Accelerating the future

EPIC Meeting on Wafer Level Optics

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Friday, November 8, 2019

Customized High Volume Testers for Wafer Level Optics

Outline

- Introduction NTS-group
- Introduction NTS Optel
- DOE and MLA test parameters
- Configuration of an optical wafer tester
- Some challenging topics:
  - Pattern imaging (optics)
  - Laser module: Single versus multimode
    Working distance & beam quality

NTS: First-tier systems supplier of (opto) mechatronic systems and mechanical modules

- Build-to-print and build-to-spec
- High complexity products
- Low volume manufacturing
- High mix of product diversity

Eindhoven

Headquartered in Eindhoven, the Netherlands

€ 270+

Million turnover

1700+

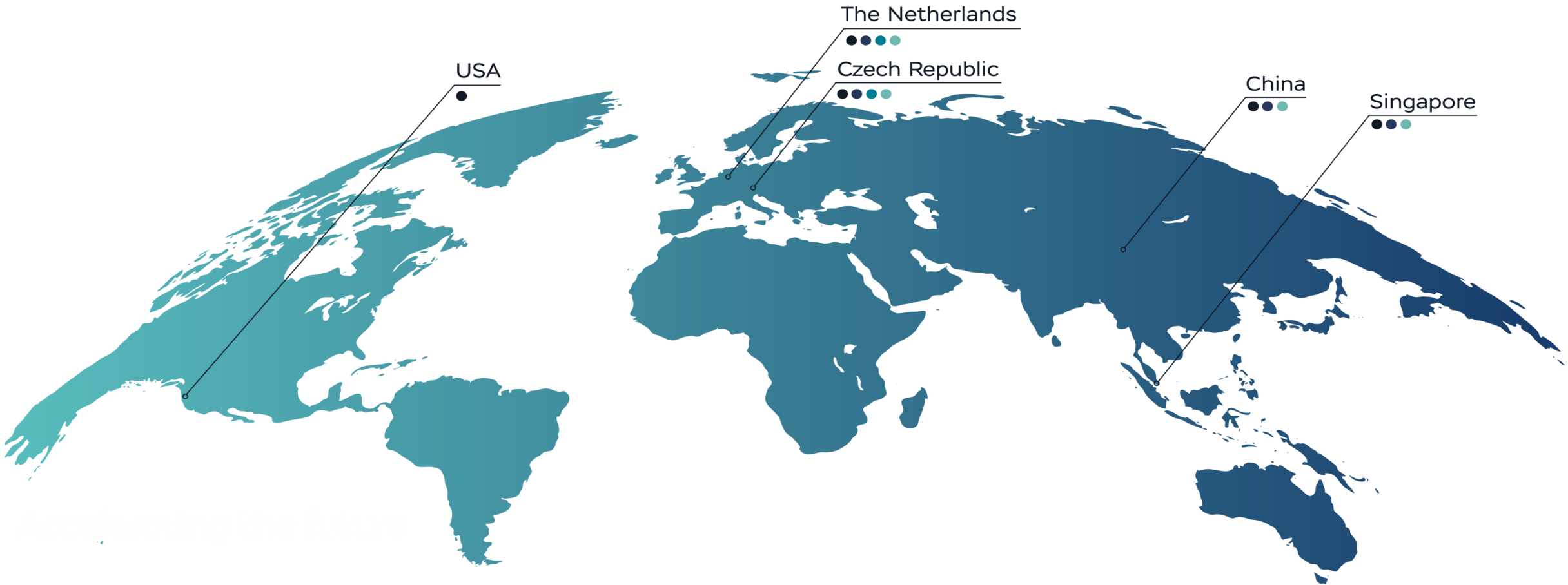
Employees worldwide

70+

Years of experience in manufacturing industry

NTS' global presence

- **Development & Engineering,**
- **Precision Components,**
- **Precision Frames & Cabinets,**
- **System Integration**

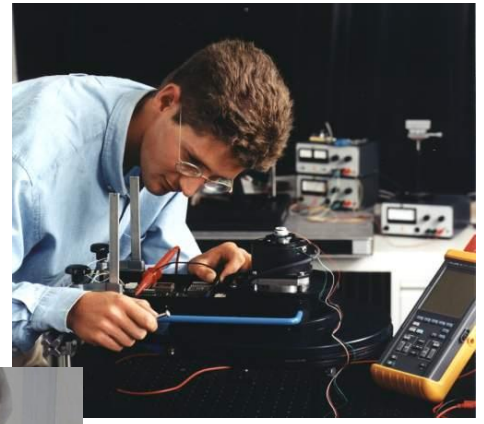


NTS Optel: Development and manufacturing of **custom** opto-mechanical systems

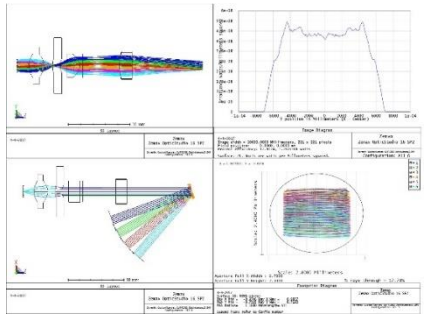
- Ray-tracing and opto-mechanics – ensuring best optical performance
- Optical tooling – enabling industrialization of your metrology solution
- Opto-mechatronic systems – custom, integrated turn-key inspection solutions

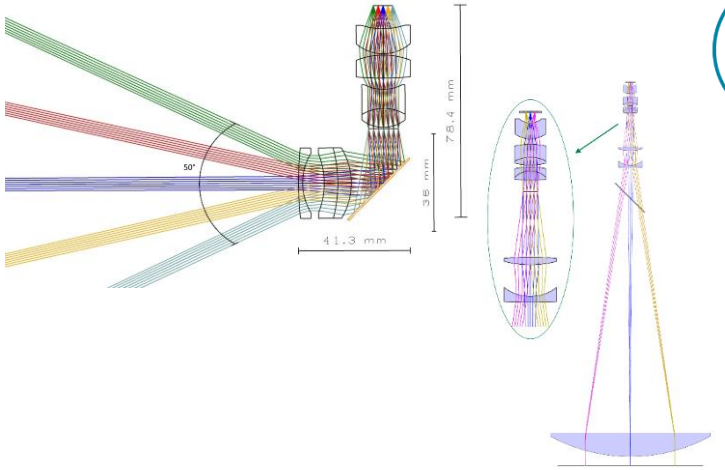
- Extensive team of highly qualified and experienced design and assembly engineers
- Design and build turn-key, one-off systems and prototypes
- In-house small and medium series production
- ISO 9001 and ISO 13485 certified

New facility April 2020



NTS Optel competences



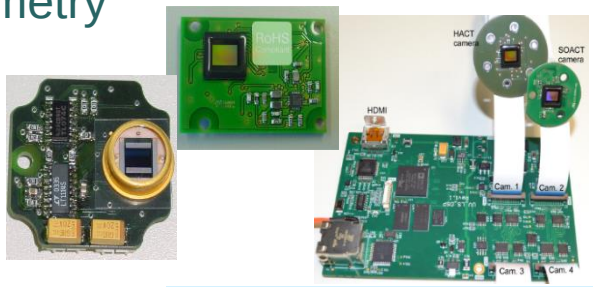


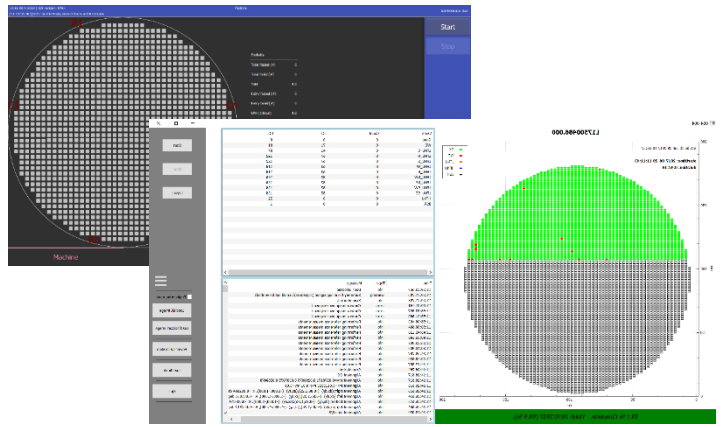
We use ray tracing for our optical designs

And apply all imaginable optical techniques:

- Vision techniques
- Laser triangulation, distance and 3D-measurement
- Laser and white light interferometry
- Laser diffraction
- Spectroscopy

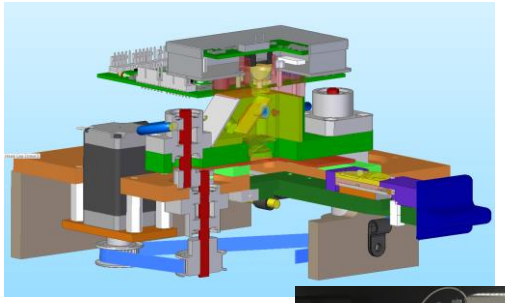
from EUV, UV, visible, NIR to IR.



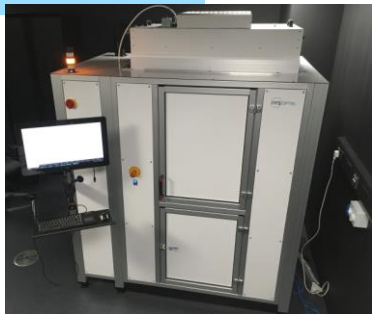


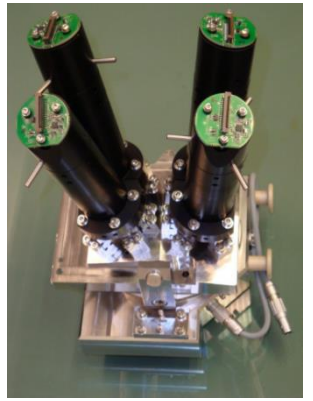
Add the electronics:

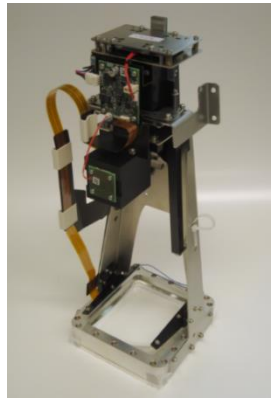
- Analog and digital electronics design
- Embedded software



We design and build the mechanics



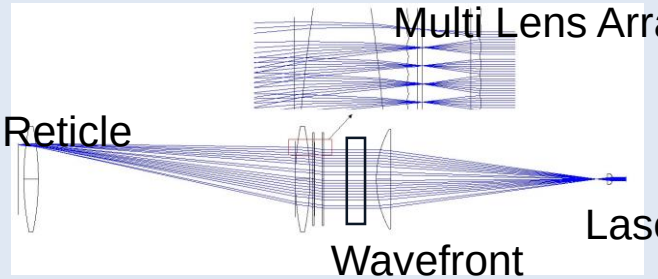


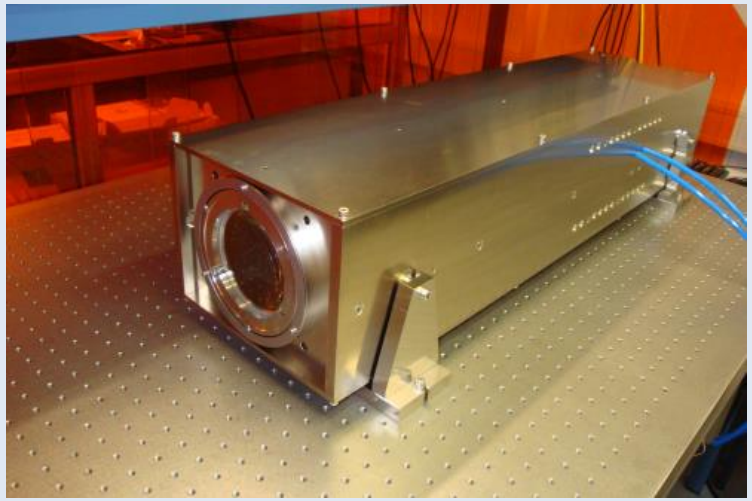


And implement software for processing, control and GUI

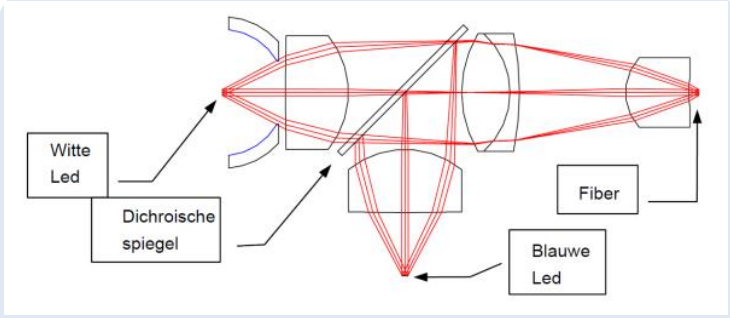
Thus, we provide complete solutions!

Some optical devices and systems



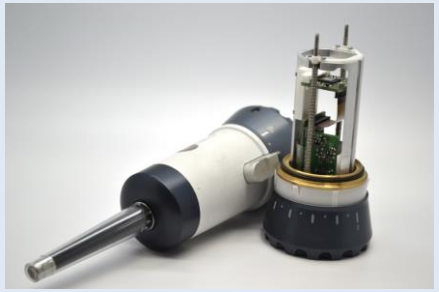


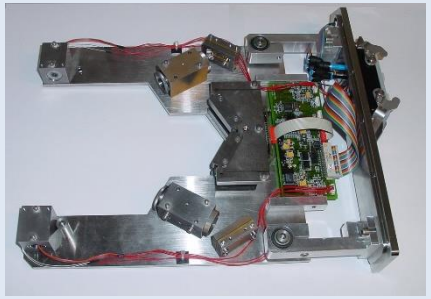
UV beam homogenizer

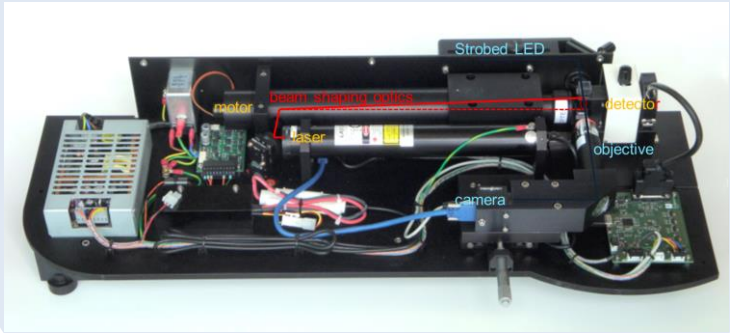


Endo-illuminator

Diverse products



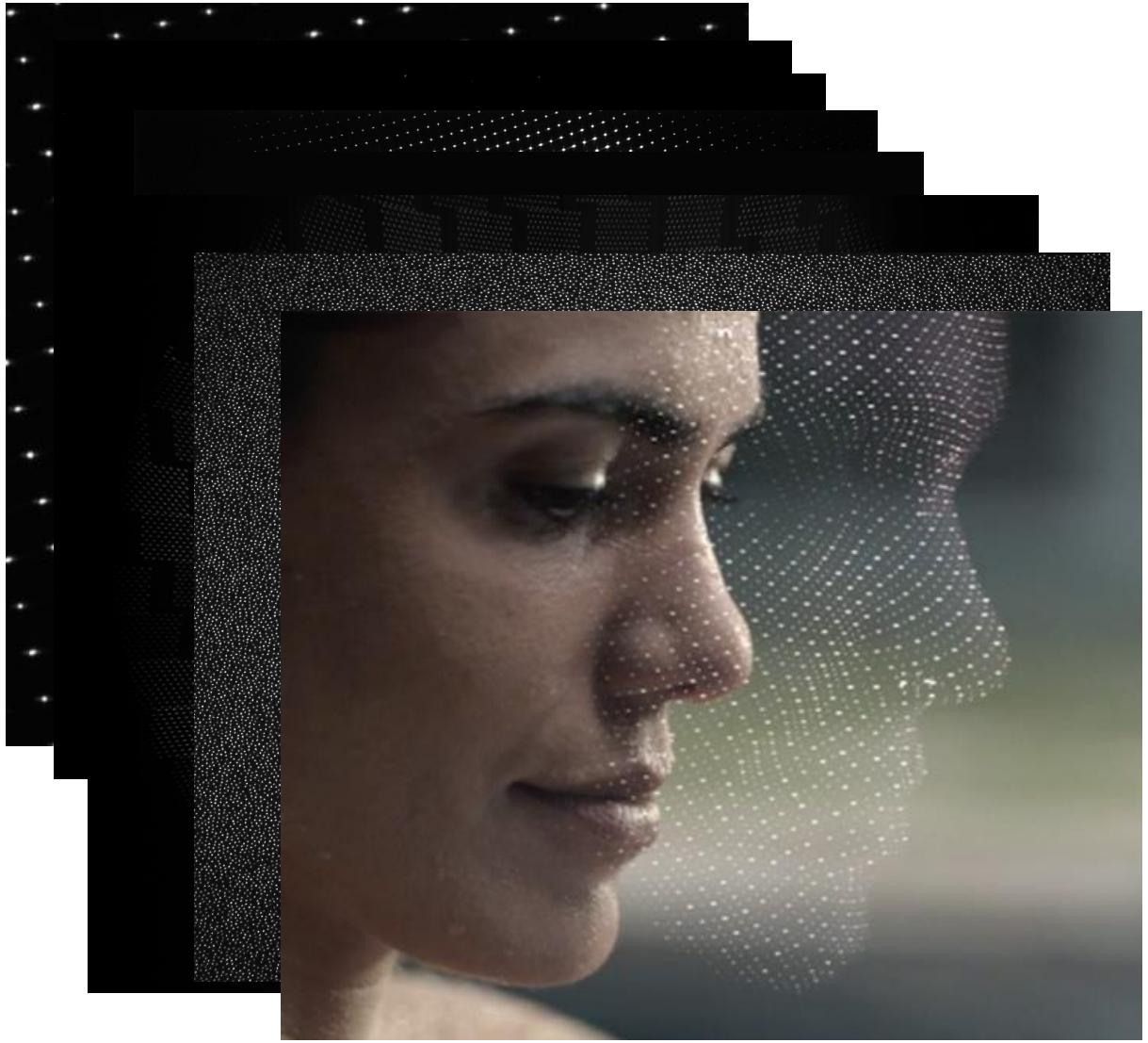




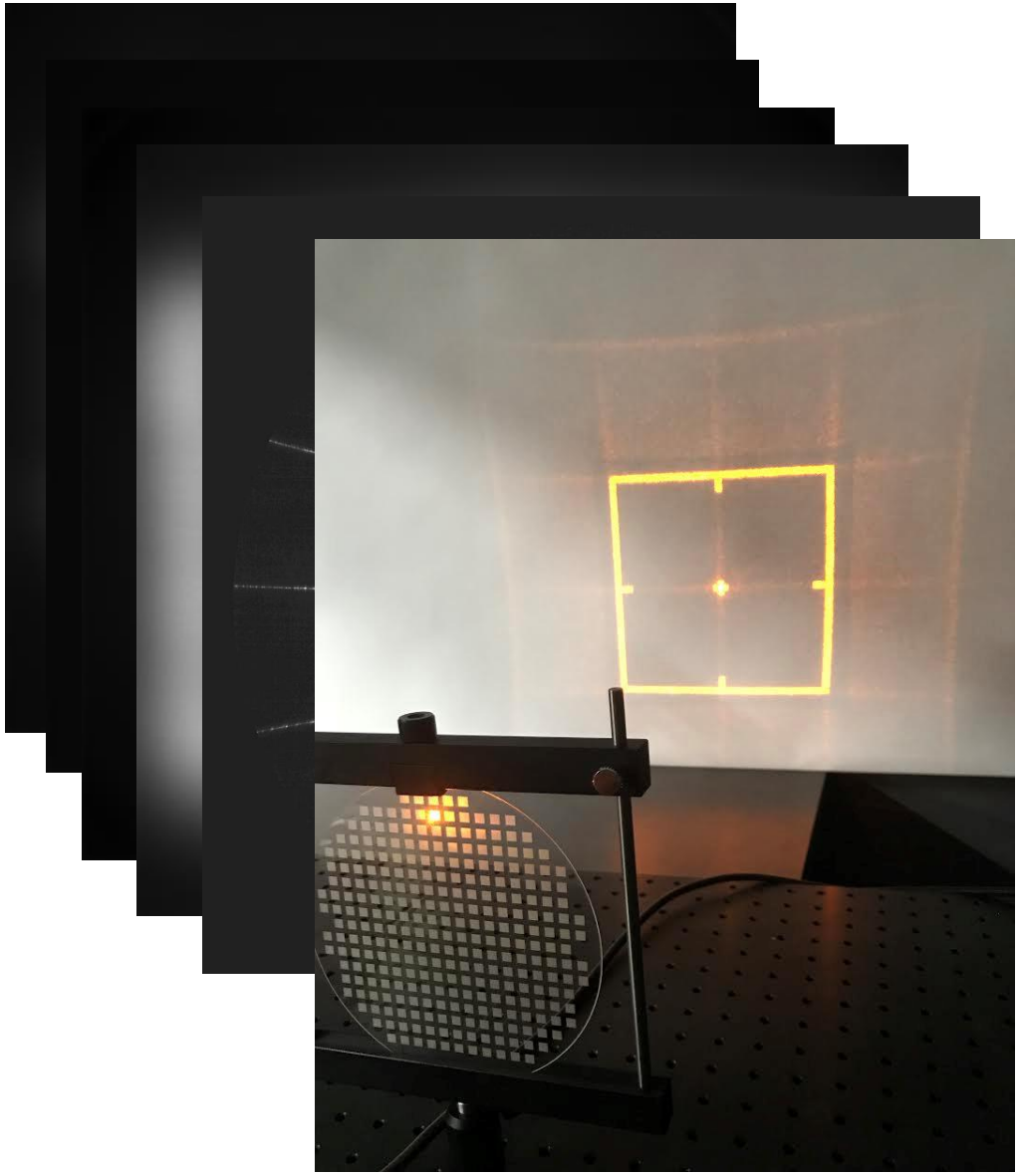
Customized (high volume) testers for optical wafers

Accelerating the future

DOE/MLA spot generators



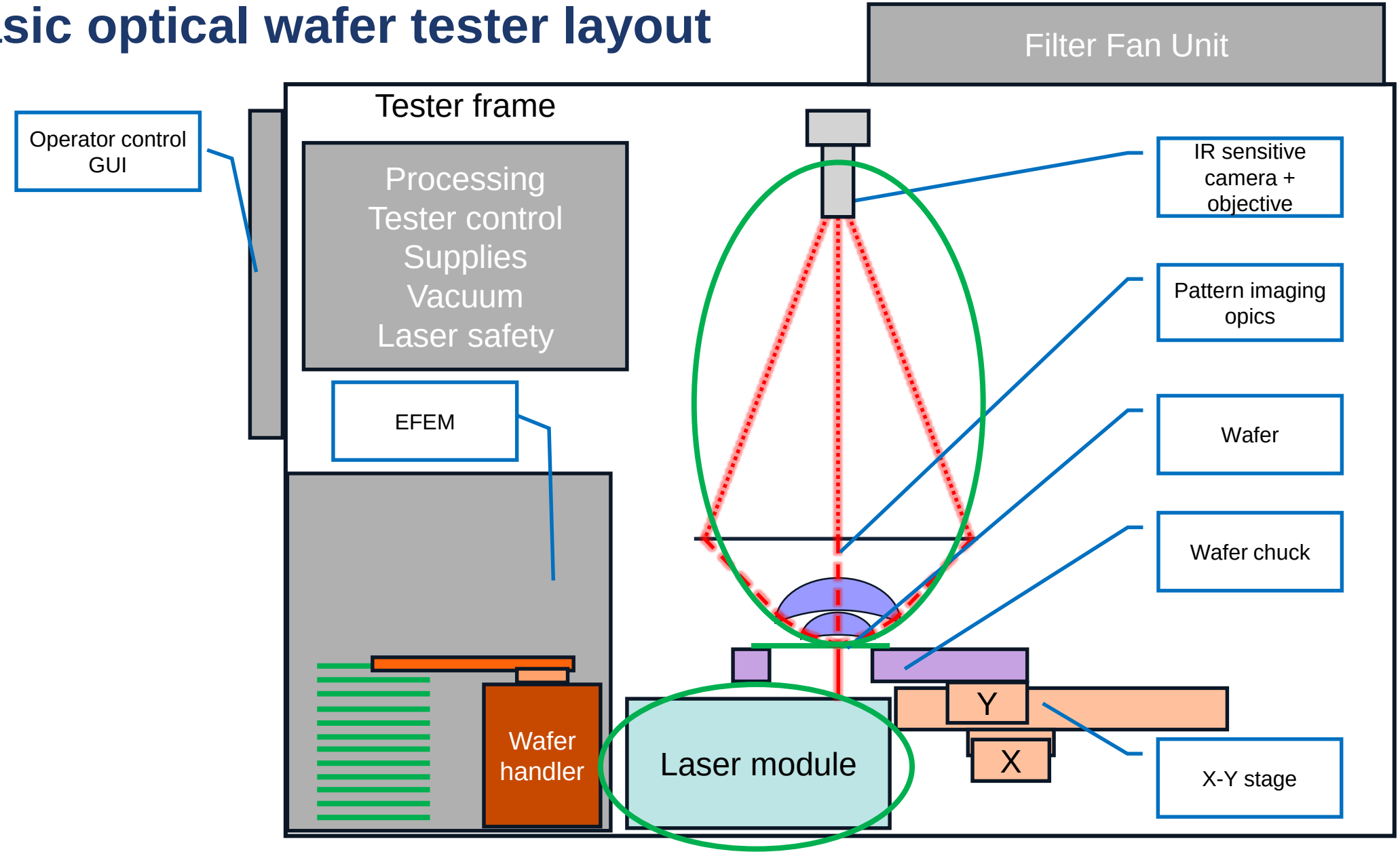
Beam shapers/homogenizers



Typical test parameters

- Relative zero order power
- Occurrence of hot-spots
- Total diffraction efficiency
- Horizontal and vertical diffraction or refraction angles (FOV)
- Relative spot or line powers
- Pattern contrast
- Spot and line quality in terms of FWHM
- Homogeneity over spot profile or diffusor profile
- Low and high frequency inhomogeneity of diffusor
- Whatever other parameters customers would like to test….

Basic optical wafer tester layout



Technical challenges

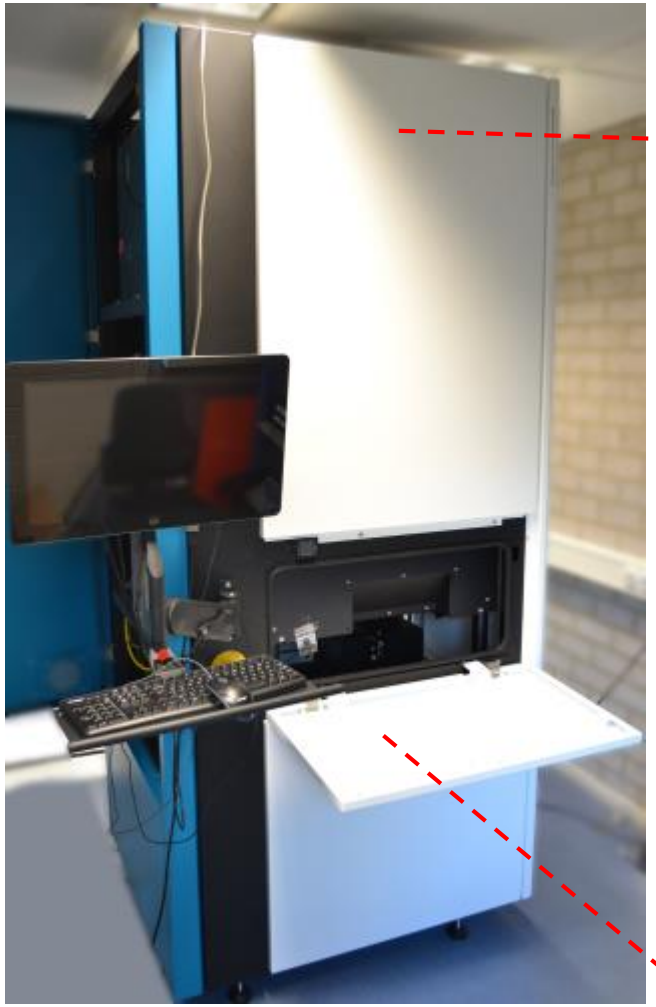
Pattern imaging optics:

- Cover a large FOV (up to 150º) with sufficient resolution
- Low sensitivity drop-off and distortion over the FOV
- Tolerant in wafer surface location
- Sufficient working distance

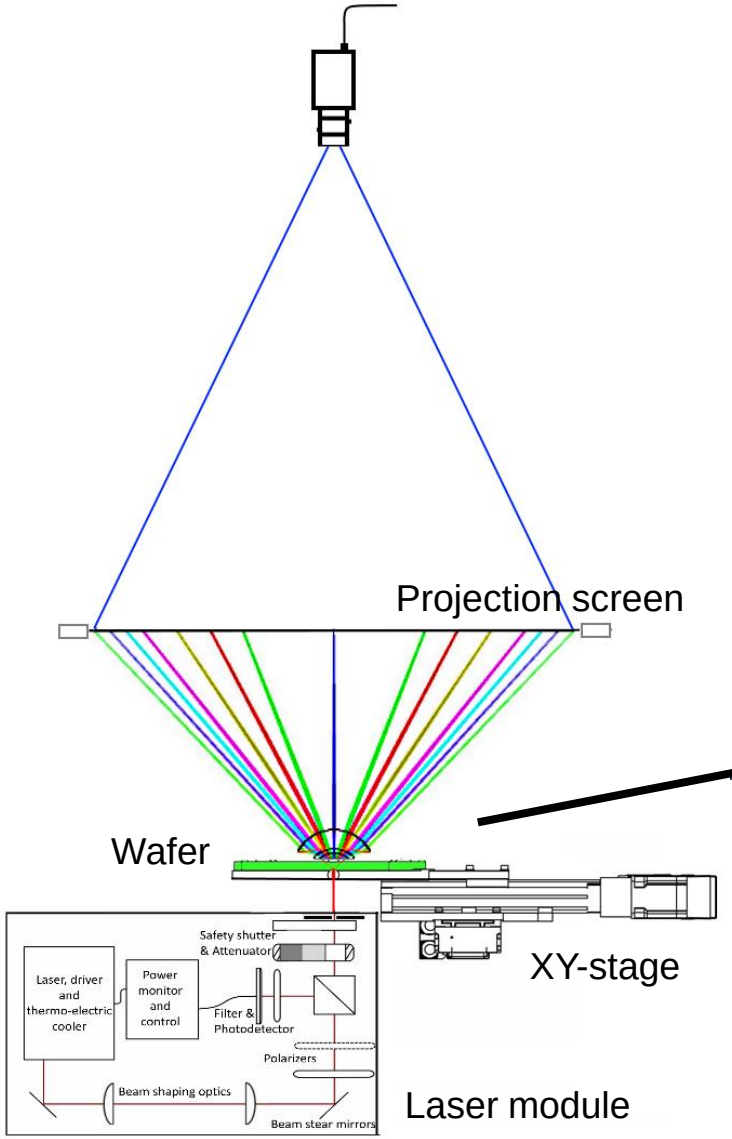
Laser module:

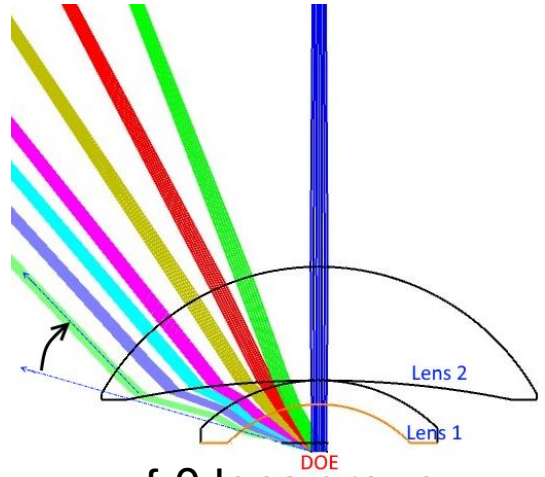
- Accurate center wavelength
- Stable operation
- Spot size fitting the active area
- High beam quality

Optical wafer tester:
direct imaging (conoscope) and rear projection imaging



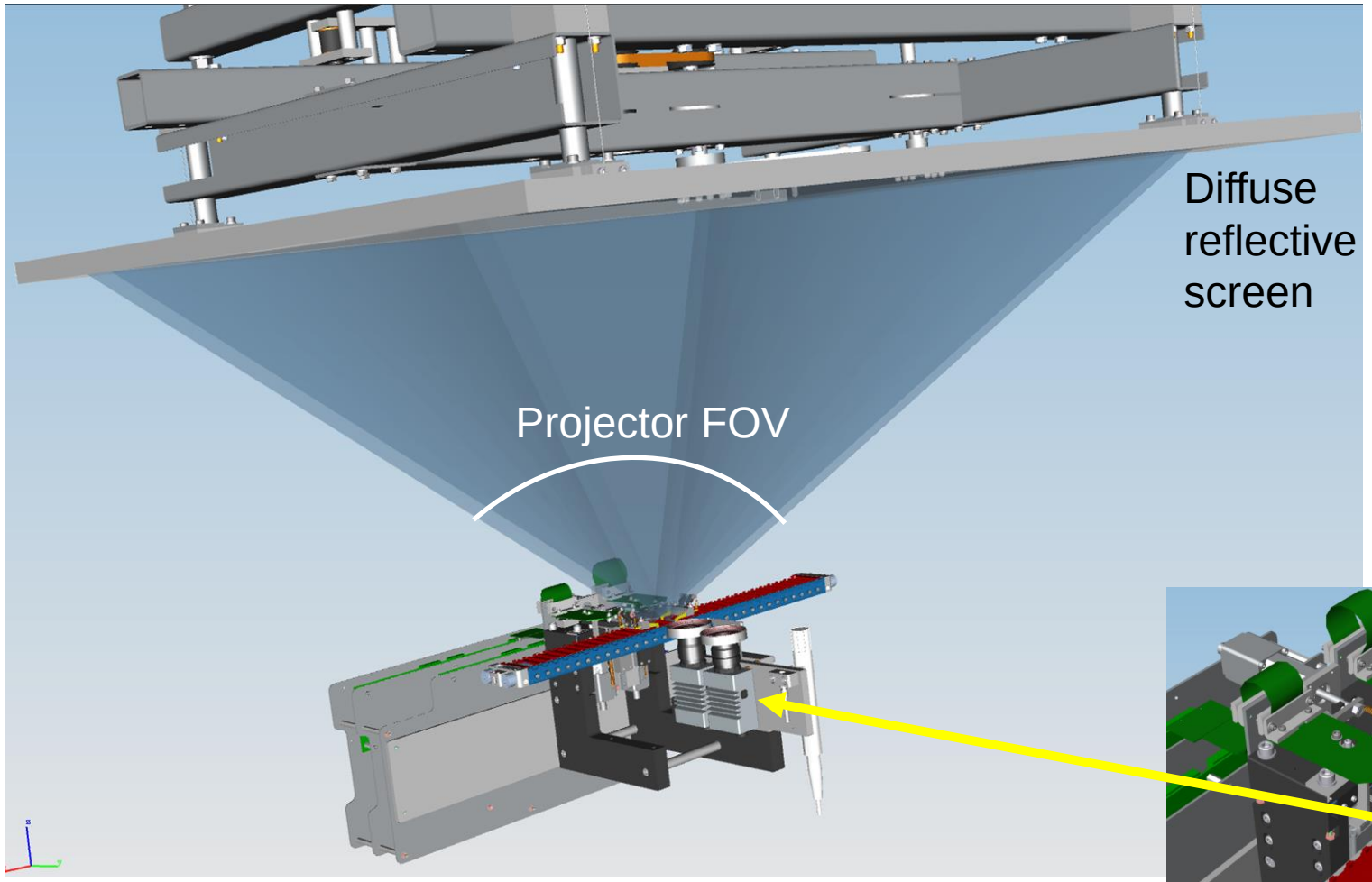
Example manual load optical wafer tester



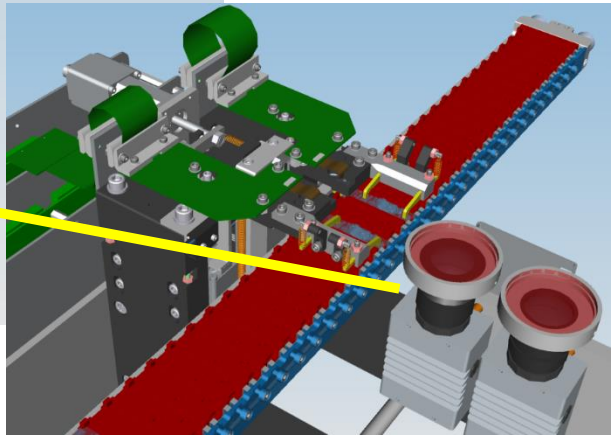


f-θ lens group

Optical wafer tester:
front projection imaging

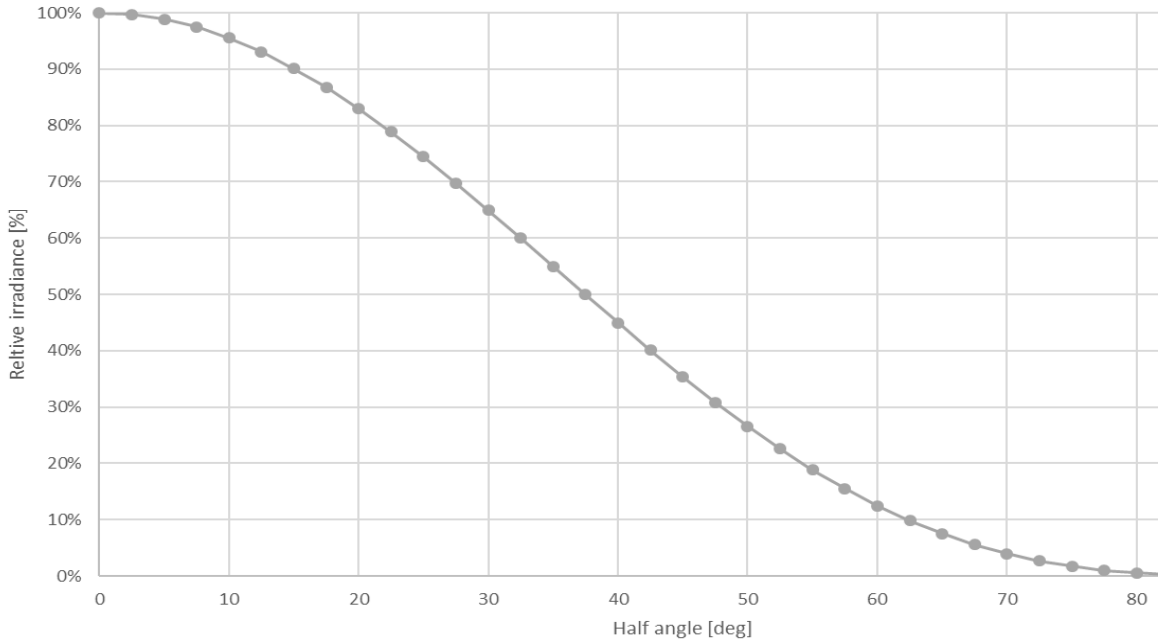


Narrow and wide field IR-camera’s

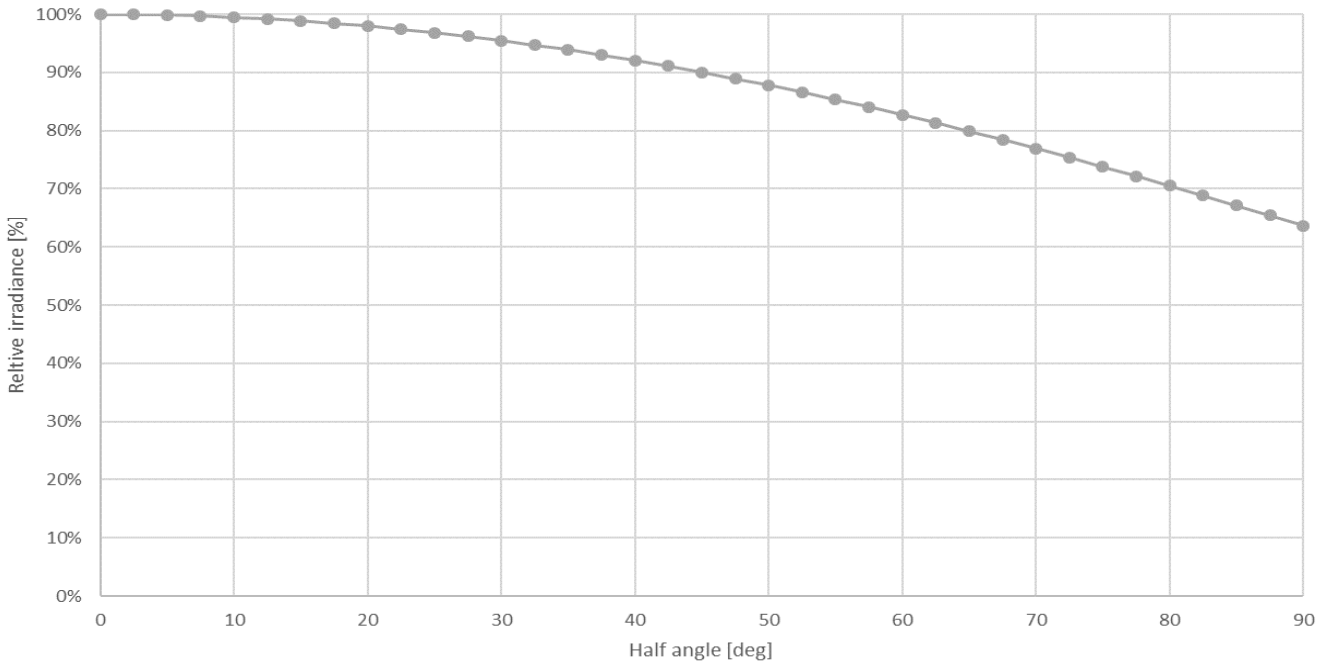


Comparison pattern imaging optics

Irradiance drop for projection on flat screen



Irradiance drop for projection using f-Θ optics



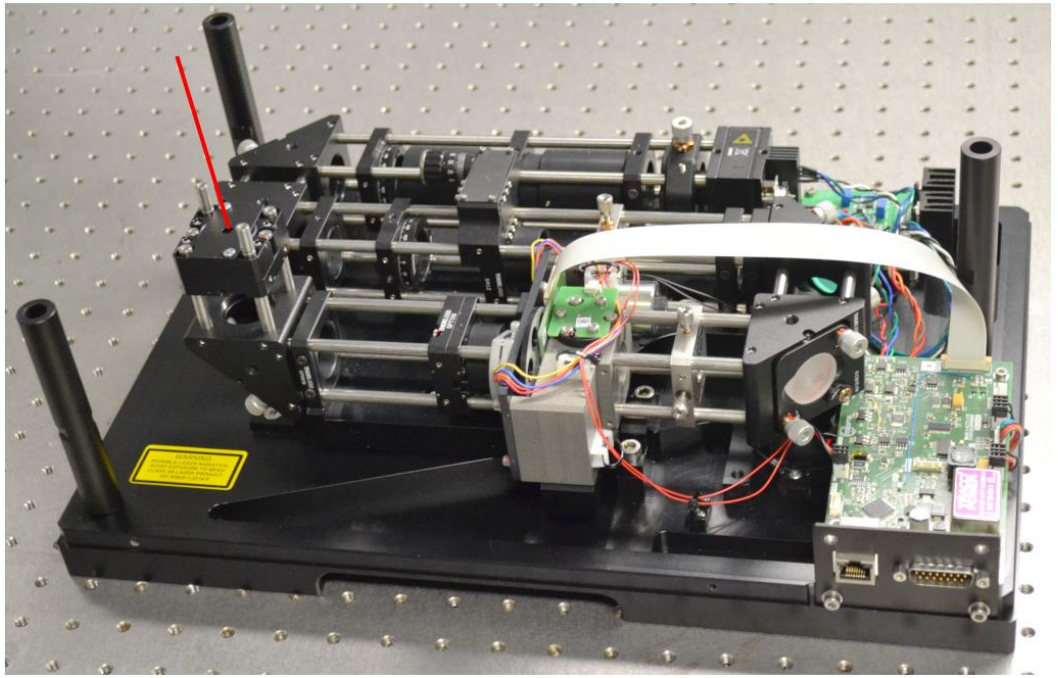
Laser module design

Customer requirements:

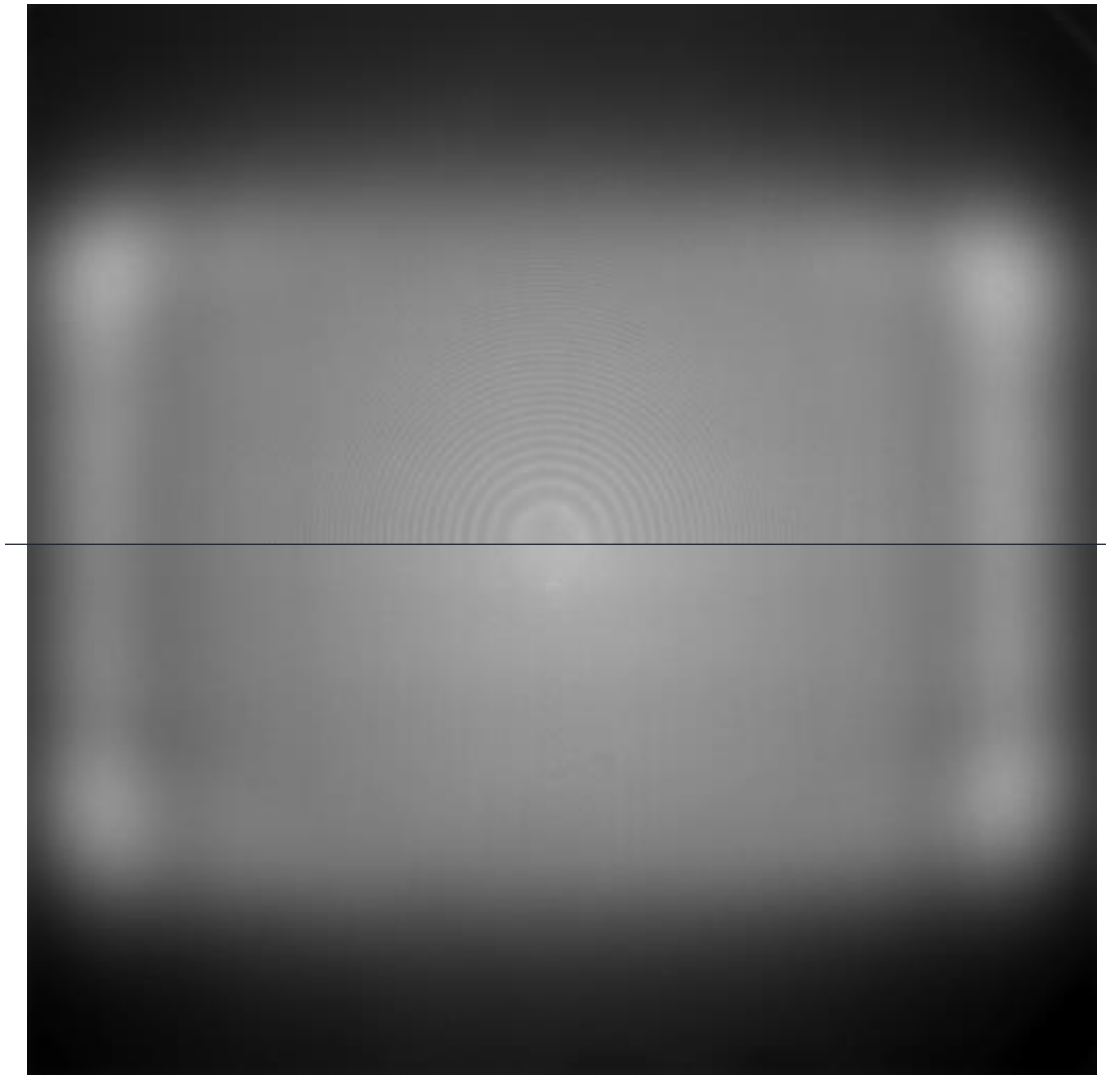
- Wavelength (630/850/940nm)
- Single mode (/multi mode)
- Beam: Collimated/focused/VCSEL mimic
- Profile: top-hat / (truncated) Gaussian
- Spot size: illuminate active area
- Polarization state

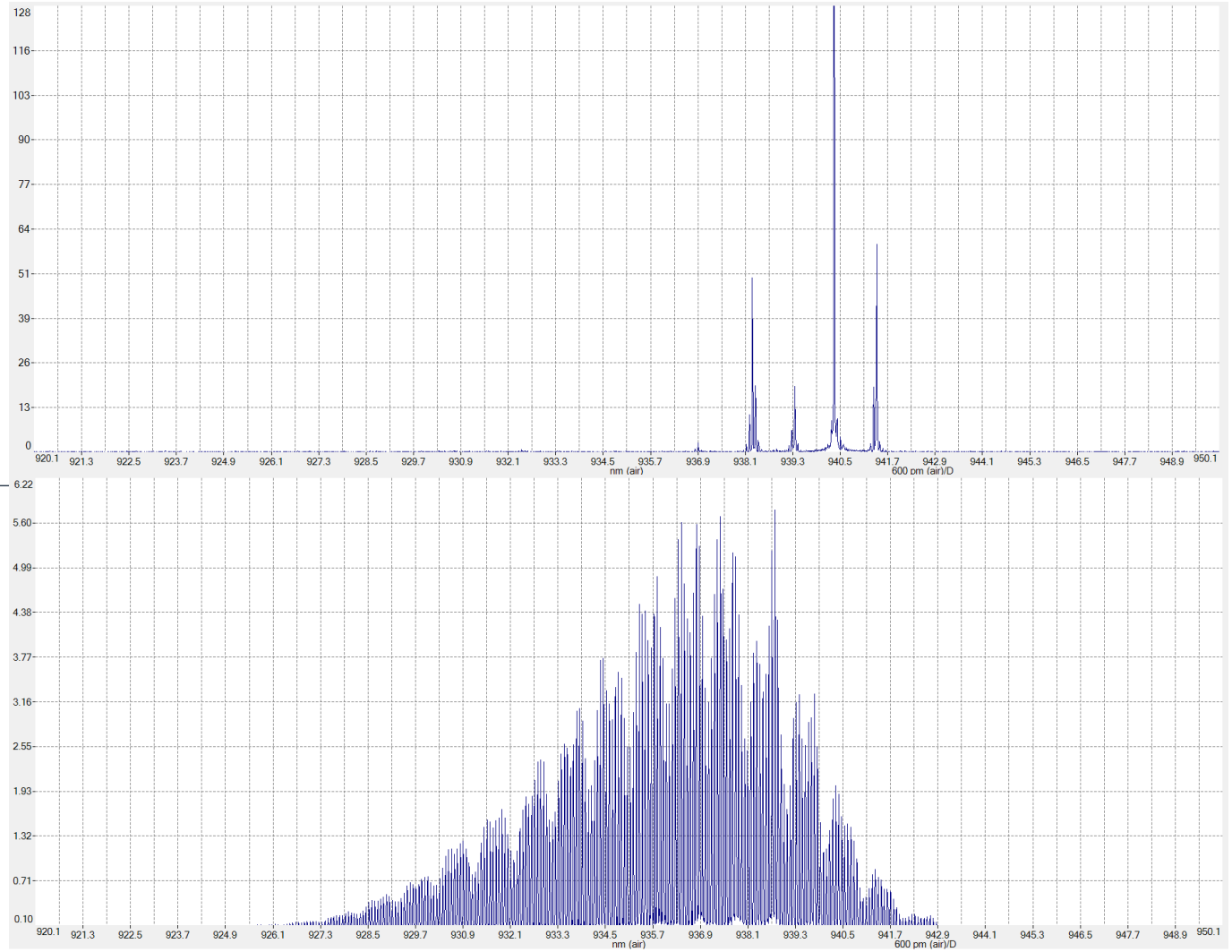
Our additional requirements:

- Working distance (for chuck clearance)
- Beam quality at wafer
- Stable operation
- Laser safety
- Controllable
- Modular and flexible

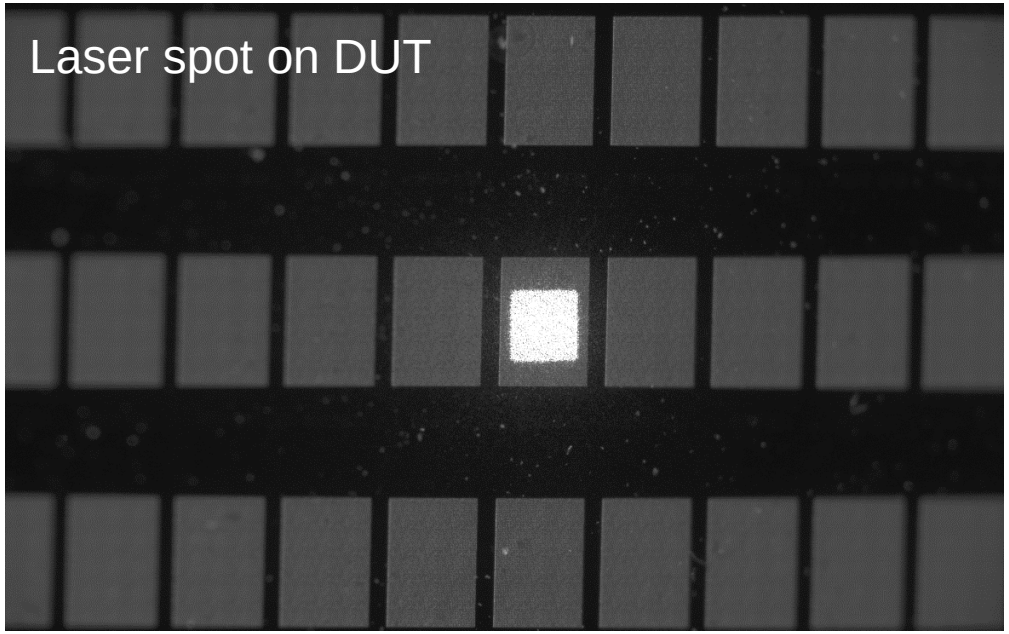


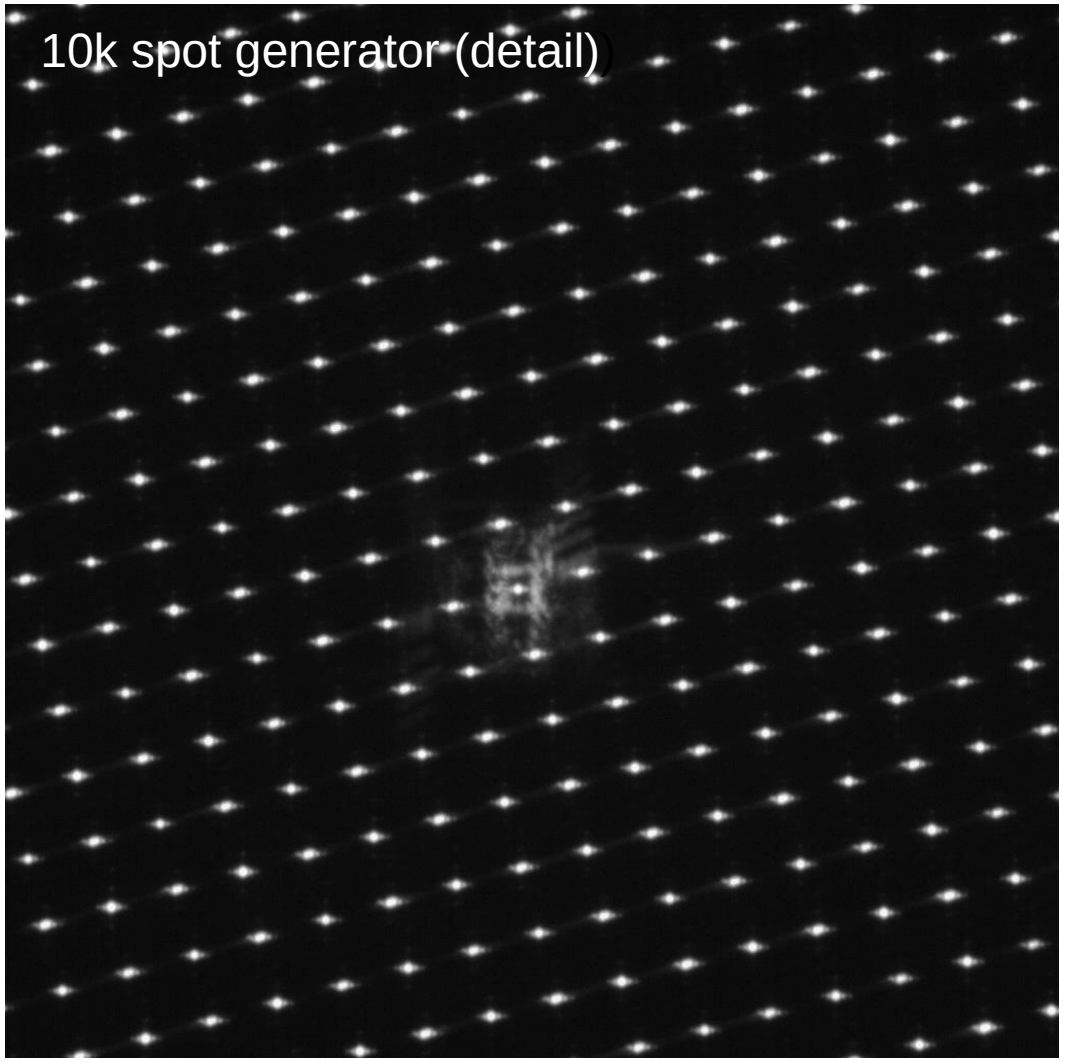
Laser RF modulation





Laser spot quality and power confinement at wafer

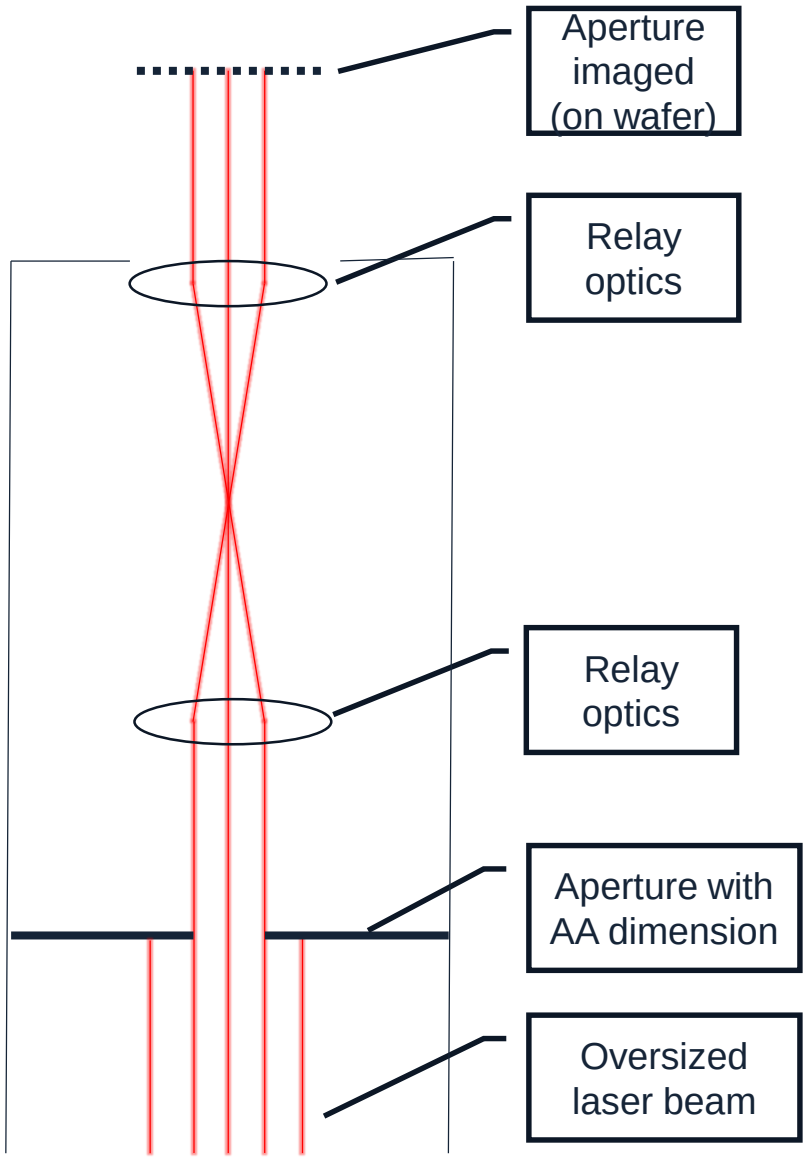




Simple calculation:

- Typically 10mW laser power at DUT
- Diffracted in 10k beams → <1µW per spot
- Scattering passing the active area ends up in ZO position
- This should be < 0.01% to remain below the 1µW

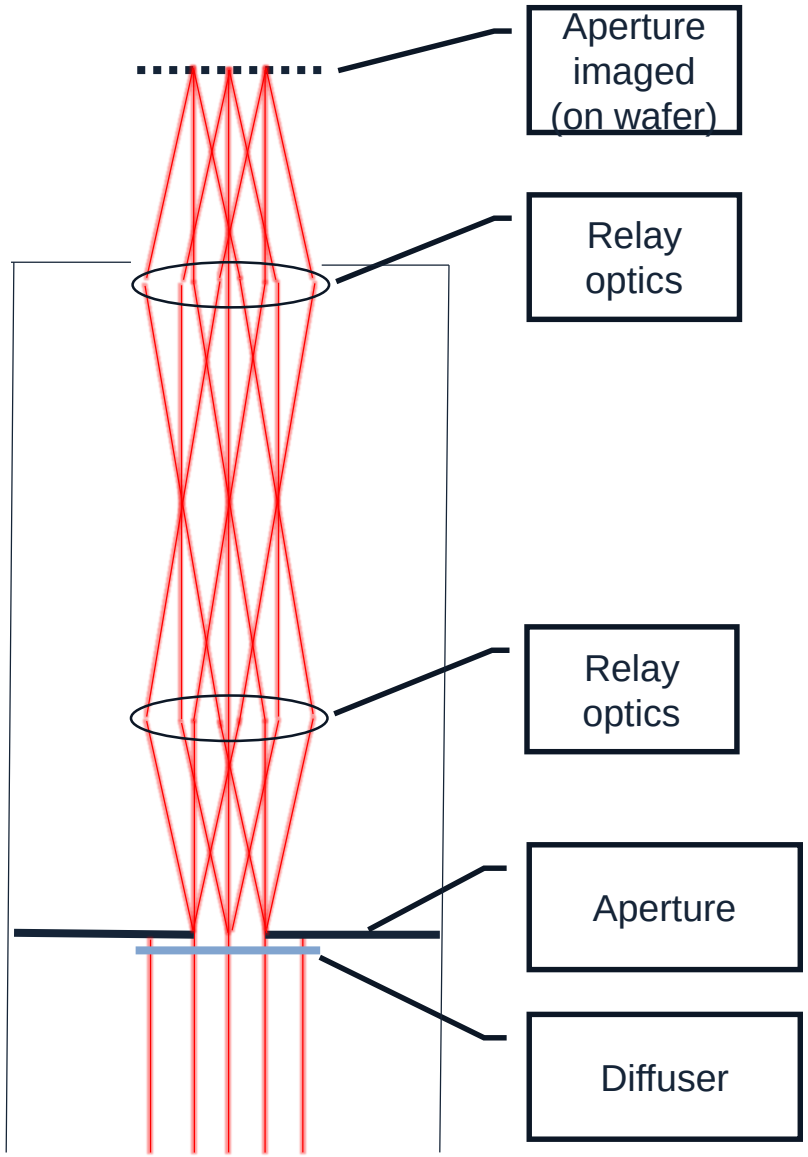
Laser working distance and spot quality



Last section of the laser module:

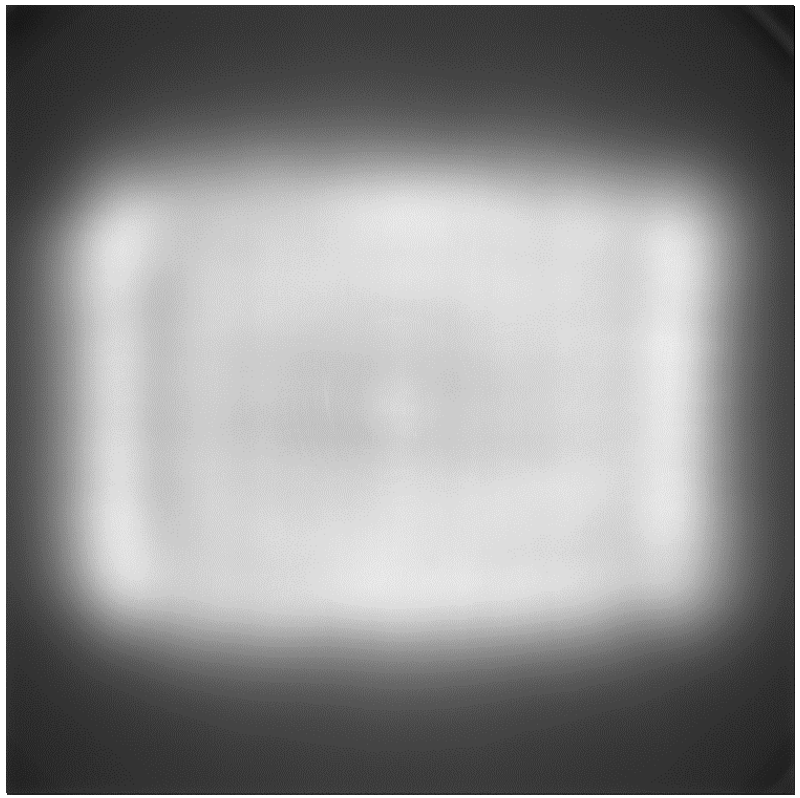
- Aperture:
  - to truncate the laser beam
  - to illuminate only the active area of the DUT
- 4F relay optics:
  - to image the aperture at the wafer level
  - to create sufficient space for the wafer chuck to move in between (50-100mm)
  - To control and confine any unwanted scattering

Laser beam to mimic VCSEL profile

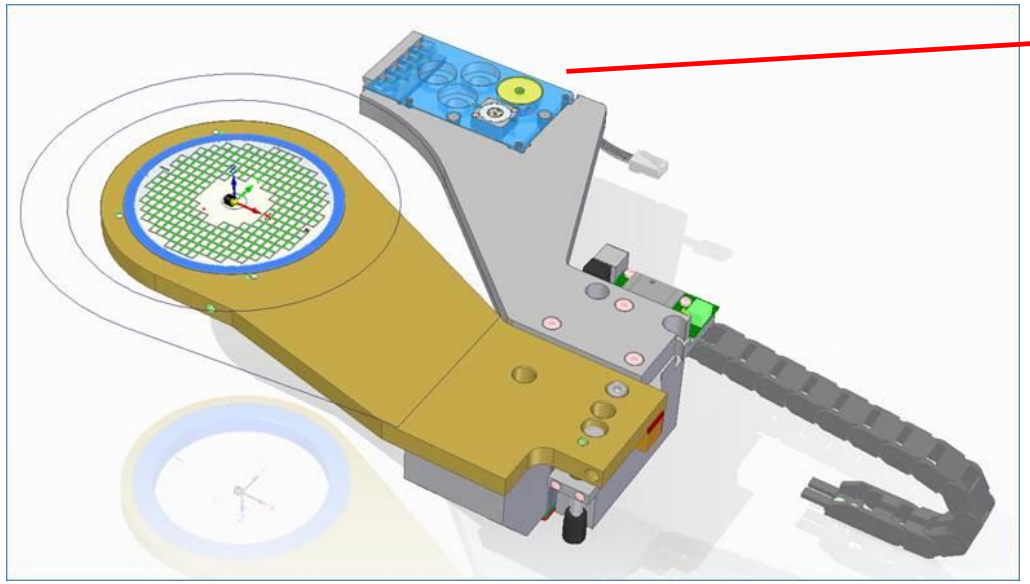


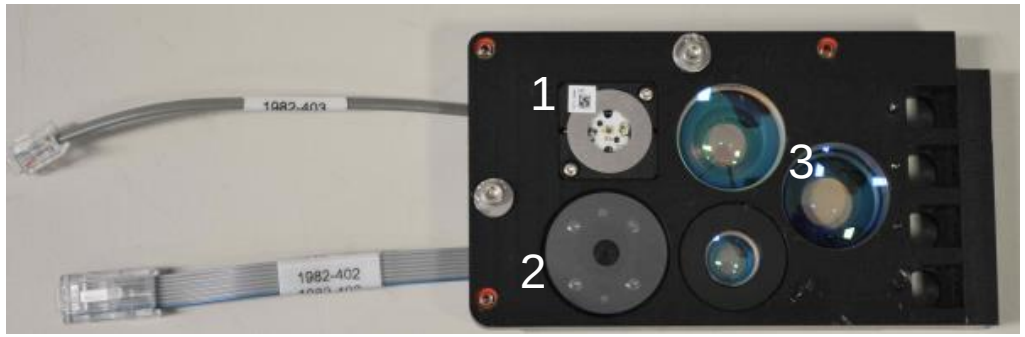
The collimated configuration is generally used to test spot / line generators

To test the device with beam angles simulating a VCSEL, a diffusor is added in front of the aperture.



Tester calibration with build-in tool

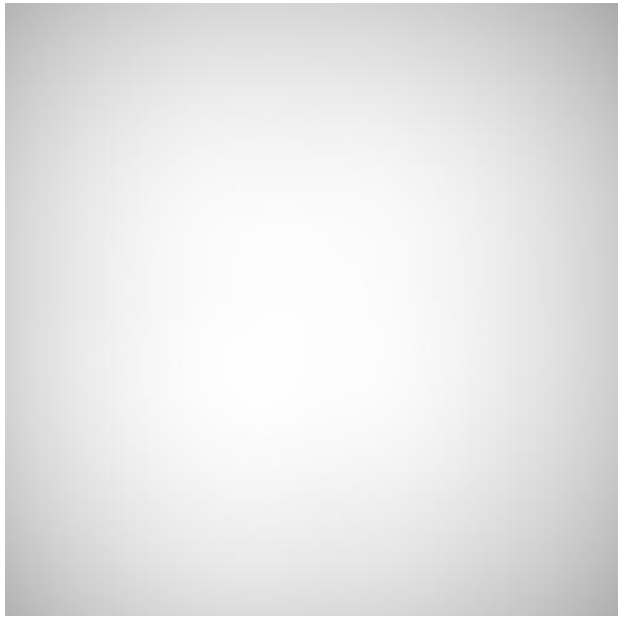




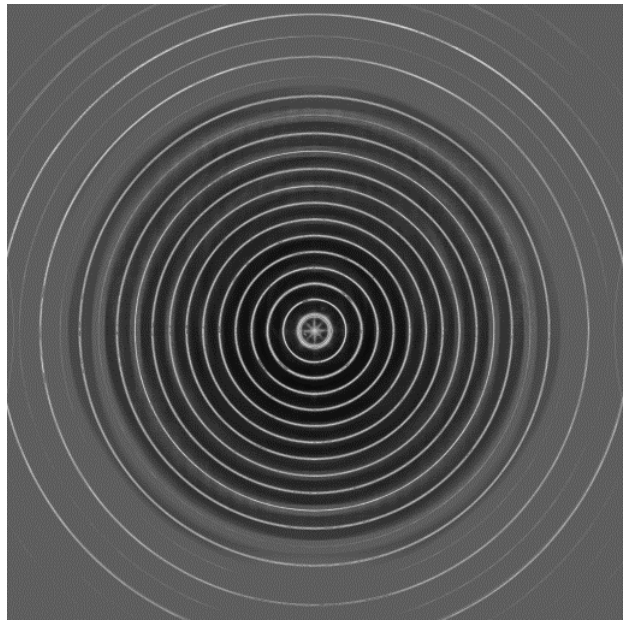
Calibration ‘tray’ enabling:

1. Sensitivity calibration with wide angle IR-LED
2. Distortion calibration with rotating grating
3. Accurate reference power measurement

Sensitivity calibration



Distorion calibration



Many more challenges for next-time meeting:

Wafer handling, gripping and clamping
- manually/EFEM,
- Use of vacuum or mechanical solutions

Bow/warp of wafer (up to 1-2 millimeters!):
- Requiring bow/warp mapping
- Tip-tilt and height corrections with

Pitch variations over wafer:
- Alignment on multiple fiducials
- Use actual elements.

Sensitivity drift of pattern imaging camera: ~0.5%/degr. @ 940nm.
- Thermal control
- Regular reference measurements

Calibration:
- Distortion,
- Sensitivity over VOF
- Laser power level (100% level)

Tester to tester variations: tester matching

UPH: Optimize camera resolution, alignment using fiducials, camera sync, multi-threading,

Serviceability: Modularity and simple first line service.

Thank you

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Design choices / customization tasks

Chuck: 120mm CD type, 200mm round glass, 150mm round, 150mm square, Embossed foil, Single and stacked wafers
Laser module design (wavelength, SM/MM, simulating divergent source, spot size, power distribution). Laser focus position
Pattern imaging technique:

- Direct imaging (conoscope): Compact,
- Front or rear projection: laser speckle reduction required, flexible in FoV, simple optics, easy configurable, thickness of rear-projection foil: broadening.
- f-theta optics: multi spot or line angle measurements, spot quality.
- Camera type and resolution.

EFEM: cassette, spindles, foup.
Frame
GUI, wafer map, recipe structure, pareto, SPC,

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