IWAPS 2019

International Workshop on Advanced Patterning Solutions

GIGAPHOTON

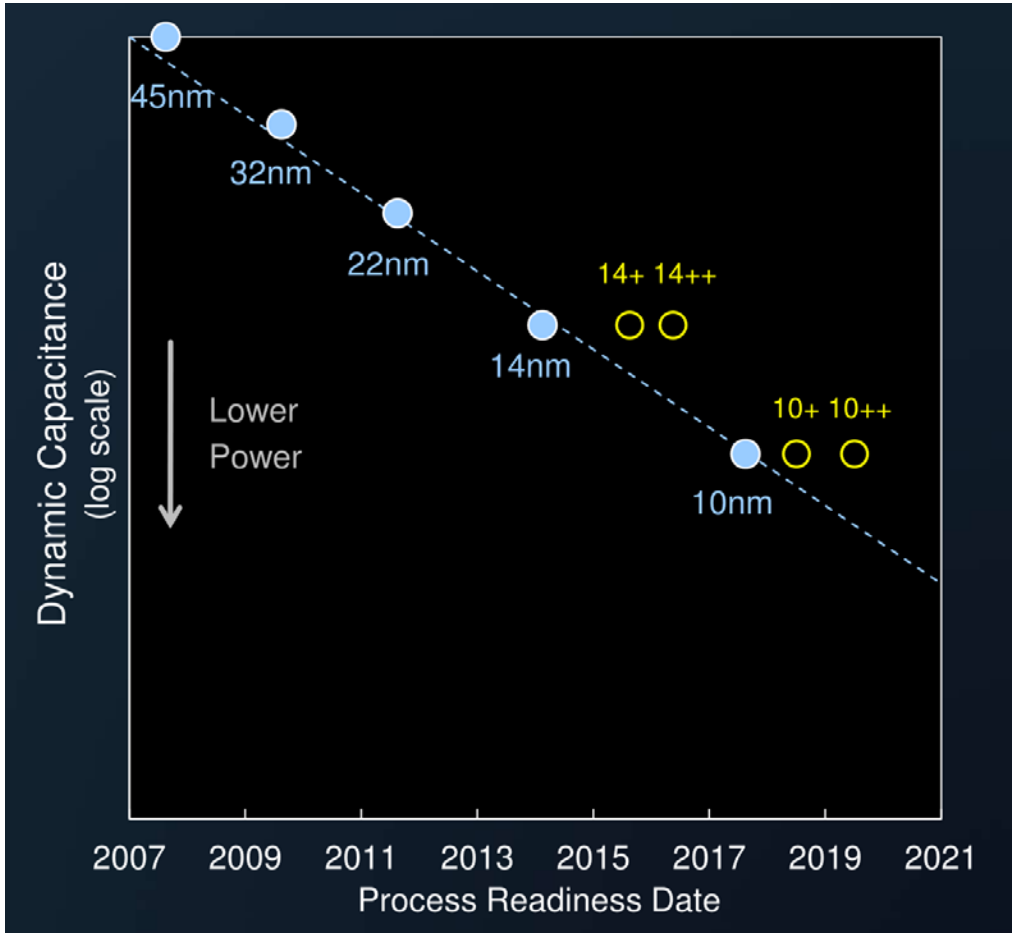
Next generation ArF lightsource "GT65A" for cutting-edge immersion lithography providing both improvement on availability and performance

Tommy Oga, Ph. D., Taku Yamazaki, Hiroaki Tsushima, Takeshi Ohta, Satoru Bushida

Agenda

- Background and motivation
- Improvements
  - Tool Availability Improvements
    - Chamber life extension
    - LNM improvements
  - Performance Improvements
    - Bandwidth (E95%) and its control
    - Flexible Spectral Profile “Spectral Engineering”
    - Speckle contrast sensitivity to LER/ LWR
- Summary

Backgrounds ~ ArFi life gets longer that required further improvements~



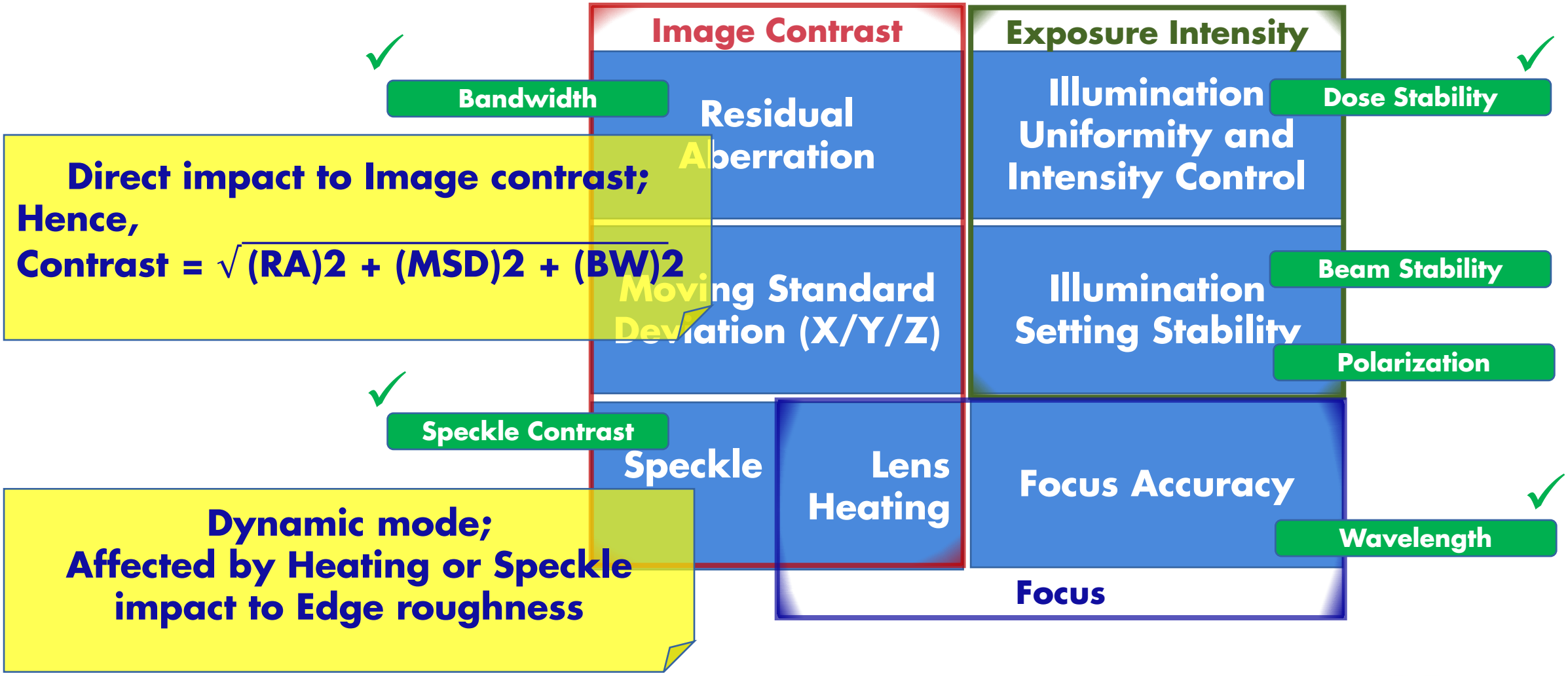
- ArFi introduced for 45nm HVM in 2007 then ArFi is for implementing 7/5nm HVM
- ArFi tool requires further utilization/ availability improvements as well as improved CD and EPE performance

Reference: Public presntation at 2014 Lithovision by Intel and 2012 Earning call

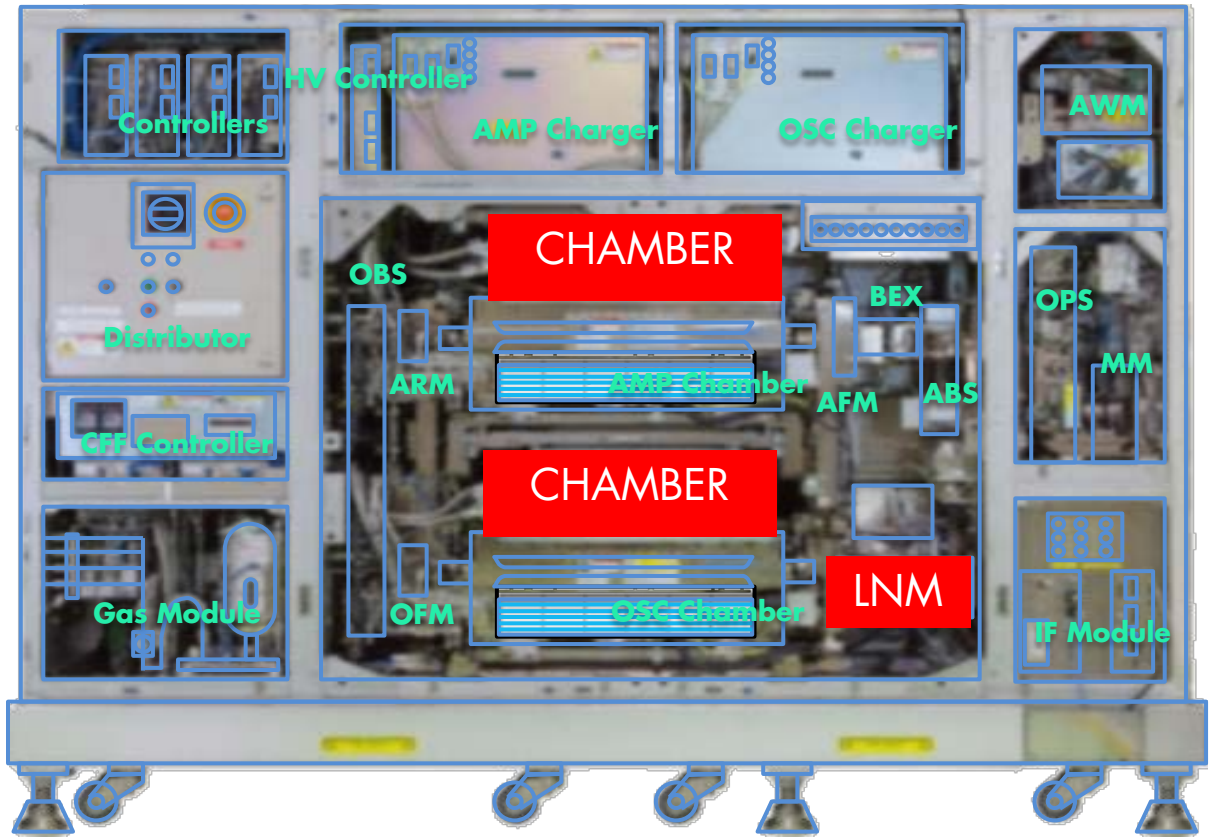
Light Source Impact to Litho printing performance

Scanner Induced

Source Contribution



Availability improvement by mean of Module Life Extension



Key modules

OSC Chamber lifetime:

Degradation key factor = Electrode

☑30Bpls to 50Bpls

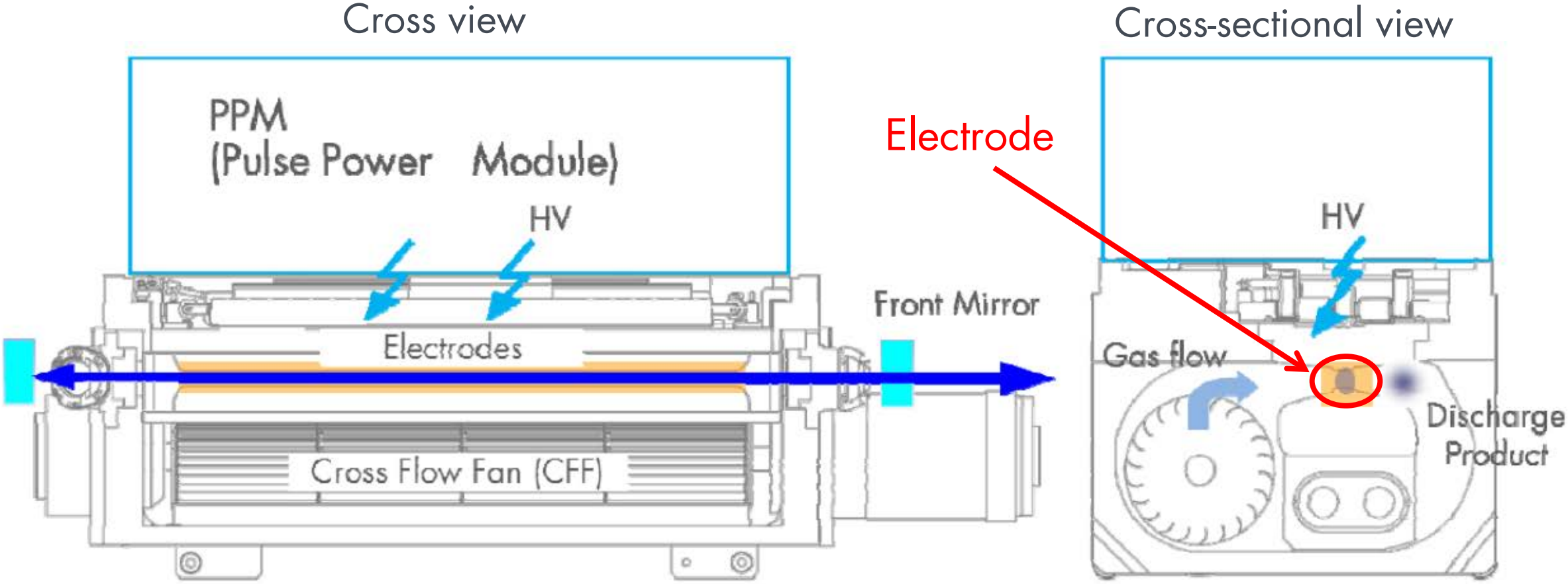
LNM lifetime:

Degradation key factor = Grating

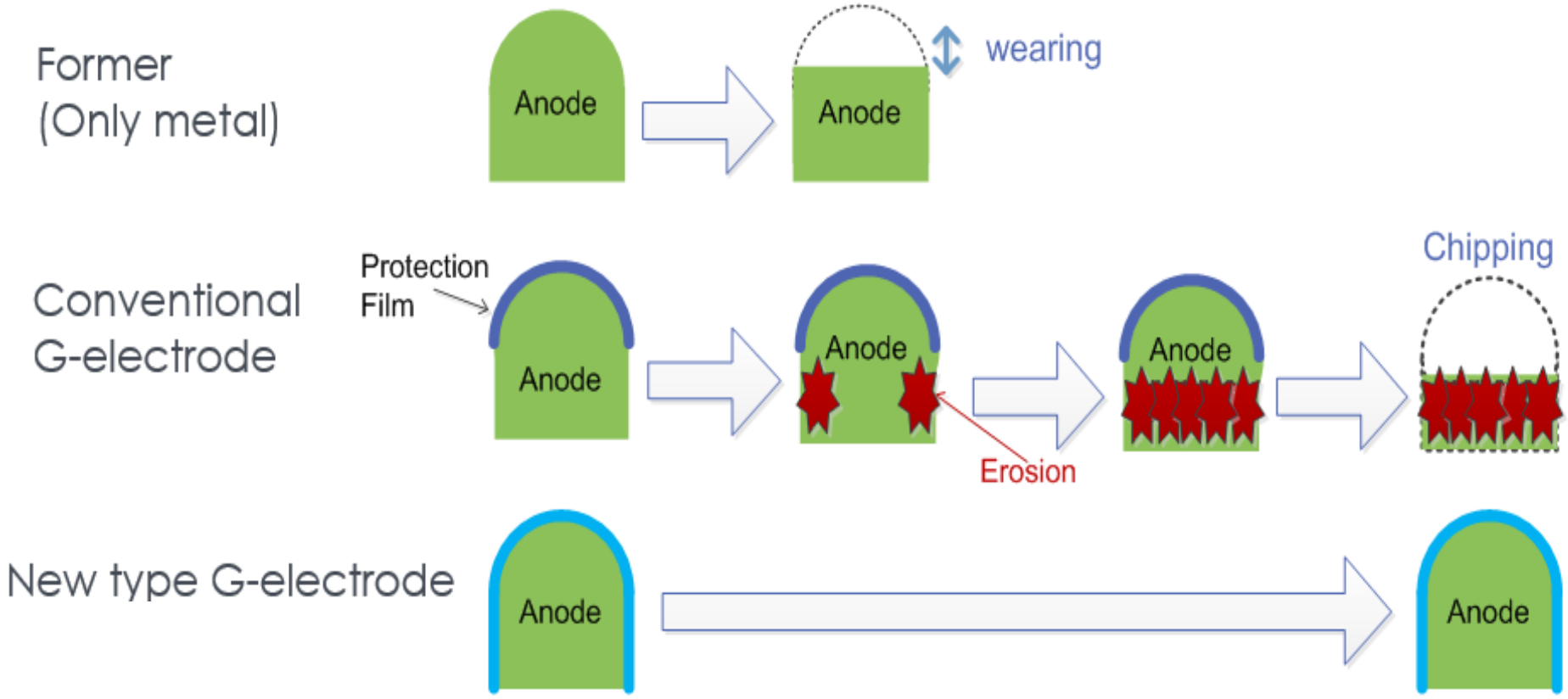
☑60Bpls to >100Bpls

Electrode wear in Chamber as only lifetime challenge

- The electrode with a chamber is degraded by high voltage discharge. This leads to degrade dose stability and decrease laser gain
- ✓ Windows demonstrate >100Bp Life
- ✓ CFF used Magnetic Bearing which has no mechanical contact >>200Bp

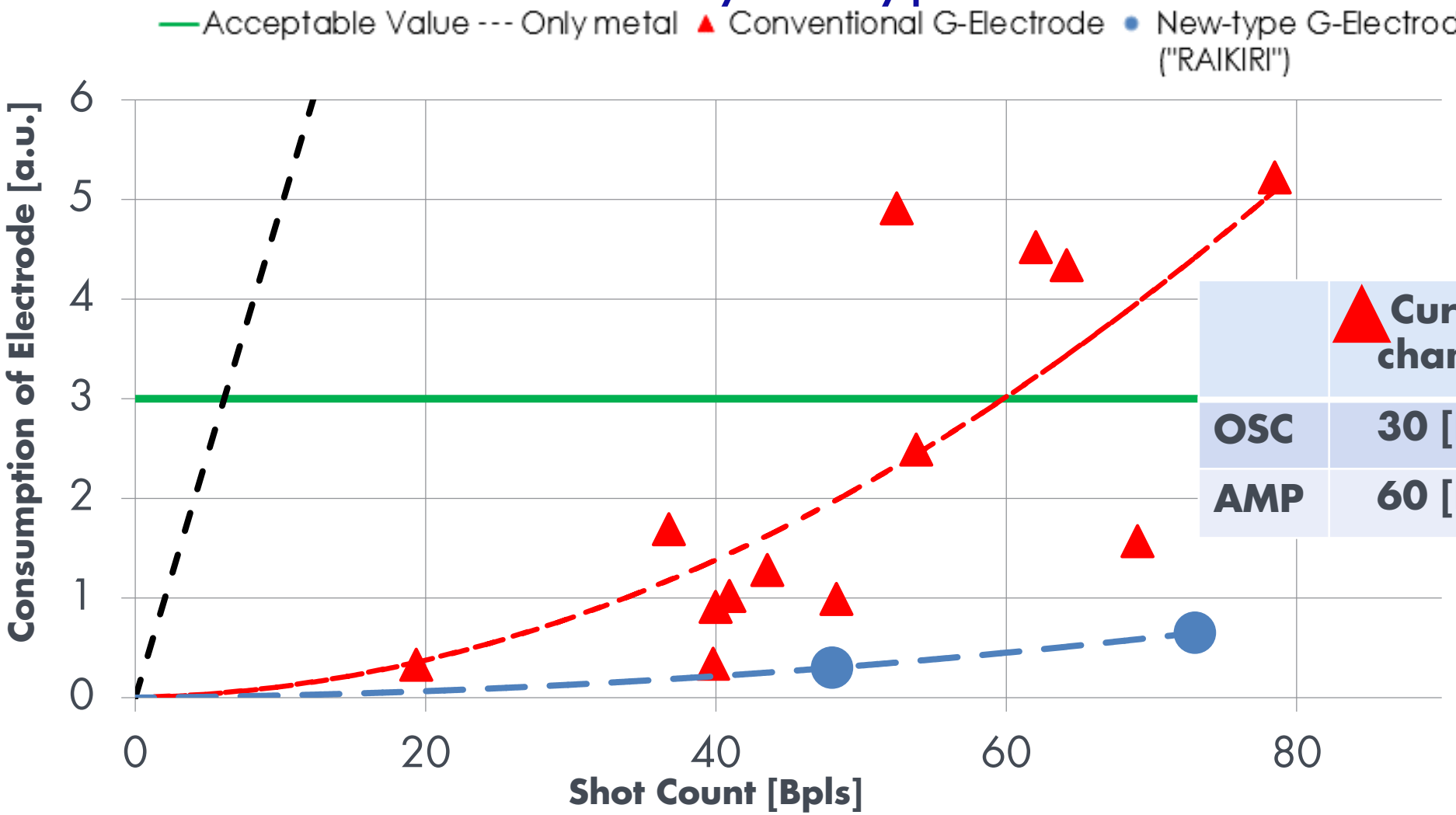


Electrode Material Engineering to extend life



Electrode wear mechanism realized and its measure by material has implemented that extends chamber life

Rate of Electrode wear by the type

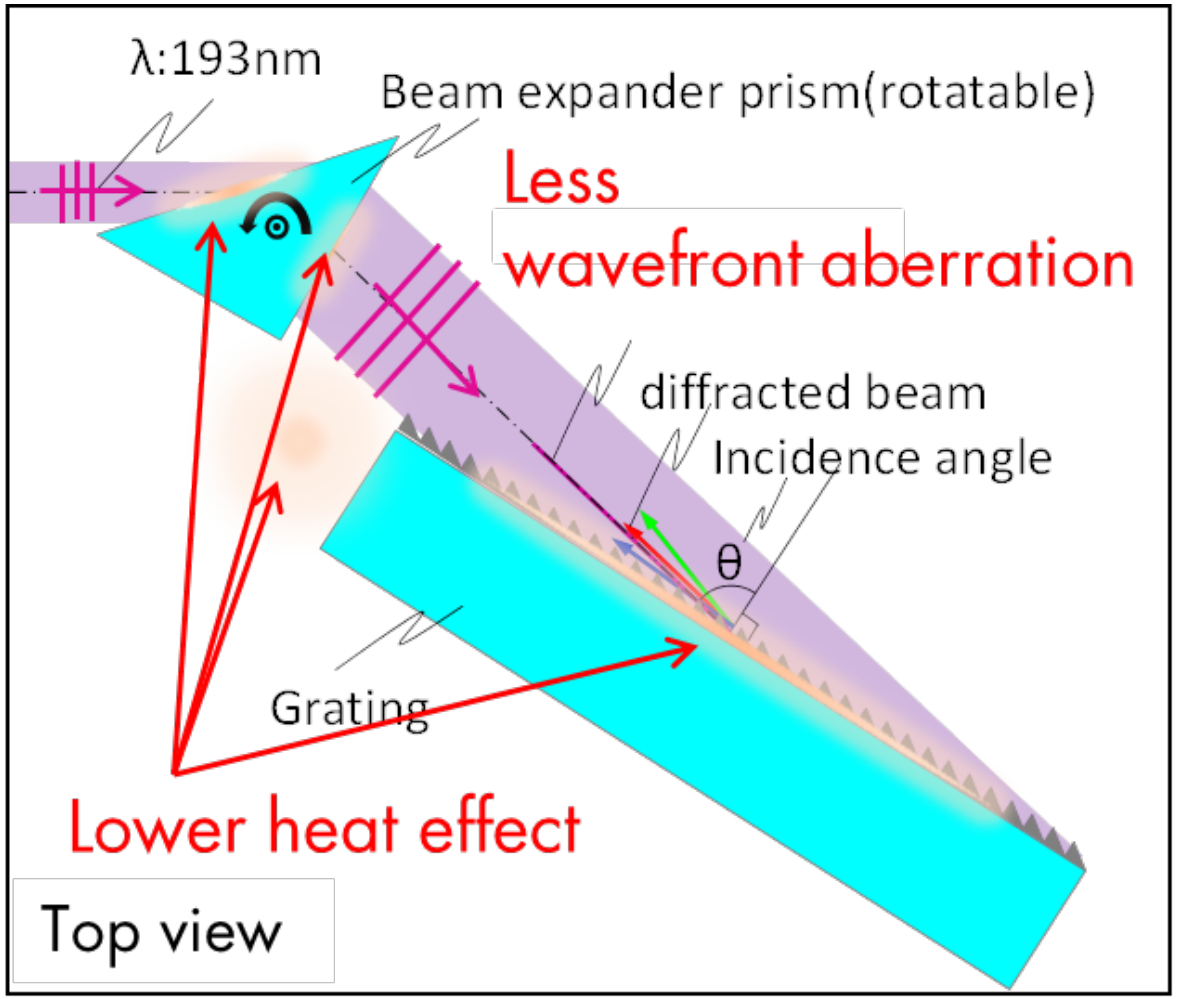


	Current chamber	New chamber
OSC	30 [Bpls]	40 [Bpls]
AMP	60 [Bpls]	80 [Bpls]

30%
Improvement

New type of Electrode provides 30% of Longer chamber life at 40Bpls for Oscillator and 80Bpls for Amp Chamber

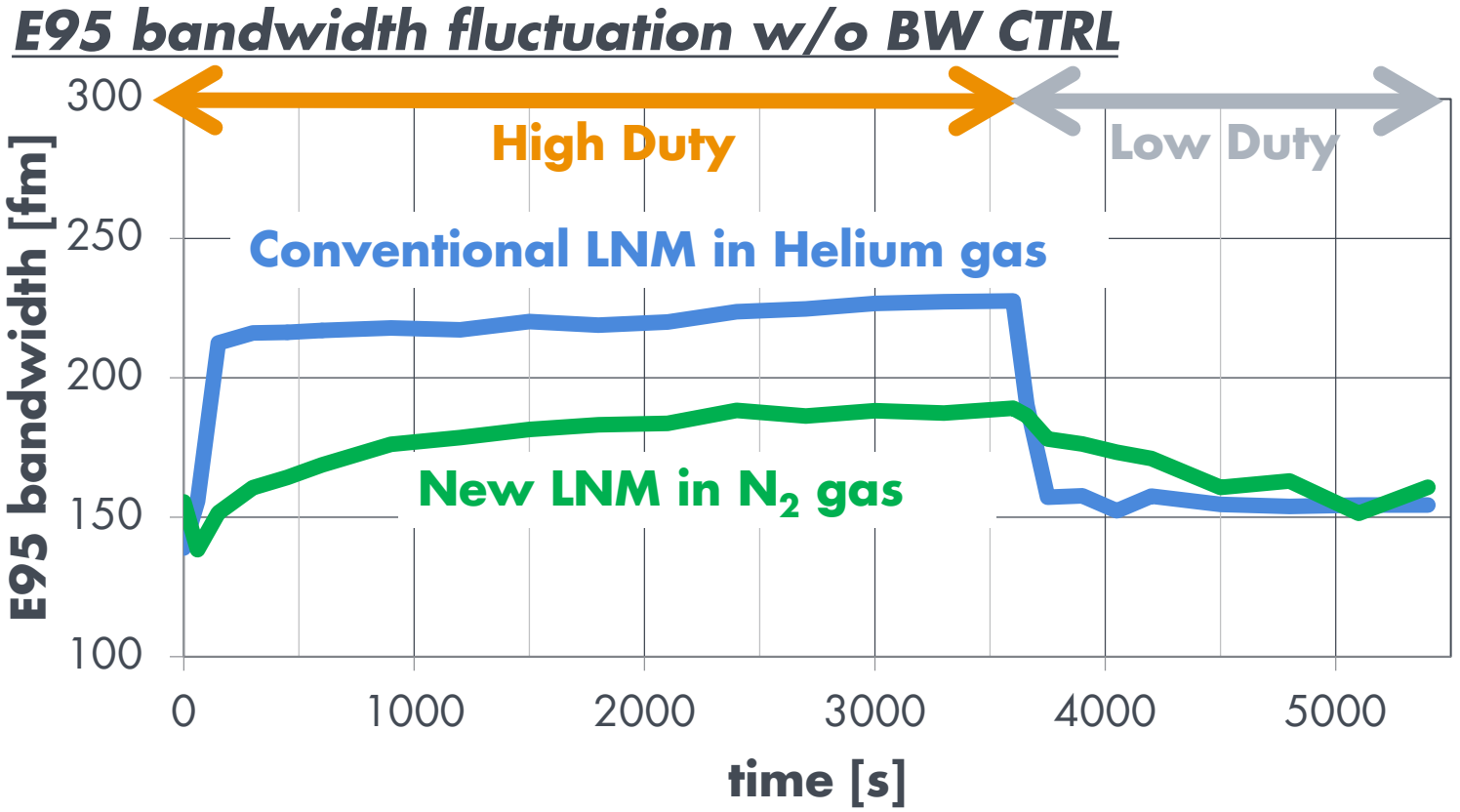
Lower heating absorption/ reflection improves E95% stability



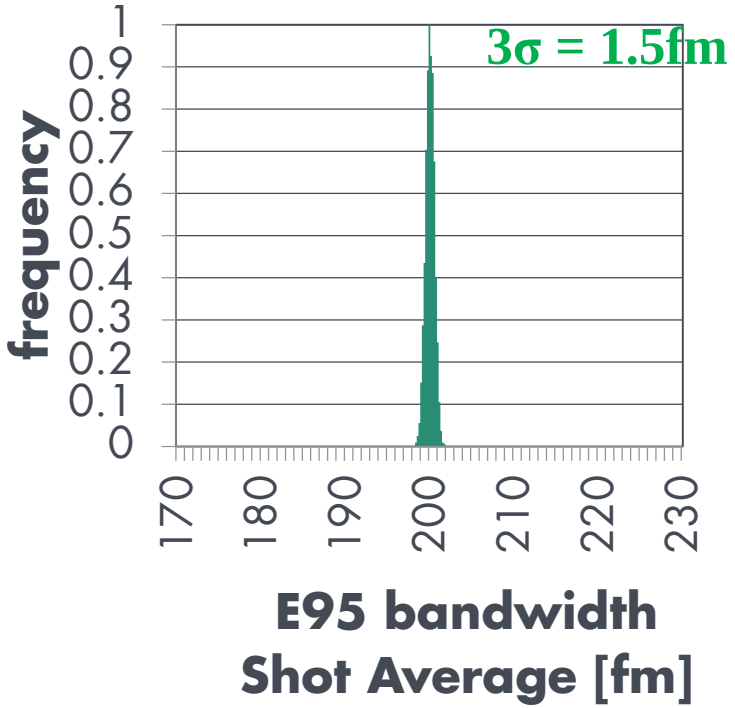
- LNM (Line Narrowing Module) is as key optics for selecting the wavelength as well as E95% Bandwidth stability
- New LNM enables 200fm E95% setting and Helium free operation

Purge gas	Index of refraction n	$\frac{dn}{dT}$
N_2	1.000315	-0.9×10^{-6}
He	1.000035	-0.09×10^{-6}

Mitigates heating effect to achieve low E95% without Helium purge



- ✓ ***New LNM***
- ✓ ***New Control Algorithm***
- ✓ ***Nitrogen Purge***



- Achieving low 200fm setting provides improved process latitude
- No Helium gas operation that mitigates a risk of Helium shortage as well as supporting CSR initiative

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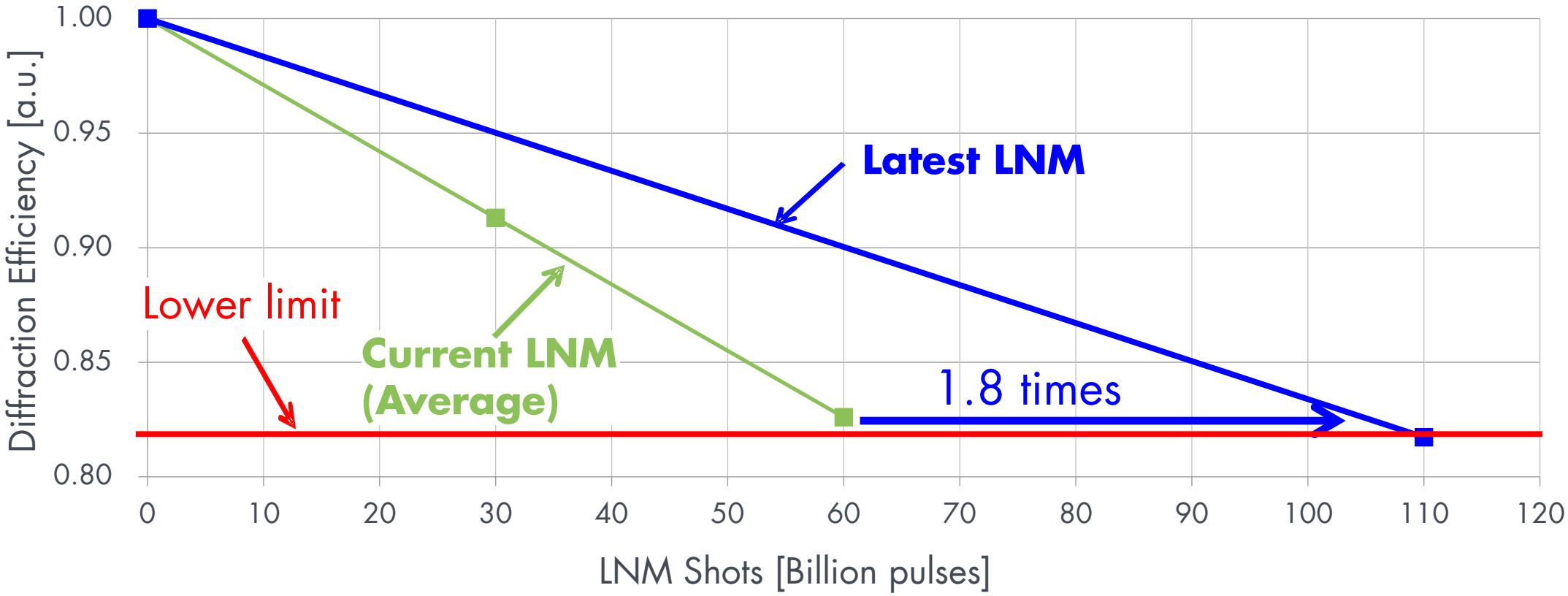
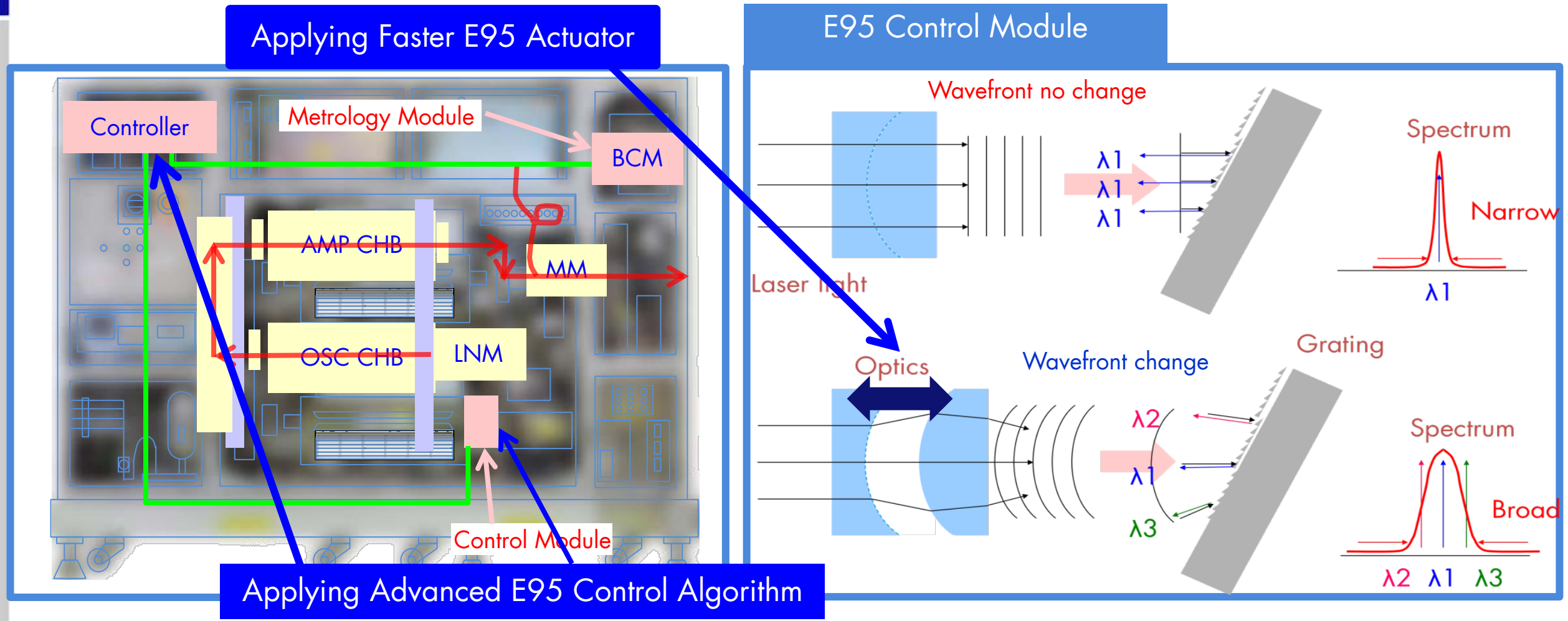
Lifetime extension of Grating by Latest LNM



Reducing the optical damage of the grating by introducing the ingenious configuration,
Lifetime of LNM extends 1.8 times compared to current LNM

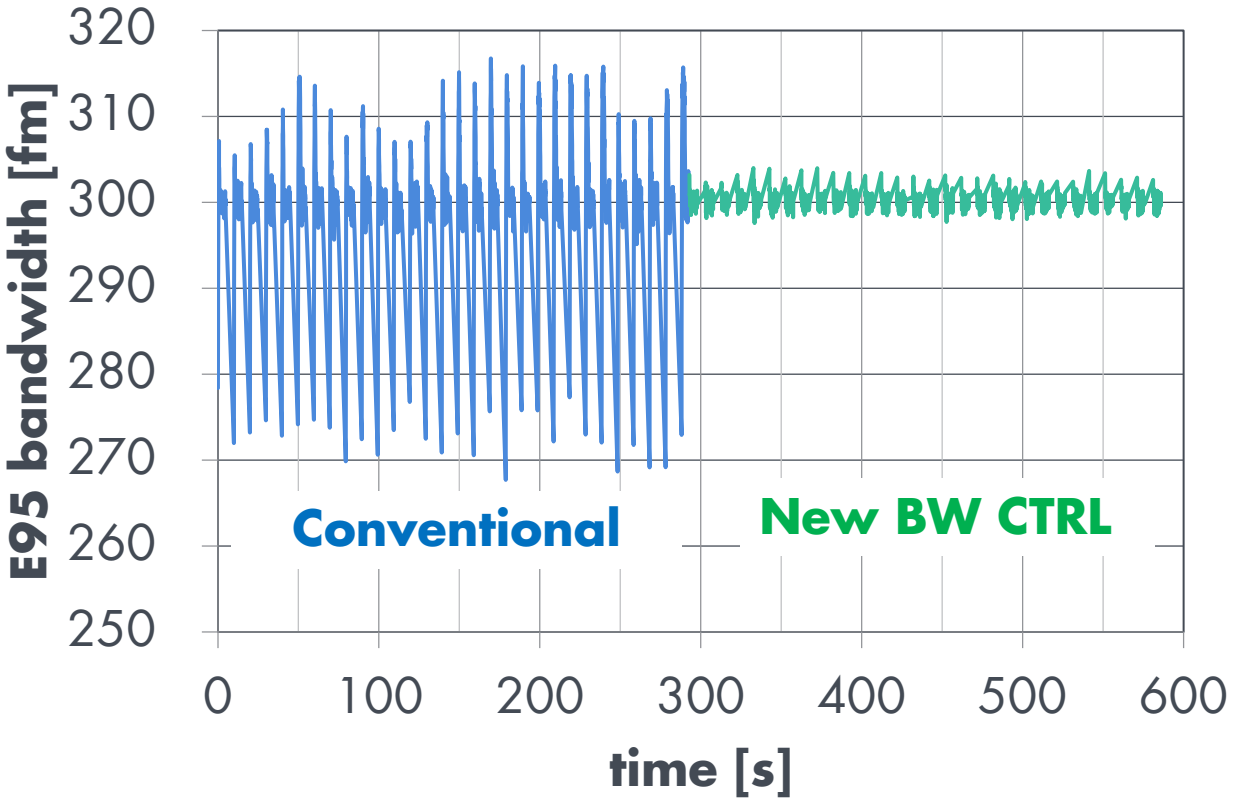
E95% Bandwidth control and stability improvement



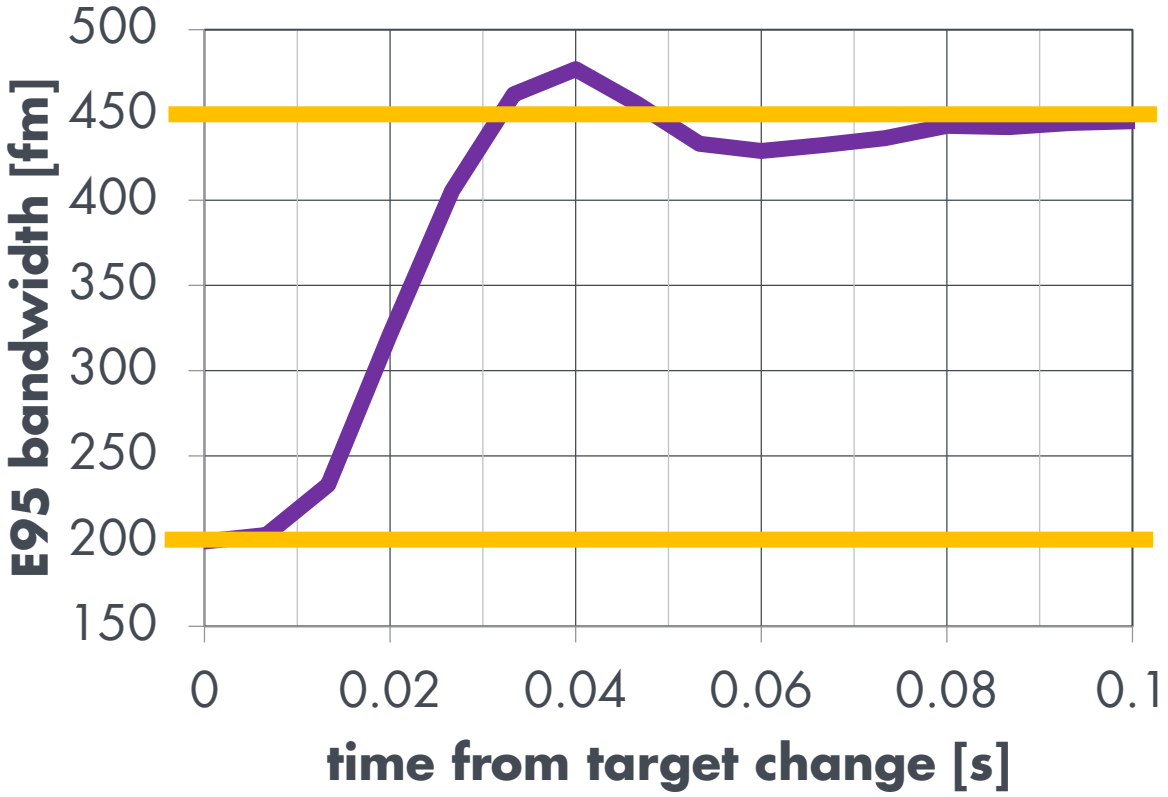
- E95% is controlled by a new actuator and advanced feedback algorithm for improving stability

New E95% active control demonstrates fast tuning and better stability

E95% Stability improvement



E95% Tuning Response Time



- E95% Stability <5fm
- Quick tuning < 100msec

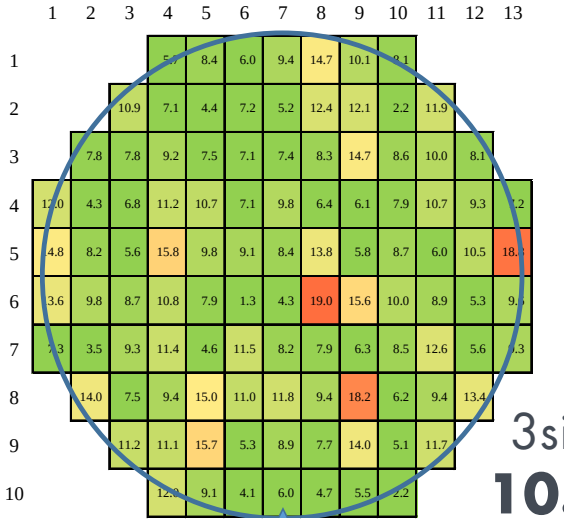
E95 Stability improvements

- Feature: 38nm Iso Line
- Illumination: Dipole

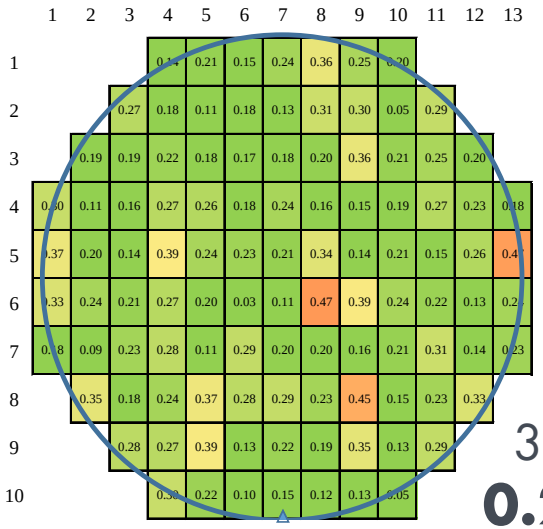
E95 Stability

CD Uniformity

Conventional



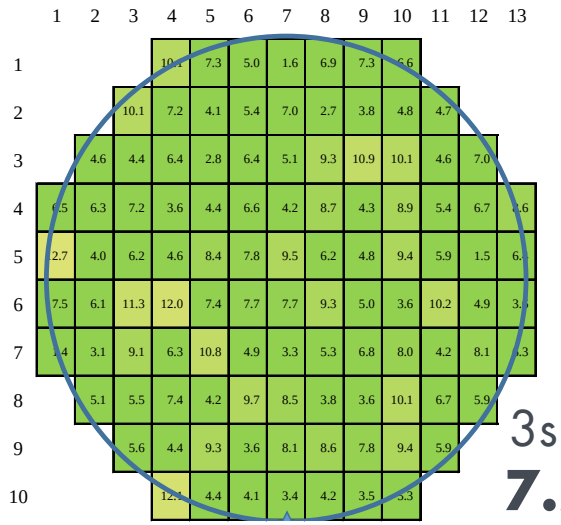
3sigma **10.6fm**



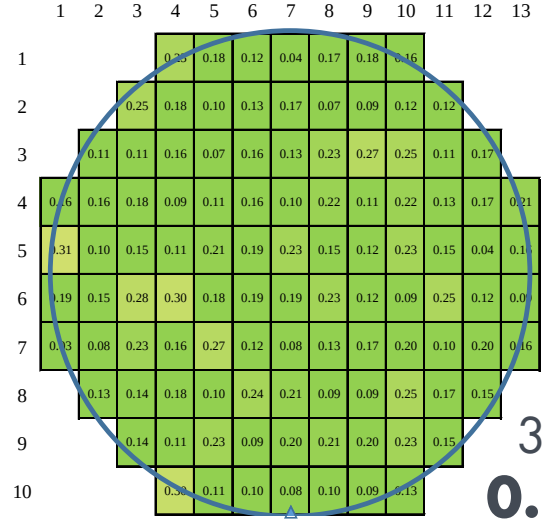
3sigma **0.26nm**

30% Improvement

New E95 Stab Optics



3sigma **7.2fm**



3sigma **0.18nm**

GT65A with New E95 Stab Optics demonstrates 30% of CDU Improvement

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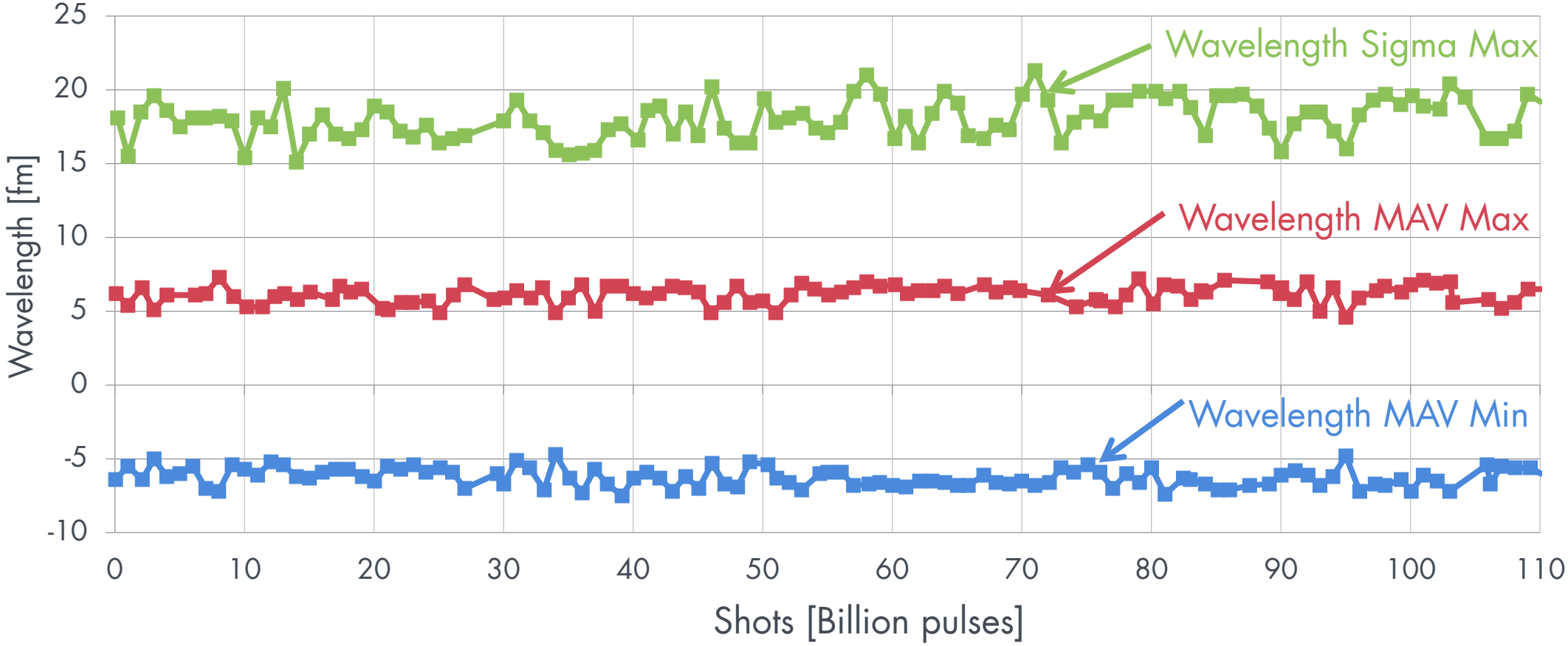
Further Chamber Life Extension in conjunction with New LNM

	Current chamber	New chamber	New Chamber + New LNM
OSC	**30 [Bpls]**	**40 [Bpls]**	**50 [Bpls]**
AMP	**60 [Bpls]**	**80 [Bpls]**	**80 [Bpls]**
Chamber Technology			
Electrode engineering		✓	✓
LNM Improvements			
Optical engineering for reducing heating absorption			✓
Diffraction efficiency improvement for Grating			✓

New chamber combining with New LNM extend chamber life at 50Bpls for Oscillator and 80Bpls for Amp chamber, enabling one time per year or longer MTBS event

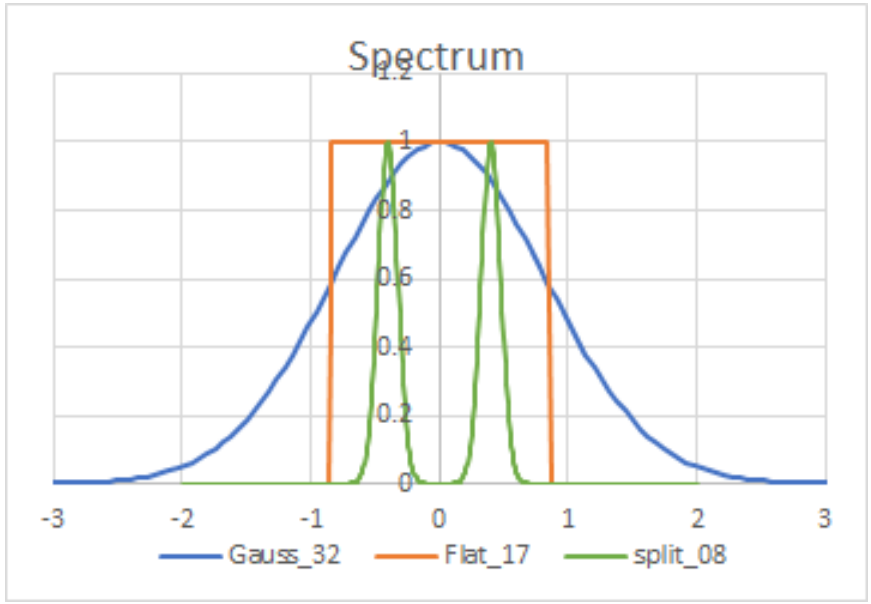
Wavelength stability at 90 W operation through 110Bpls LNM Life Test



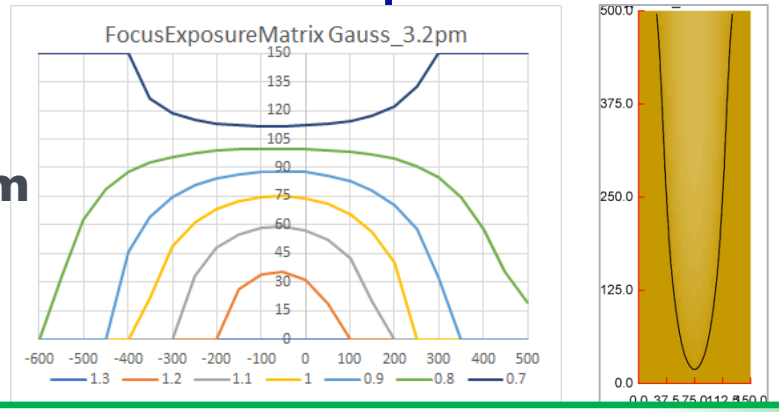
New LNM provides wavelength stability low below 10fm of Sigma through LNM Life even at 90W operation

Spectral Engineering enables process latitude improvements

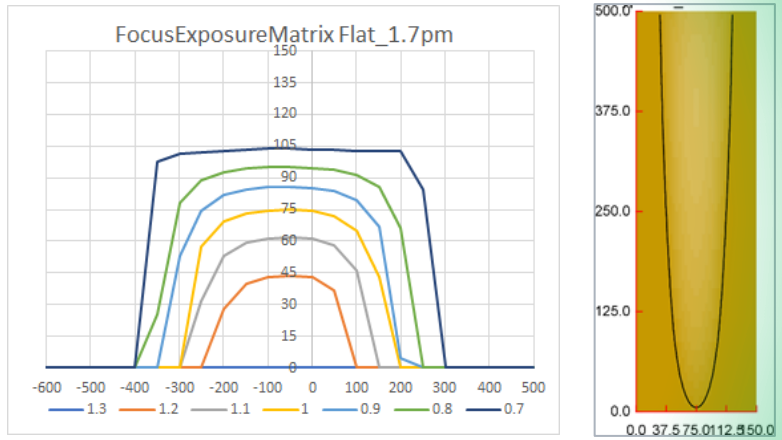
- 3 spectral settings obtained 300nm DOF



Gauss E95=3.2pm



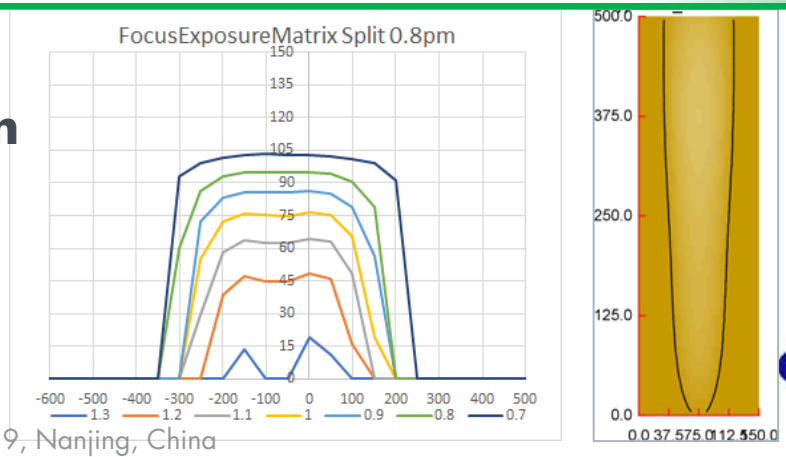
Flat Top 1.7pm



Could be an optimum

- Dose +/-10%, +/-20%, +/-30%

Dual Peak Separation 0.8pm E95=0.3pm



- Conditions
  - 150nm pitch, 75nm hole (Mask Bias +15nm)
  - 500nmt Positive tone resist
  - ArF NA = 1.35 immersion, Annular σ_{out}=0.95,σ_{in}=0.6

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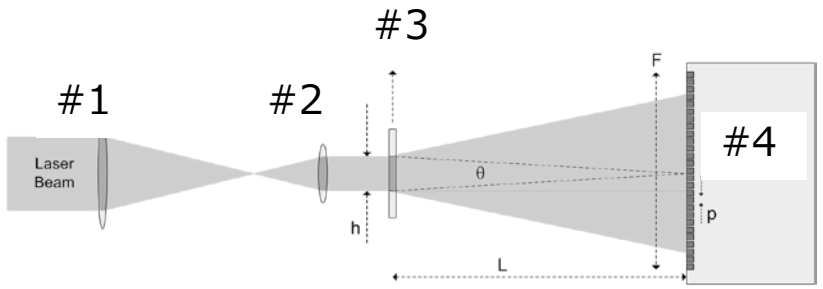
Speckle Contrast and its measurement result

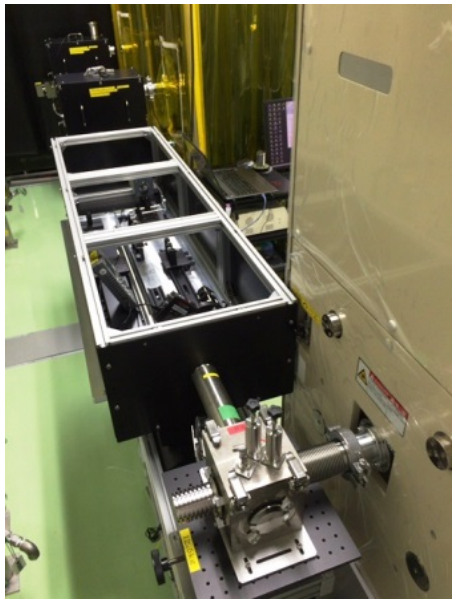


#1, #2 : Plano-convex lens
#3 : Diffuser
#4 : CCD camera

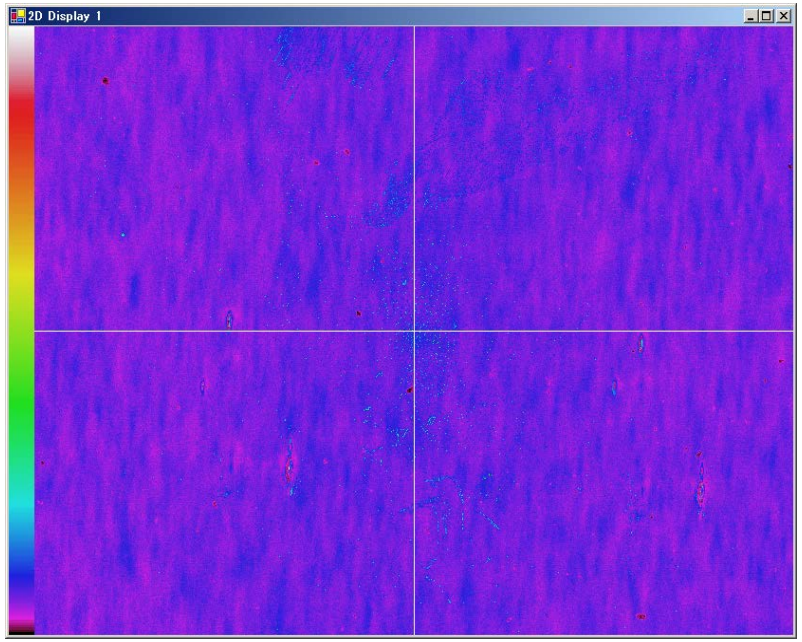
From speckle pattern:

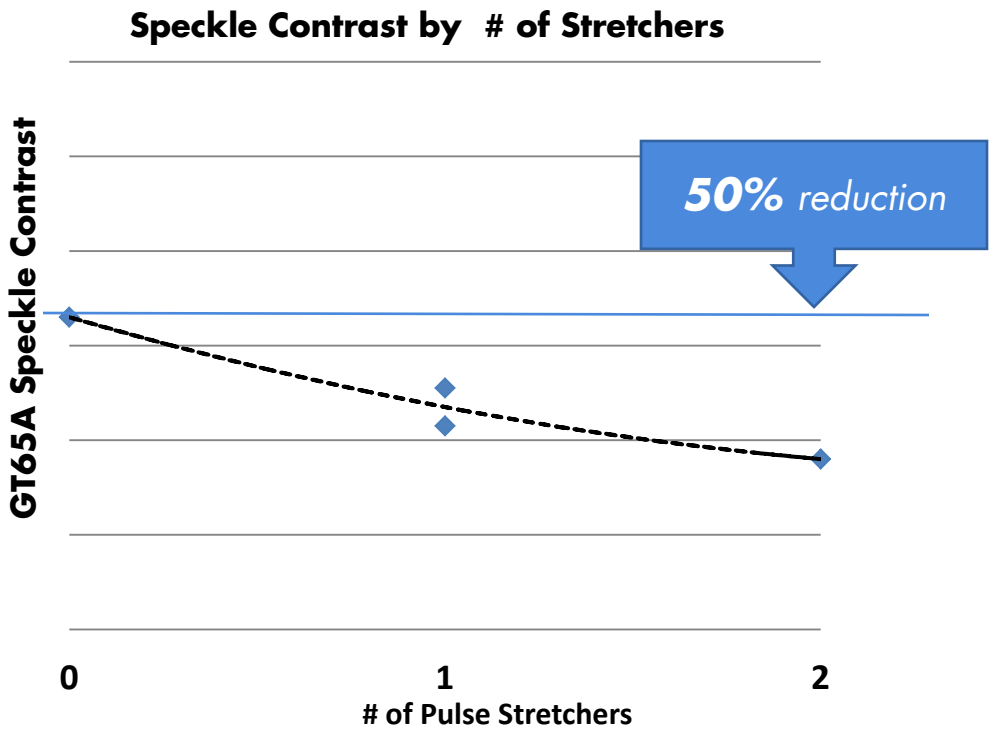
$$SC \equiv \frac{\sigma}{\bar{I}}$$

$\bar{I}$: Average of intensity distribution
σ: Standard deviation of intensity distribution



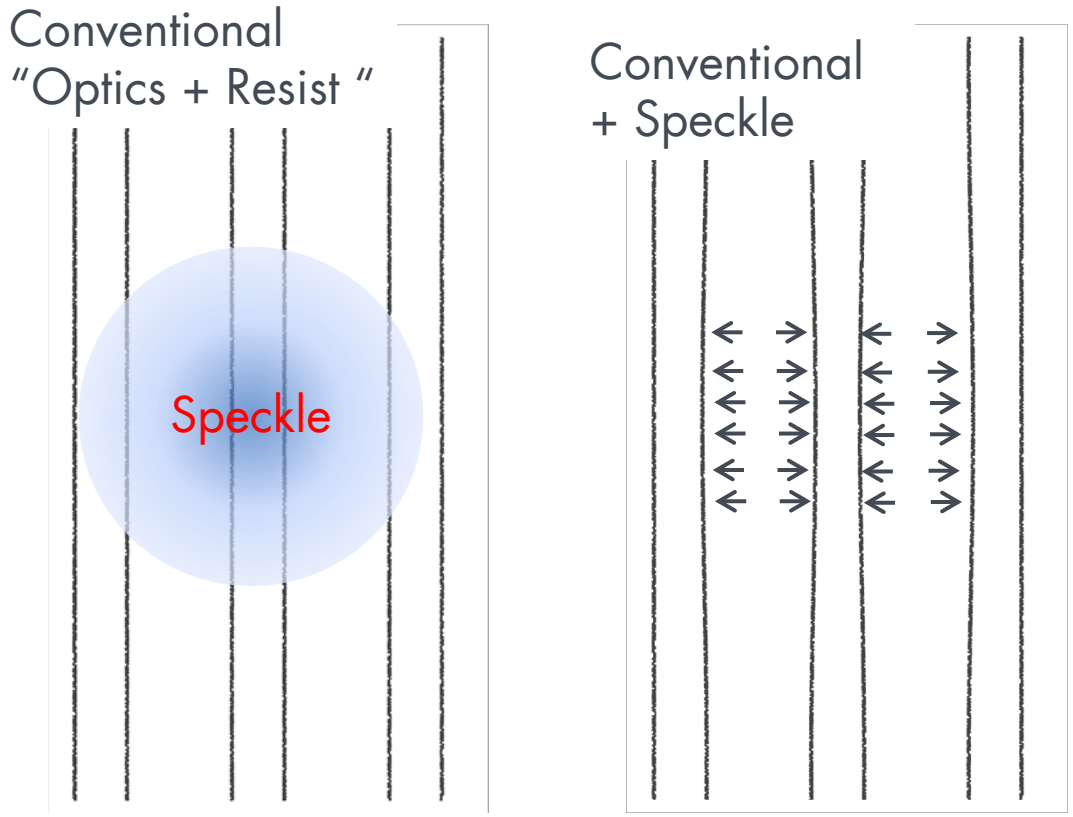
Speckle 2D Image





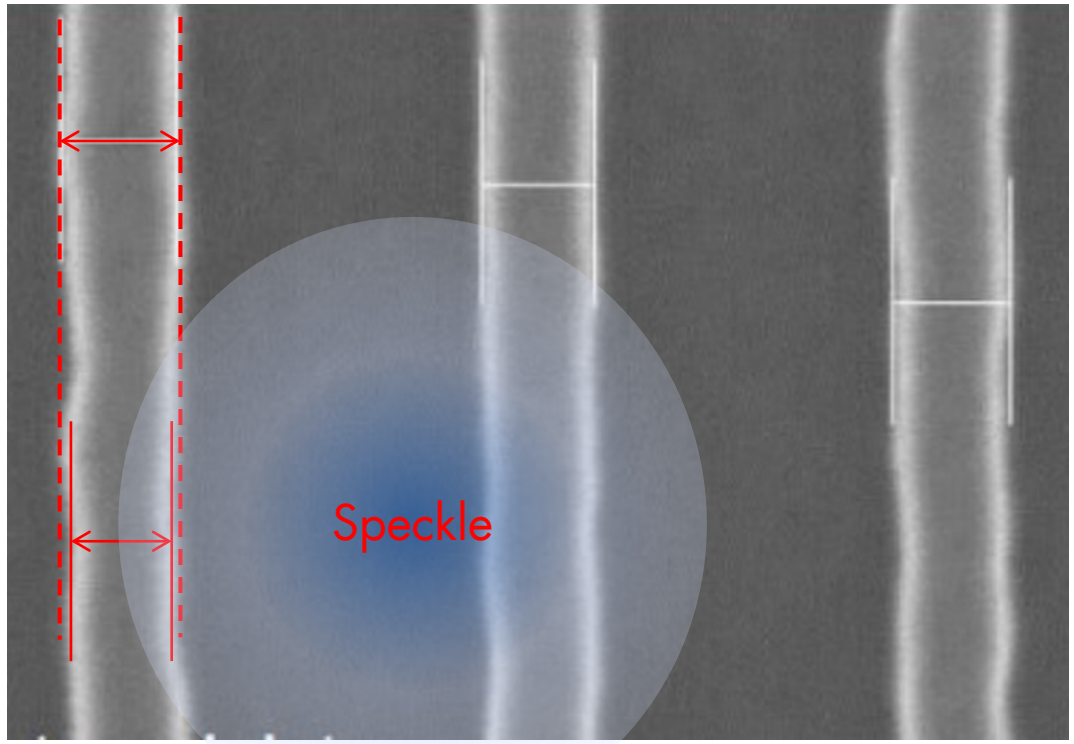
Actual Speckle contrast is measured that showing very low contrast %

Speckle Impact to LWR/ LER



Conventional LWR/ LER = High Frequency
Speckle LWR/ LER = Lower Frequency

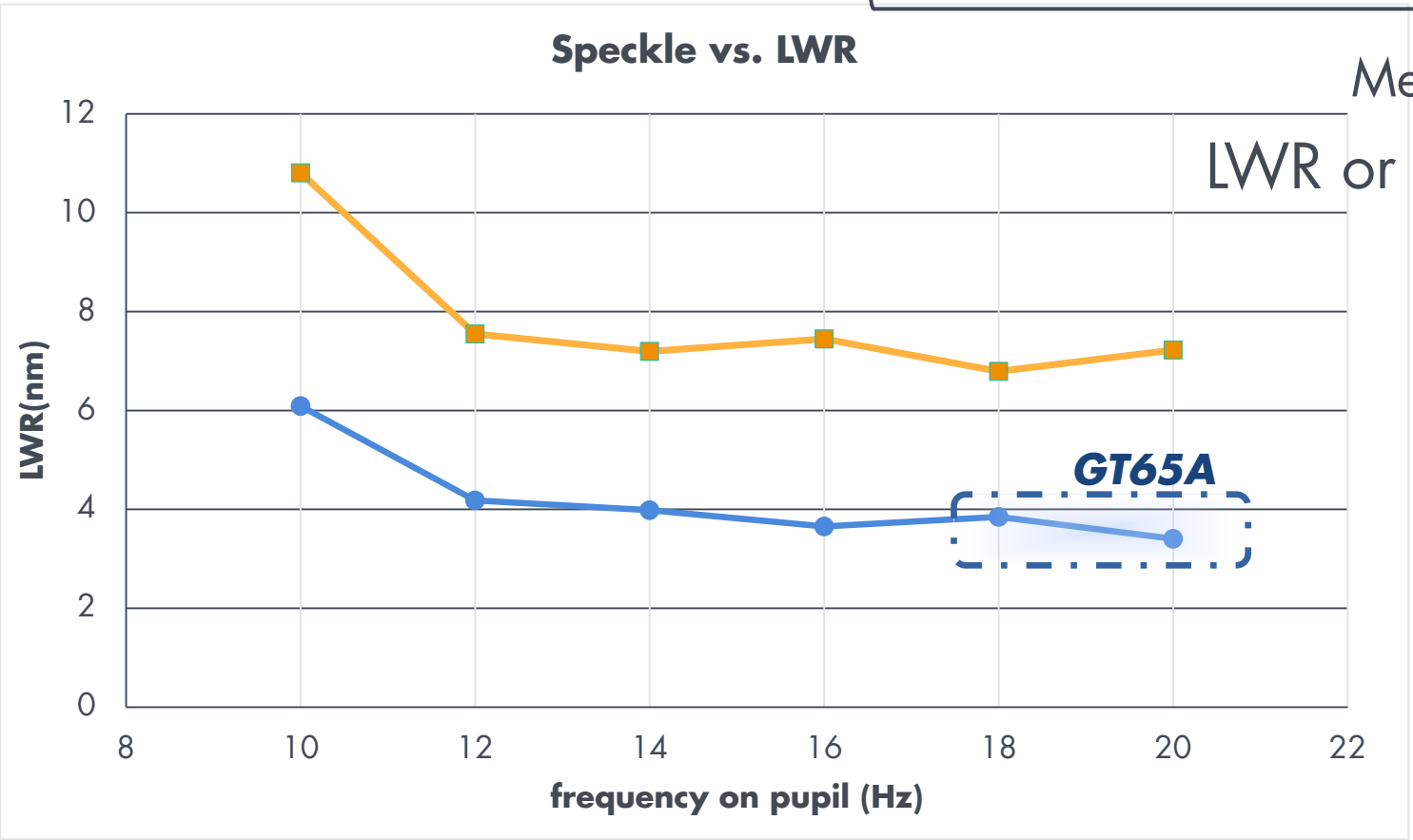
Speckle induced LER/ LWR



LWR = 10nm for 38nm Line
@ No pulse stretch

Speckle Impact to LWR/ LER

$$\text{Speckle Contrast } *= \sqrt{\frac{1}{N_{scanning}}} \cdot \underbrace{\frac{1}{\sqrt{N_{polarization\ states}}} \cdot \sqrt{\frac{\lambda^2}{A_{field}\,\Omega_{divergence}} + \frac{\tau_{coherence}}{TIS}}}_{\text{Measured}}$$



$$\text{LWR or LER} = \sqrt{(R)^2 + (O)^2 + (S)^2 + (M)^2}$$

R: Resist
O: Optics
S: Speckle
M: Measurement

- Feature: 38nm Line and 76nm Space
- Illumination: Dipole
- Resist: NRD

GT65A demonstrates low Speckle impact to LWR/ LER observing below 4 nm on wafer

* ASML paper at SPIE Proc. SPIE 7274, Optical Microlithography XXII, 72741R (2009)

Summary

Cutting-Edge GT65A with State-of-the-art technologies provides Process Yield and Tool Availability improvements which capable for 5/7nm Node the latest Lithography processes

GT65A

Process Yield and its Latitude improvement

	Conventional	Latest light source: GT65A
E95 BW stability	300 fm±30 fm wafer average	±1.5 fm <wafer average <10 fm field average 3σ
E95 BW set point	300 fm	Down to 200fm w/ Tuning
Spectral Engineering	Gaussian @300 fm	Option with Dual Peak or Flat Top
Speckle Contrast	TiS base Pulse stretching	50% SC reduction

Availability improvement to chipmakers

enabling <1 time a year maintenance

	Conventional [Bpls]	GT65A [Bpls]
OSC CH Lifetime	30	50
AMP CH Lifetime	60	80
LNM	60	100

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The Future is Today

THANK YOU

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