Status of Adlyte's light source for inspection tools

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June 13 2019

Highlights

- Adlyte AG, a Swiss Company, has been developing unique Laser Produced Plasma light source technology over last 10+ years for use in semiconductor production
- Very high brightness droplet-based light source for next generation wafer and mask inspection tools, covering from around 0.1 nm to 200 nm wavelength
- Two prototype light sources have been developed, built and tested (together with tool makers) over the last 5 years, exceeding technical requirements
- Adlyte has designed and is in the process of building HMV version of the light source for use in 24/7 applications in the Fab by 2H 2019
- Modular and extendable architecture, have operated using various fuel (Sn, In, Ga,...)
- De-risked technology with strong IP protection through a suite of patent portfolio

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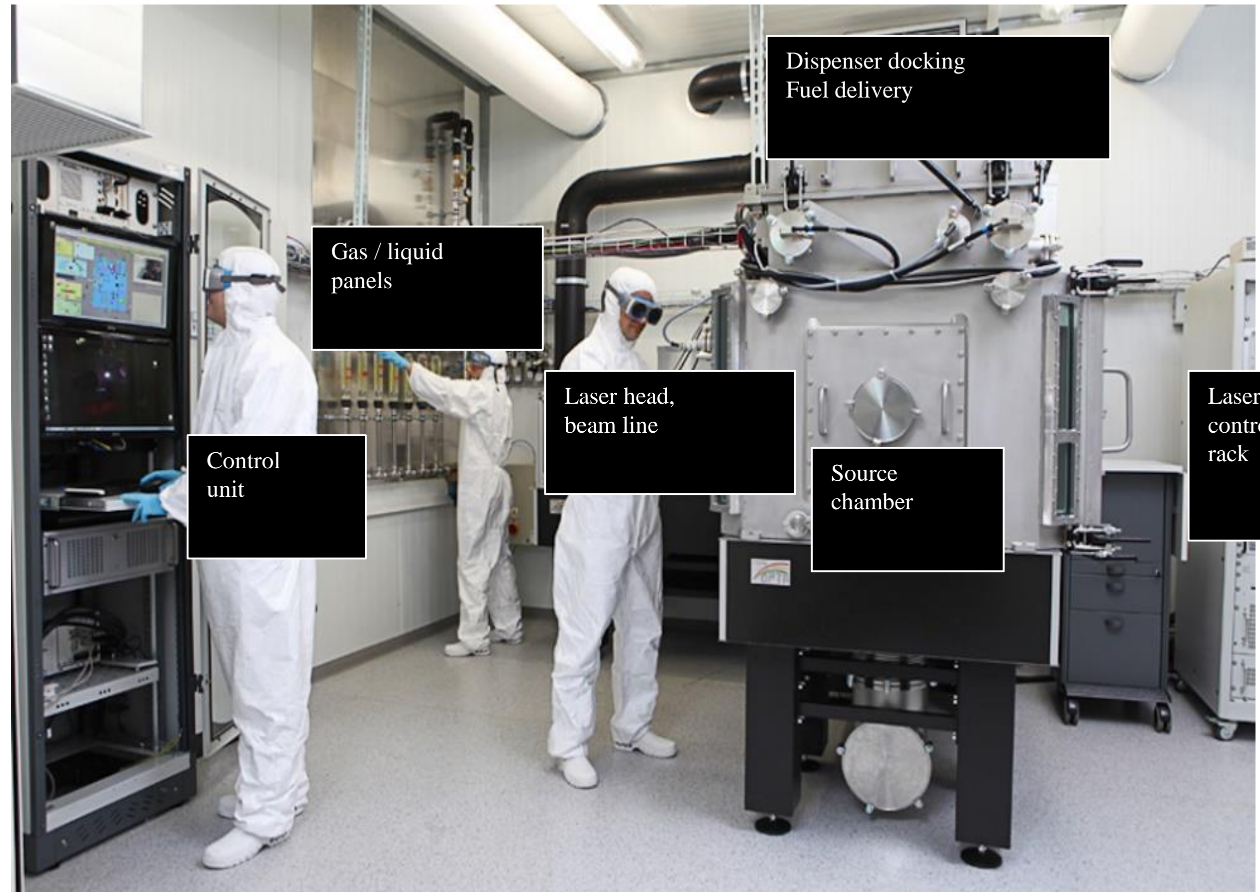
LPP Light Source Key Components

- Tin Droplet dispenser
- Collector
- Debris mitigation
- Laser
- Triggering and alignment
- Plasma characterization
- IF interconnect



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Adlyte’s light source

- Nd:YAG laser: average power of 1.6 kW, λ = 1.064 µm,10-20 kHz rep. rate
- In-house droplet dispenser with >30 µm tin droplet generation
- Closed loop droplet tracking system with laser triggering on individual droplets enables droplet-laser alignment within <10% of droplet diameter.
- Debris mitigated grazing incidence collector, including clean IF module with imaging capability.
- Compatible with various collector configurations
- Full diagnostic including in-band energy monitors and out-of-band spectroscopy

Parameters	Value	
Laser power on target	1300	W
Laser frequency	10-20	kHz
Laser focal spot, FWHM	75	µm
Conversion efficiency	>1	%
Source power at the source	>13	W
Peak source brightness	350	W/mm^2sr

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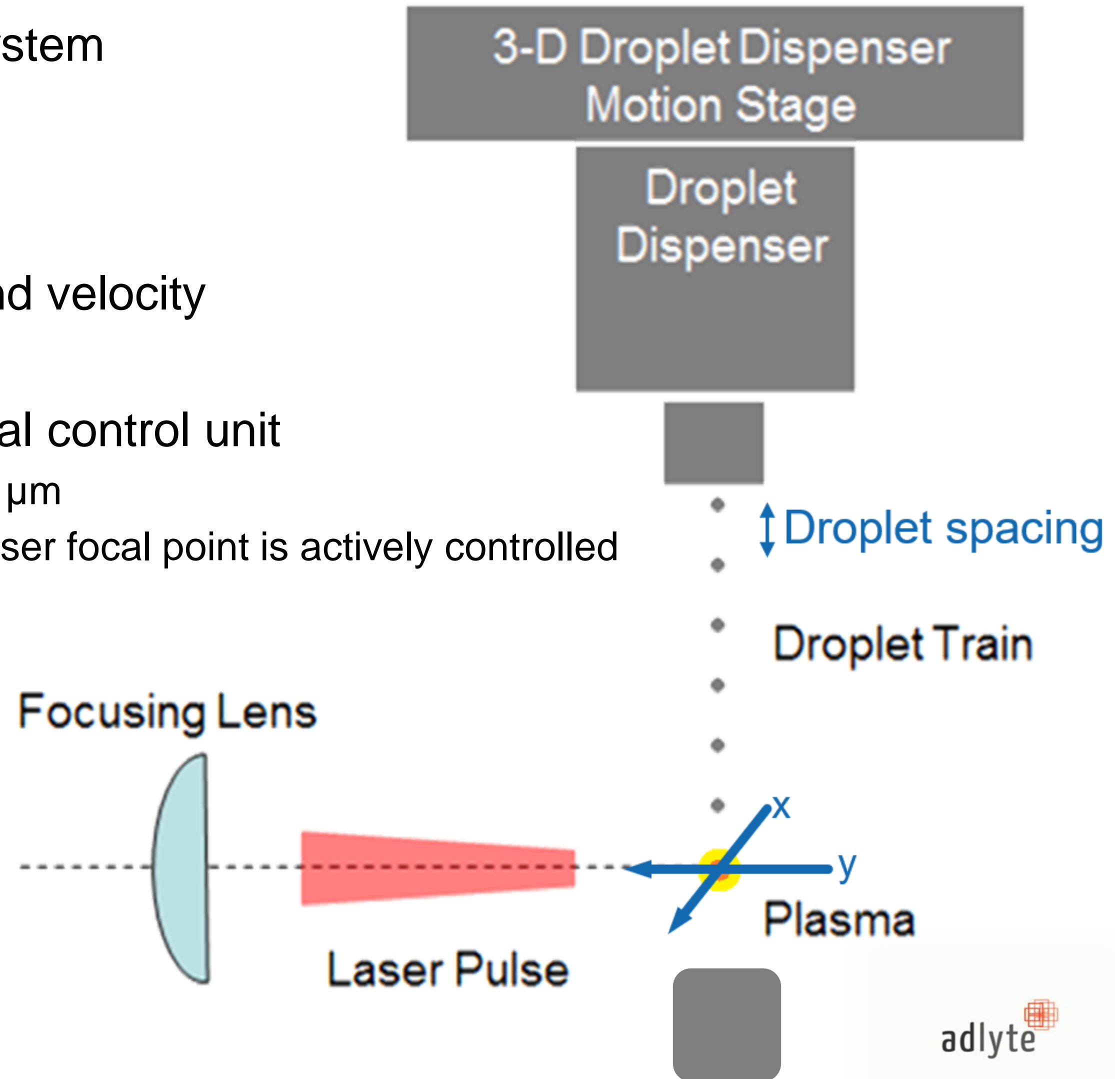
Source system overview

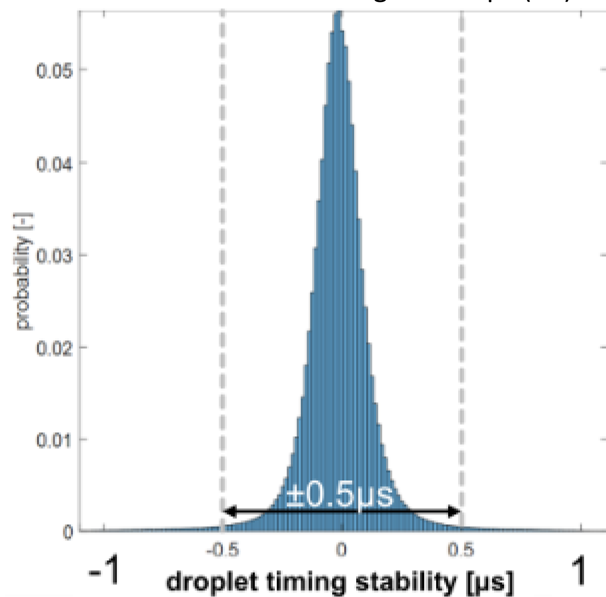
- Automated laser triggering system
  - frequency from 8 kHz to 20 kHz
  - Adjusted timing offset
- Adjustable droplet frequency
- Adjustable droplet spacing and velocity

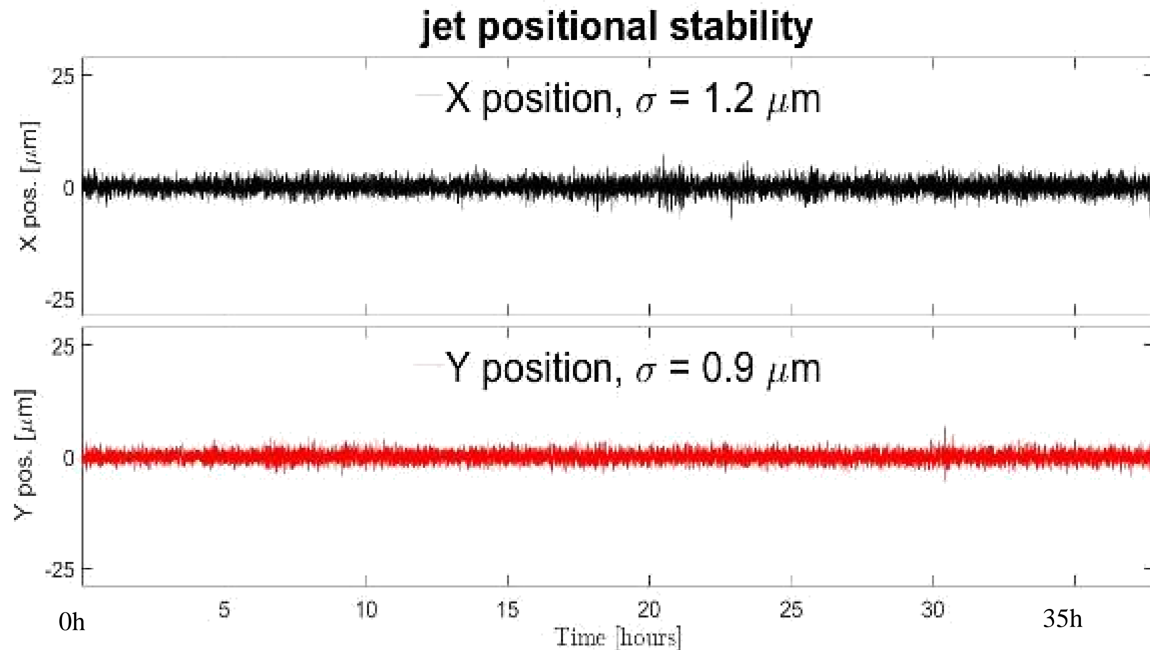
- Automated feedback positional control unit
  - Tracking system resolution < 0.2 µm
  - Relative droplet position to the laser focal point is actively controlled
  - Input control parameters
    - E-Mon signals
    - Tracking signals
  - Automated alignment

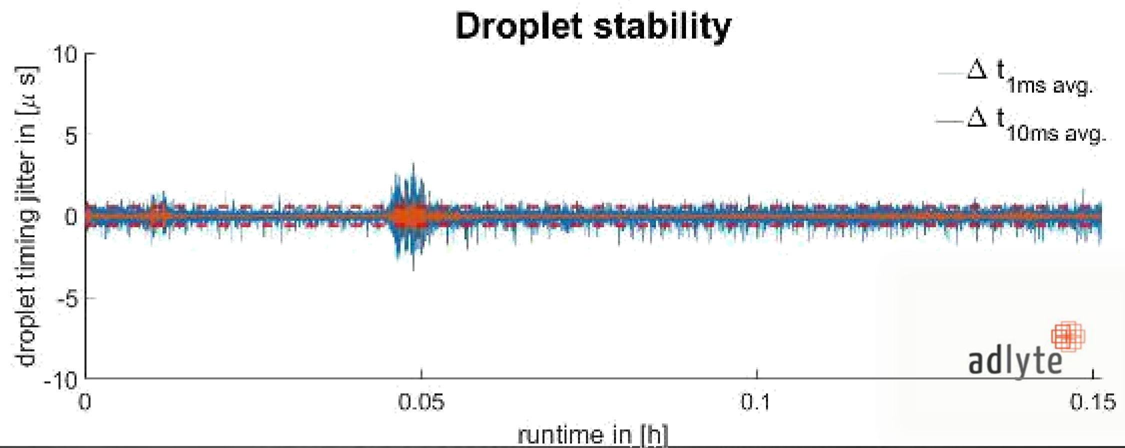


Updated source capability and runtime

- V7 droplet generator tested
- > 35 hour continuous runtime
- Proven positional stability
- Stable droplet frequency
- Droplet timing stability:
  - Champion data
    - 1 ms avg. = 0.55 µs (3σ)
    - 10 ms avg. = 0.34 µs (3σ)







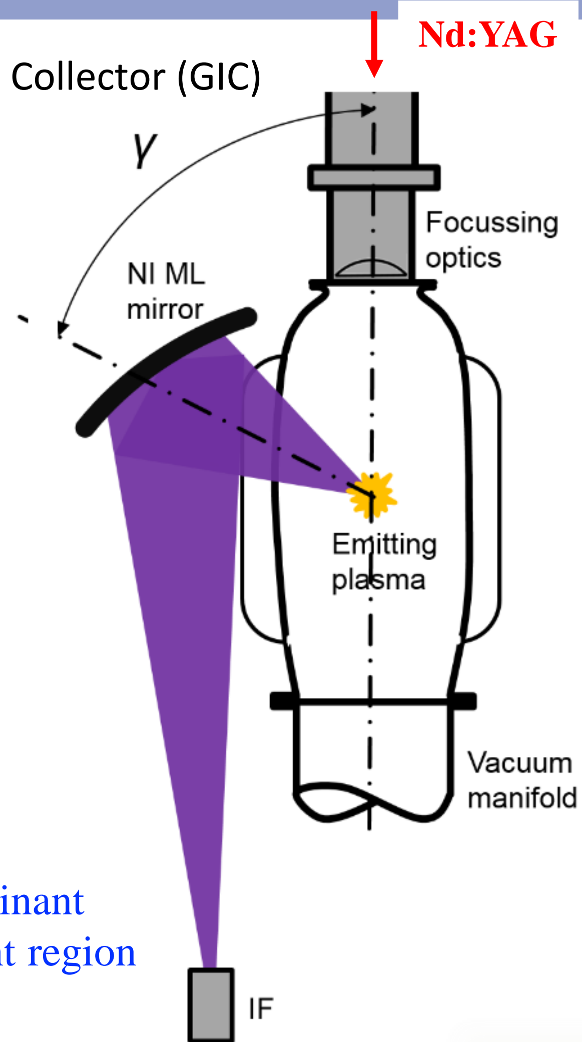
First bounce collector optic placement

- Both Normal Incidence Collector (NIC) and Grazing Incidence Collector (GIC) configurations are used depending on the application
- Placement for diagnostics and imaging is optimized

Optimum collector location

1
0.8
0.6
0.4
0.2
0
Sn deposition (-)
40 60 80 100 120 140
γ (deg)
1
0.8
0.6
0.4
0.2
0
Ion damage potential (-)

Dominant fragment region



Trade-off between ion exposure and tin deposition: typically optimum btw. 40 – 90°
Larger neutral cluster dominant region narrows optimum collector location

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Cleanliness through reduced Debris Formation and Debris Mitigation

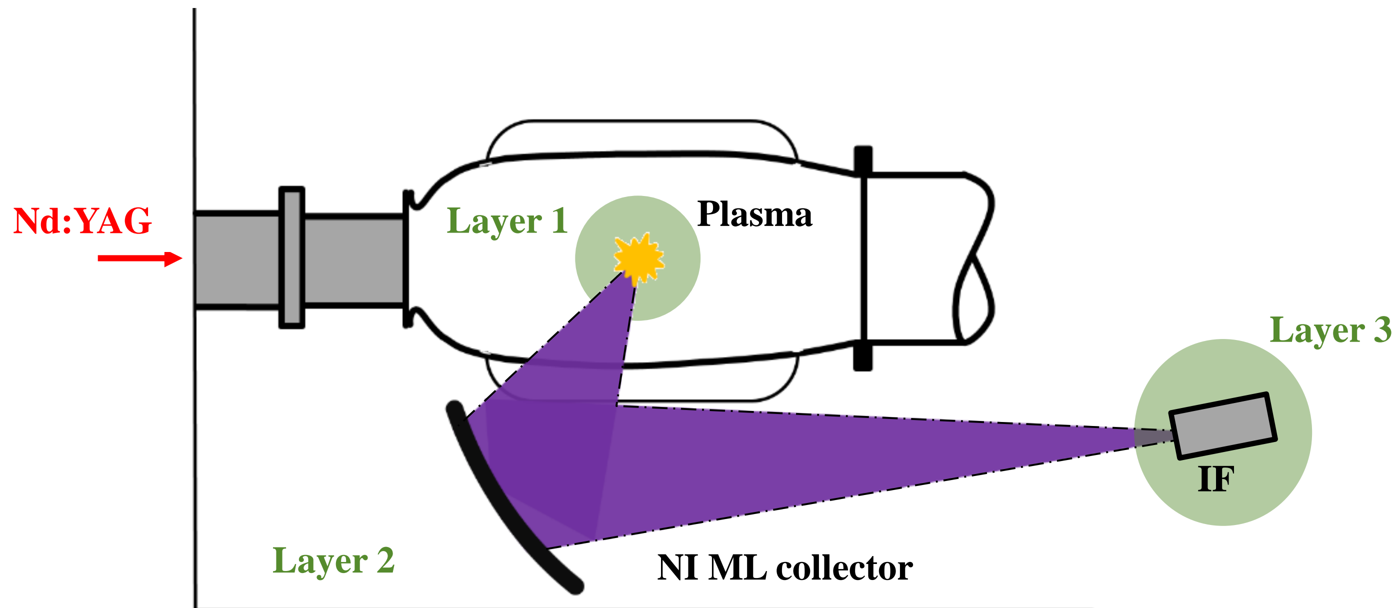
A. Limit debris formation

B. Mitigate debris

LAYER 1. Control debris around plasma

LAYER 2. Control debris in the collector module

LAYER 3. Control debris at IF



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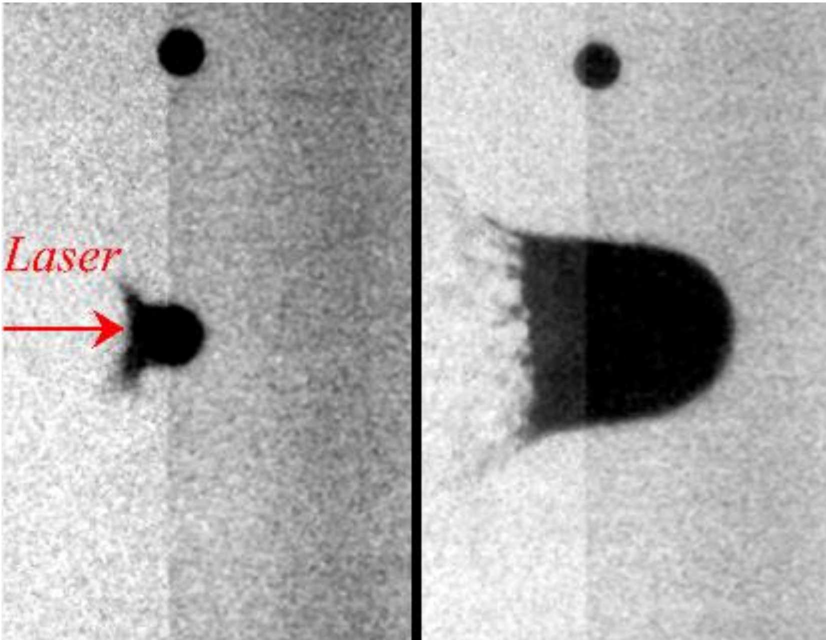
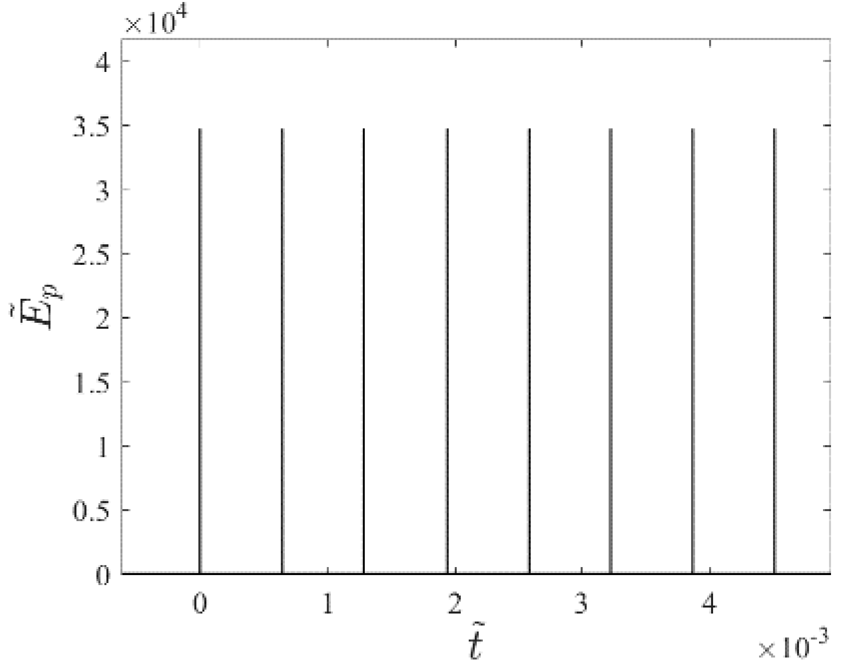
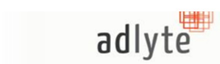
Advanced Target Shaping Prior to Plasma to Improve CoO

- Bursts of picosecond laser pulses allow for high order degrees of control of target shape

$$\tilde{E}_p \equiv \frac{E_p}{\sigma \cdot d_0^2}$$



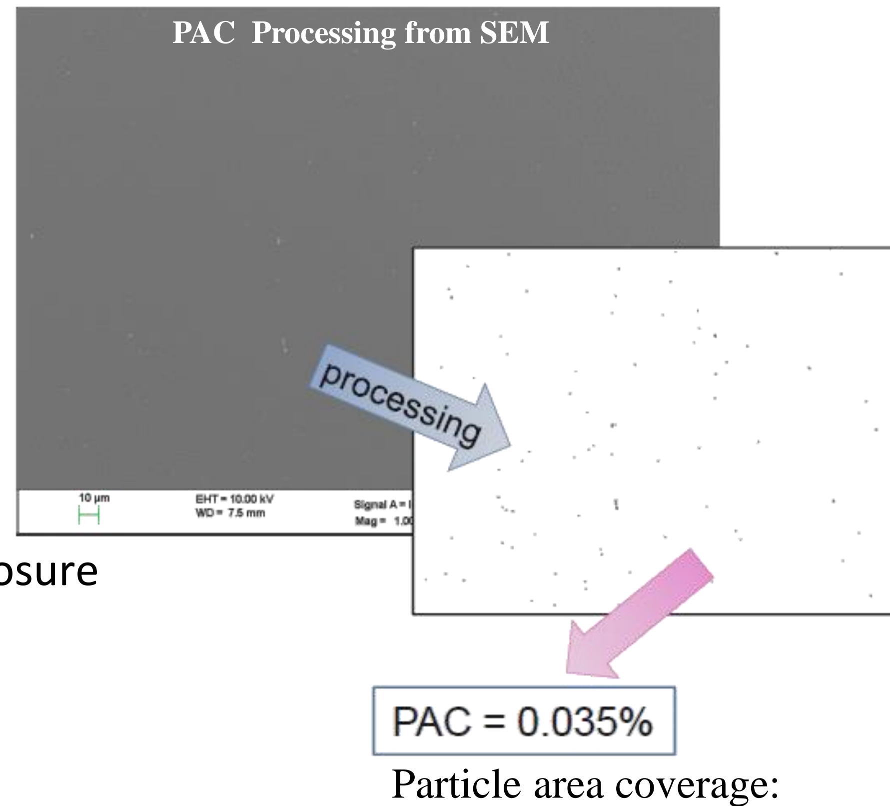




*figures: from submission D. Hudgins et al., 2018 Phys. Rev. E

Results lifetime assessment of EUV collection optics

- Measurement set-up for grazing incidence collection optics
  - Microscopy – Particle Area Coverage (PAC)
    - At nominal collector distance:
      0.1 % after 14 hours of exposure
  - SEM – PAC
    - At nominal collector distance:
      PAC = 0.035 %
  - EUV reflectometry
    - No reflectivity loss after 14 hours of exposure
      (no changes detectable below ~1 %)
  - XPS
    - At nominal collector distance:
      No differences detectable after sample exposure



- Acknowledgment
  - Carl Zeiss SMT for collaboration and agreement to publish

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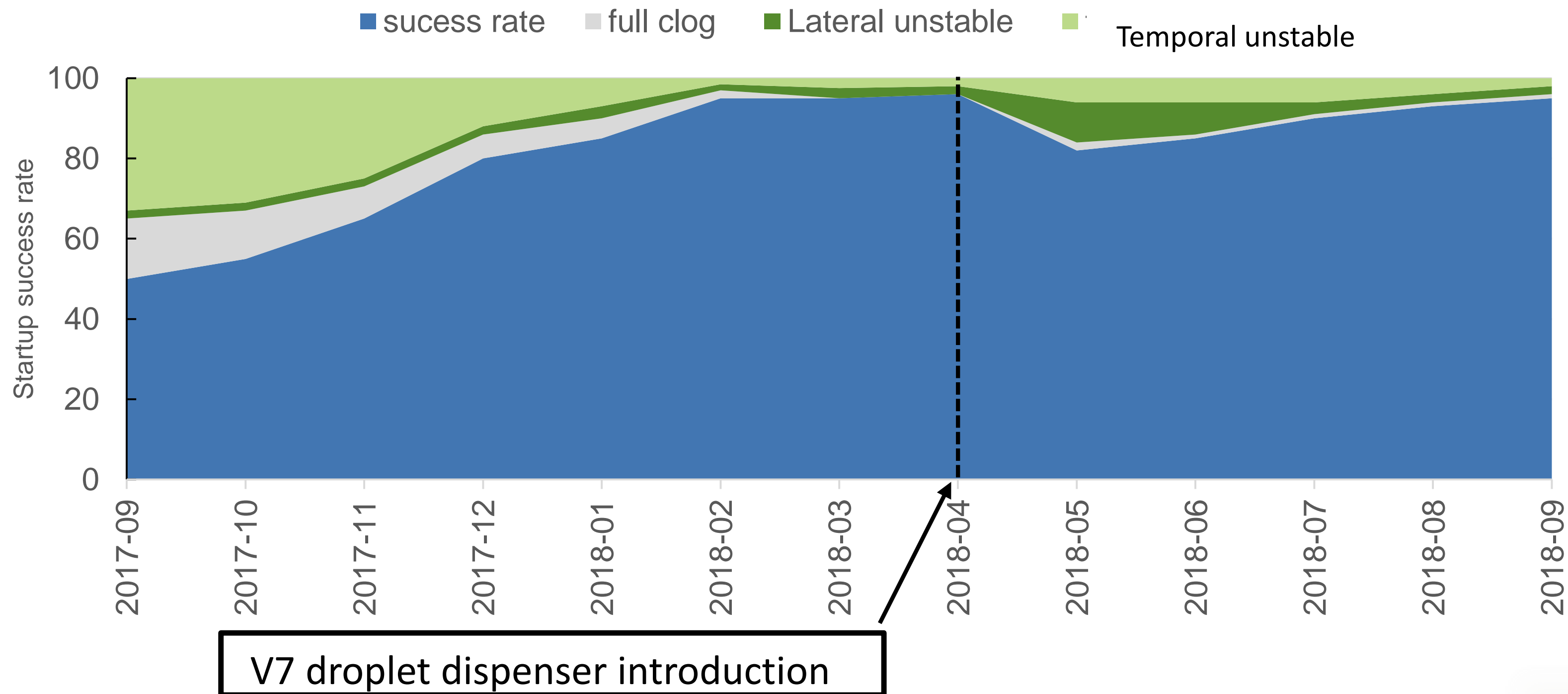
Facility Continual Improvements of Availability

- Continual improvement in droplet disperser, control system and thermal management allows availability rate of 95+ %



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Recent Progress

- Continuous source operation of up to 35 hours demonstrated
- Major improvements relating to thermal management of the source for long term operation and Sn recovery
- Developed and demonstrated Pre- pulse conditioning droplet capability
- A 2X reduction in the foot print and the volume claim

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Roadmap Items

- Incorporated capability for hot swap in HVM
- Integrated load locks assembly including quick connect components to maintain thermal conditions and increase uptime
- Set up specialized droplet assembly testing and calibrations
- 24 by 7 operational capability
- Integrate packaging to allow us to run system for one month without refill
- Optimize CoO for range of applications

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Applications of LPP EUV Light Sources for inspection HVM

Field	Application
Actinic Mask Inspection	AIMS Mask Blank Inspection Mask Patterned Inspection
Wafer Inspection & Metrology	Dark and Bright Field Wafer Inspection, Metrology

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Ga, In and Sn Spectra at 30 to 50 nm:

He-0.1mbar

Fuel: Gallium

GaV
GaV–32.23 nm
GaIV–37.39 nm
GaIV–42.28 nm
Ga

Fuel: Indium

InV–31.69 nm
InV
37.0 nm
37.29 nm
37.58 nm
37.86 nm
38.27 nm
38.86 nm
39.38 nm
39.77 nm
40.01 nm
40.73 nm
InIV–47.93 nm
In

Fuel: Tin

SnVII
SnV–35.51 nm
SnV–36.08 nm
SnV–37.21 nm
38.48 nm
39.09 nm
40.93 nm
Sn

Spectral Radiance [μJ/nm]

Wavelength [nm]

- Indium has higher spectral radiance in He with respect to Sn and Ga

Integrated Power (Watt)

Range (nm)	Ga	In	Sn
30-50	0.27	1.70	0.69
117-137	0.94	1.66	1.34
30-163	2.38	5.8	3.7

Summary

- Stable droplet generation (Dispenser V7) > 35 hours continuous operation with improved stability: $3\sigma = 0.55\ \mu s$ (1 ms time averaged)
- Validated source brightness of >300 W/mm^2 sr at 11 kHz for 80 µm source
- Three layer debris mitigation strategy including plasma site, collector and IF. Verified source cleanliness on first bounce collection optics
- Grazing and normal incidence collectors integrated in source.
- Beta light source operated as over the last 5 years, producing clean photons for inspection
- Automated operation over hundreds of hours, with validated cleanliness
- Process of building a new clean room for HVM manufacturing

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Adlyte Source Ready for HVM

For present AND future nodes for both Wafer and Mask Inspection