# Integration of III-V components on VTT's 3µm SOI platform

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VTT

# Overview of slides

- **Introduction:**
  - Applications for silicon photonics
  - 3 µm SOI PIC overview
  - Straight waveguides
  - Up-reflecting mirrors
  - Light coupling

- **Integration of RSOA to 3 µm SOI PIC**
  - Hybrid integration development
  - Post alignment confirmation using glass chips for X-/Y- axis
  - Results from glass chips bonding
  - Z-axis misalignment and solution
  - Flip-chip bonding with RSOA
  - Alignment check
  - Optical test and results
- **Q and A**

# Main application areas for Si photonics

Health and wellness

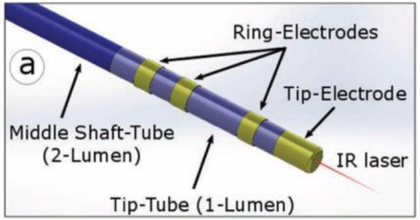
3D sensing and imaging

Communication & computing

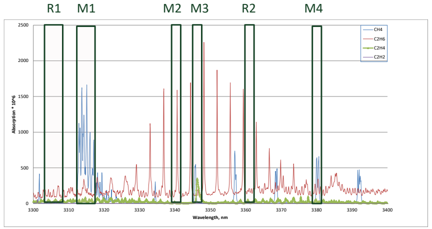
Industrial sensors

Military & Aerospace

Quantum







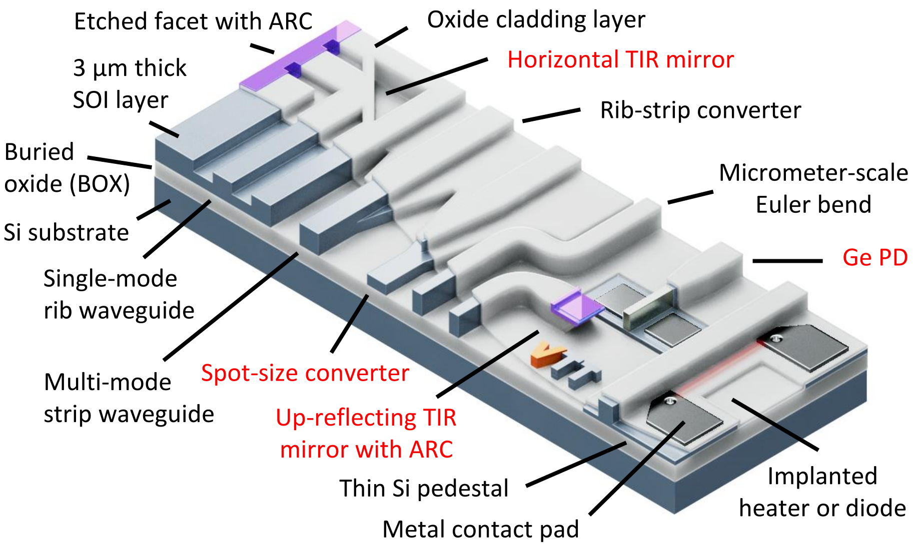

# 3 µm SOI ay VTT: Overview

VTT

*Passive and active PICs in 3 µm thick SOI*

## Advantages

Broadband, polarization independent and low-loss I/O coupling (horizontal or vertical)
Rib and strip waveguides with low propagation loss (0.04 – 0.15 dB/cm)
Ultra broadband SM operation with rib waveguide mode strippers (1.2 – 6 µm)
Polarization independent (zero birefringence) and low-loss passives
Ultra-dense integration with Euler bends and horizontal TIR mirrors
Tolerant to ~1 W optical power
Tolerant to fabrication errors
Up to 40 GHz Ge photodiodes



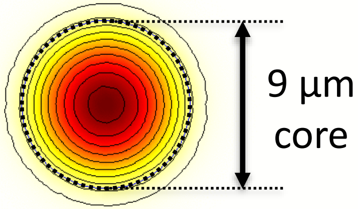

## Present limitations

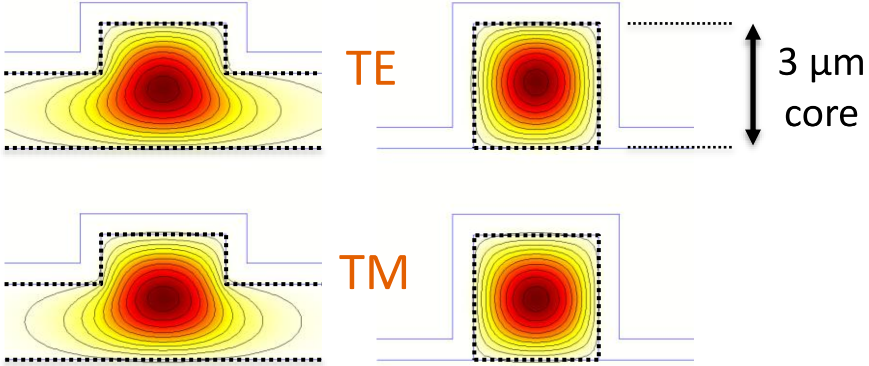
- Lack of fast modulators (GHz)
- Difficult coupling to microrings (too high strip waveguide confinement, too long directional and MMI couplers)
- Topography limits the accuracy of fabrication
- Higher-order mode excitation must be avoided with good designs and accurate I/O alignment

# 3 µm SOI: Straight waveguides

VTT

**Ultra-high mode confinement into the Si core**
**Ultra-broadband, low-loss and polarization independent operation enabled by** small mode overlap with side-wall roughness and material interfaces




*Norm of the E field plotted as a function of wavelength (material absorption and dispersion ignored)*

Reference: Standard single-mode fiber

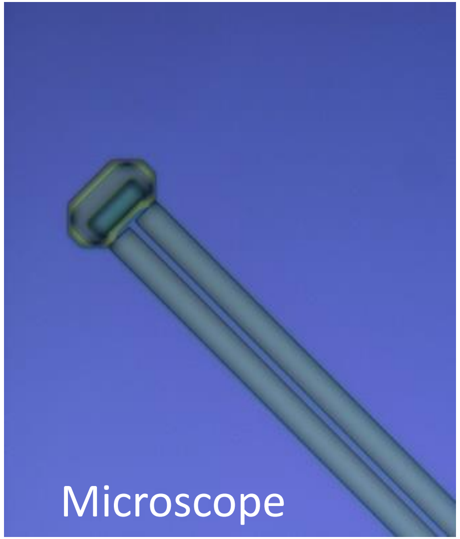
3 µm SOI (SM rib)

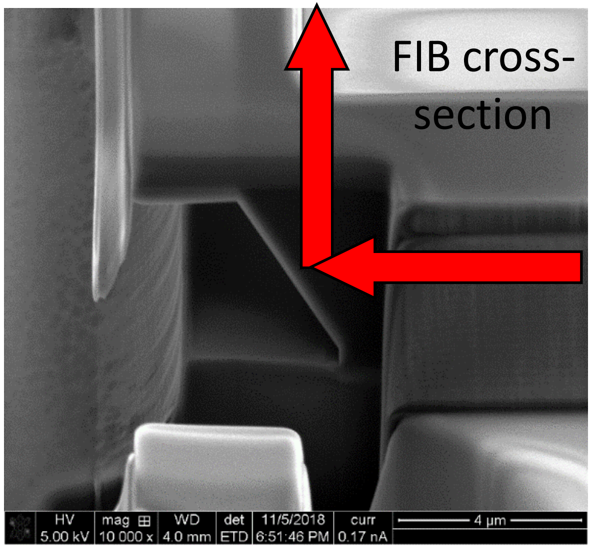
3 µm SOI (MM strip)

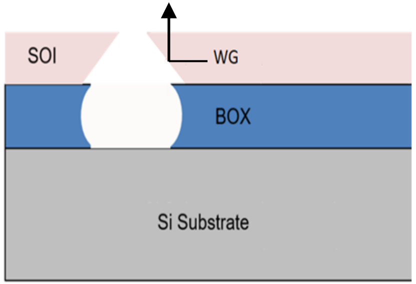
1.2 µm 1.5 µm 1.8 µm 2.1 µm 2.4 µm 2.7 µm 3.0 µm 3.3 µm 3.6 µm 3.9 µm 4.2 µm

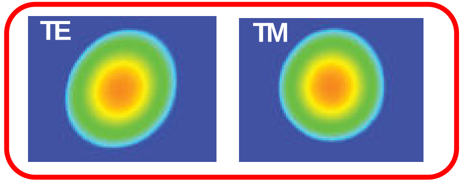
# 3 µm SOI: Up-reflecting mirrors

**Up-reflecting total internal reflection mirrors for wafer-level testing, VCSEL & PD integration and vertical fiber coupling**
**Coupling loss down to 0.5 dB**



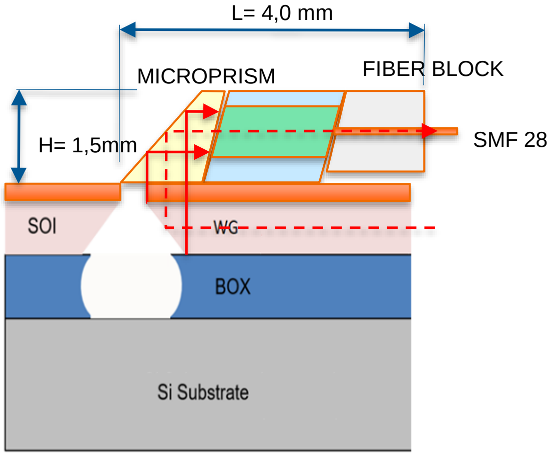



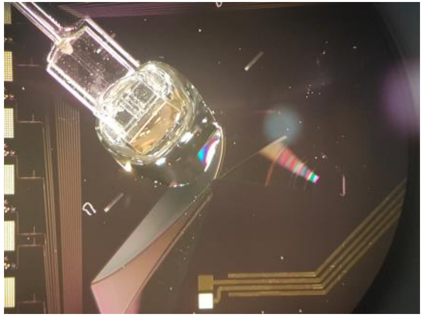



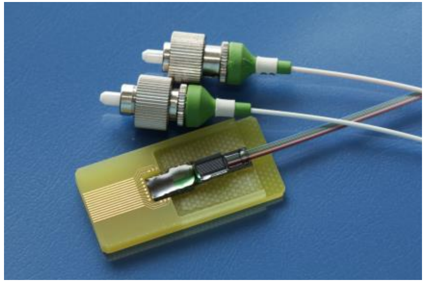

IR-camera images from top

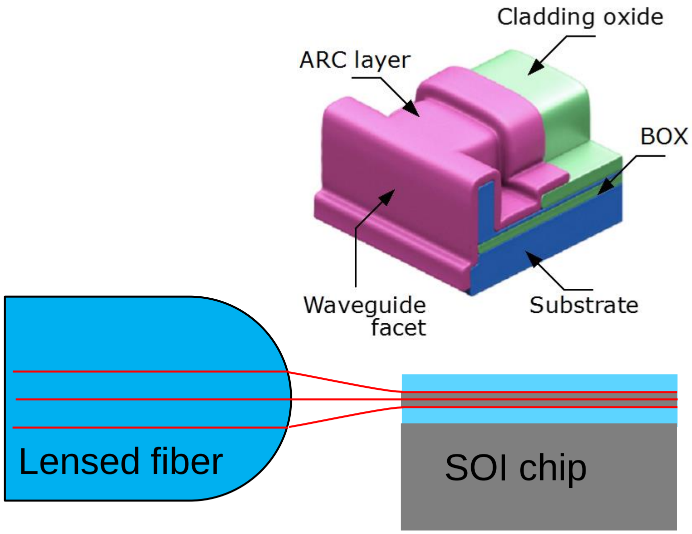
# 3 µm SOI: Fiber coupling

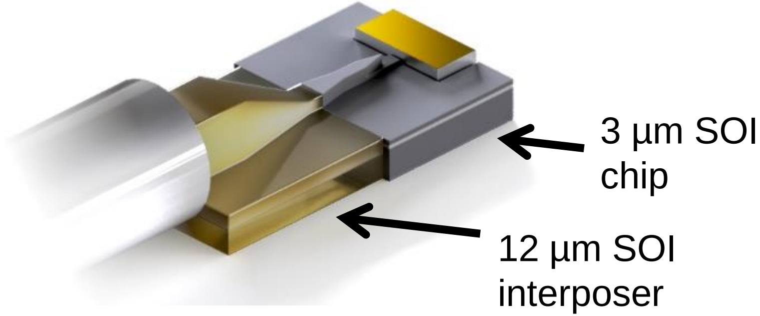
**Coupling loss from etched facets or up-reflecting mirrors to lensed fiber ~0.5 dB**
**Separate interposers for coupling to standard SMF**



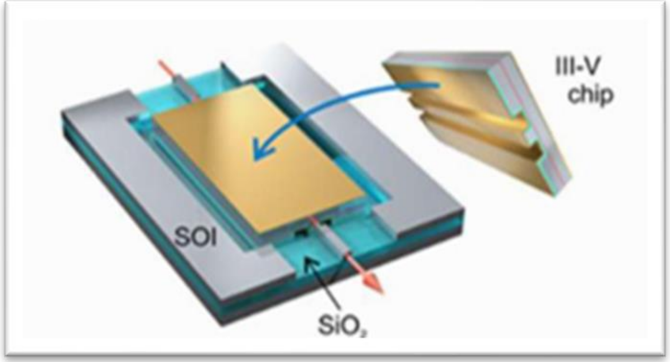







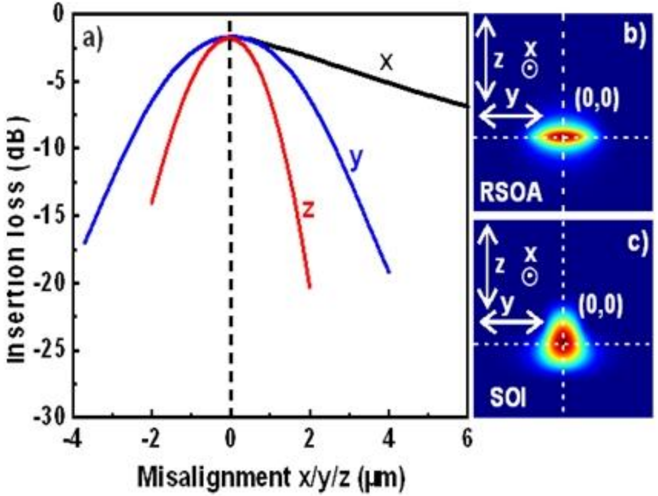
# Integration of III-V components on VTT's 3µm SOI platform




## Objectives

- Proper solder alloy
- Proper bonding structure
- Proper bonding condition

- Sub-micron post-bond accuracy
- High yield
- Precise optical alignment
- High bonding strength



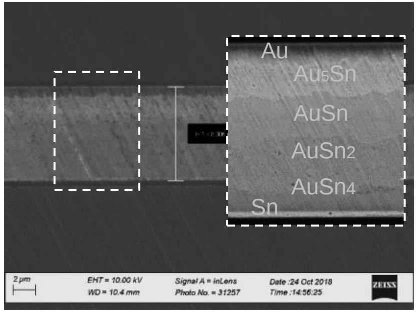
# Hybrid integration development (< 1μm align accuracy)

## Solder development

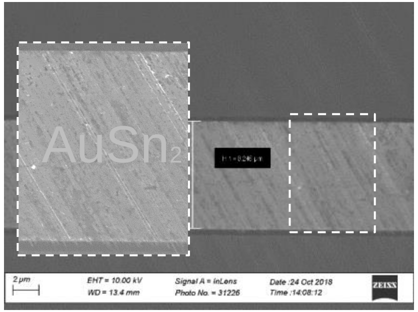
## Bonding scheme

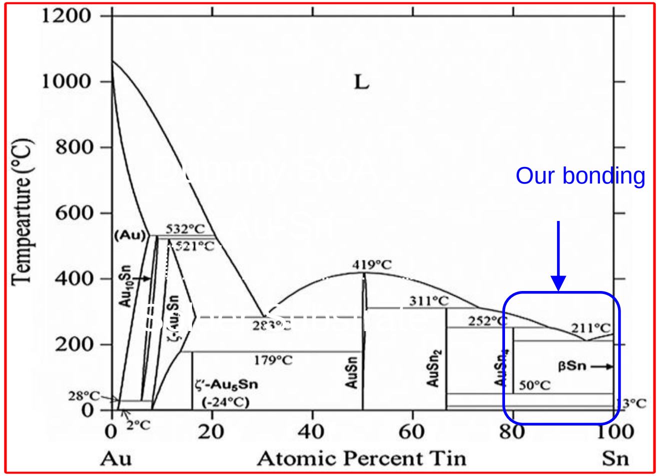
## Flip-chip bonding condition

**190°C (Chuck) and 220°C (Arm)**




**250°C (Chuck) and 250°C (Arm)**




- Our bonding will be done Sn rich area
- Au-Sn solder bonding at 220 ~ 250 °C
- Au-Sn squeezing for Z-axis alignment
- Void free bonding
- Intermetallic form after bonding
- Multiple chip bonding on same Si photonic substrate
- Good shear strength (>>4MPa)

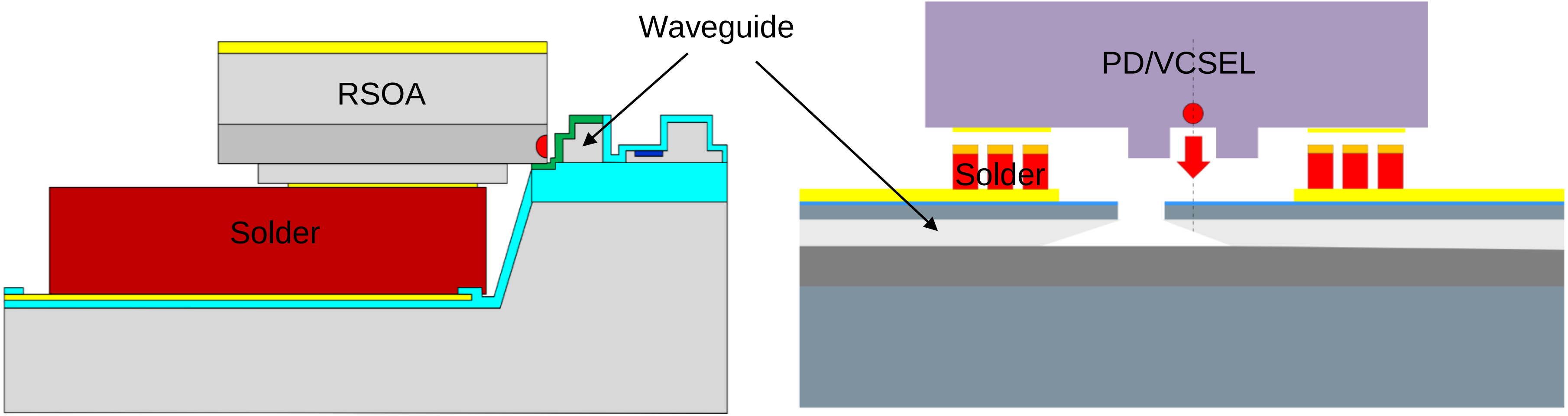
Things to consider

Stress

Thermal conductivity

# Hybrid integration development

## Solder development
## Bonding scheme
## Flip-chip bonding condition




Coupling to edge of the Si waveguide

Coupling onto the up-reflecting mirror

# Hybrid integration development (< 1µm align accuracy)

VTT

## Solder development

## Bonding scheme

## Flip-chip bonding condition

- Our bonding will be done Sn rich area
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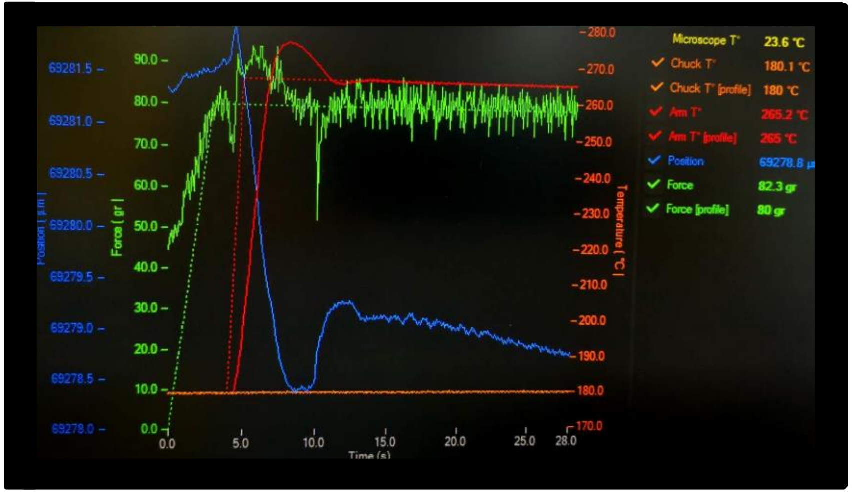
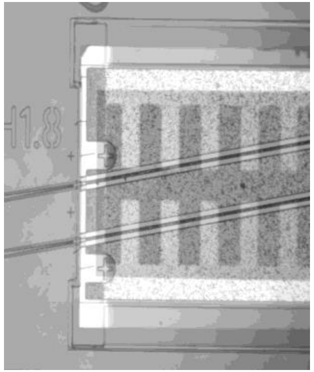
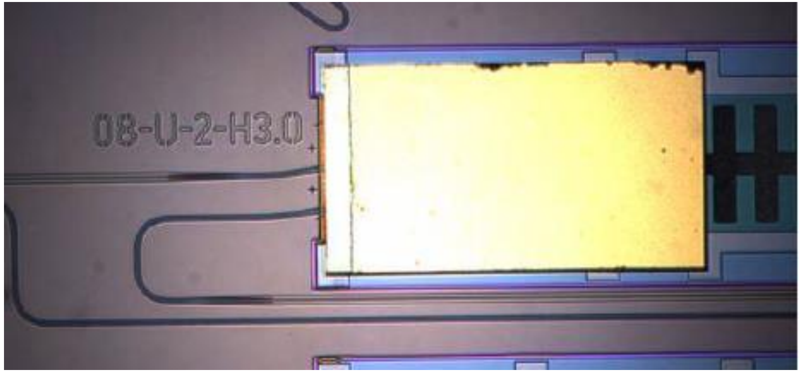
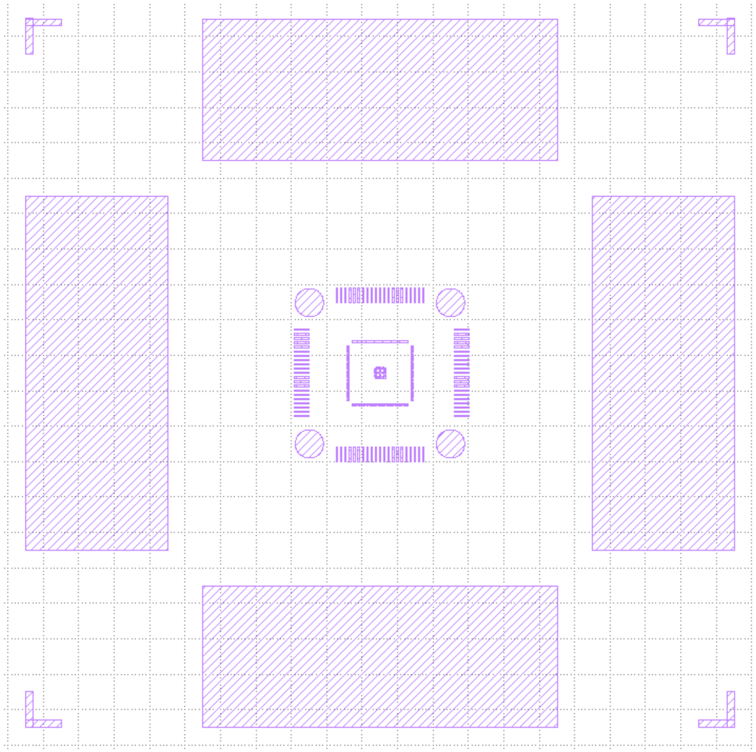


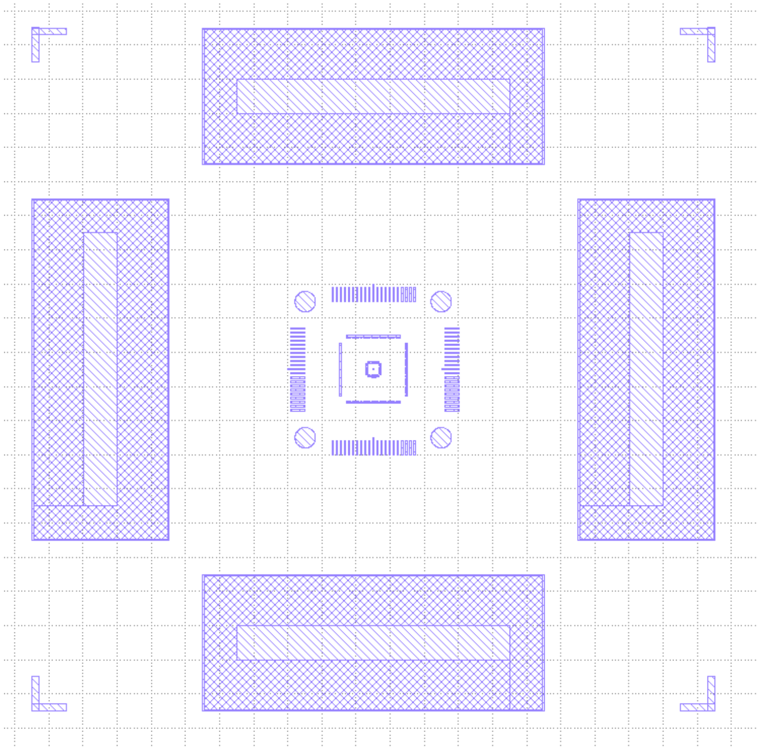



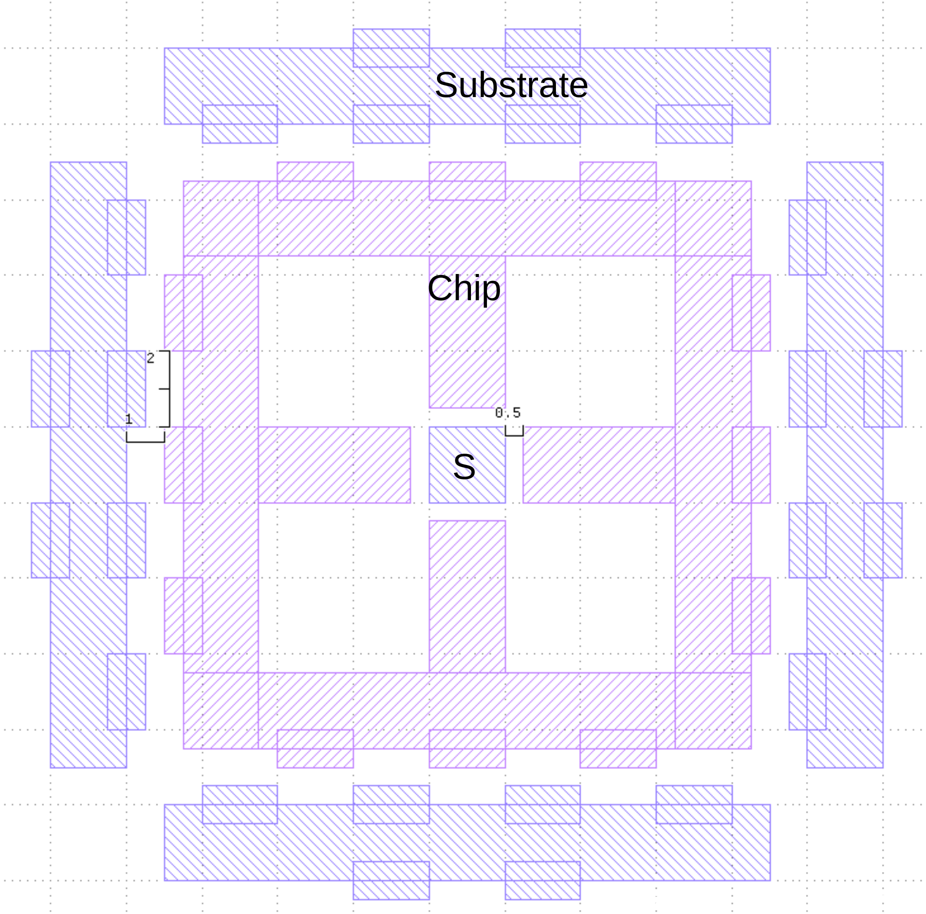

Force
Time
Temperature

# Glass chip for post bonding accuracy check: Femto 2



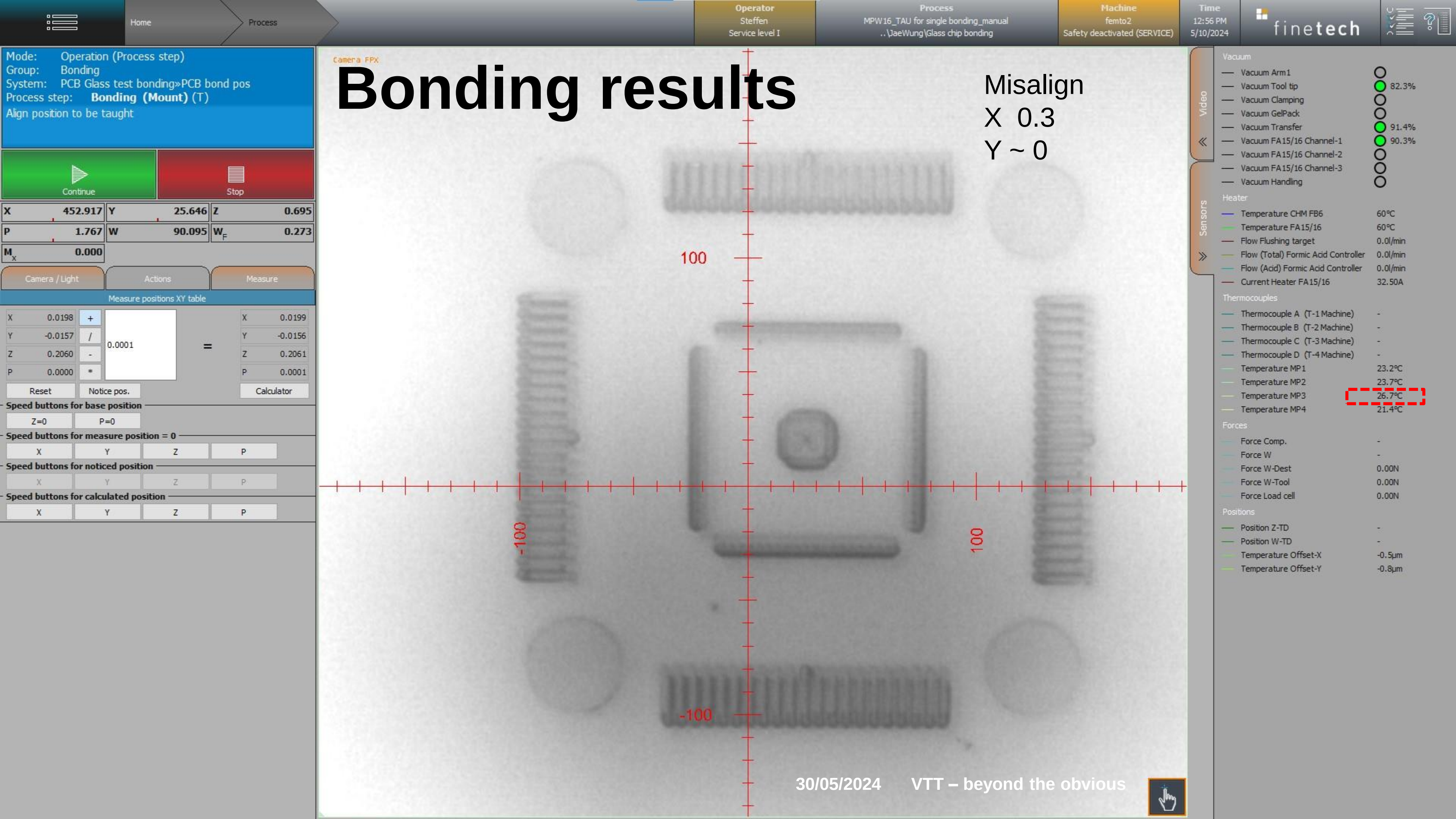


# Alignment; < 0.5 μm align accuracy (pass or fail)



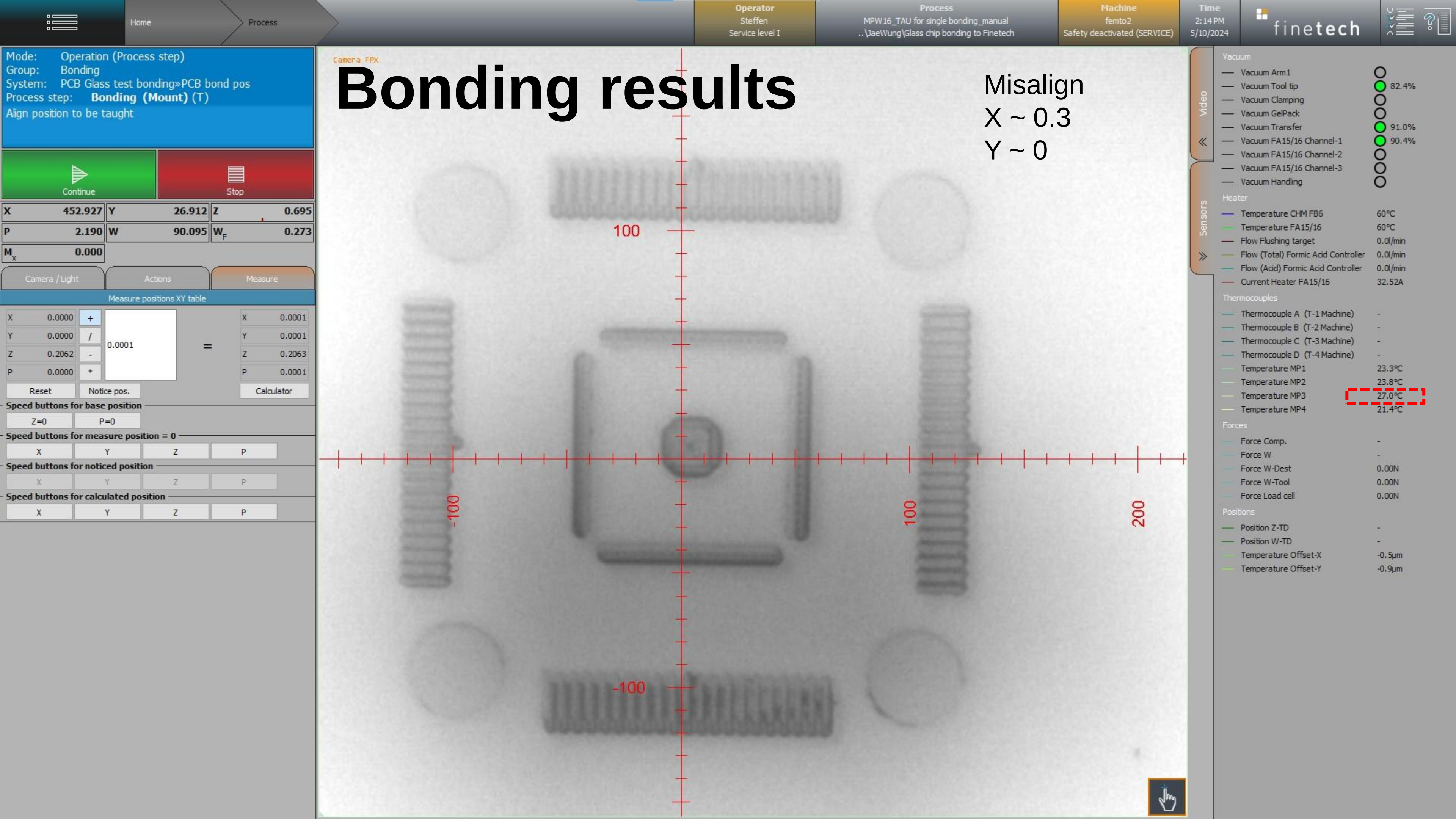
# Bonding results

Misalign
X 0.3
Y ~ 0



# Bonding results

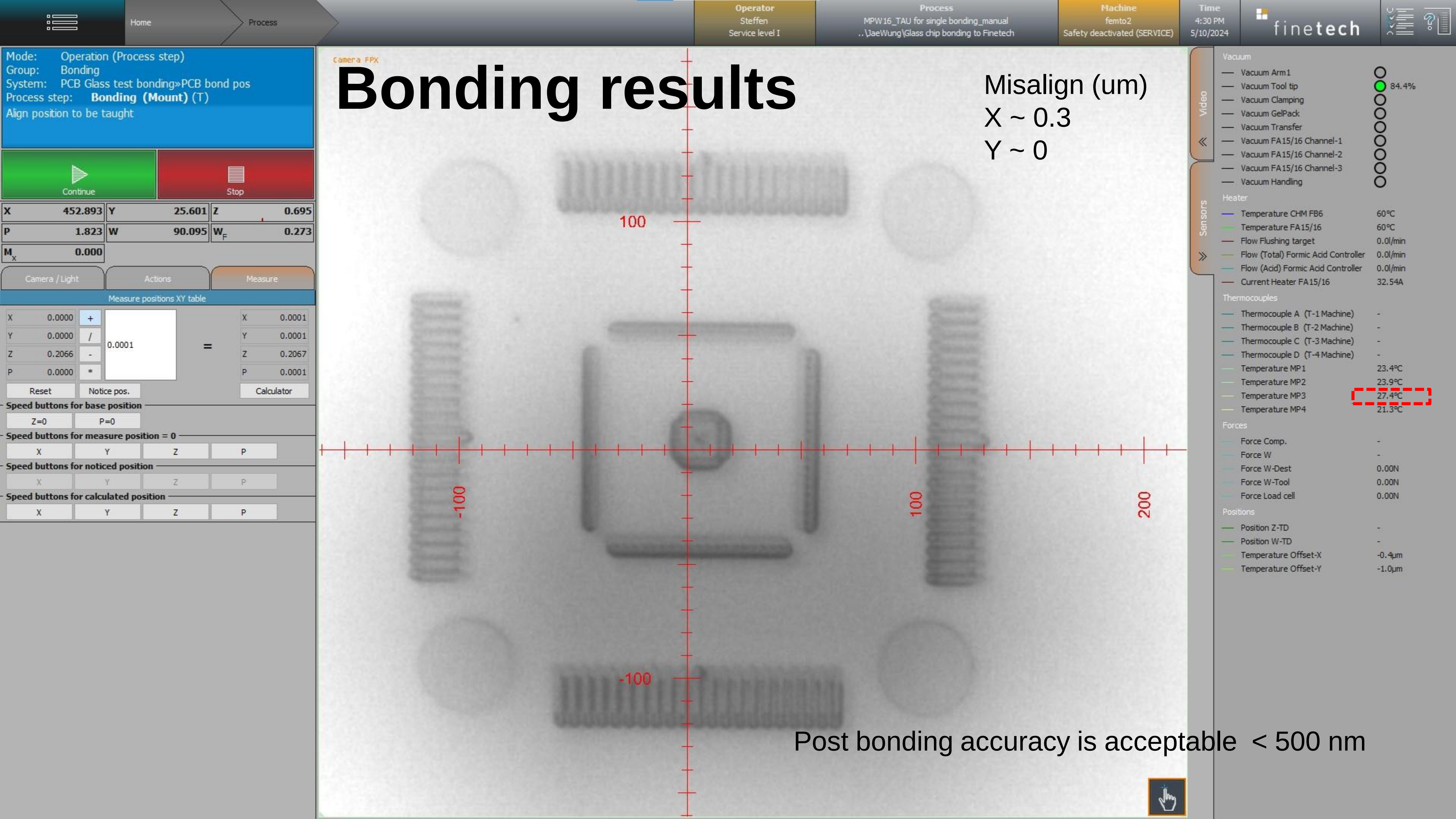
Misalign
X ~ 0.3
Y ~ 0



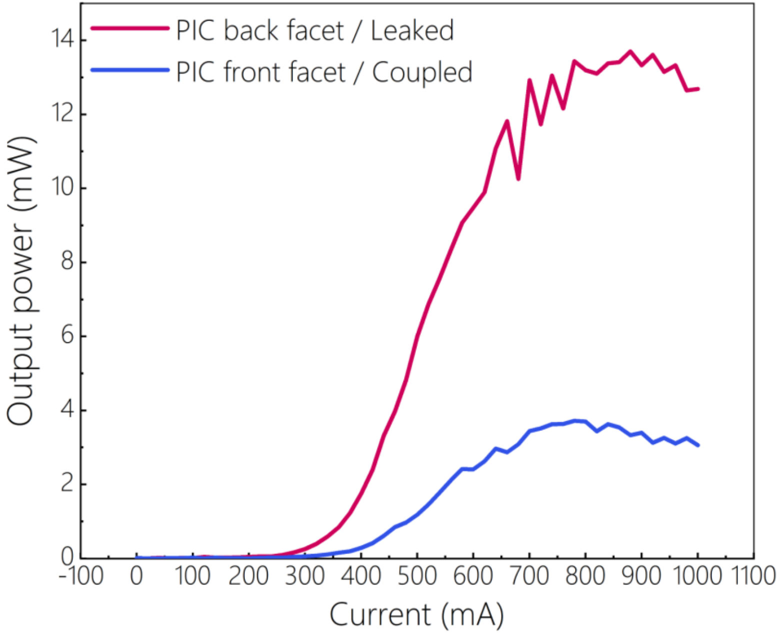
# Bonding results

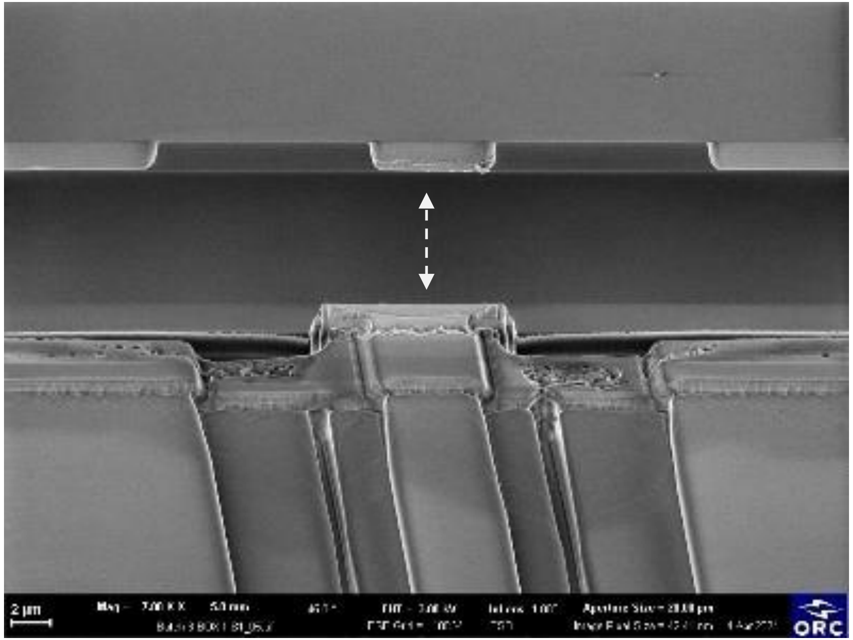
Misalign (um)
X ~ 0.3
Y ~ 0

Post bonding accuracy is acceptable < 500 nm



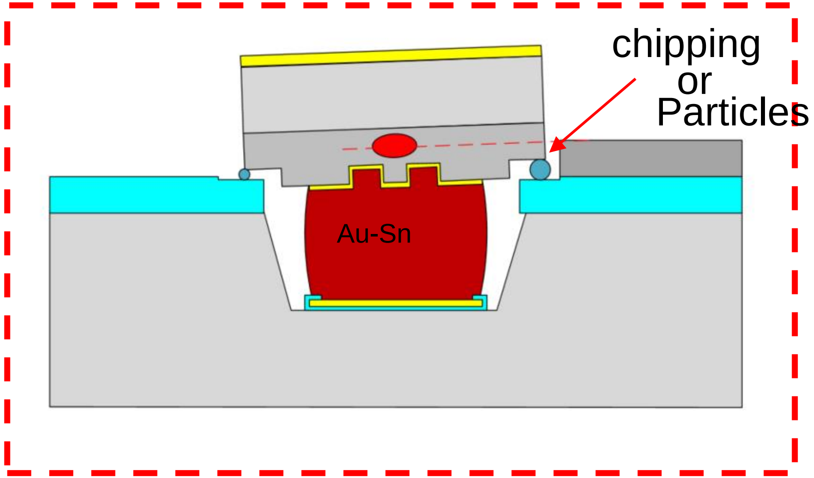
# Very low optical coupling due to….

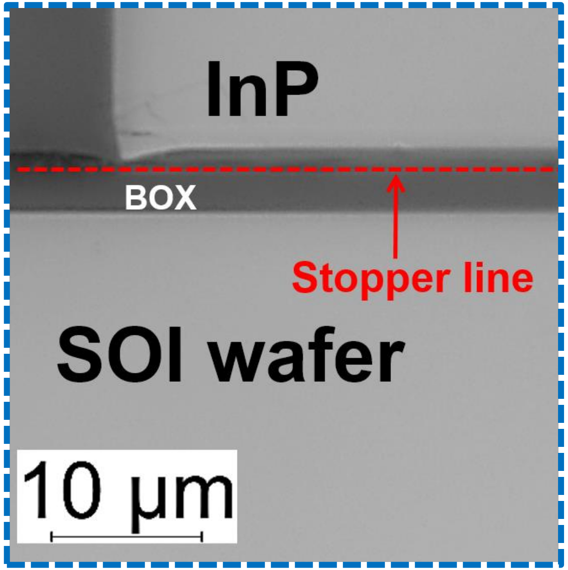


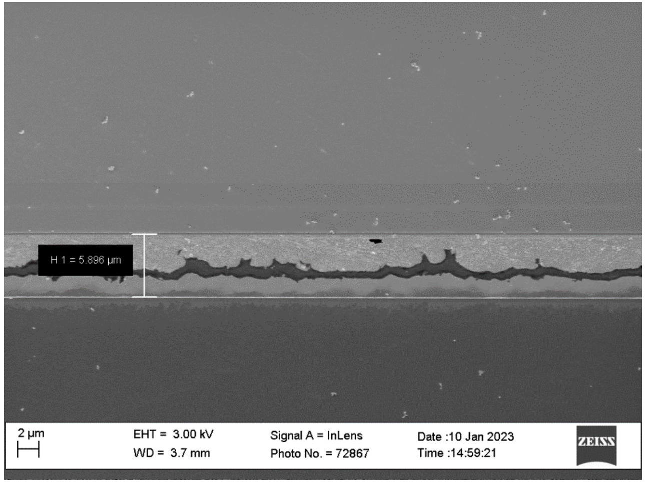
# Hybrid integration development

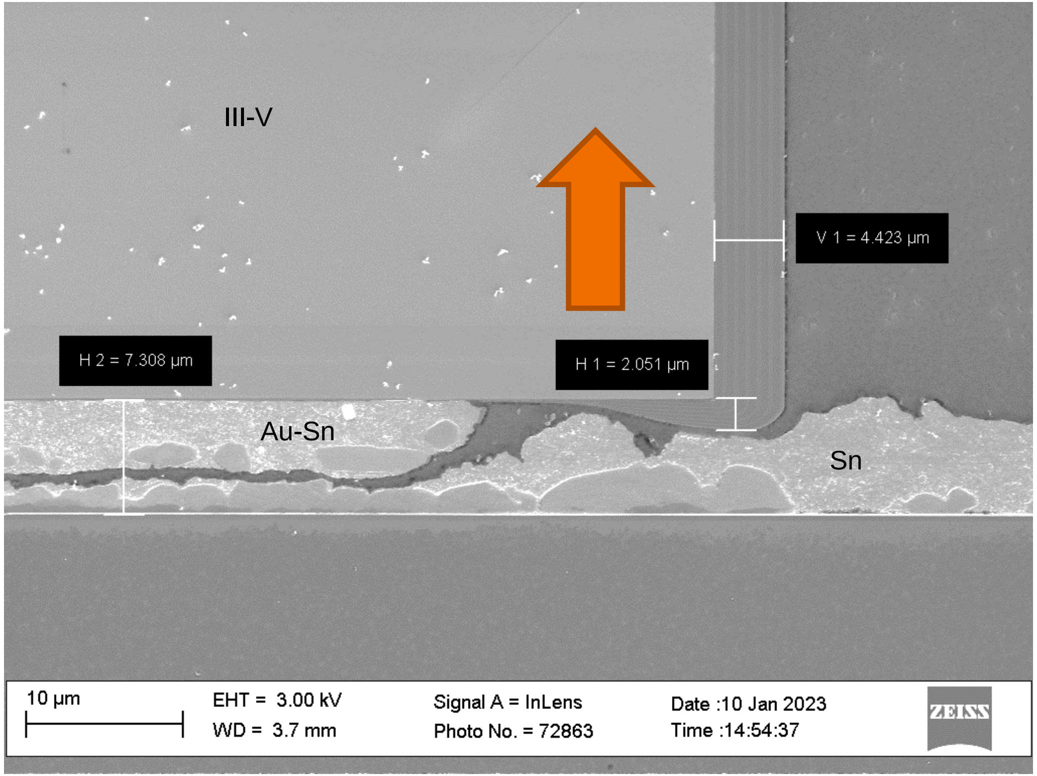
Issues : **Z-axis mis-alignment due to particles or/and chipping**



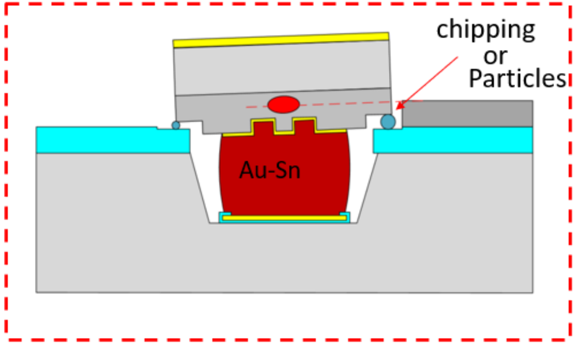



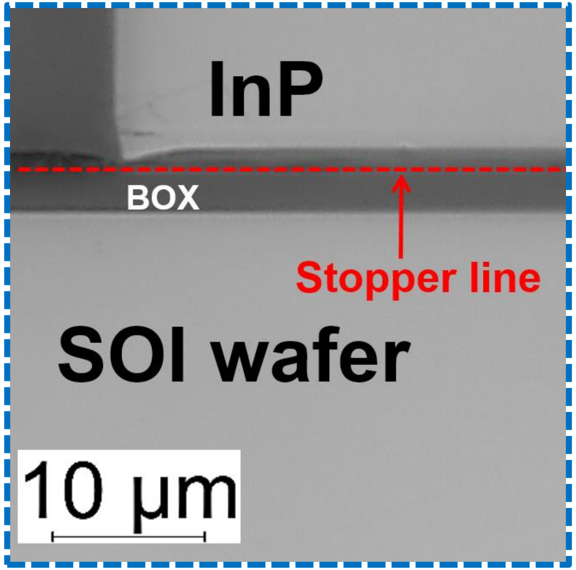
# Discussion : Optical performance needed to be improved



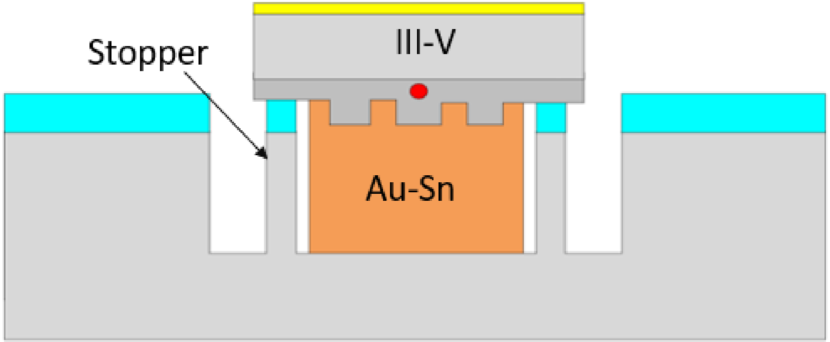



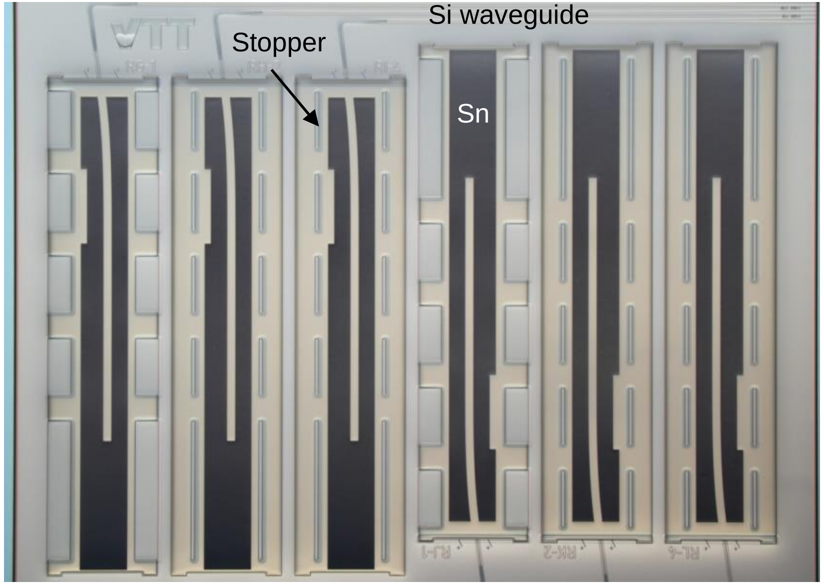
# Solution



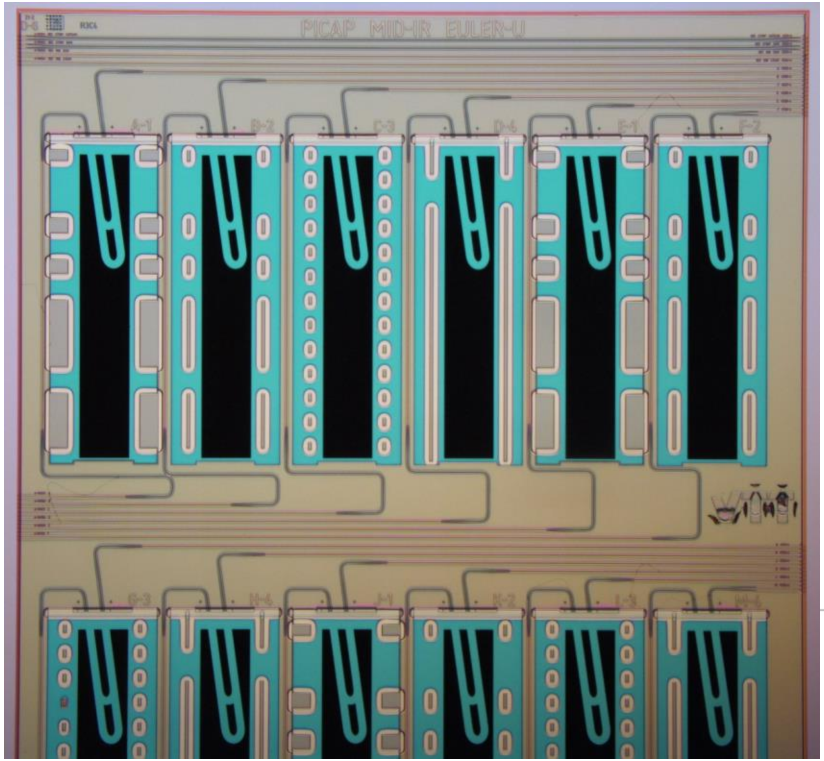



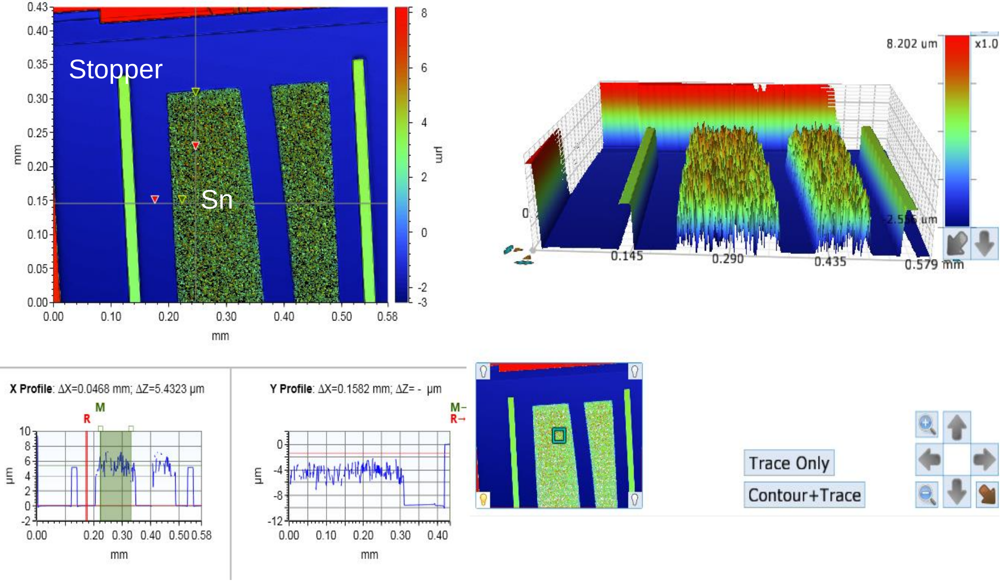

# MPW12



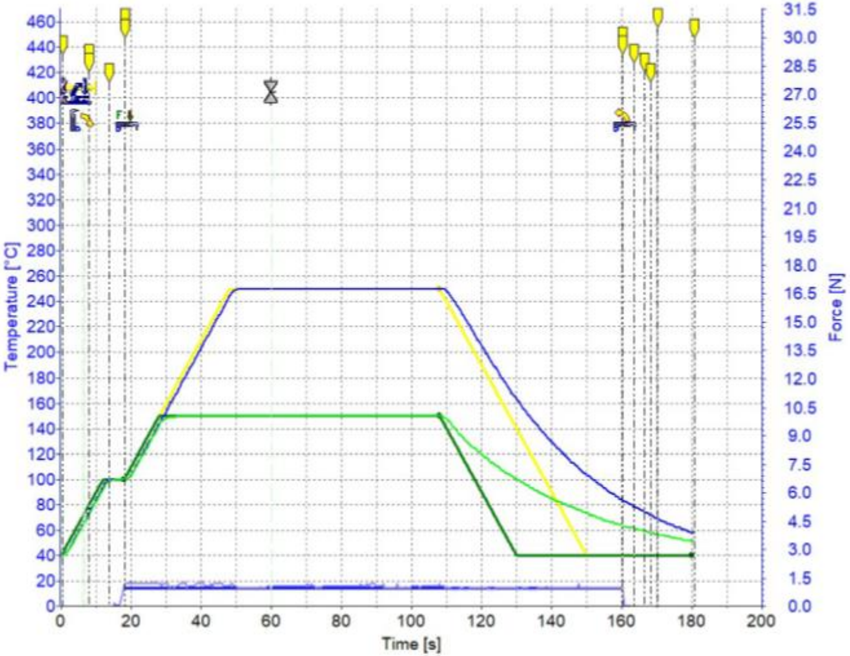



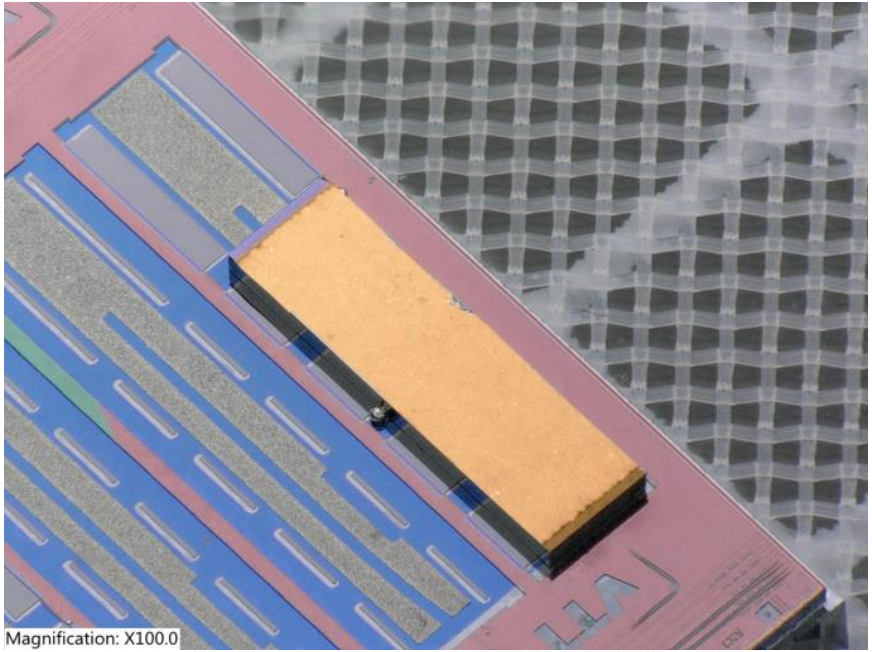
# Flip-chip bonding : Solder Mount



# Flip-chip bonding

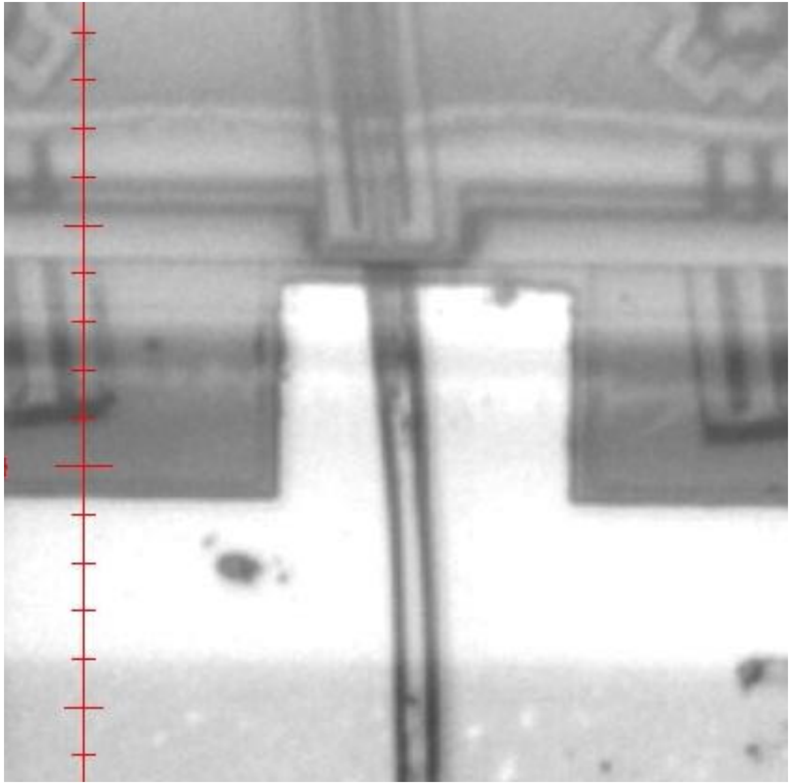


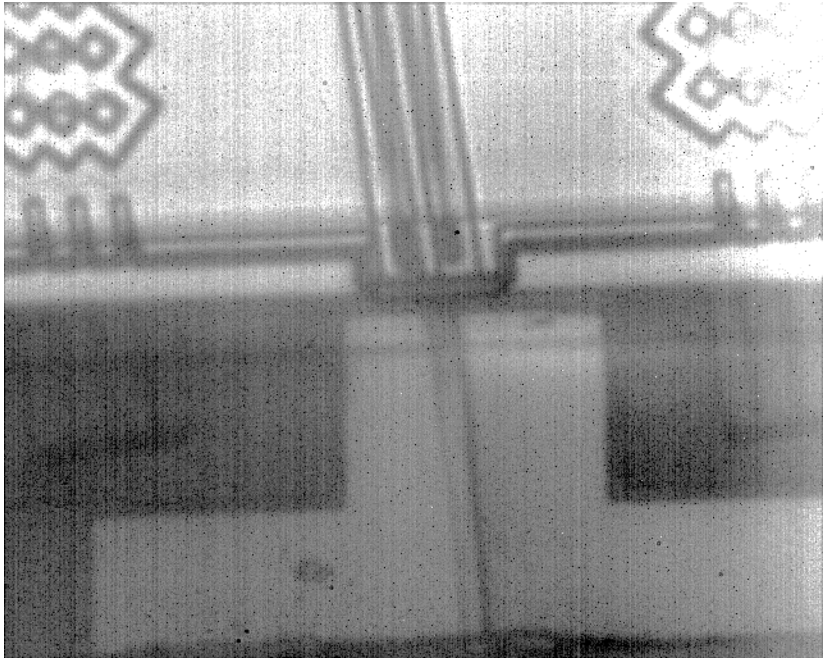

**Flip-chip bonder optimization needed**

# RSOA flip-chip bonding results

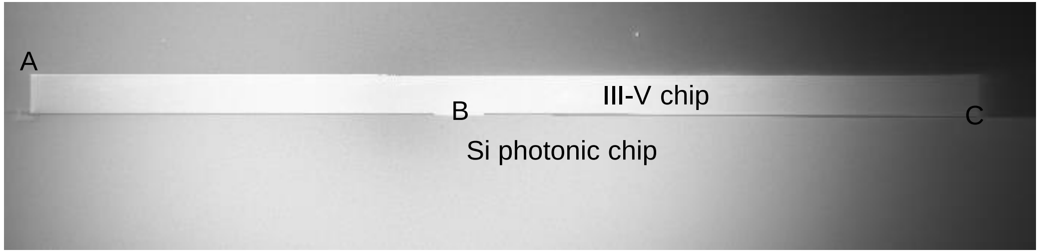
Alignment before bonding (Femto 2 optical image)



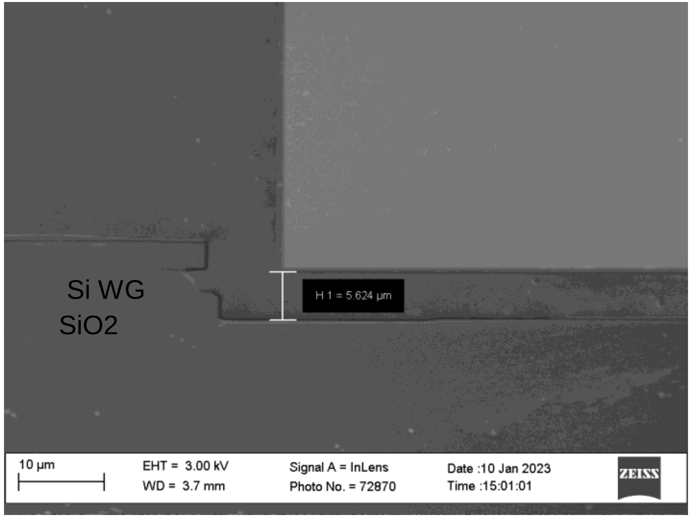
Alignment after bonding (**IR image**)



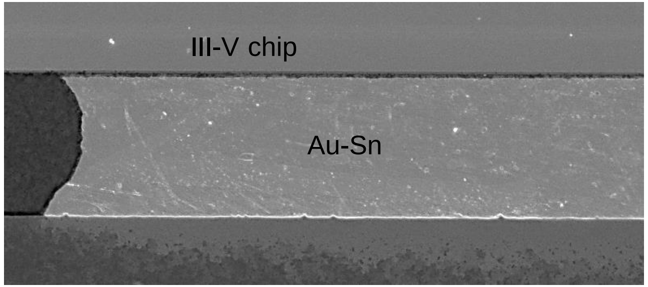
# Cross SEM images



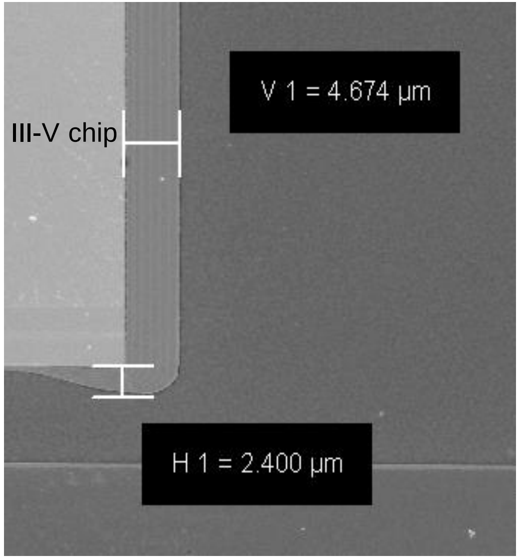

A




B




C



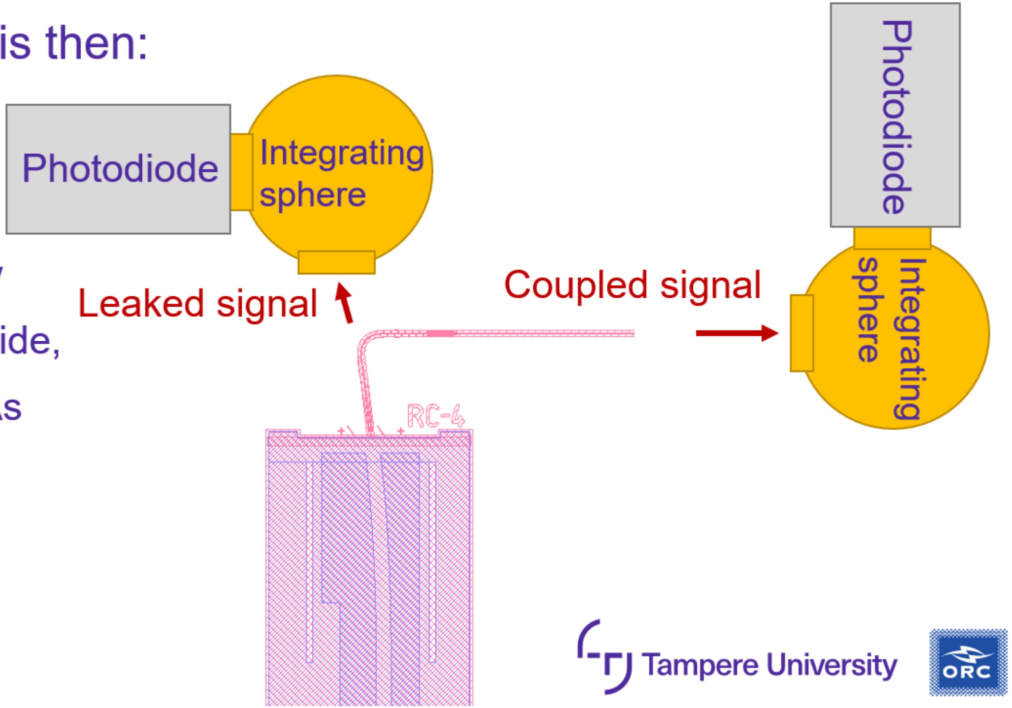
# Outline of the measurements

- Pulsed current (100 kHz, 10% duty cycle) was injected to RSOA with probe needles
- ”Leaked signal” and ”coupled signal” was measured utilizing an integrating sphere
- Estimated ”coupling efficiency” is then:

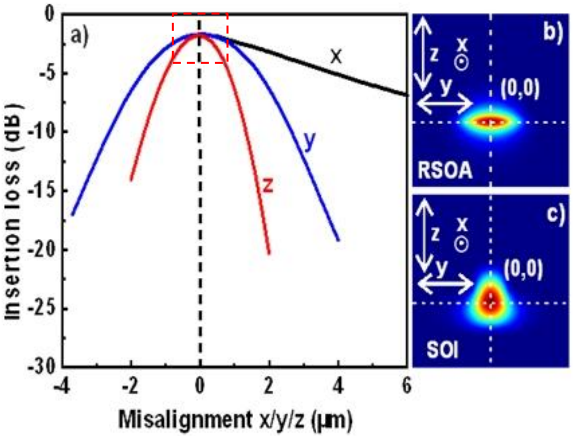
$$\frac{\text{Coupled signal}}{\text{Leaked signal} + \text{Coupled signal}}$$

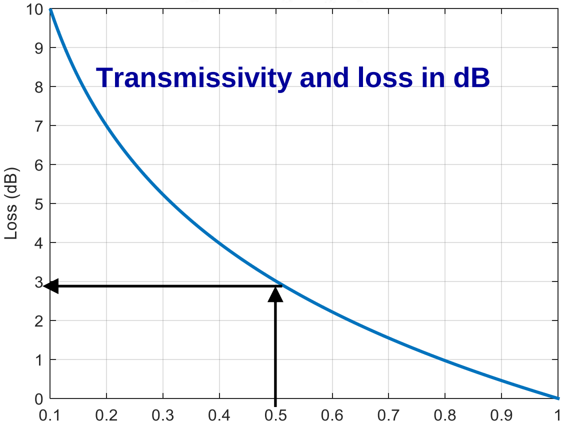
- This is not the actual coupling efficiency, but gives some idea of how much light is coupled into the waveguide, and allows one to compare the RSOAs
- ”Total signal” was also calculated:

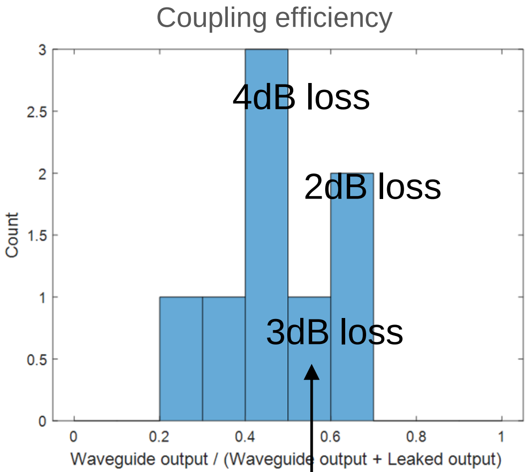
$$\text{Leaked signal} + \text{Coupled signal}$$

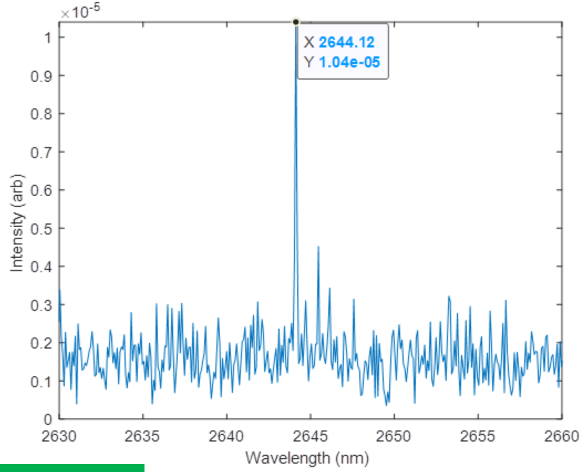


# Achievements till now




Basic loss ~2 dB due to mode mismatch

+

Optical misalign

1 dB loss

+

Other issues :AR coating ….

**Thank you very much**

**Q and A**