Enabling Volume-Compatible Photonic Medical Devices Through Hybrid Integration Assembly

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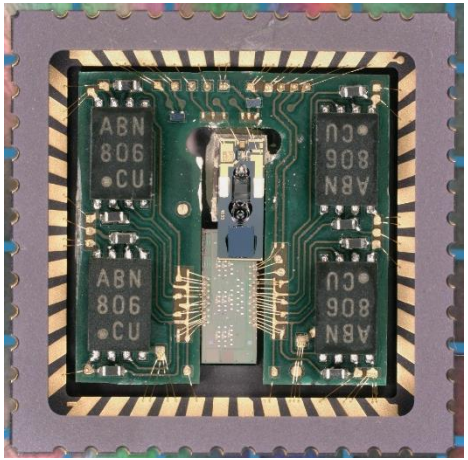
4. Medtronic Bakken Research Center, Maastricht, The Netherlands.



InSiDe Photonic Sub-package

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Contents

- Laser Doppler Vibrometry and the InSiDe Project
- Challenges and opportunities for scaled manufacturing
- Wafer-level Micro-Optical Bench assembly
- Volume-compatible photonic integration
- Q&A

Laser Doppler Vibrometry and InSiDe

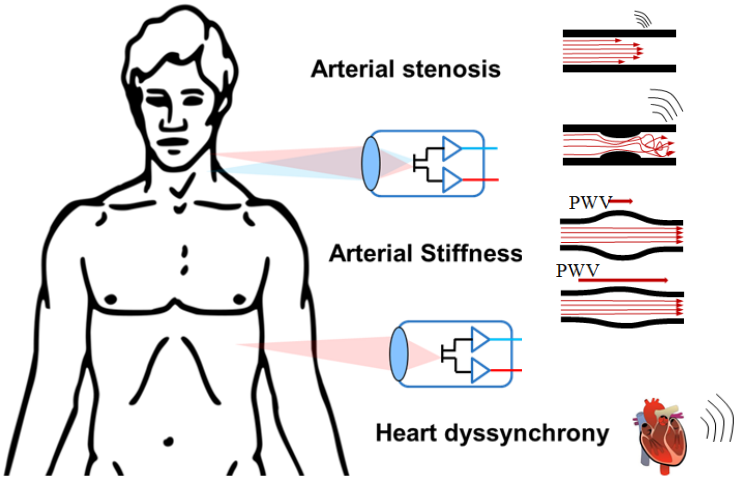


Fig. 1: Biomarkers measured using Laser Doppler Vibrometry

- Cardiovascular Diseases (CVDs) leading cause of death worldwide
- Early intervention required
- Non-invasive diagnosis using biomarkers

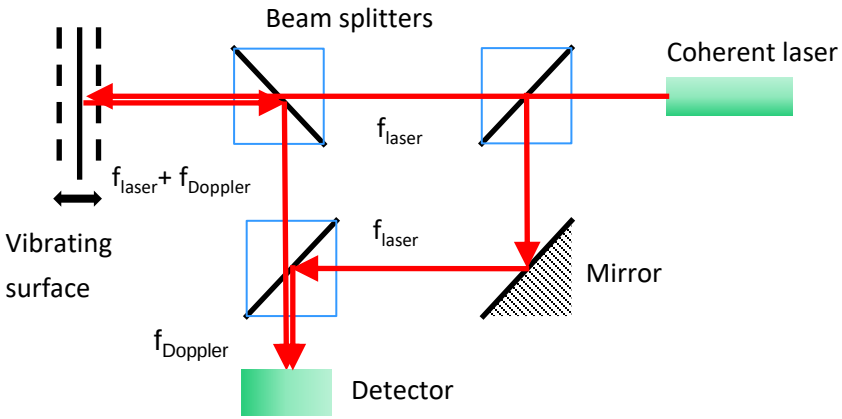


Fig. 2: Laser Doppler Vibrometer optical circuit schematic

- LDV measures surface using non-contact optical signals
- Signal reflected from surface is Doppler shifted
- Can calculate displacement and velocity of surface

Laser Doppler Vibrometry and InSiDe

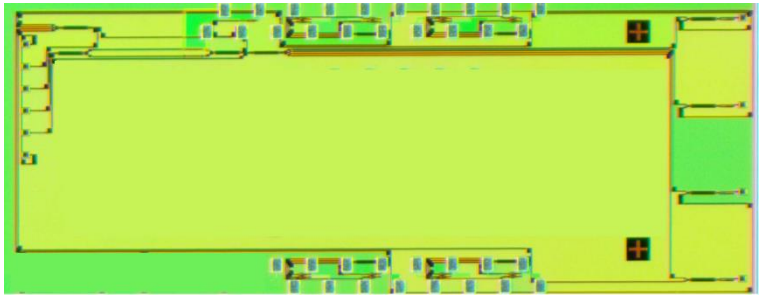


Fig. 3: Silicon photonic integrated circuit replaces the bulky free-space optical components to miniaturise the laser-doppler vibrometer circuit

- Silicon-based PIC technology miniaturises LDV circuit technology
- Silicon platforms offer low-cost scalability
- MOB integration instead of external laser source allows for compact design

Fig. 4: Measuring arterial stiffness using InSiDe LDV medical device

- Laser Doppler Vibrometry optical sensor used as a hand-held diagnostic tool
- Multi-beam allows transient events to be measured without accurate alignment
- Clinical validation in 2024 by Inserm

Challenges and opportunities for scaling

Scalability Requirements for LDV Medical Device

- Parallel manufacturing of electronic printed circuit board and photonic sub-assembly
- Higher-speed photonic integration and subassembly

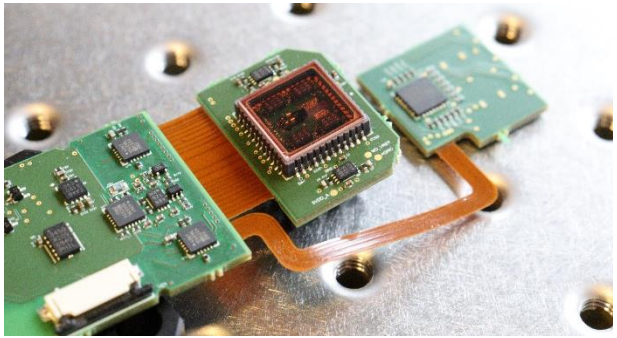


Fig. 5: Electronic PCB and photonic sub-assembly of InSiDe medical device

Methods for higher-speed photonic subassembly

- Wafer-level MOB assembly techniques
- High-speed pick and place of passively aligned components
- Scalable MOB integration techniques

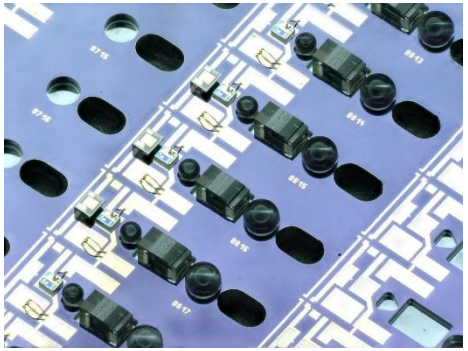
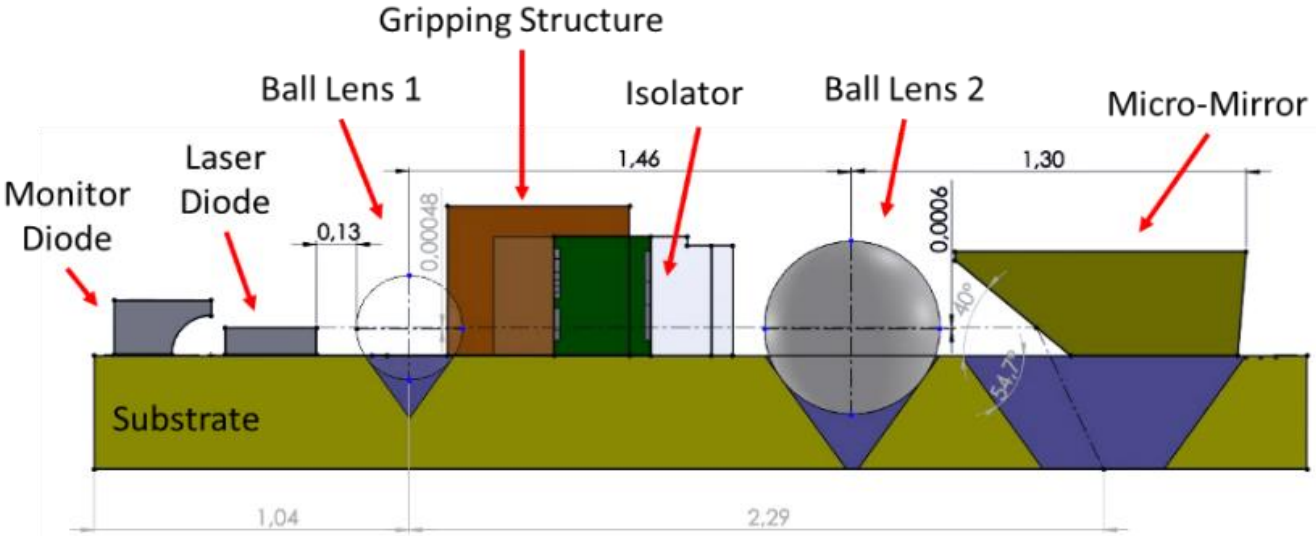


Fig. 6: Assembly of micro-optics on silicon wafer MOB substrate

Micro-Optical Bench (MOB) Design



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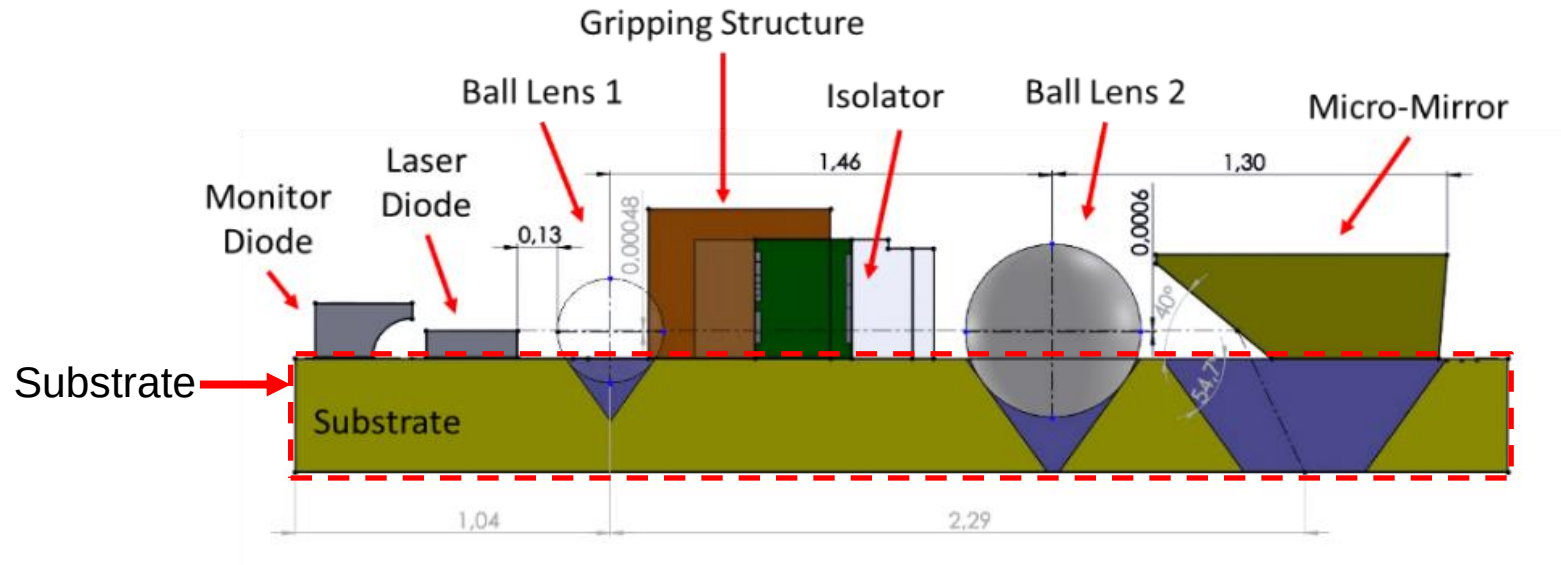

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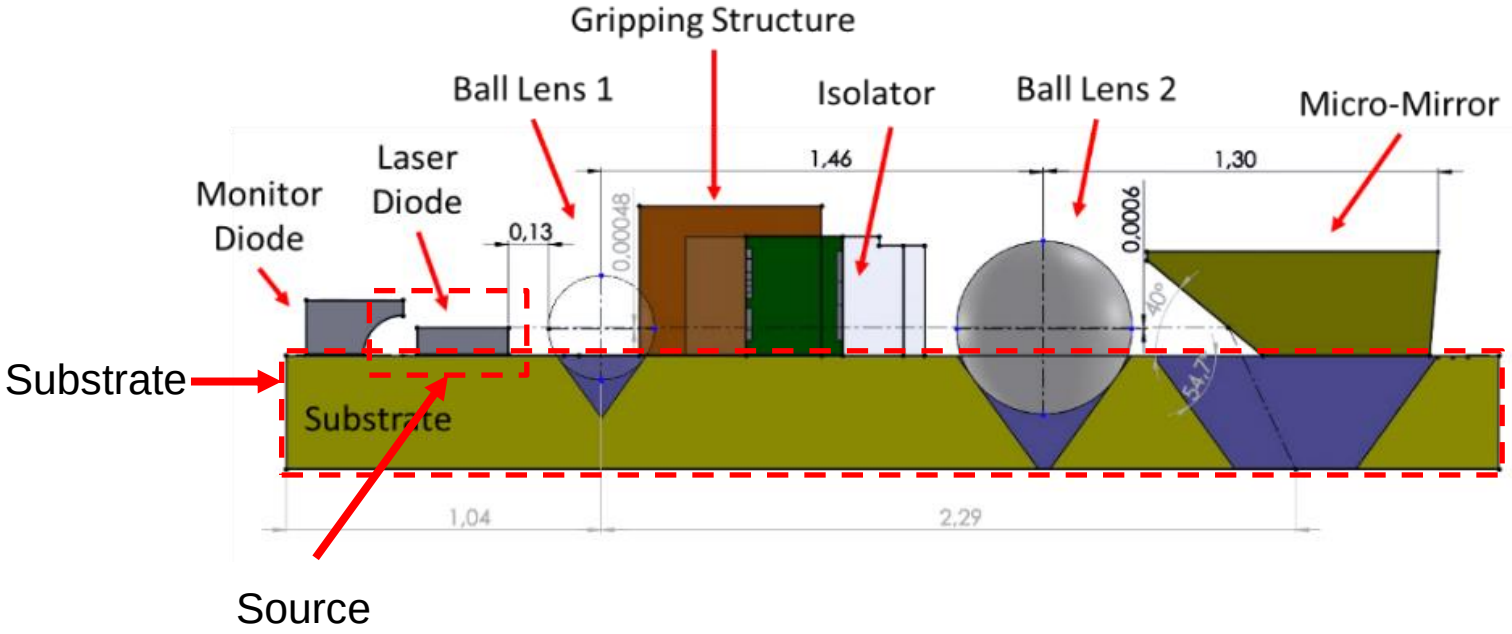

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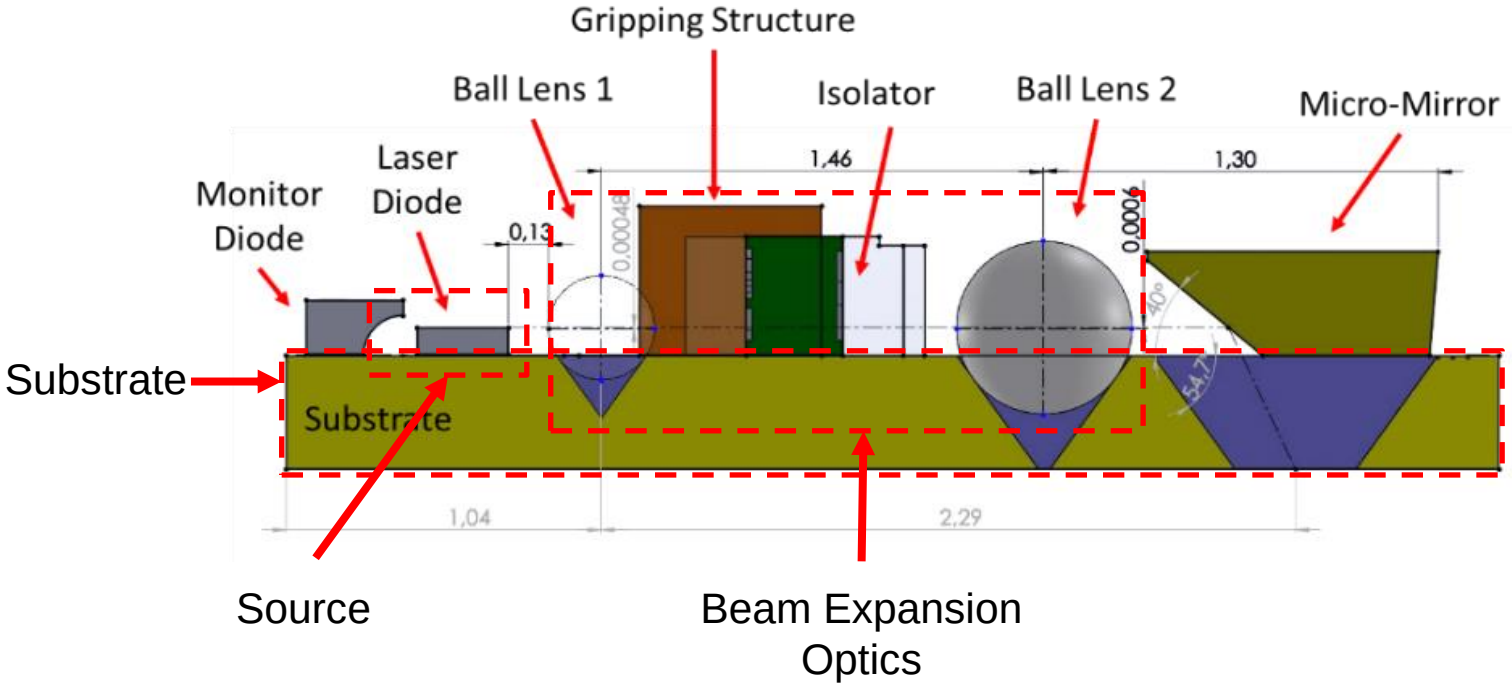

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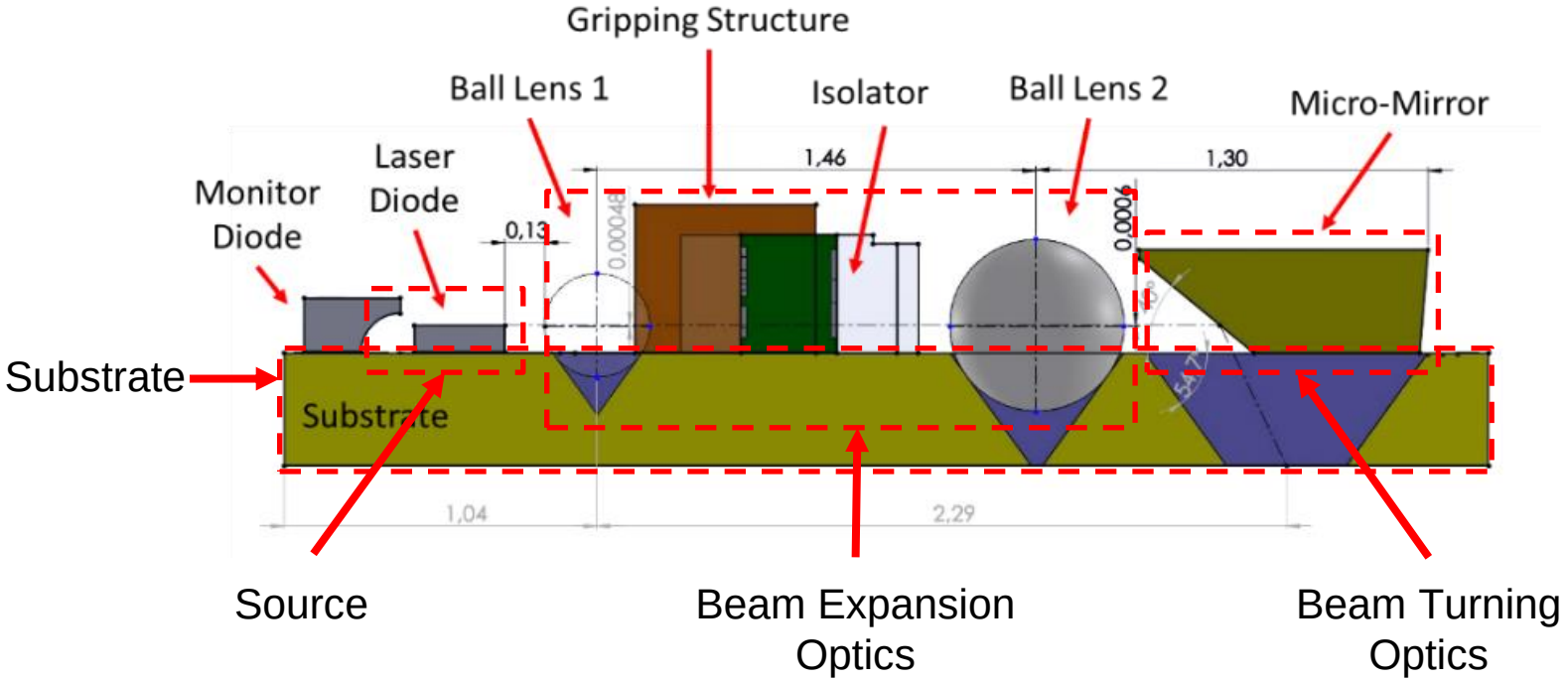

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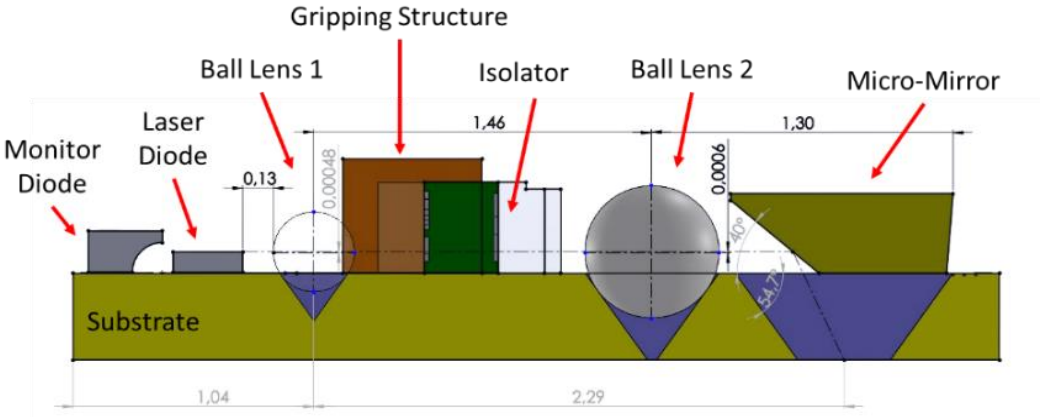


Fig. 7: Side-view schematic of micro-optical bench (MOB)

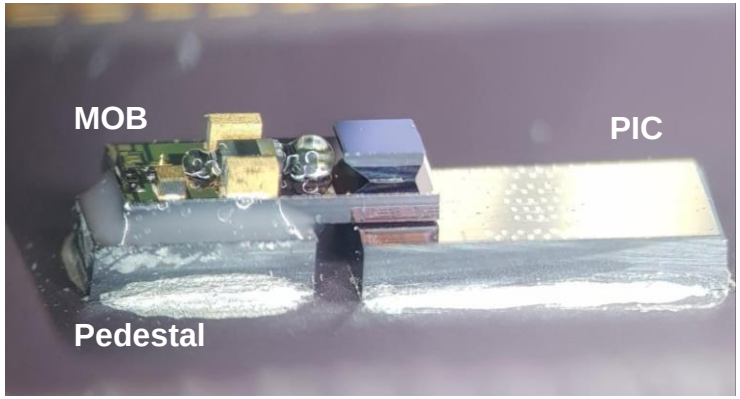
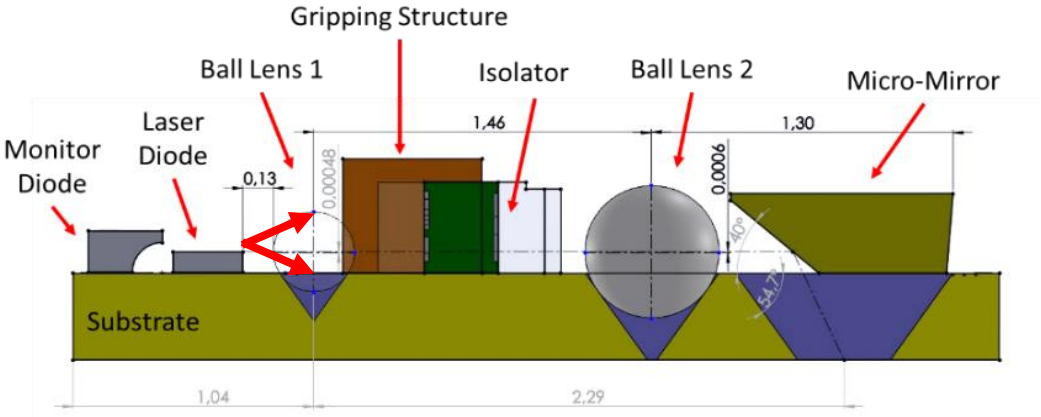


Fig. 8: MOB integrated to PIC

Micro-Optical Bench (MOB) Design



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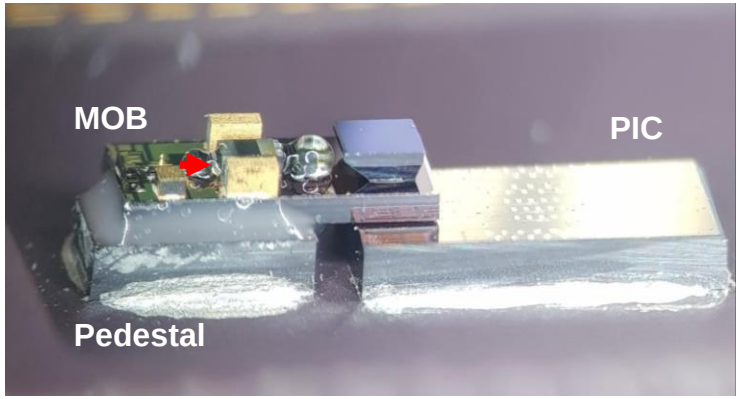
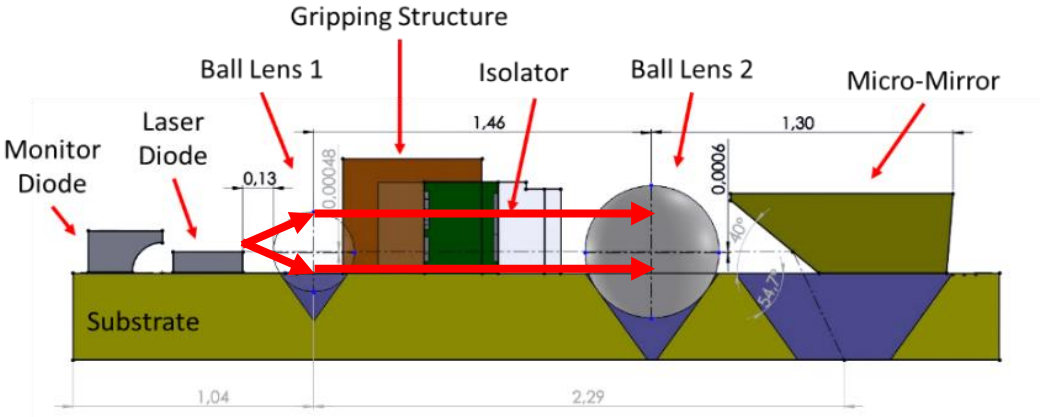


Fig. 8: MOB integrated to PIC

Laser light leaves laser diode and enters ball lens

Micro-Optical Bench (MOB) Design



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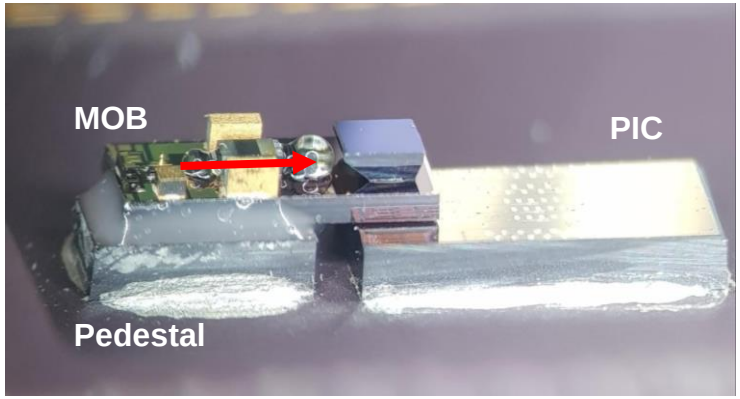
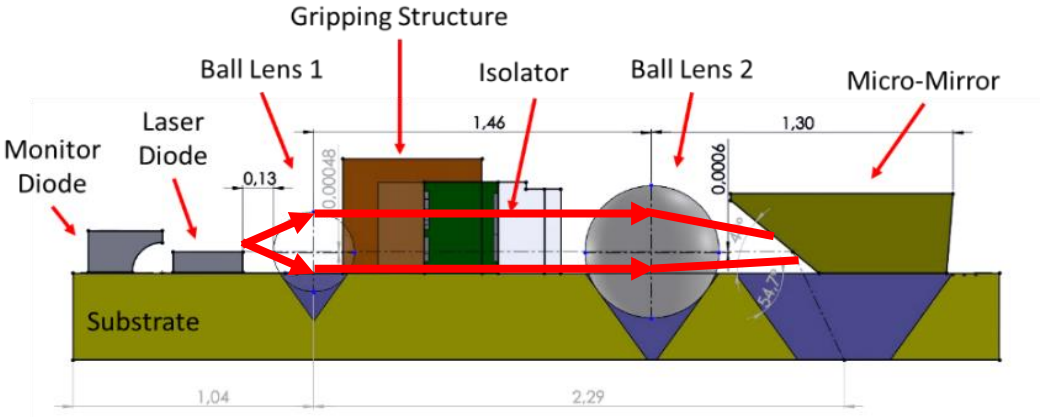


Fig. 8: MOB integrated to PIC

Beam is collimated and travels through isolator

Micro-Optical Bench (MOB) Design



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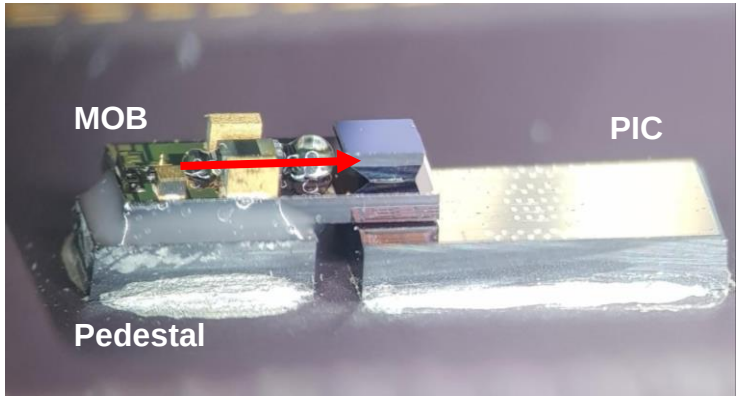
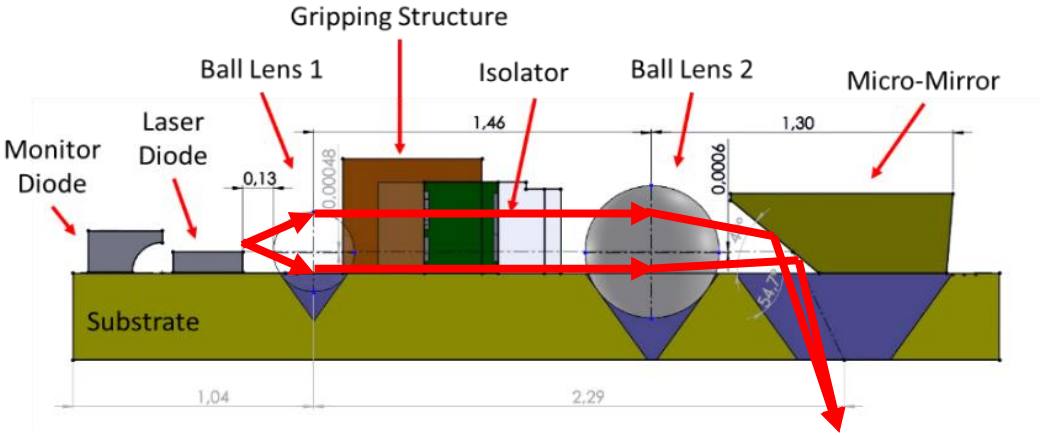


Fig. 8: MOB integrated to PIC

Beam is focused using second ball lens

Micro-Optical Bench (MOB) Design



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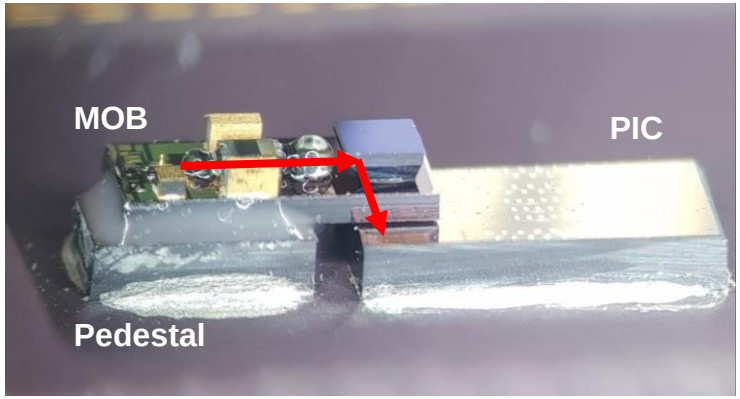


Fig. 8: MOB integrated to PIC

Beam is turned at correct angle of incidence and focuses below substrate

Wafer-level Micro-Optical Bench assembly

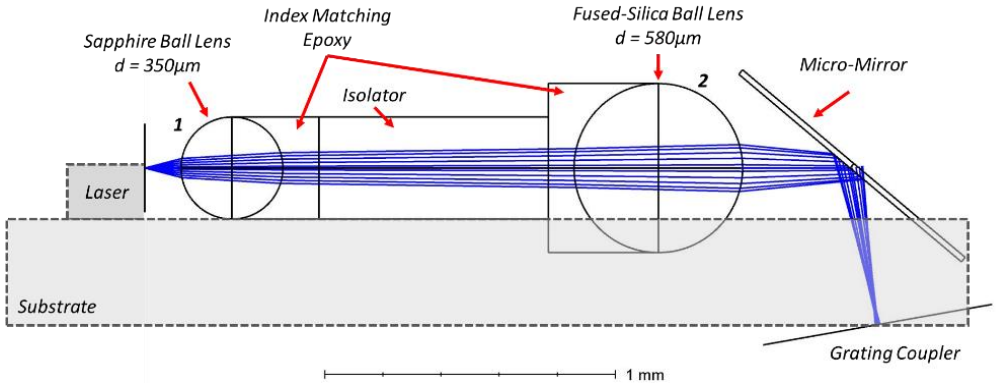


Fig. 9: Zemax design of MOB

- MOB corrects angle of incidence to grating coupler and enlarges MFD
- Results in more-relaxed alignment tolerances for MOB integration

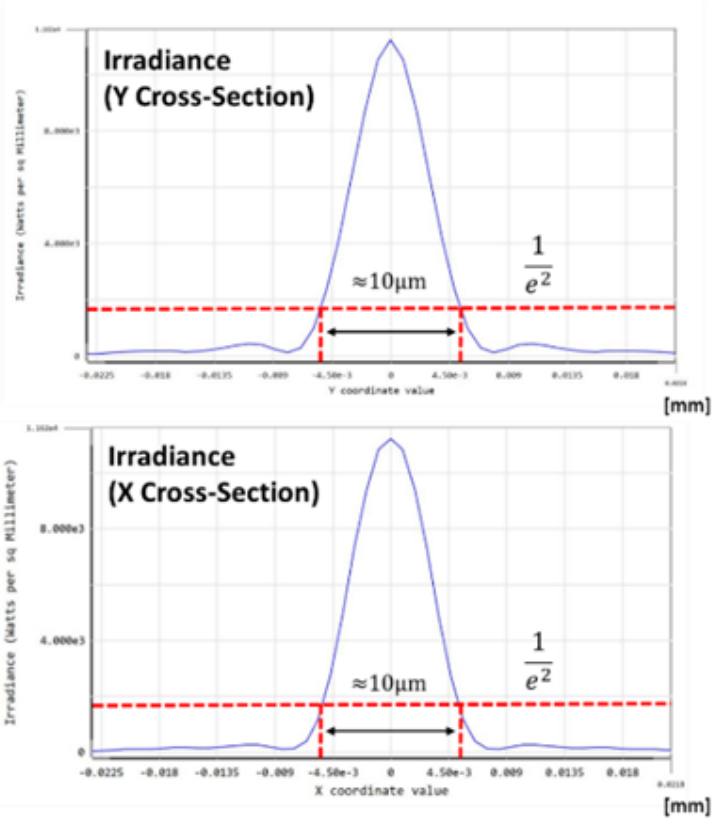
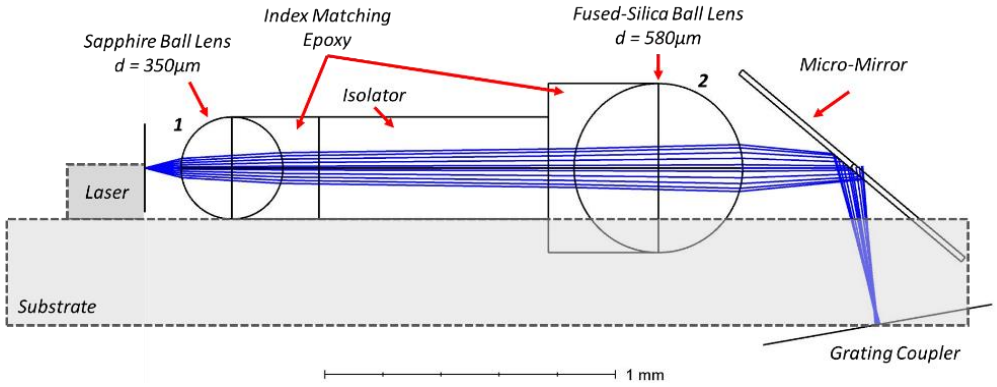


Fig. 10: Simulated mode-field diameter of MOB

Wafer-level Micro-Optical Bench assembly



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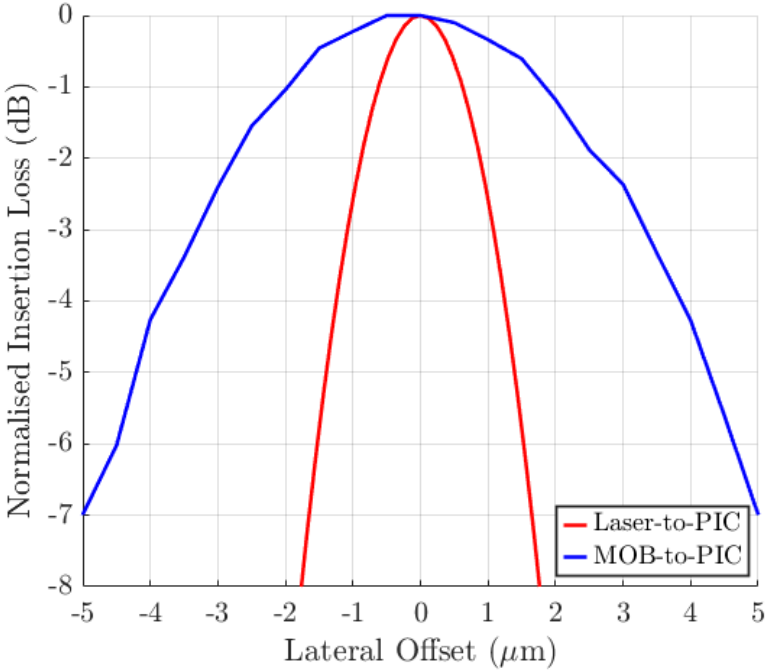


Fig. 11: Laser-to-PIC and MOB-to-PIC alignment tolerances

Wafer-level Micro-Optical Bench assembly

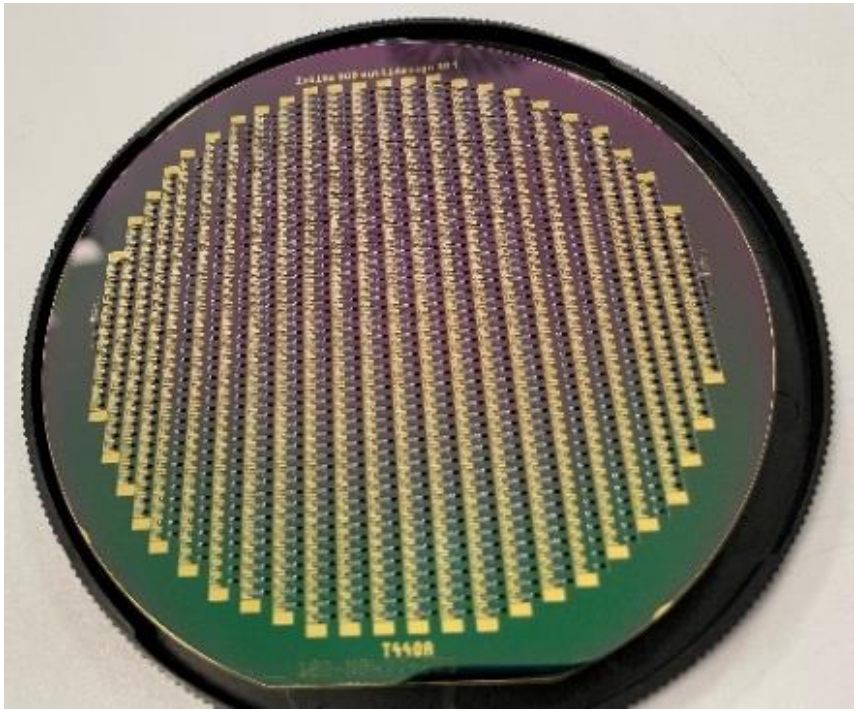


Fig. 12: Bare silicon wafer of etched MOB substrates

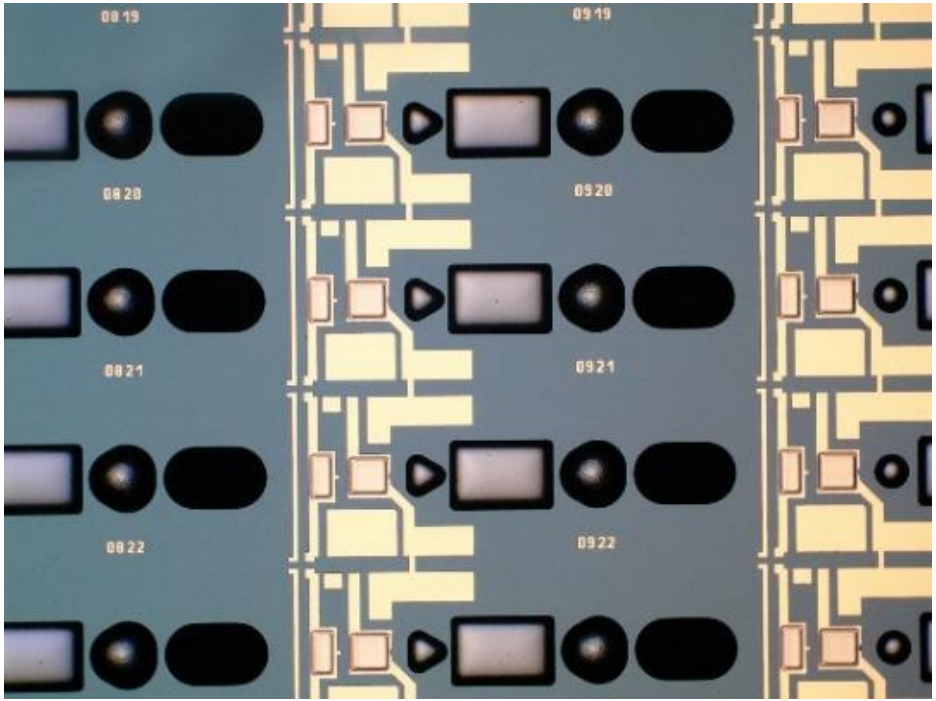


Fig. 13: Optimised modified recess shape for ball lens alignment to silicon substrate

Wafer-level Micro-Optical Bench assembly

- High speed pick and place assembly of optical components
- Laser and monitor diodes are attached using a laser-assisted solder reflow process
- Wafer-scale process development.
- Lead-time significantly reduced

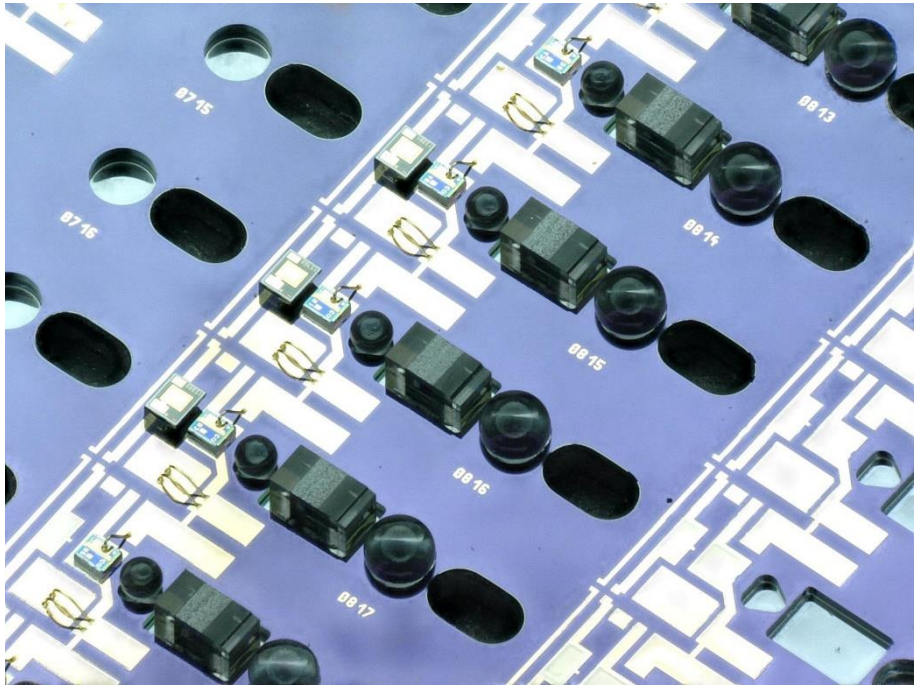


Fig. 14: Wafer of MOB assemblies before dicing and micro-mirror attachment

Volume-Compatible Photonic Integration

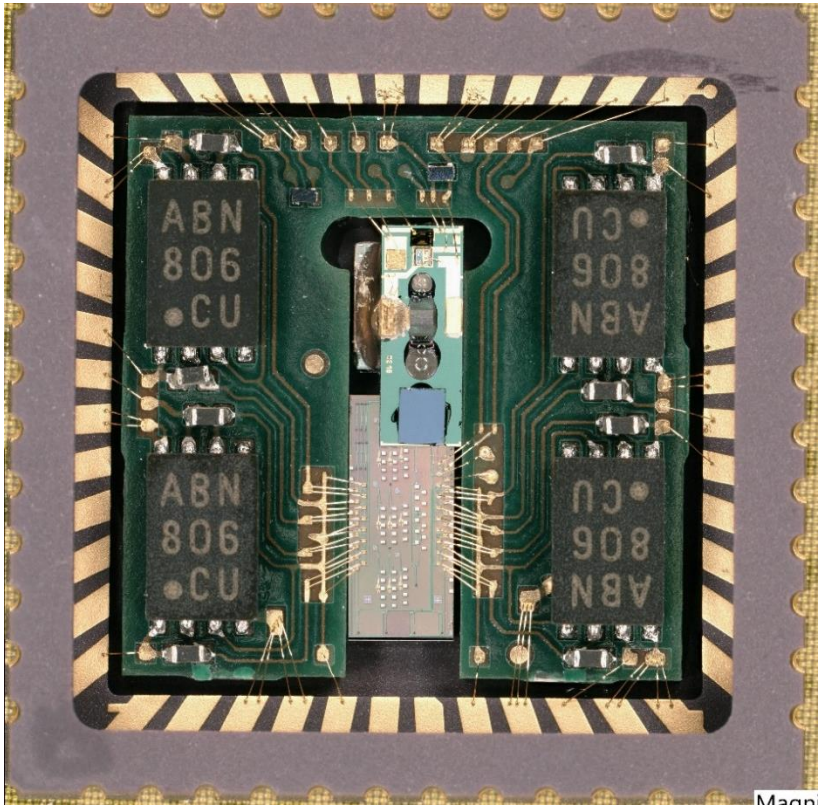
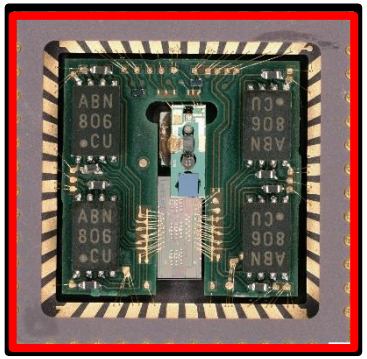
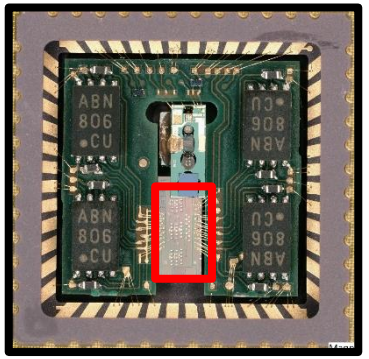


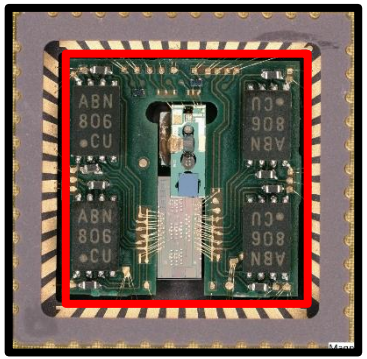
Fig. 15: Photonic Subpackage Design



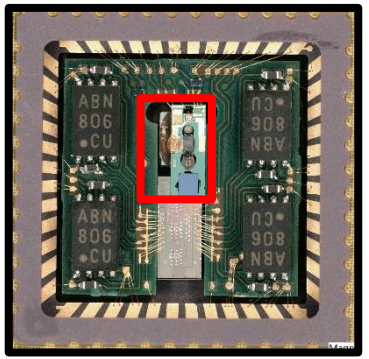
Kyocera QFN Package



PIC Integration

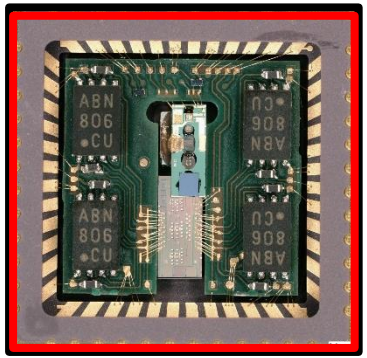


Interposer Integration



MOB Integration

Kyocera QFN Subpackage



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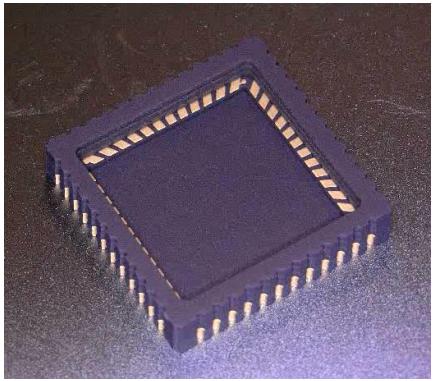


Fig. 16: Empty QFN Package

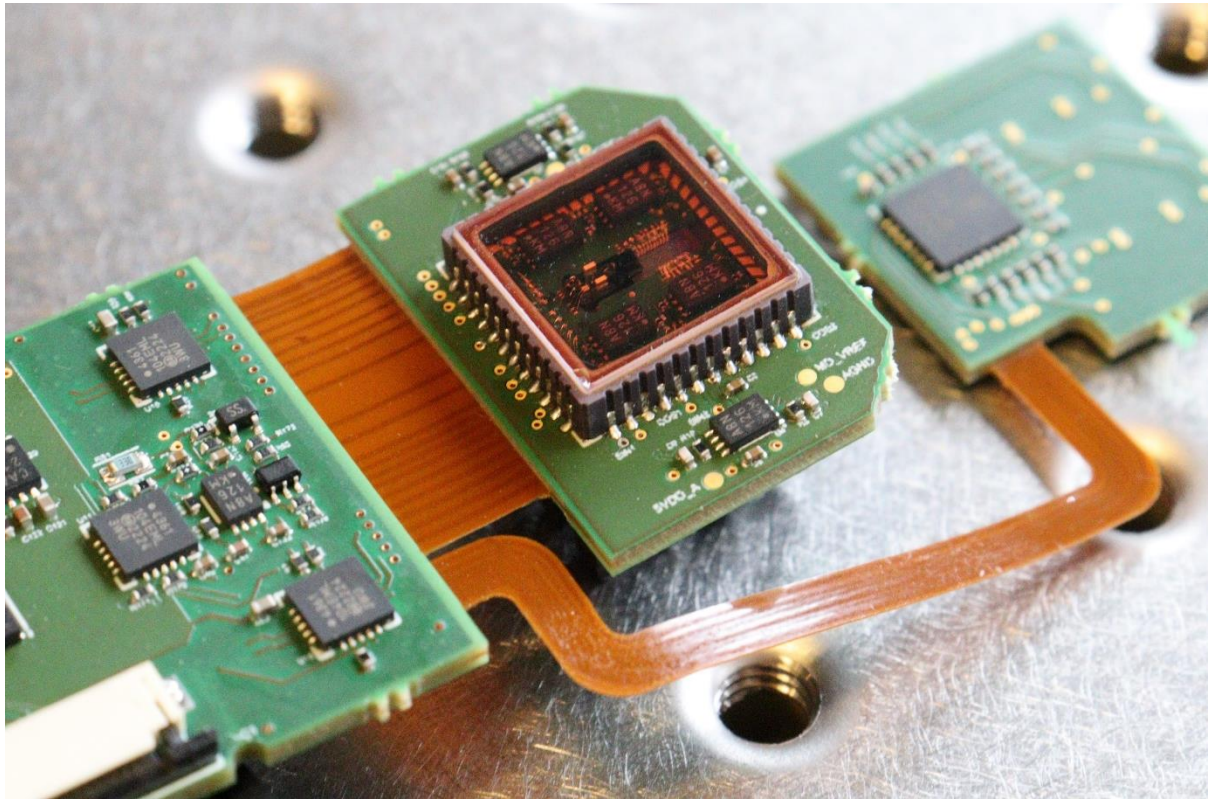
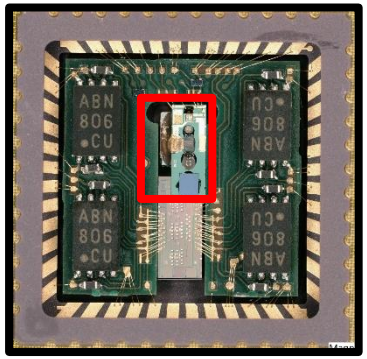


Fig. 17: Photonic Subpackage Integrated into main medical device PCB

PIC and Pedestal Integration



PIC Integration

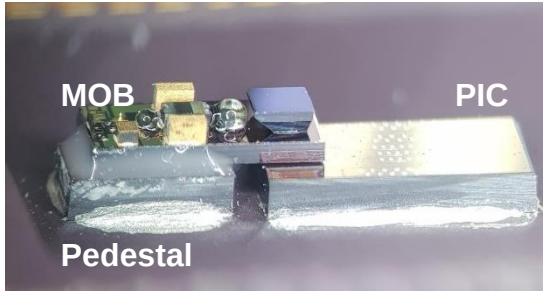


Fig. 18: PIC and Pedestal Side-View

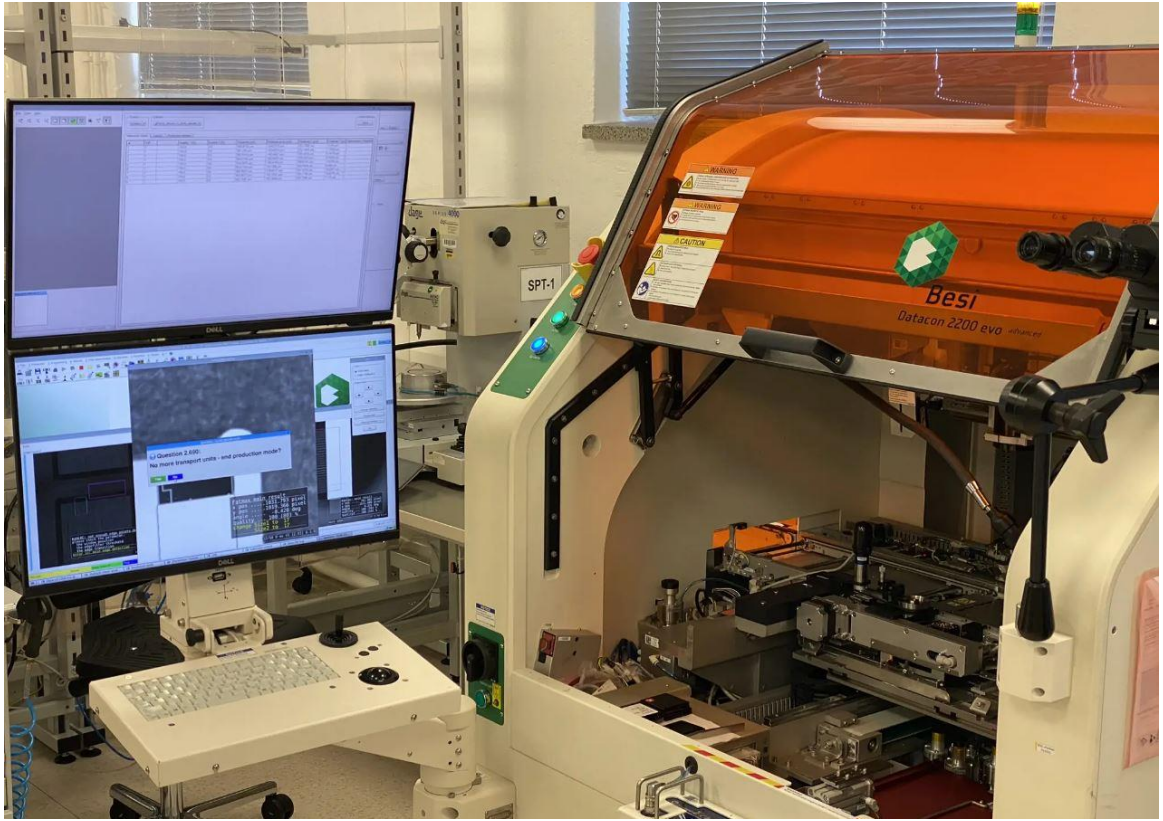
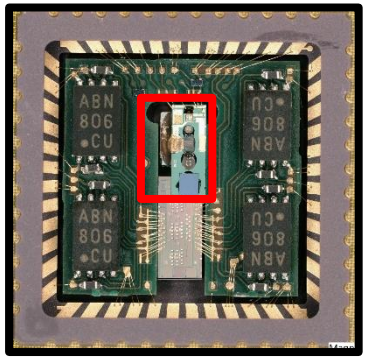
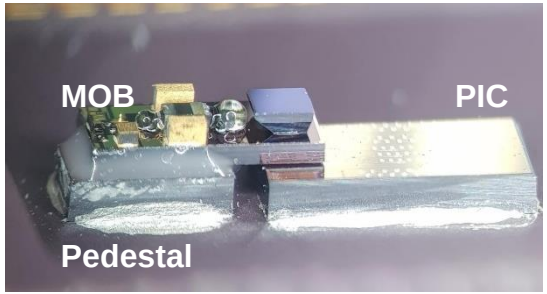


Fig. 19: Besi Datacon Automatic Pick-and-Place Machine

PIC and Pedestal Integration



PIC Integration



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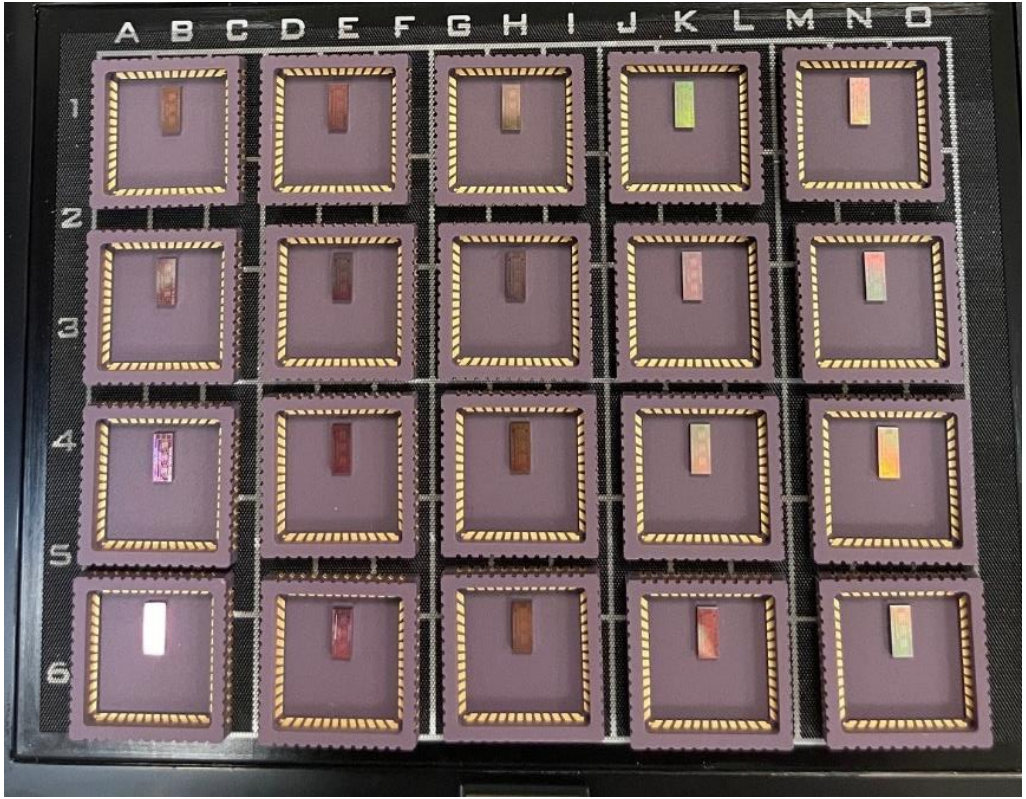
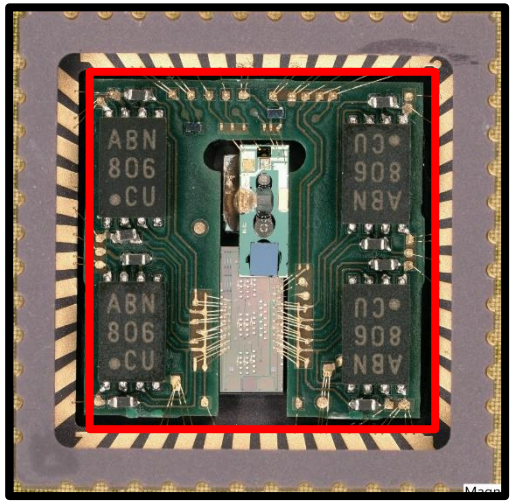


Fig. 20: Gel-Pak of Kyocera QFN with PIC attached

Interposer Integration and Wirebonding



Interposer Integration

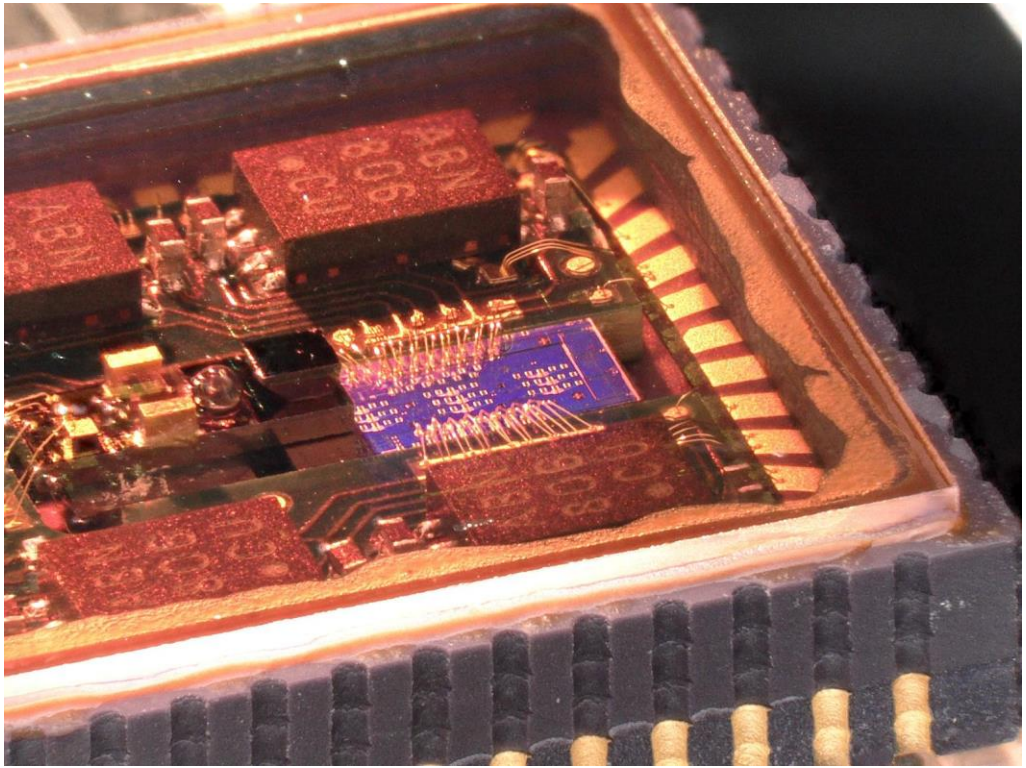
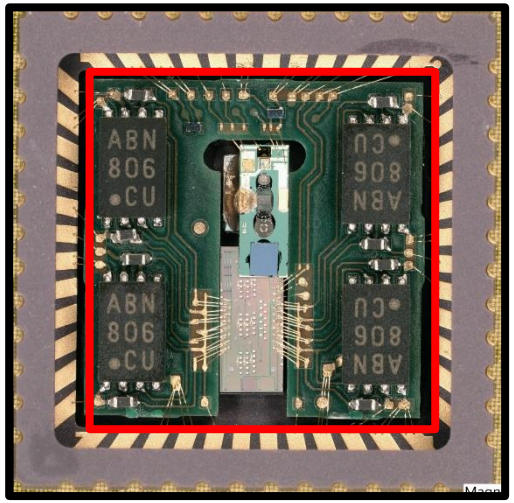


Fig. 21: Wire Bonding of PIC to Interposer

Interposer Integration and Wirebonding



Interposer Integration

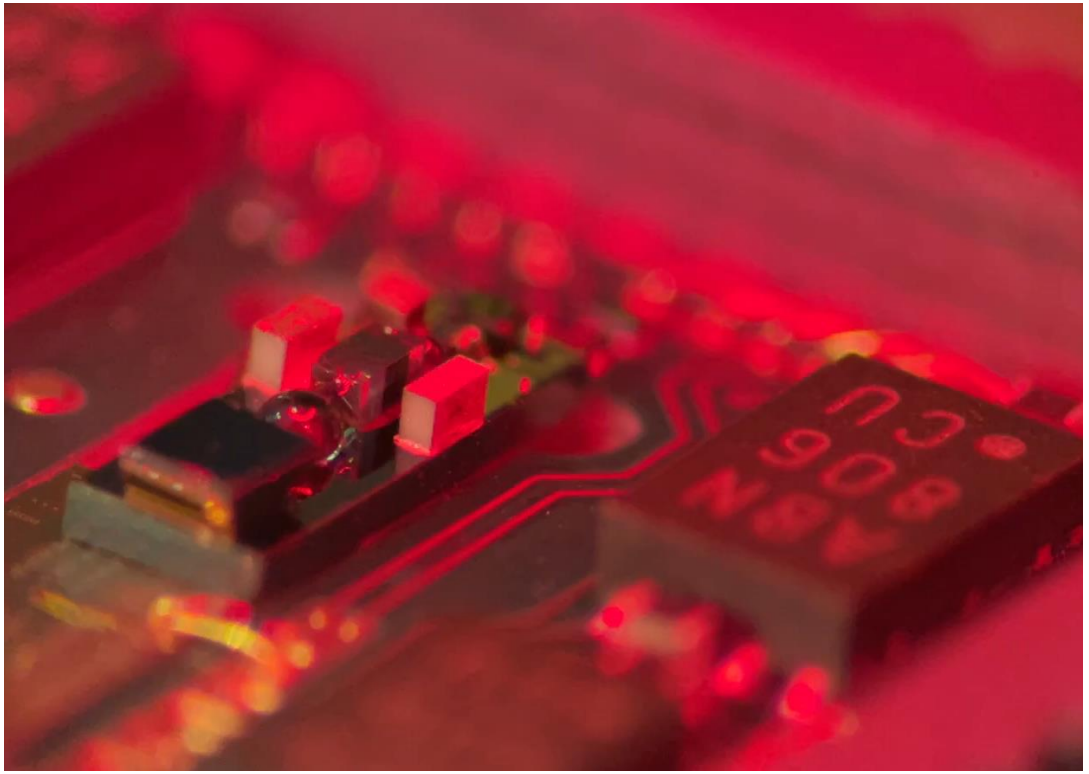
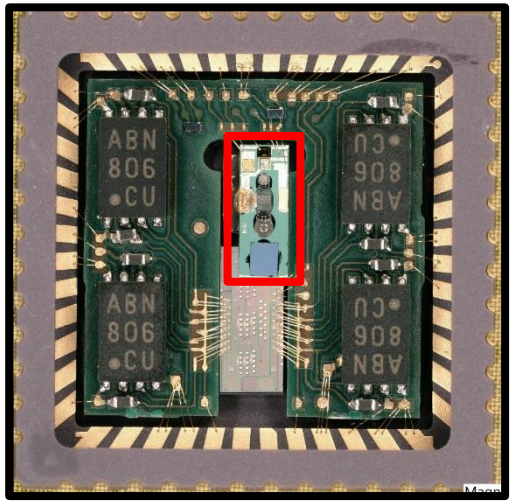


Fig. 22: Wire Bonding of MOB to Interposer

MOB Active Integration



MOB Integration

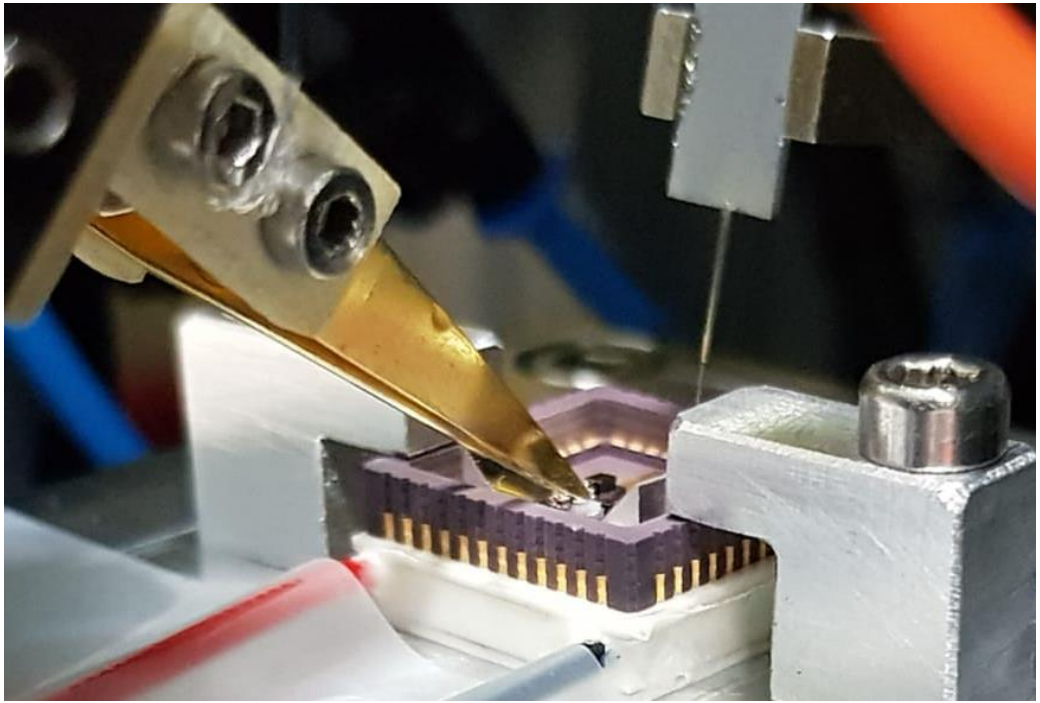
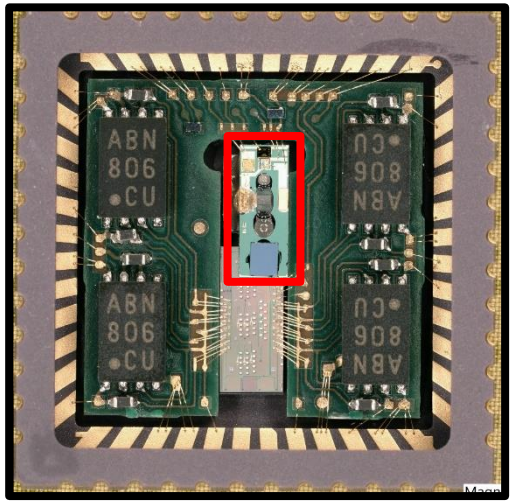


Fig. 23: MOB active alignment setup

MOB Active Integration



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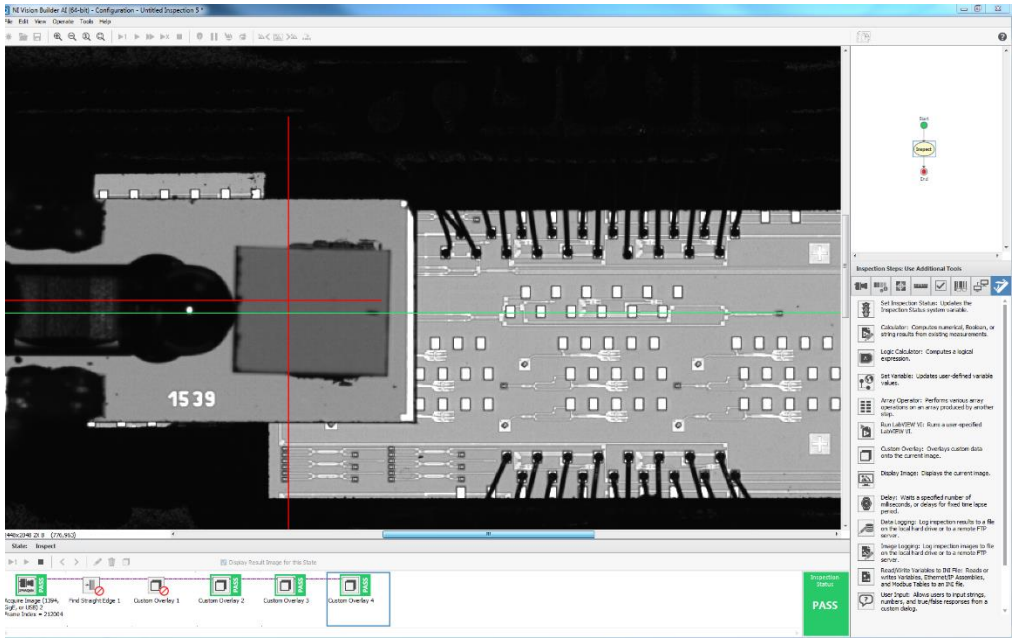
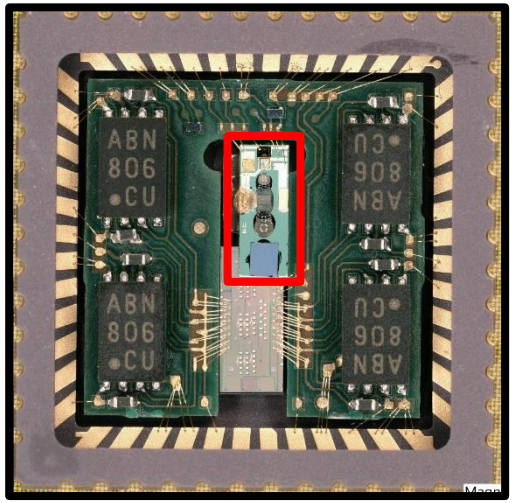


Fig. 24: Top-view of MOB Active Alignment

MOB Active Integration



MOB Integration

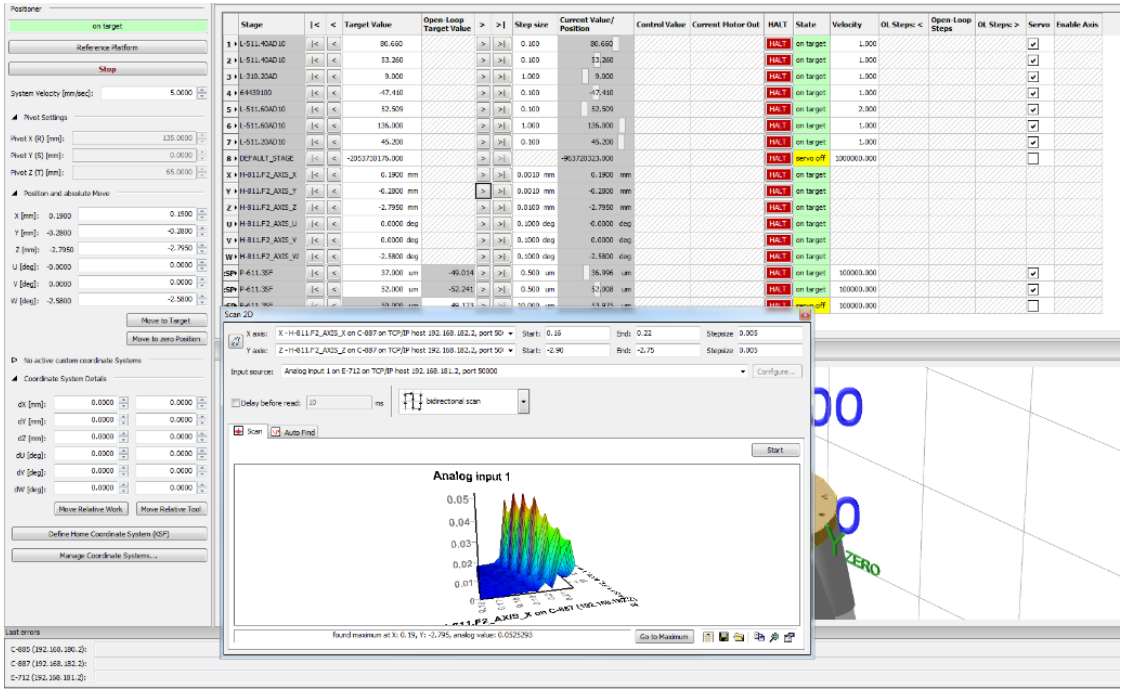


Fig. 25: Automated MOB Active Alignment Process

Challenges and opportunities for scaling

Summary

- Parallelising the electronic and photonic subassemblies of the medical device.
- Highly-scalable wafer-level MOB assembly
- High-speed photonic integration and subassembly

Further Work

- Wafer-level MOB-to-PIC integration before photonic subassembly
- Epoxy-free MOB-to-PIC integration
- MOB variation

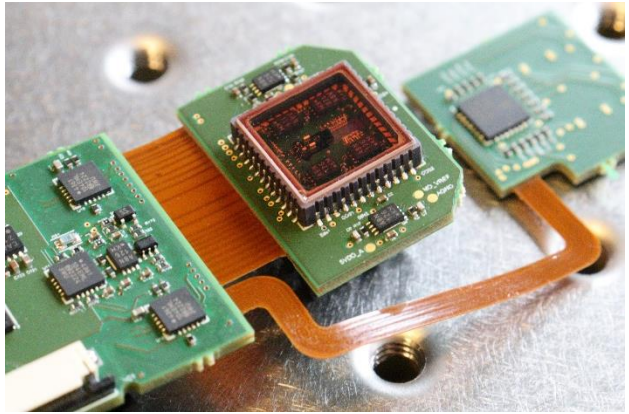


Fig. 17 (rep): Photonic Subpackage Integrated into main medical device PCB

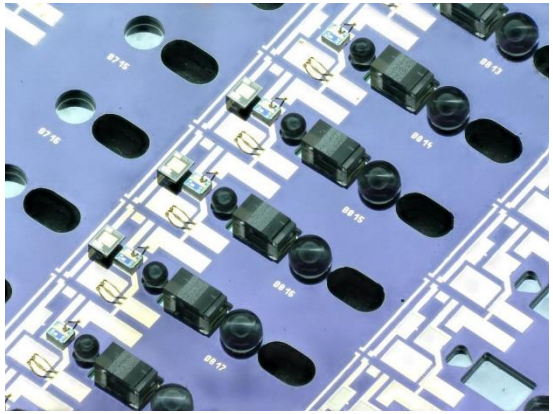
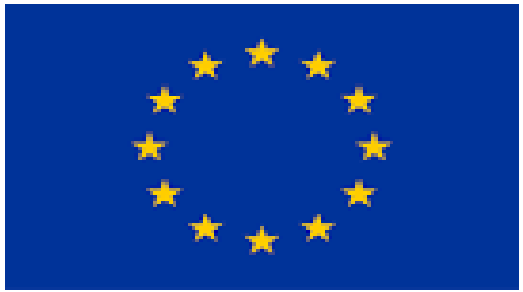


Fig. 14 (rep): Wafer of MOB assemblies before dicing and micro-mirror attachment



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Questions and Answers

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