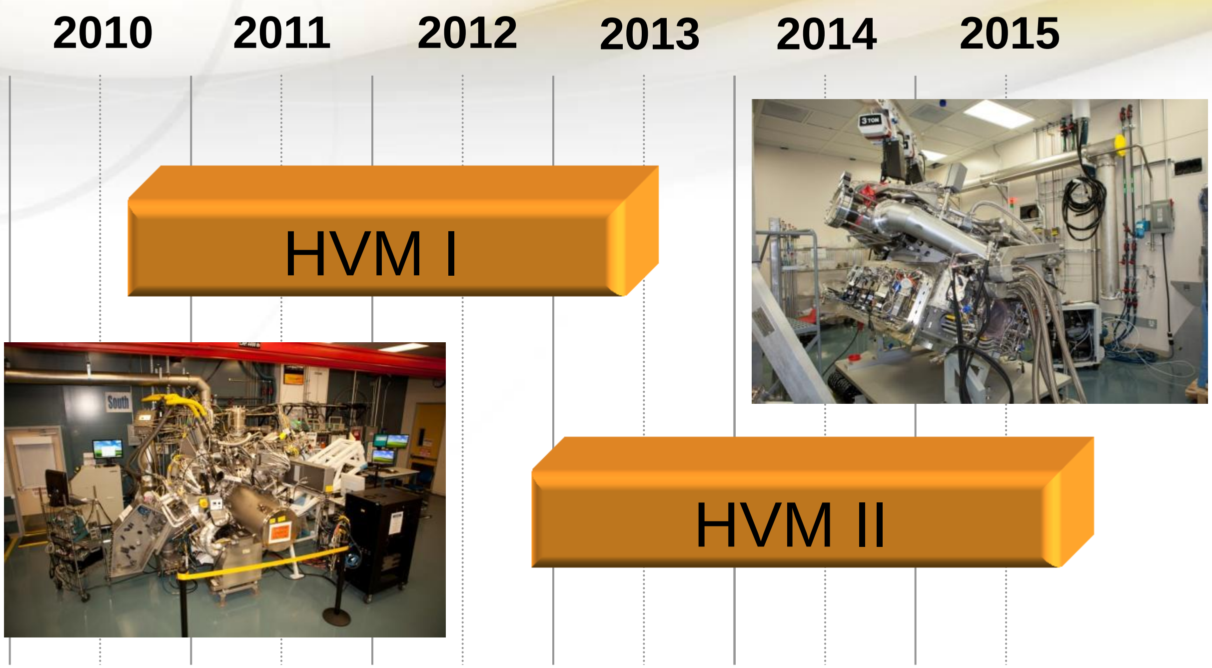
High-Duty-Cycle Demonstration Status (P7)

Expose power (calc.)	40W
Raw power (mean)	60W
Raw power (peak)	70W
CO_2 power	17kW
Test length	~10min
Duty Cycle	80%





EUV Source Roadmap



HVM I

- 10 sources in operation
- 5 installed at Fabs
- 5 for development at Cymer / ASML

HVM II

- 1st source delivered
- 4 in integration

EUV Source Power Roadmap					
Source Model	HVM I	HVM II	HVM II	HVM II	HVM II
Average Laser Power (kW)	20	23	24	31	43
In-band CE (%)	2.0	2.0	2.5	2.5	3.0
Clean EUV Power (W)	**60**	**80**	**125**	**160**	**250**

Summary

- 10 HVM I sources are installed and operational, 5 at chipmaker fabs, 3 being used in San Diego for prepulse development and collector life testing, and 2 at ASML for scanner development
- HVM I source EUV average power in the field is 9-13W with better than <0.5% dose stability and capability of >100 wafers per day productivity
- Collector lifetime of 45 billion pulses (~4 months) achieved in the field
- Prepulse Development: 50W average power at 80% duty cycle demonstrated; up to 90W in-burst power at 20% duty cycle with 90% of dies <1% dose stability
- First HVM II source for ASML NXE 3300 scanner is delivered, integration of the next several are in process

Acknowledgements

Thank you!

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