IWAPS 2023

A modern energy efficient laser-based mask writers, made in Sweden

2023-10-26 幸克昭博士 Dr. Kezhao Xing[1,*]

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[1]Mycronic AB (Sweden), [2]Mycronic Co., Ltd. (South Korea), [3]Mycronic Co., Ltd. (P.R China),

MYCRONIC

瑞典

国土：45万 平方公里（面积>德国）

人口：1,054万 人

位置：地处北欧万里之遥

诺贝尔奖发源地

高科技，高福利的国家

- 幸克昭博士，华中科大激光专业毕业，瑞典表面物理和化学博士，Senior Specialist，在MYCRONIC工作超过23年， 主要负责光刻机的开发工艺优化和整合

Worldwide **footprint**

More than 40 years
of experience in innovation

Mycronic is represented
in more than 50 countries

The power of innovation
is proven by more than 500 patents

More than 2,000 employees
in 12 countries

More than 28,000 production systems
at more than 5,500 customers

Headquartered in Stockholm, and our mask writers are all produced in Sweden

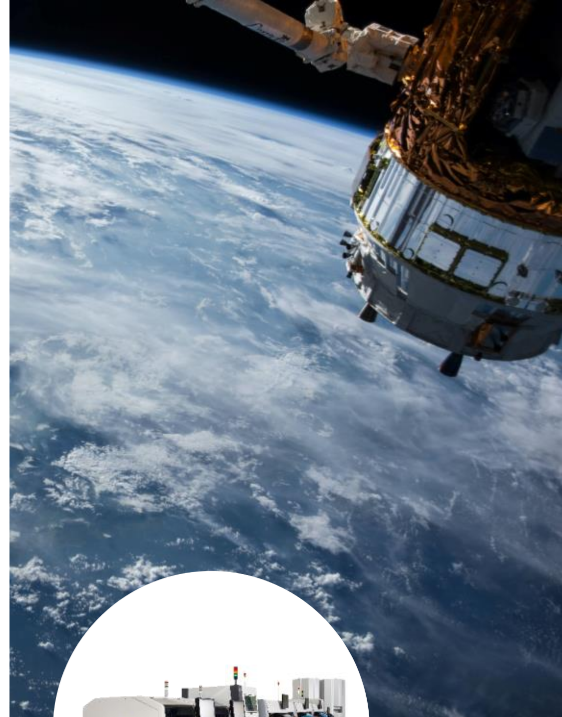
Mycronic's **four divisions**

Pattern Generators

Display, Semiconductor

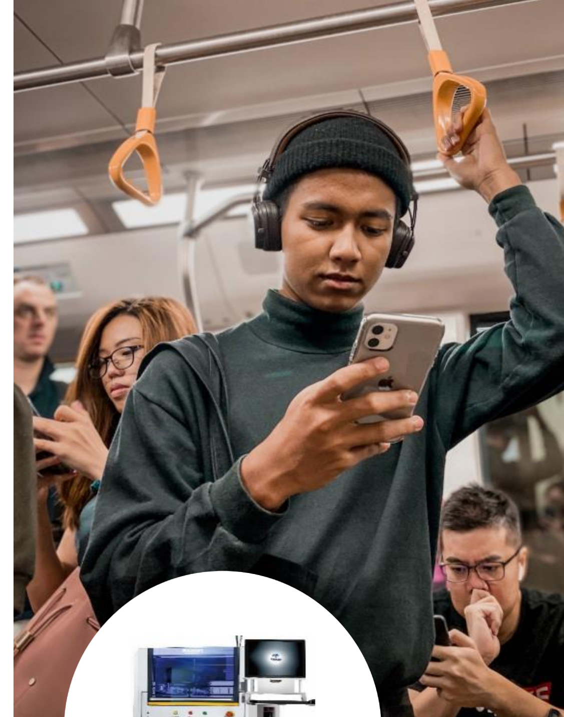
High Flex

Medical, Industrial, Aerospace & Defense



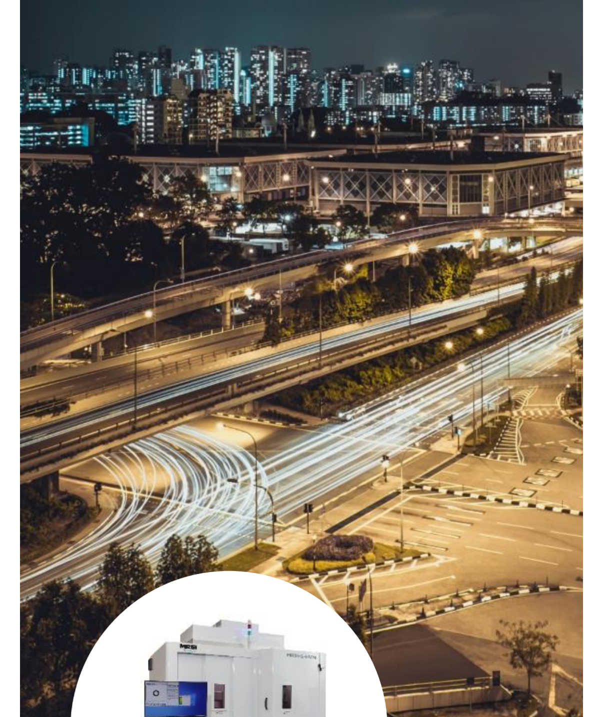
High Volume

Mobile phones, Computer, Semiconductor, Automotive, Consumer



Global Technologies

Telecom/Datacom, Aerospace & Defense Automotive, Medical, Semiconductor



New Mask Writer – SLX series

First Launched in October 2019

29
i-Line
SLX1， SLX2

15
DUV
SLX3 系列

To date 44 SLX systems sold worldwide

with several repeat orders

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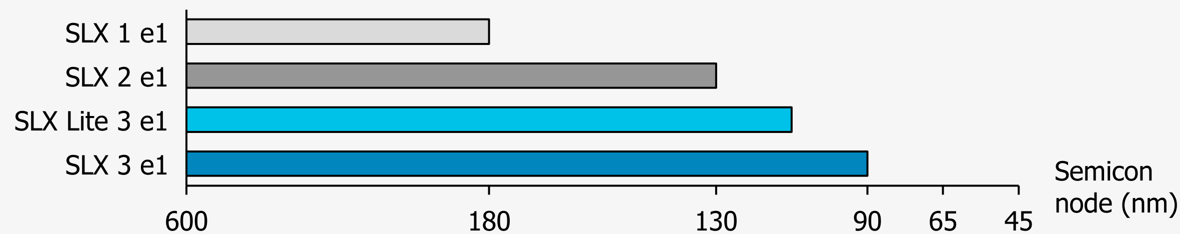
Semiconductor mask writer: Mycronic SLX series, four models

- **Built on an "Evo" control platform**
  - Modernized platform for both HW and SW perspective
  - Platform share within Mycronic Pattern Generators
  - REACH and RoHS 2 compliant
- **Two i-line and two DUV models**
  - SLX 1: I-line model optimized for high throughput
  - SLX 2: A well-balanced i-line model aiming for both productivity and quality
  - SLX Lite 3: A DUV model optimized for PSM
  - SLX 3: DUV tool addressable up to around 90 nm nodes



[Addressable semicon node by SLX models]

The design strategy Mycronic SLX systems

Proven technologies on modern platform

Writing strategy to meet both image quality and productivity

Beam splitter
Generate multibeam from single source

Modulator
Modulate each beam by fed pattern data

Solid State Laser
Low power consumption & Environment-friendly

Deflector
Generate Microsweep

Datapath
Feed pattern data to modulator

Zerodur stage
X & Y linear movement

Y

X

Microsweep Y

Scanstrip
X

激光器

控制信号

射频驱动

压电换能器

+1级衍射光

0 级光

目标

Life Cycle Analysis

A method to calculate the environmental impact of a product during its entire life cycle

Assumptions and prerequisites

- **LCA inline with ISO 14044 standard**
  - ReCiPe 2016 Midpoint (Hierarchist) method in commercial LCA software SimaPro 9.1 used
- This study is a cradle to grave assessment
  - It starts with raw material acquisition and ends with the disposal of the product

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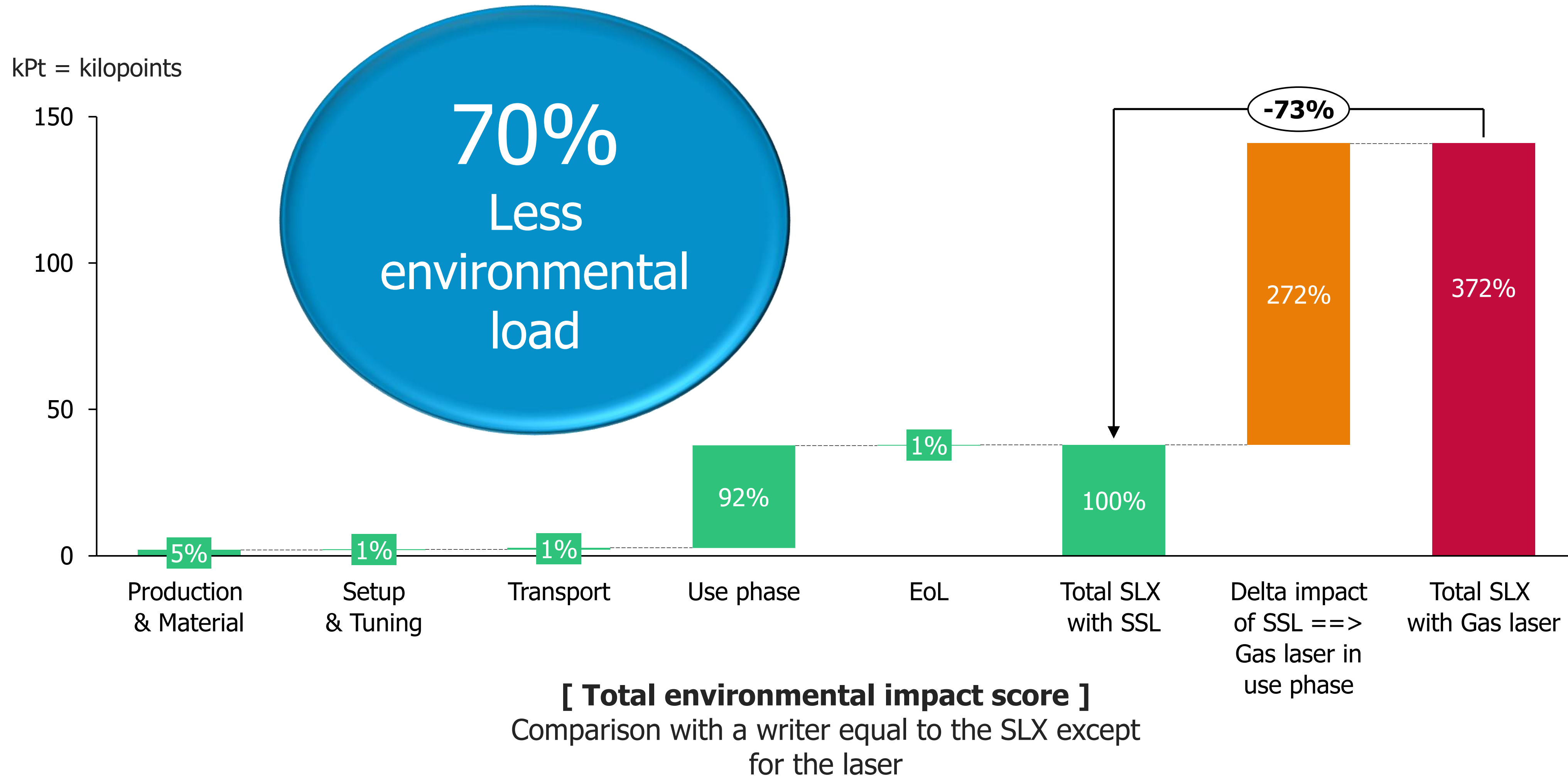
LC Phase wise Contribution Analysis – Gas laser vs Solid state laser

~70% less total environmental load with SLX vs an old gas laser-based mask writer



[Total environmental impact score]
Comparison with a writer equal to the SLX except for the laser

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Solid State Laser
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Deflector
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Datapath
Feed pattern data to modulator

Y

X

Zerodur stage
X & Y linear movement

Microsweep Y

Scanstrip X

目标

+1级衍射光

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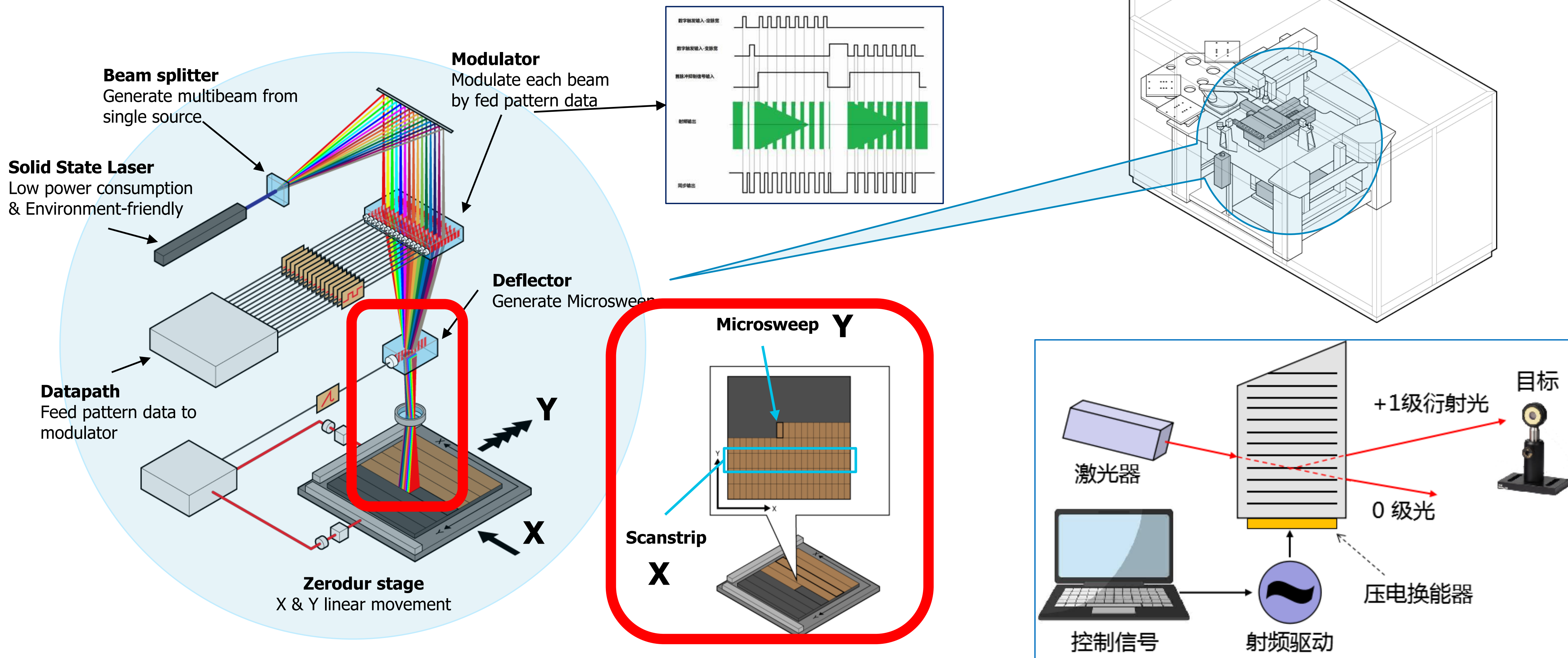
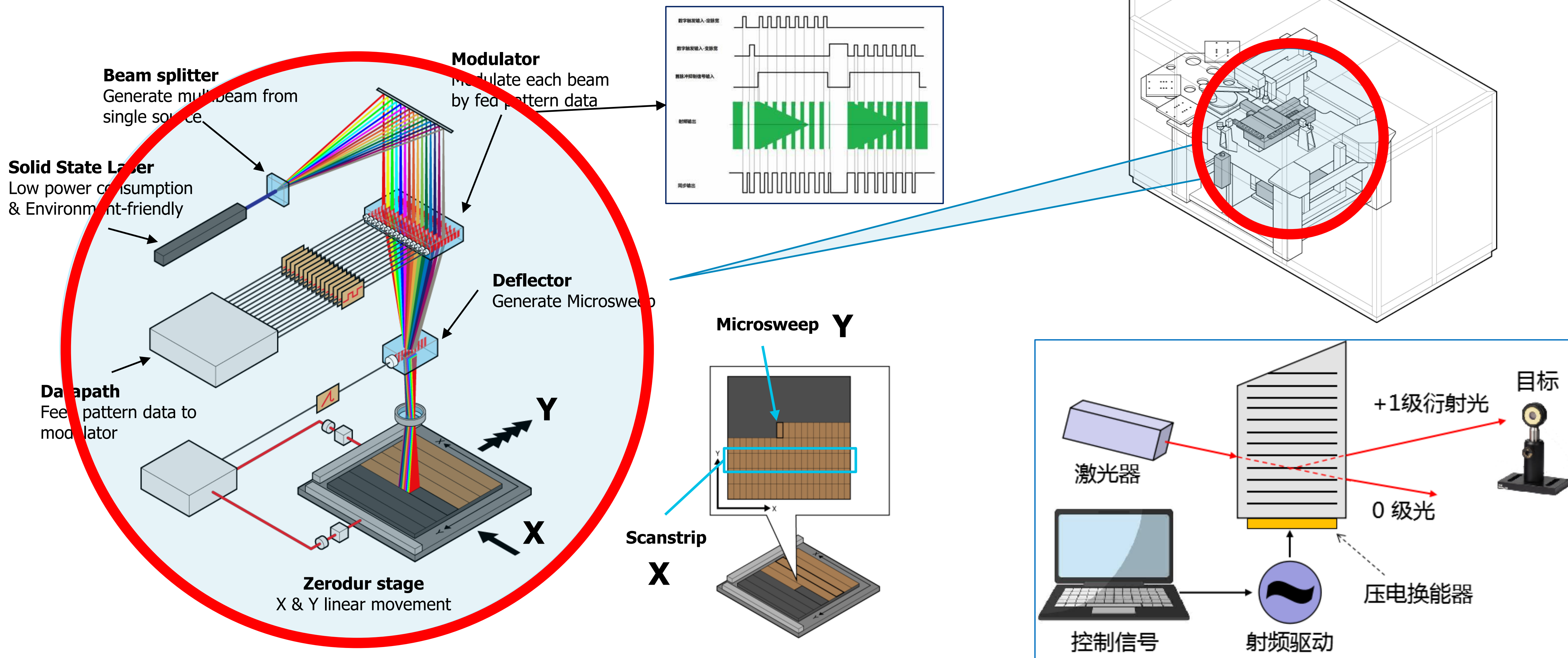


Proven technologies on modern platform

Writing strategy to meet both image quality and productivity



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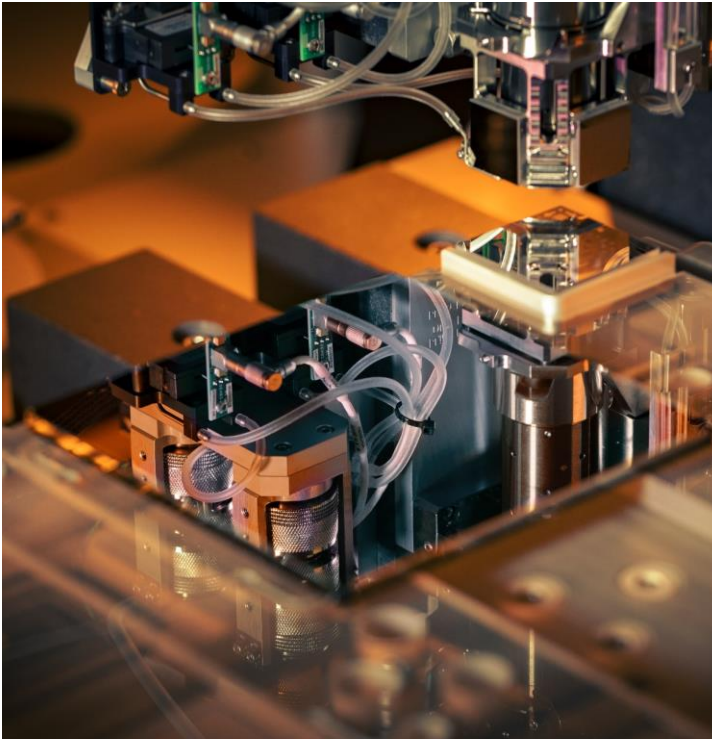
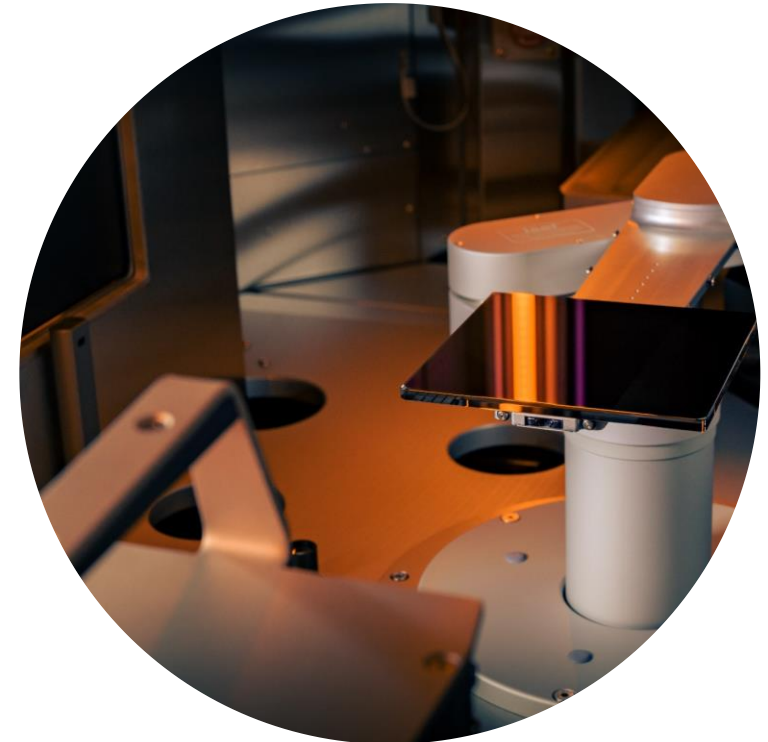
Proven technologies on modern platform

Writing strategy to meet both image quality and productivity



- Fixed optical head
  - Friction free dual cylindrical air bearings
  - Single axis voice coil with glass scale encoder
- X & Y stage movement
  - Movement control uses position feedback by glass scale at X & Y
  - Interferometers used for pattern position determination
  - Motion and position control decoupled, extends window for optimal performance
- Multibeam with modulator and deflector



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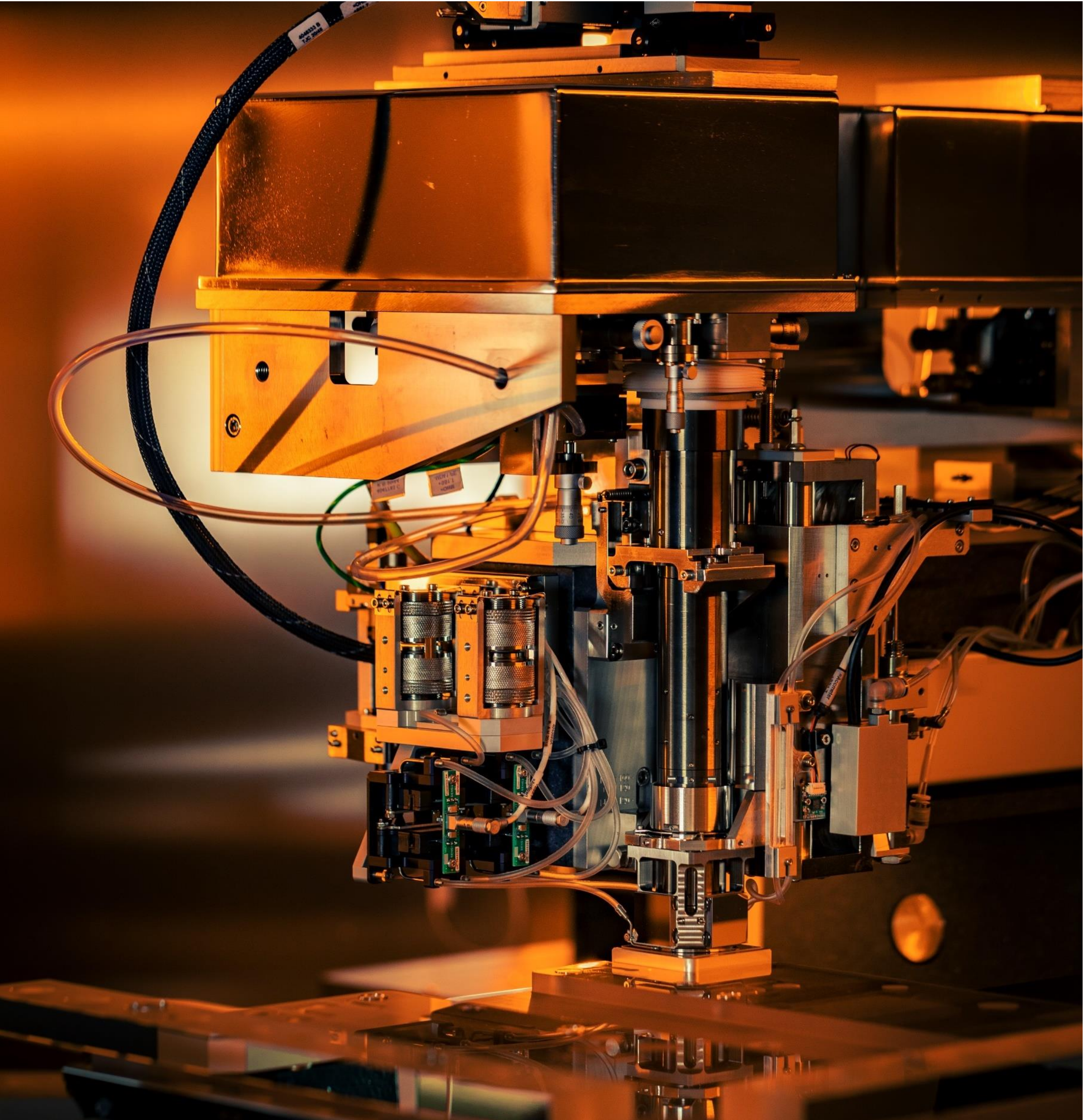

SLX3 DUVwriter, key features

- Solid State Laserr enabling low power consumption and environmental-friendly operation
- Unprecedented writing speed utilizing parallelized multibeam exposure and minimized overhead
- Field proven offline data path with write time independent of pattern complexity
- Contamination free and reliable platform with unmatched uptime
- Wide range of configuration options
- Qualified with standard DUV process using FEP-171 resist or i-line process IP3500

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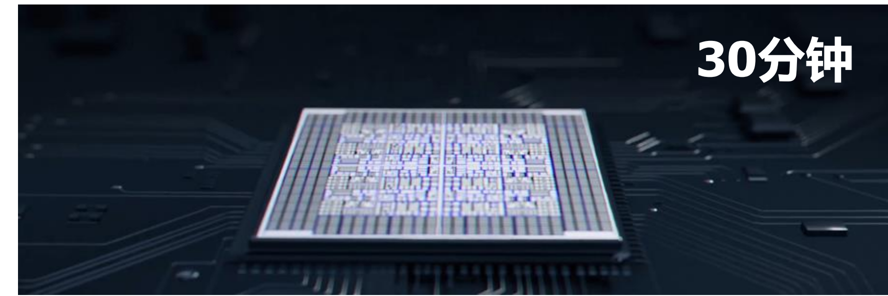
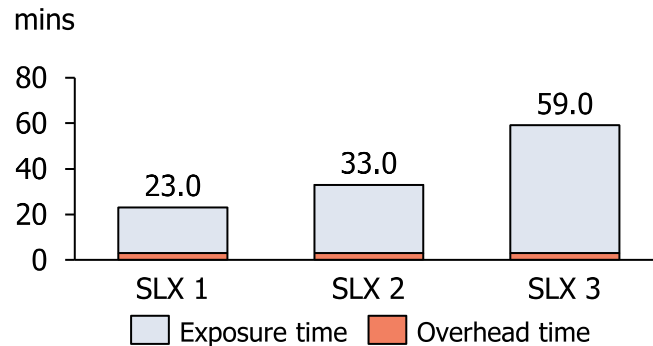
High Throughput: SLX series

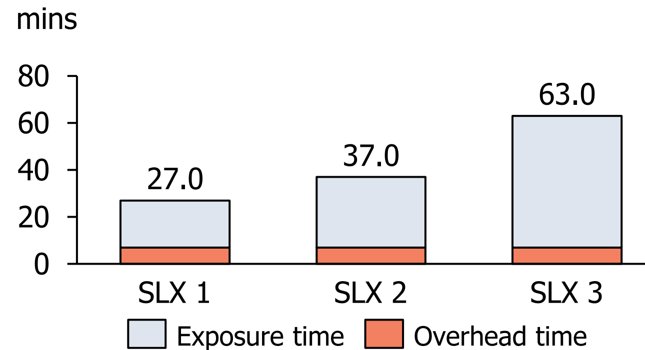
Enhancing turnaround time with optimized sequence





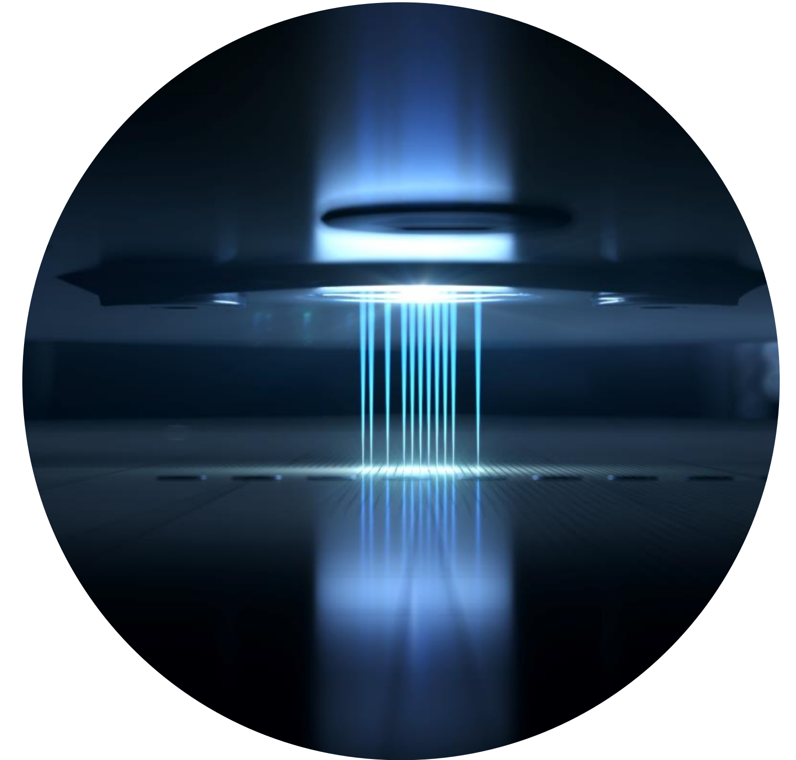
Exposure time Overhead time

Binary Mask Exposure times
Estimate turnaround time between SLX models (full 6” mask / 1 pass)



Exposure time Overhead time

2nd Layer Exposure times
Estimate turnaround time between SLX models (full 6” mask / 1 pass)



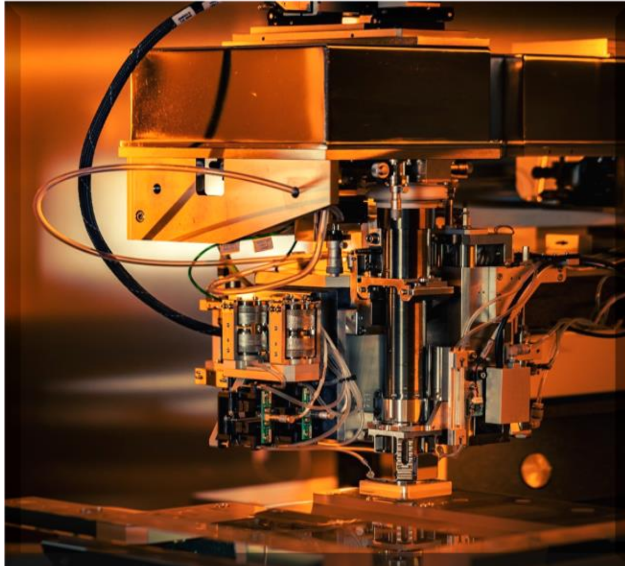
High throughput with enhanced turnaround time of the SLX provides secondary advantages

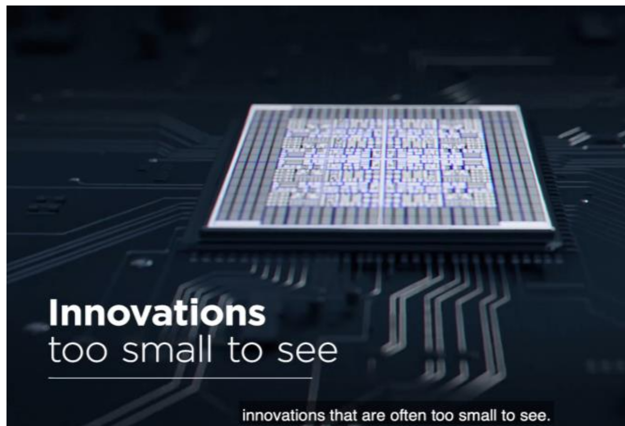
- Less mask writers required for same amounts of masks ➔ More efficient used of cleanroom
- SLX produces more masks for the same environmental footprint ➔ Less environmental impact per mask

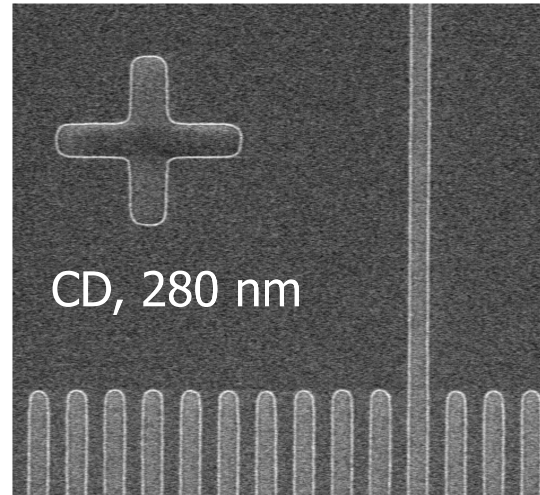
SLX series: Mask quality

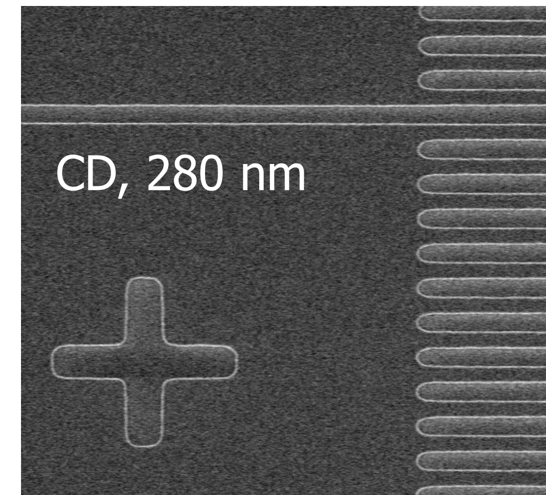
SLX 3, achieved results

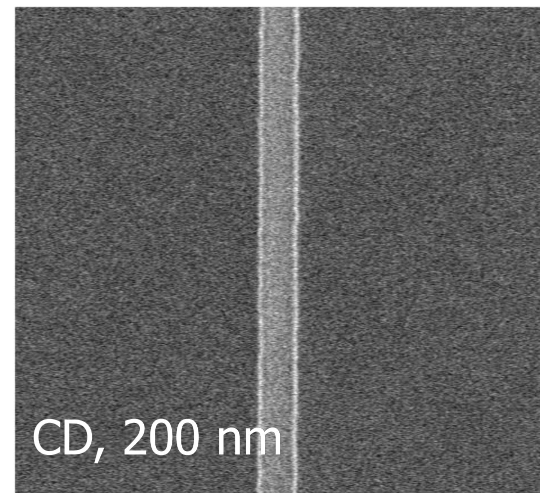
Resolution

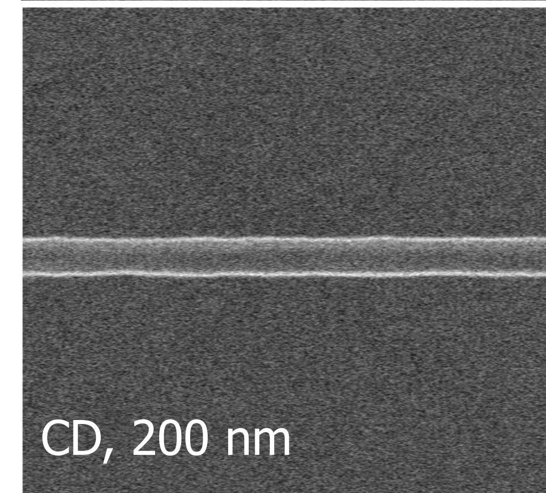












SLX 3 Printing

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SLX 3, achieved results in 3 pass writing

CD Uniformity: **max<5.5nm**

Resist dose threshold

- The resist edge can be moved into correct position by dose correction of the edge beam

Corrected

XCD	411.7	412.8	414.4	413.0	411.6	416.5	414.4	412.2	414.5	411.4	413.6	413.4	411.7
	412.7	412.3	413.4	412.4	415.5	413.6	415.0	411.7	413.9	411.3	413.1	409.0	410.0
	412.3	416.3	412.2	411.1	415.3	411.2	413.5	411.8	412.9	411.3	412.3	410.1	412.0
	414.2	413.9	413.3	415.4	414.8	414.9	412.1	414.8	408.6	414.0	412.9	410.8	416.3
	410.4	415.9	414.3	414.5	415.1	417.5	411.6	411.6	413.9	413.4	416.4	412.9	415.8
	412.8	410.6	409.9	413.9	414.8	410.2	414.0	412.8	415.2	413.9	411.8	411.4	413.1
	411.6	414.4	411.4	413.8	416.7	411.8	414.5	414.1	415.6	411.4	412.0	414.7	412.5
	413.2	411.3	410.3	411.2	416.1	414.2	414.2	412.2	412.3	411.4	409.9	412.1	409.2
	413.9	411.6	413.8	413.4	415.1	415.1	410.9	412.0	412.8	413.5	410.7	410.6	412.0
	413.0	413.7	415.0	413.8	416.6	413.0	414.7	415.6	411.5	413.3	414.7	413.0	411.7
	413.8	412.5	416.4	413.1	416.6	411.3	415.7	412.9	414.6	413.6	414.0	412.5	414.4
	410.0	410.9	409.6	412.8	417.3	411.3	414.8	410.6	412.9	412.2	413.1	413.5	412.5
	410.1	412.1	410.3	412.0	412.7	414.5	414.4	415.2	414.7	412.6	412.7	410.8	412.8
YCD	412.7	415.0	413.9	414.5	416.1	412.0	412.9	412.9	411.5	412.1	412.0	411.7	414.3
	414.7	410.6	412.5	411.4	412.2	412.3	410.8	409.6	410.1	410.6	411.5	412.3	413.8
	412.4	412.6	410.2	412.4	413.2	410.1	410.7	411.6	412.6	409.6	410.6	410.9	412.8
	409.9	411.3	410.8	412.0	412.5	411.2	410.1	409.7	411.8	408.7	413.4	413.0	414.8
	411.5	412.8	412.4	412.9	412.9	412.9	412.6	410.7	411.2	413.4	412.7	414.9	413.3
	410.9	411.5	410.2	413.3	412.0	411.9	410.8	412.0	409.5	409.7	410.3	413.9	412.9
	411.1	412.2	412.1	410.9	412.1	411.5	411.2	411.8	412.3	411.9	411.4	412.5	412.9
	410.4	410.9	410.9	411.7	411.8	412.4	410.7	410.3	409.4	410.2	411.1	412.9	412.3
	411.4	410.8	412.1	412.2	411.7	412.9	410.1	412.6	411.6	411.3	412.3	412.0	414.2
	410.9	411.0	412.2	414.8	411.6	412.7	412.7	412.9	411.5	411.3	411.2	412.8	413.7
	411.0	411.7	412.9	412.7	413.8	412.5	410.1	412.5	410.5	413.0	411.5	414.4	411.6
	412.6	411.7	412.0	413.5	411.5	412.0	411.8	412.3	413.2	411.1	409.2	413.1	413.3
	412.2	411.8	409.3	412.2	411.7	412.7	413.7	412.3	411.9	412.0	413.2	413.0	415.7

	X	Y
CD Uniformity (3σ)	5.5 nm	3.9 nm

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SLX 3, achieved results

CD Linearity: **max <10nm** (400-1500nm)

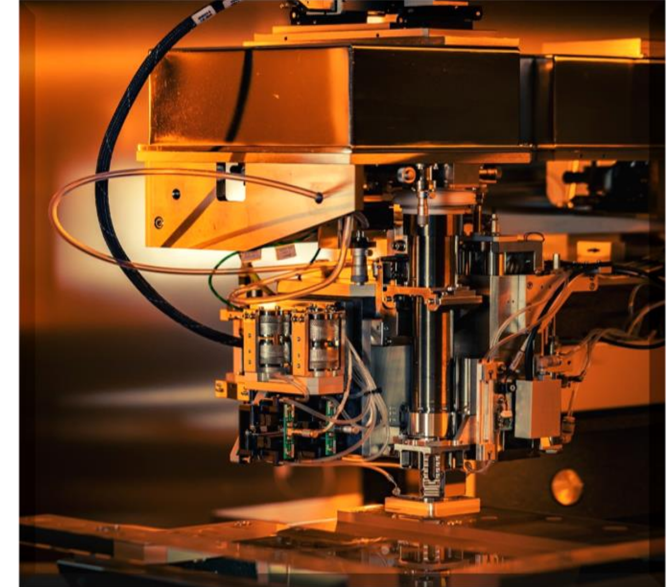
Linearity / Clear Lines

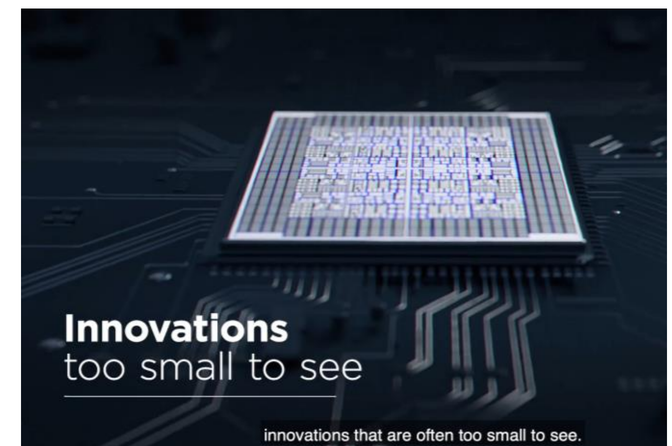
MTN (nm): 25, 20, 15, 10, 5, 0, -5, -10, -15, -20, -25

Design CD (nm): 150, 300, 450, 600, 750, 900, 1050, 1200, 1350, 1500

Legend: XCD, YCD

	X	Y
CD Linearity (Max-Min) 400 nm – 1500 nm	9.5 nm	6.7 nm

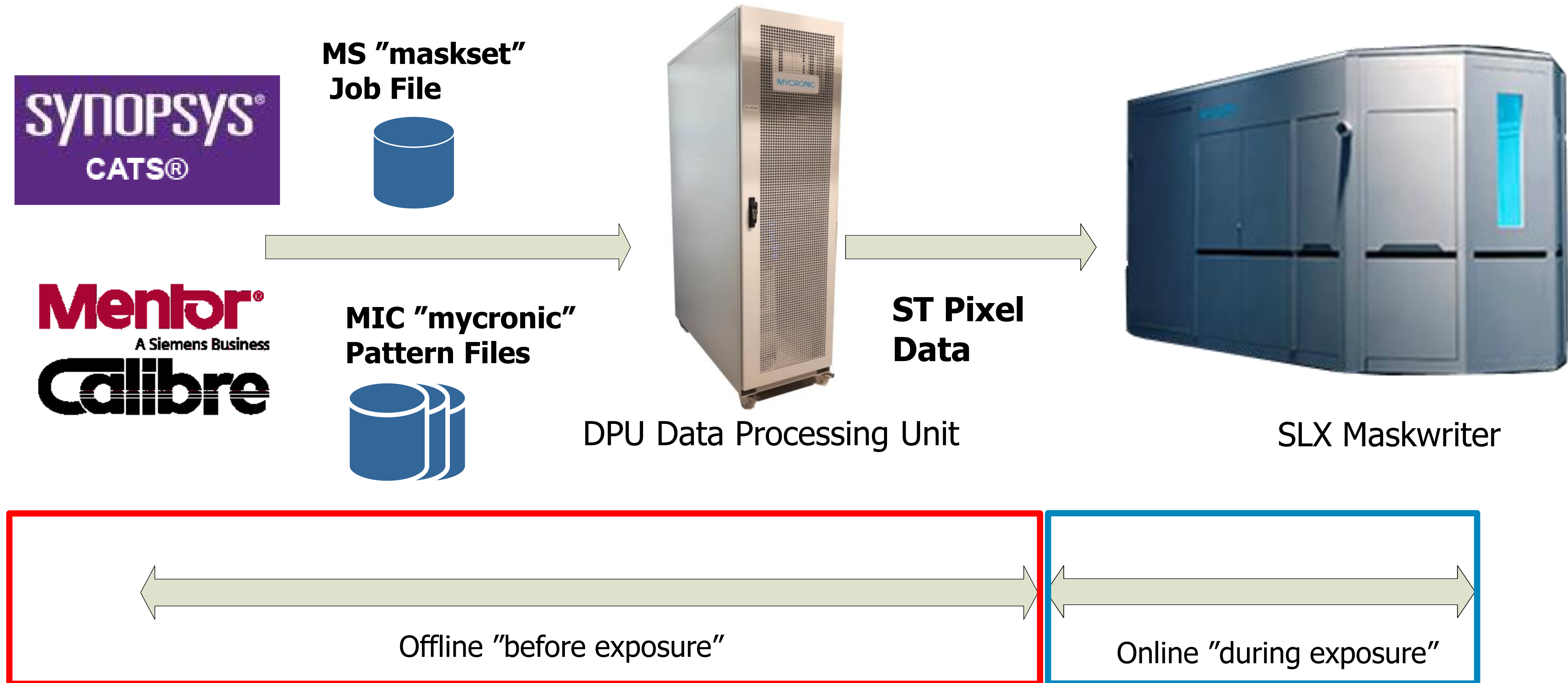




SLX 3 Printing

SLX systems: Integrations

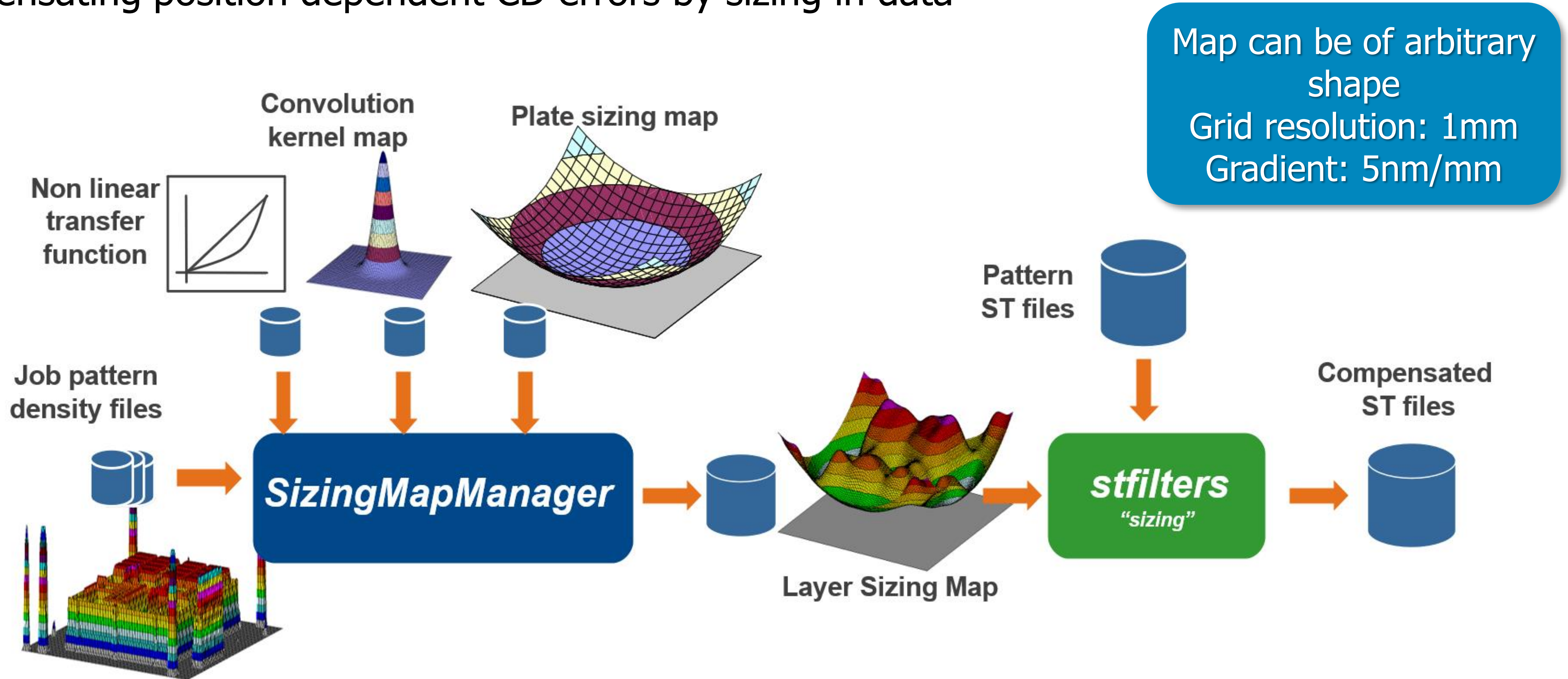
Integration at the customer site: Pattern Data



Process match: Process Equalizer

Compensating position dependent CD errors by sizing in data

Map can be of arbitrary shape
Grid resolution: 1mm
Gradient: 5nm/mm



Process compensation: Process Equalizer

SLX 2, Global CD Uniformity, with and without a rotational symmetric best fit

879.5	866.3	864.8	866.7	870.6	865.7	878.2	870.8	870.7	871	872.3	871.2	879.2
872.6	867.6	866.9	868.4	859.3	864.4	870.8	864.2	861	867	862.1	869.4	877.8
869.9	876.3	859.8	861.7	865.9	855.2	859.8	858.1	867.6	869.1	869.7	870.5	871.9
868	879.1	859.5	860.3	854.9	864.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
876.2	868.7	860.7	861.2	864.2	852.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
870.7	873.8	866.6	859.3	863.8	858.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
869.6	868.1	858.9	867.4	860.9	858.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
870.8	871.7	862.6	859.2	868.7	867.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
877.6	869.6	872	863.7	865	860.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
877.1	872.1	871	867.8	861.2	870.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
882.7	876.7	870.8	873.4	879	866.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
883.5	872.1	876	875.7	874.4	874.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
884.3	880.2	879.8	887.2	879.7	882.7	875.9	882.3	882.9	881.1	882	881.9	888

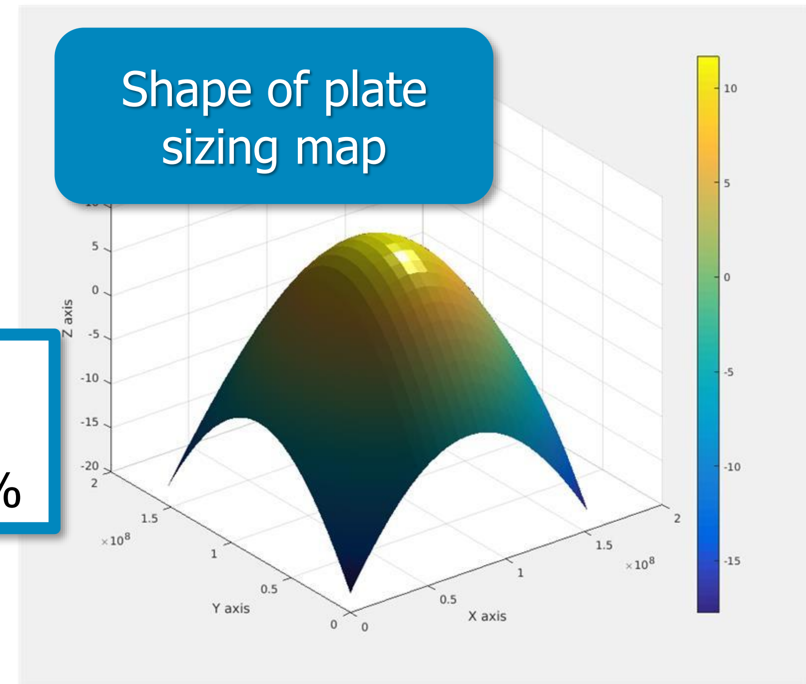
Exposed without plate sizing map
13x13
CDU 3σ: 23.4nm

891.1	882.7	884.9	888	895.2	883	889.3	889.8	887.9	892.6	889.3	877.1	888.3
887.2	880.9	884.1	887.8	881.4	881.3	885.8	883.3	883.8	881.5	879.5	877.5	885.6
881.9	883.6	881.8	879.1	884.4	882.3	880	879.3	888.9	886.6	890.7	882.8	885.4
886	894.1	879.6	880.4	877.8	885.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
886	888.2	877.4	882.4	891.5	878.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
889.1	891.1	882.1	878.5	881.2	879.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
884.7	881.5	878	888	885	884.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
884.4	887.1	883.5	880.7	884.1	884.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
887.1	883.4	887.8	878.5	888	878.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
882.6	879	880.3	882.8	876.4	883.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
883.1	884.1	882.1	884.7	891.5	874.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
877.8	881.3	879	882.5	884.4	882.1	876.8	881.6	876.4	881.5	880.3	885.1	888
880.4	885	879.8	879.6	881.8	886.9	879.7	886.9	880	885.8	885.4	882.2	889.5

Exposed with plate sizing map
13x13
CDU 3σ: 12.5nm

A reduction of the global CDU with almost 50%

Shape of plate sizing map



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OPC

Compensating for lithographic corner pullpack and line shorting

- The compensation is applied on ST rasterized pattern data.
- CE works on all corners with an opening angle of 90°, inner and outer, and with sides parallel to the X- and Y-axes, ”Manhattan”.

Corner Enhancement

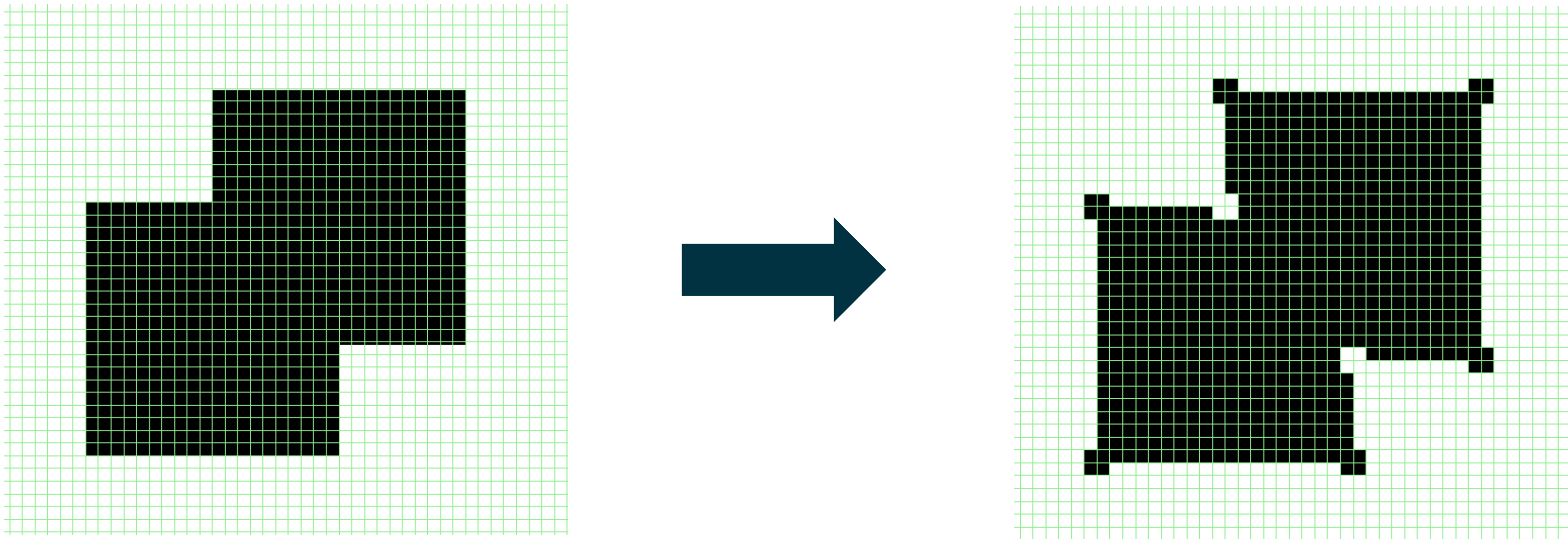

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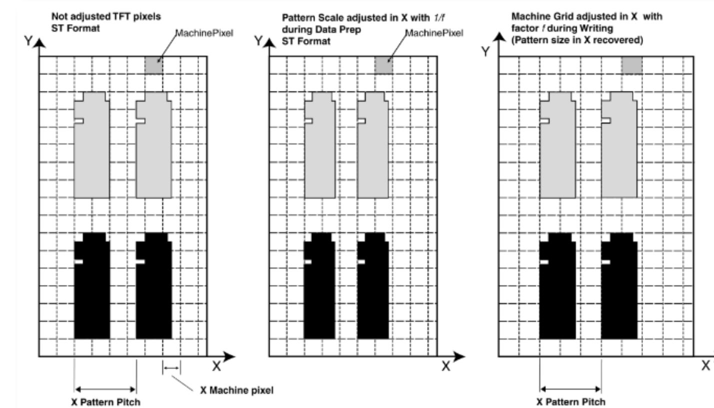
Image sensor

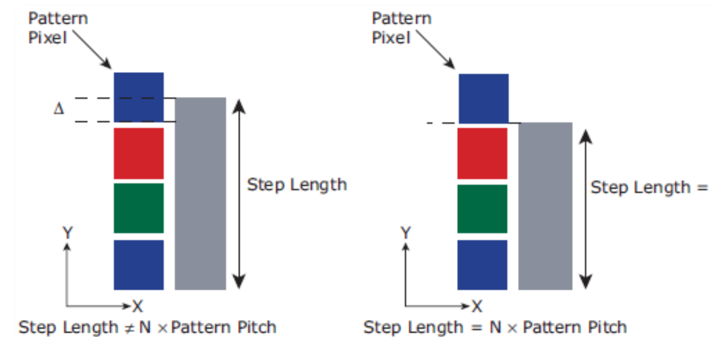
Ensure “Mura” sensitive application

- Mura control tools is made up with three functions
    - X-pitch optimization
    - Y-pitch optimization
    - Step height adjustment
- The function is for customers that aim for “Mura” sensitive application such as imaging sensor or similar applications with cyclical pattern descriptions



X-pitch optimization

The distance from one pixel to the next one is adjusted matching to machine grid in X-direction



Step height adjustment

Function to adjust sweep length matching to multiple of pattern pitches

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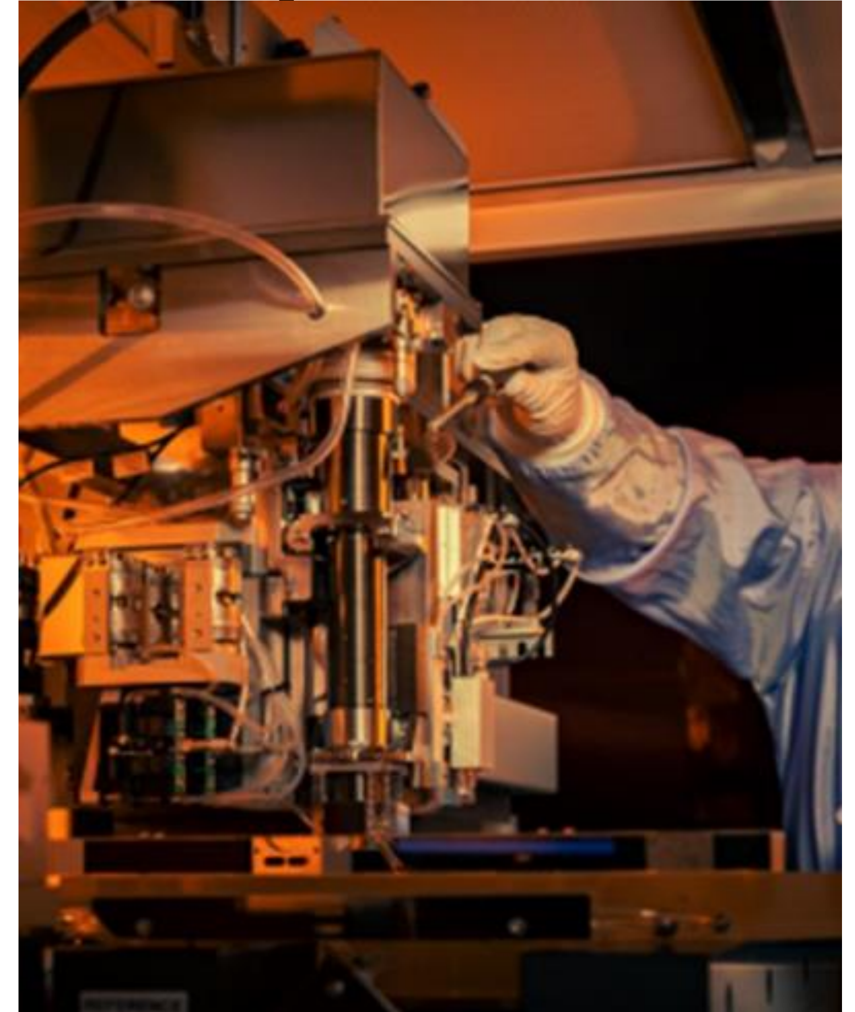
Mycronic service coverage: Worldwide

On request: 24-7



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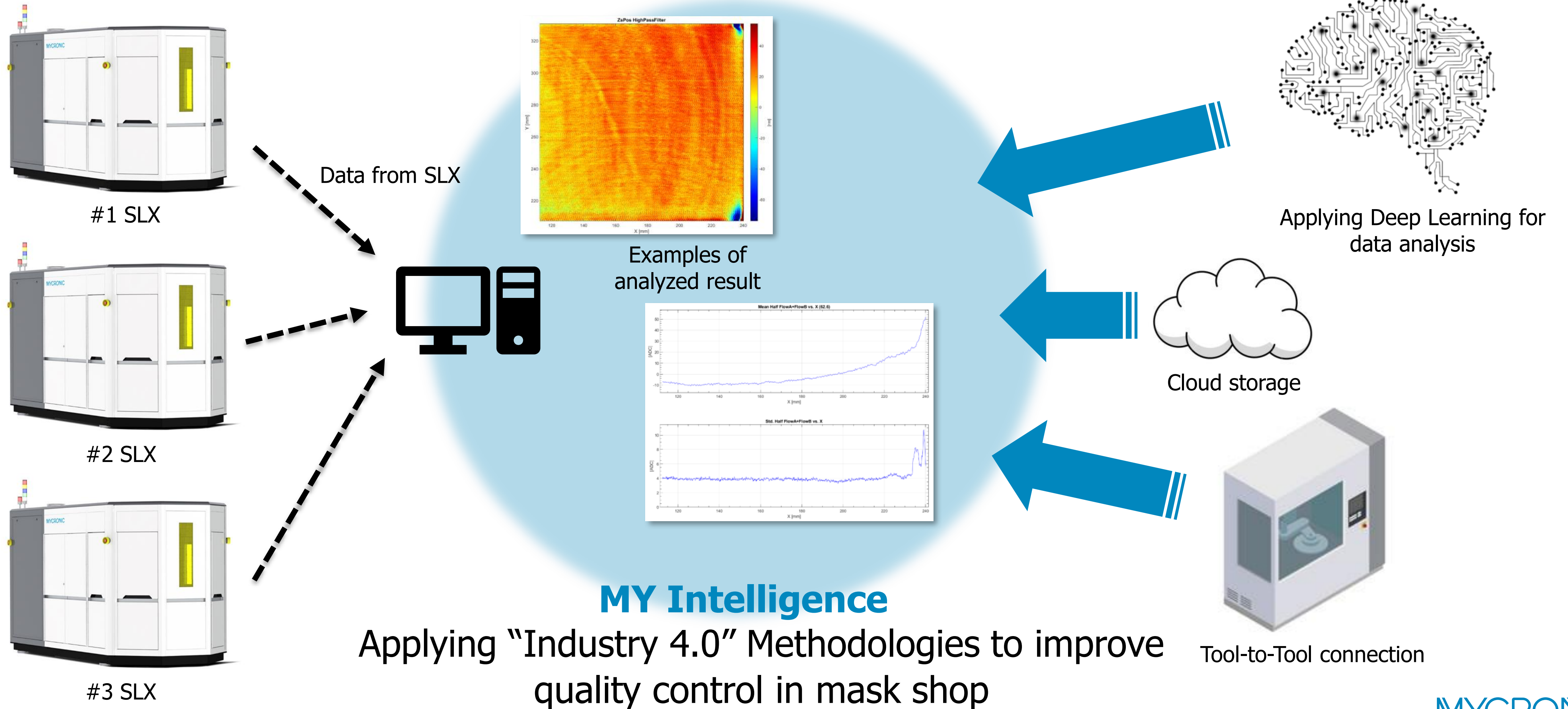
Application at the customer site: AI& Machine Leaning



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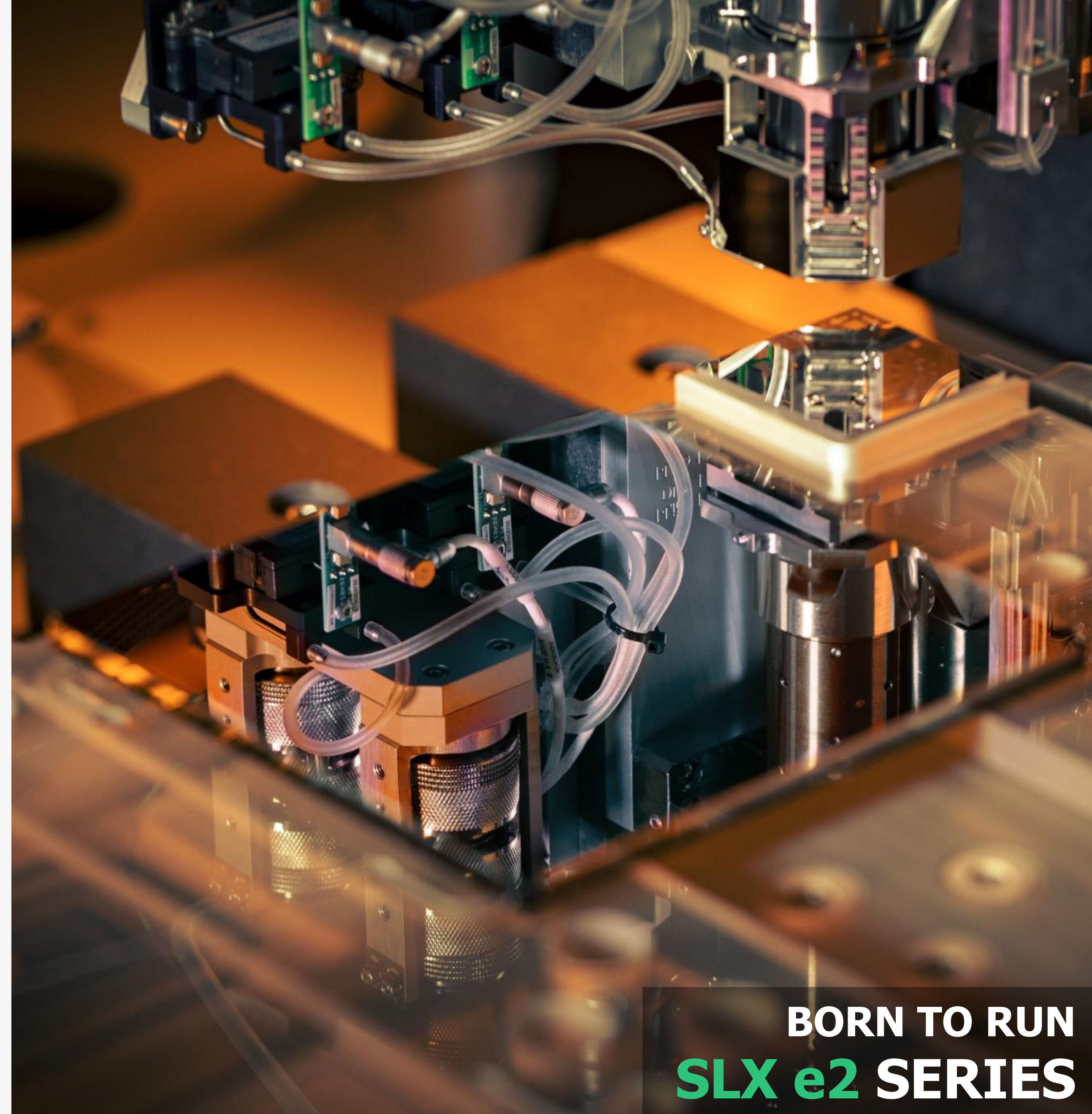
Summary

- SLX series is designed with aspect on low environmental impact
- The SLX has been well accepted by market, with extremely high throughput, and high ROI
- Mycronic commits for continuous evolvement of SLX series and as a part of that, the SLX e2 series was introduced last year。 SLX e2 will extend addressable layers through finer resolution and tighter specifications and enable data collection and analysis through My Intelligence



SLX series, committed for continuous evolvement

Mycronic's long team ambition in semicon industry

Build up experience in mask writer through Semicon and Display applications

Launch of SLX e1 series built on **shared modern platform**

Low environmental impact
~70% lower environmental load, primarily driven by a reduction of power consumption in the use phase

Very stable and reliable platform
- Prexision uptime >97%
- SLX uptime already >90%

Continuous development on **Data analytic** through CDLe, launch of **MY Intelligence SW**

- **Mycronic** is planning a comprehensive development program to develop the tool and optimize platform over the coming years
- Long term ambition 3-5 years
  - >2X productivity at a given performance
  - Push both i-line and DUV capability one semicon node

Bringing tomorrow's electronics to life

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