

ADVANCED PHOTONIC MATERIALS, COMPONENTS AND LASER PROCESSES ENABLING THE METAVERSE

EPIC Meeting on Photonics for AR/VR/MR

May 12th, 2023

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Senior Director Marketing - Consumer Electronics

OUTLINE

1. **Company Background**
2. **Components and Modules for Sensing**
3. **Materials and Components for Displays**
4. **Lasers for Display Manufacturing**
5. **Conclusion**

COHERENT COMPANY BACKGROUND

II-VI IS NOW COHERENT



FROM A FOUNDATION OF MATERIALS AND IMAGINATION, WE ENABLE EXCITING MEGATRENDS

1971

Year Founded

28,000+

Employees⁽²⁾

4,400+

Engineering &
Technology Employees⁽²⁾

3,000+

Patents⁽²⁾

**VERTICAL
INTEGRATION**

Materials, Components,
Subsystems, Systems
and Service

COHR

Nasdaq

\$4.8 B

FY22
Revenue⁽¹⁾

\$65 B

Available
Market⁽²⁾

130

Locations

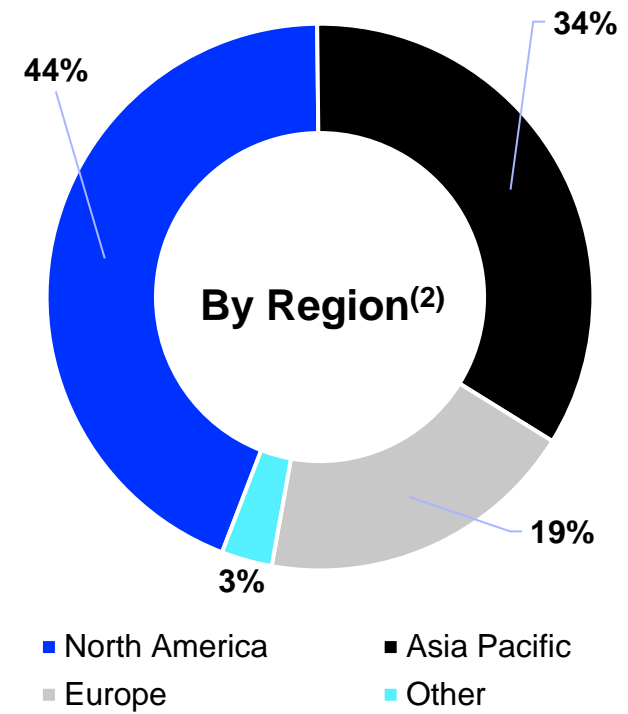
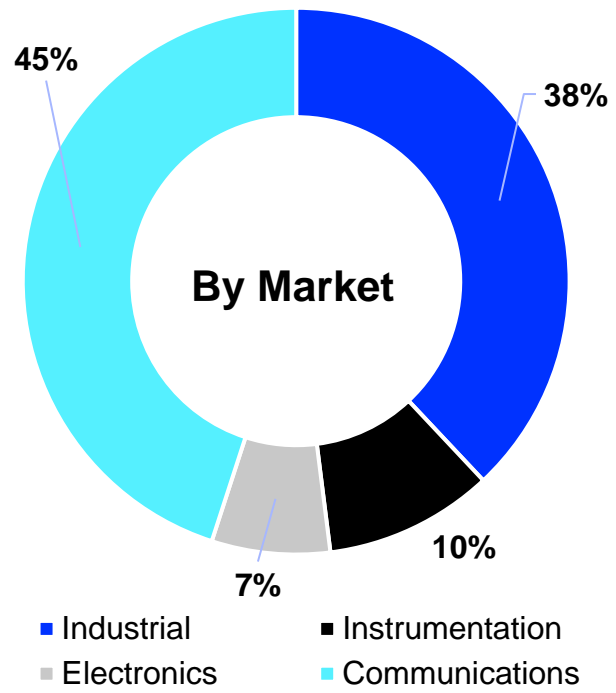
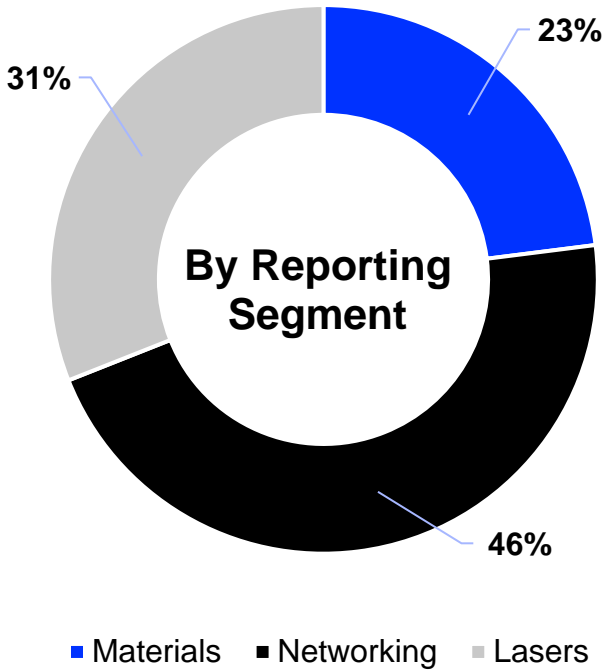
24

Countries

(1) Proforma revenue combines II-VI FY22 revenue (as of FYE 6/30/22) and Coherent 6/30/22 TTM.

(2) As of July 1, 2023

\$4.8 BILLION OF REVENUE IN FY22

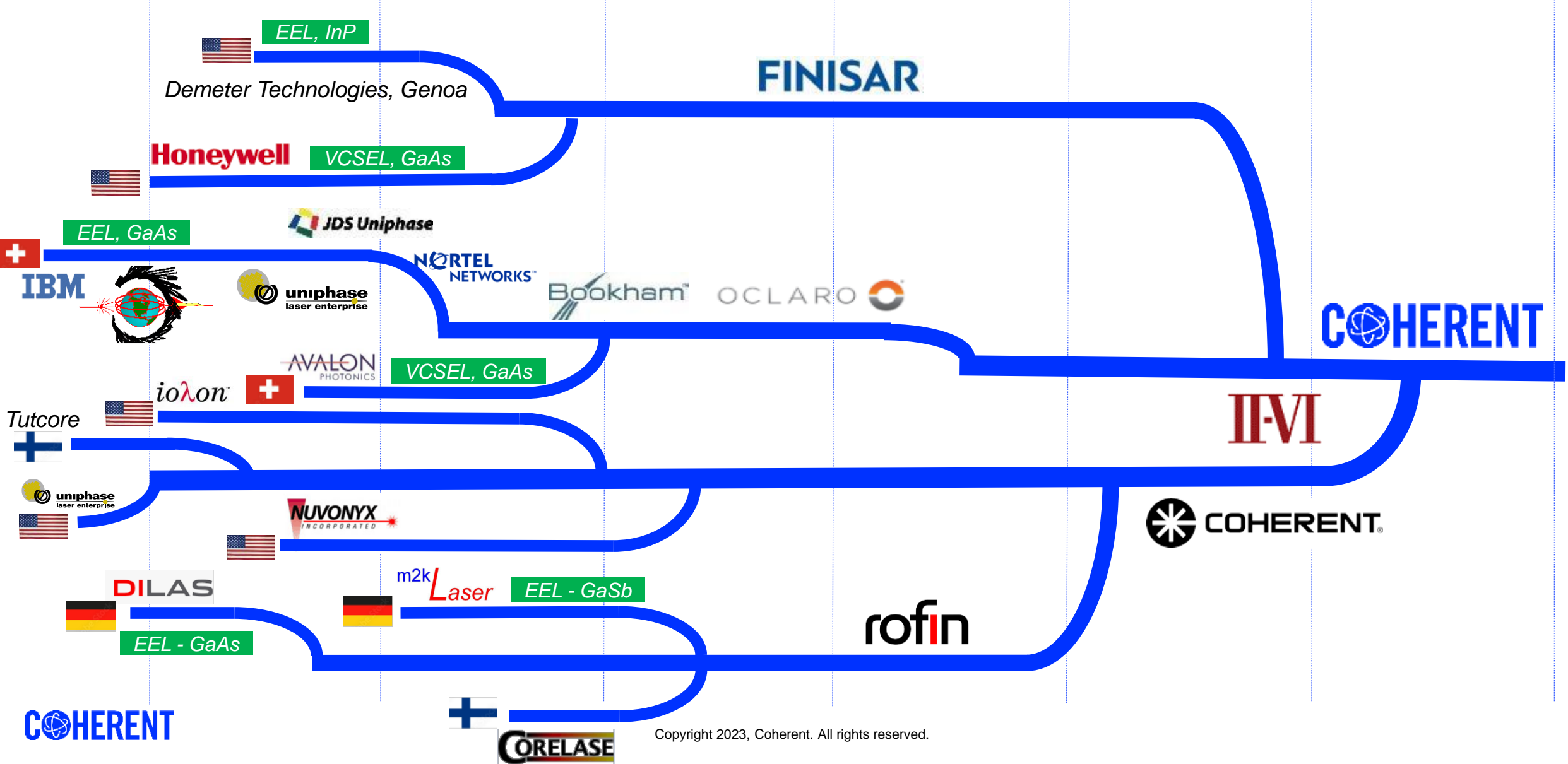


(1) Proforma revenue combines II-VI FY22 revenue (as of FYE 6/30/22) and Coherent 6/30/22 TTM.

(2) II-VI Incorporated revenue by region is based on customer headquarter address; Coherent, Inc. revenue by region is based on customer ship to address.

30+ YEARS OF EXPERIENCE IN DIODE LASER TECHNOLOGY

1995 2000 2005 2010 2015 2020 2025



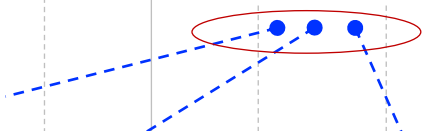
VCSELS - OUR CLAIM TO FAME IN CONSUMER ELECTRONICS



Laser Enterprise,
Zurich



II-VI EpiWorks,
Champaign



II-VI OED, Warren



II-VI OED, Easton



II-VI Sherman

3-inch production

6-inch production



Logitech

2001: first VCSEL shipped
for Optical interconnects



2006: Start of VCSEL supply
for computer mouse
>350 million units shipped as of today

Blackberry



2011: Start of VCSEL supply
for trackpad in smartphones
>25m units shipped 2011-2013

Daimler group



2015: Start of VCSEL supply
for trackpad in steering wheel
>12m units shipped



2017: Start of VCSEL supply
for 3D sensing in smartphones
>500m units shipped



2019: VCSEL
chips for auto
focus assist in
mobile phones

2018: In Cabin
illumination module for
gesture control
>1M units



2005









2010

2015

2020



LASERS IN CONSUMER ELECTRONICS - WHAT COMES NEXT?

1980s		2000s	2010s	2020s			
Laser Printer	CD/DVD	Mouse	Gaming	Mobile	VR/MR	AR	Wearables
							
Laser Writing	Read/Write Head	Position Sensing	Full Body Tracking	Proximity Sensor Range Sensor Biometric Authentication 3D Scanning	3D Scanning Leg-/Hand Tracking Facial Expression Capture Eye Tracking Laser Beam Scanner (AR)	Vital-Sign Sensing Bio-Sensing Environmental Sensing	

COMPONENTS AND MODULES FOR SENSING

OPTICAL SENSORS IN AR GLASSES



- Low power consumption
- Light and compact
- Long range
- Large FOV
- High resolution
- Robustness to sunlight

AR Sensor Use Sases



3D Scanning



Eye Tracking



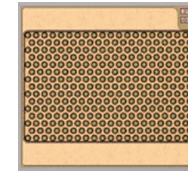
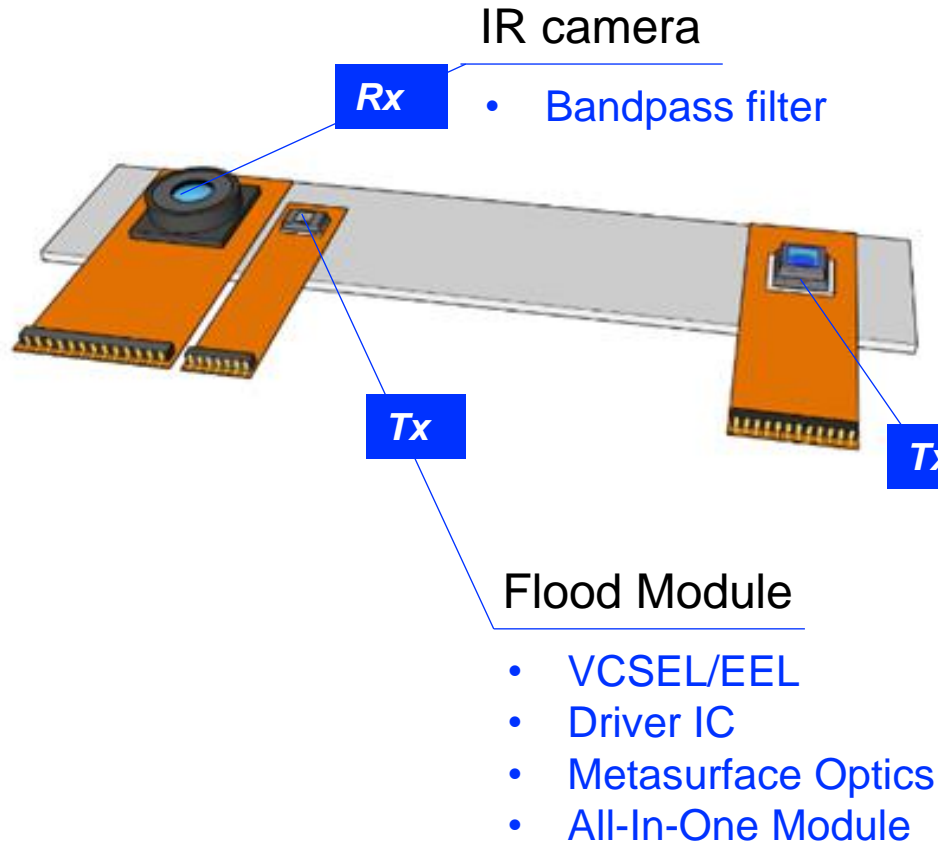
Facial Tracking



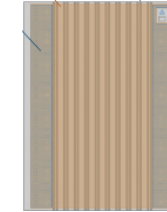
Body Tracking

COMPONENTS AND MODULES FOR ADVANCED SENSING

3D Camera/ Sensor



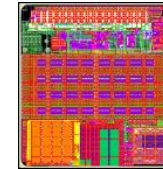
VCSEL arrays
(NIR, SWIR)



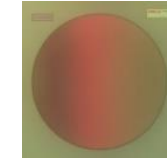
Edge Emitters
(NIR, SWIR, MIR)



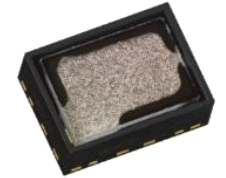
Photo Detectors
(NIR, SWIR)



Laser Driver ICs



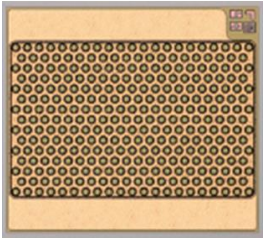
Diffractive Optics



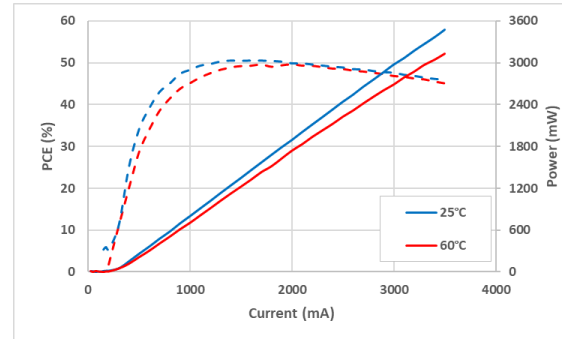
SMT Illumination
Modules

NEAR-INFRARED VCSELS

World-Leading VCSEL Platform

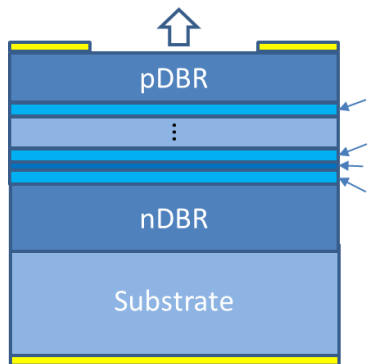


- ✓ 940nm multi-mode VCSEL
- ✓ Best-in-class performance
- ✓ Best-in-class reliability
- ✓ Custom-designs with fast time to market



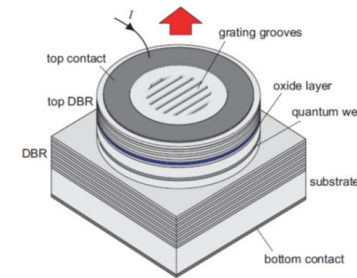
- ✓ US-based in-house manufacturing
- ✓ Mature 150mm manufacturing platform
- ✓ Vertically integrated from epitaxy to test
- ✓ Over 2 billion VCSELs shipped

Multi-Junction VCSEL



- ✓ 850 and 940nm
- ✓ Higher power
- ✓ Higher speed
- ✓ Better efficiency
- ✓ More compact

Single-mode VCSEL with polarization lock



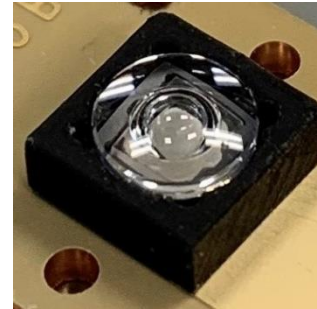
- ✓ 850 and 940nm
- ✓ Narrower band
- ✓ Sharper pulses
- ✓ Lower system losses

NEAR-INFRARED ILLUMINATION MODULES

Coherent VCSEL Package Platform



- ✓ SMT package
- ✓ Includes monitor photodiode
- ✓ Compact form factor
- ✓ Compatible with any VCSEL type
- ✓ Diffusers or pattern projectors
- ✓ High efficiency



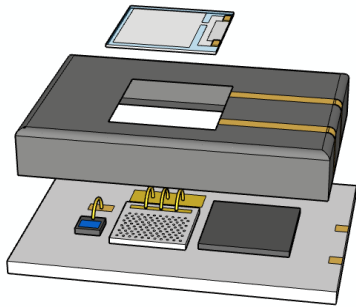
Custom packages available

Example:

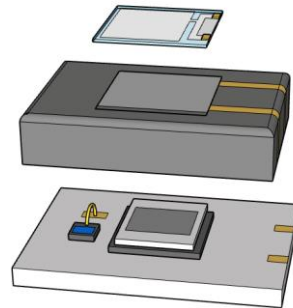
- Ultra-Wide Field-Of-Illumination
- Up to 170° x 130°
- Optional ITO layer for crack detection

Como platform: 2-in-1 package

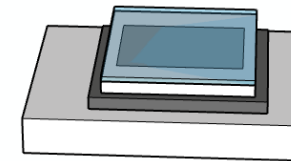
Next-Generation VCSEL Packages



3-in-1 package



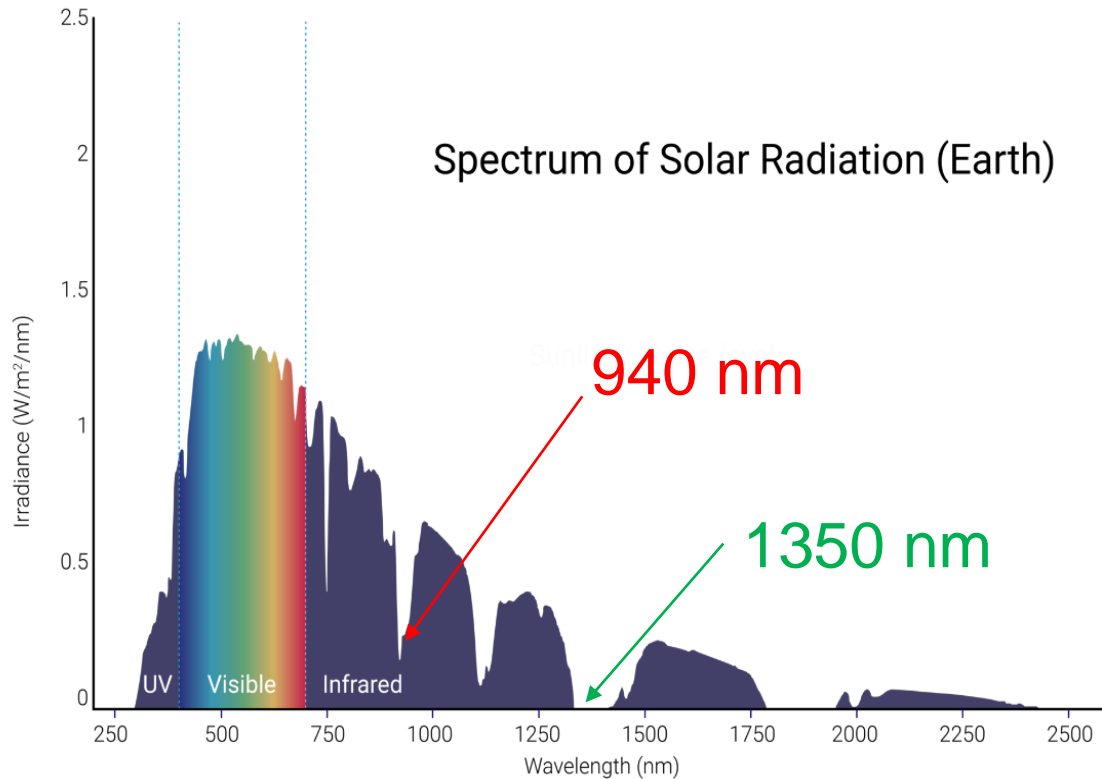
**Bottom emission VCSEL
stacked on driver IC**



**Stacked chip
package with optics**

- ✓ More compact
- ✓ Higher speed
- ✓ Better thermal performance
- ✓ Better optical performance
- ✓ Lower cost

RATIONALE FOR MOVING FROM NIR TO SWIR



No background sunlight at sea level



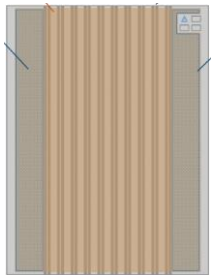
Eye-safe at 10x higher power levels

SWIR enables improved 3D sensing performance: Better SNR, longer range, lower power

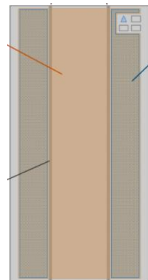
SHORTWAVE-INFRARED LASERS, PHOTO-DIODES AND ILLUMINATION MODULES

Edge-Emitting Lasers

- ✓ Wavelength 1380nm, other available on request
- ✓ Broad-Area Laser or Single-Mode Laser Array
- ✓ High-power, up to 3W
- ✓ Efficiency above 35%



Single-Mode
Laser Array



Broad Area
Laser

Photo-Diodes

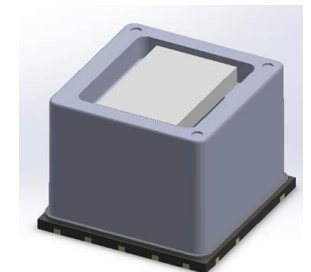
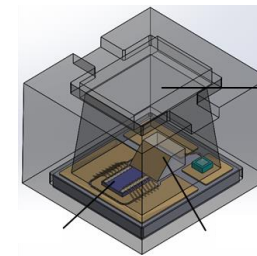
- ✓ PIN diode technology
- ✓ Broad sensitivity range
- ✓ Optional filter integration
- ✓ For proximity or scanning sensor architectures



SWIR Photo-
Diodes

Illumination Modules

- ✓ SWIR illumination module with 3W output power
- ✓ SMT package
- ✓ Diffusor with 72x58°, other FOVs on request



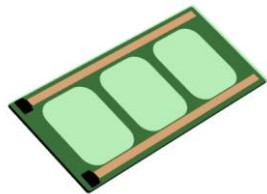
SWIR Illumination
Modules

MATERIALS AND COMPONENTS FOR AR DISPLAYS

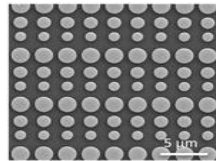
COMPONENTS FOR AR-DISPLAYS

Display Projector (Engine)

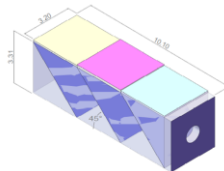
- **Micro-Lens Arrays for Collimation**
- RGB Beam Combiner
- Optical Windows and Mirrors
- Thin-film polarizers



Windows, Mirros, Filters

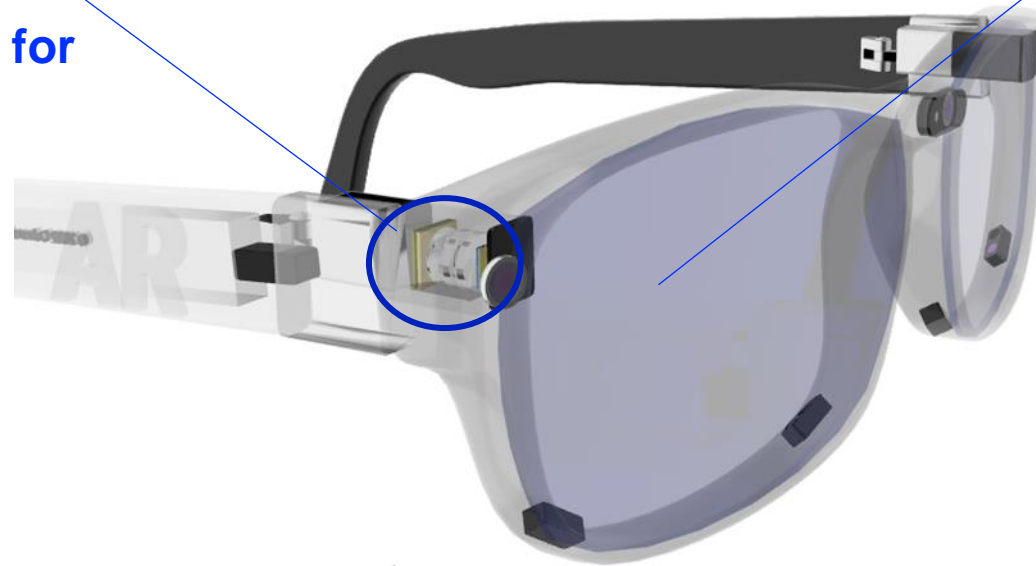


Meta-Surface Lenses



RGB beam combiner

AR Display



Optical Combiner

- **High-Index Crystal Substrates**
- Glass Wafer Manufacturing
- Waveguide Manufacturing
 - Optical Coatings
 - Diffractive Couplers



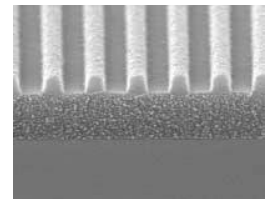
High-Index substrates



Glass wafers



Optical Coatings



Diffractive Couplers

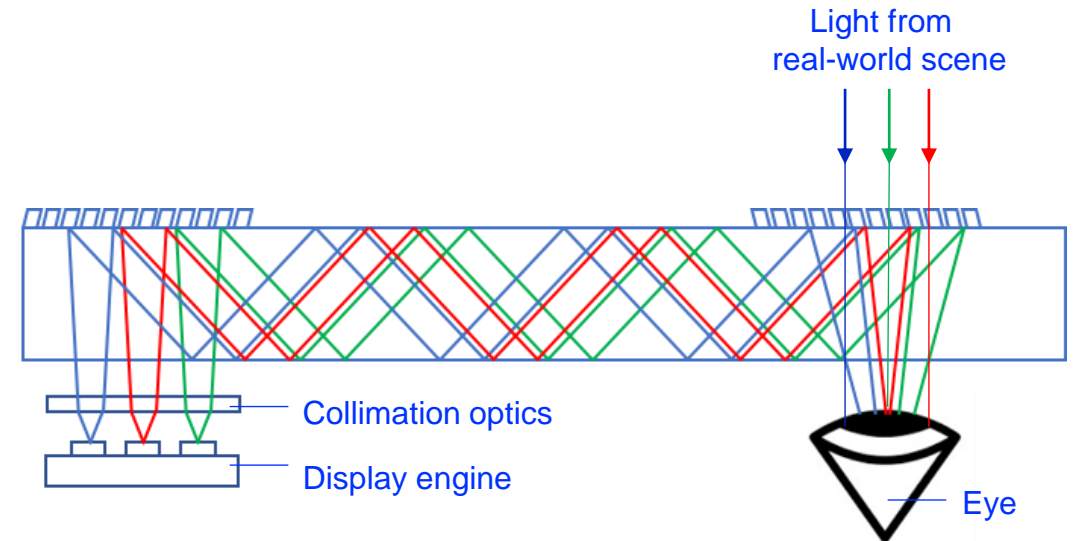
COLLIMATION OPTICS FOR MICRO-LED DISPLAYS

In AR displays, light travels through an optical combiner before it reaches the user's eye.

Micro-LED displays require collimation optics:

- **Improved light extraction**
Minimize unwanted reflection or absorption inside the display module.
- **Efficient coupling**
A narrow beam angle is required for high coupling efficiency into waveguide
- **Low color noise**
Stray light must be suppressed to limit cross-talk between adjacent emitters.

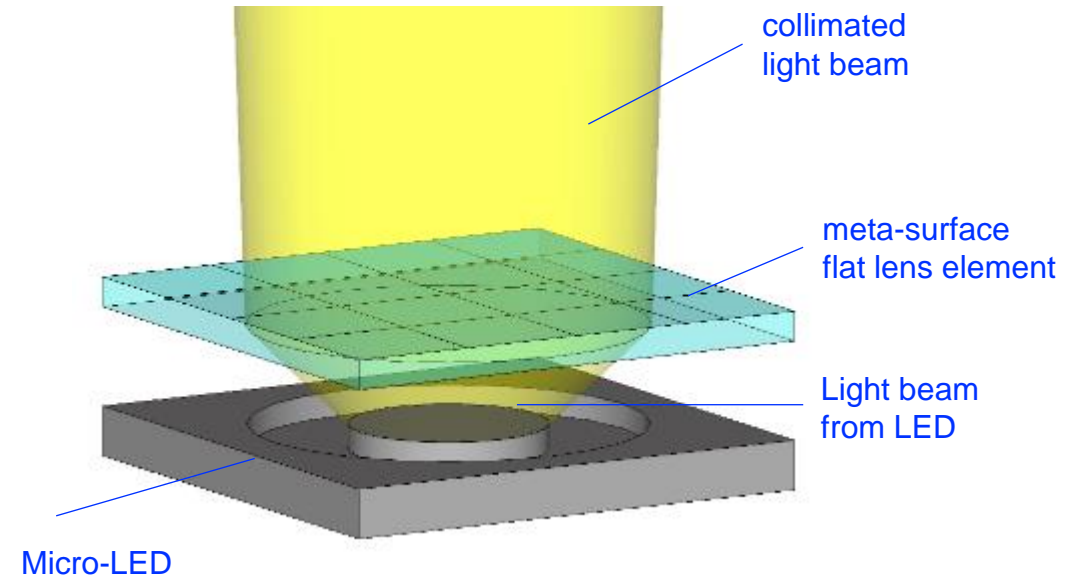
Optical Combiner



COLLIMATION OPTICS FOR MICRO-LED DISPLAYS

Diffractive Meta-Optics are best suited for collimation of uLED displays.

- Meta-Optics is only technology that can achieve required sub-micron feature and overlay accuracy.
- Highly compact form factor with single flat lens element
- Integration feasible at wafer or at array level
- High optical efficiency
- Inorganic material system for high mechanical, thermal and environmental stability
- Scalable wafer-level process based on semiconductor manufacturing techniques
- Excellent uniformity intra-wafer and wafer-to-wafer



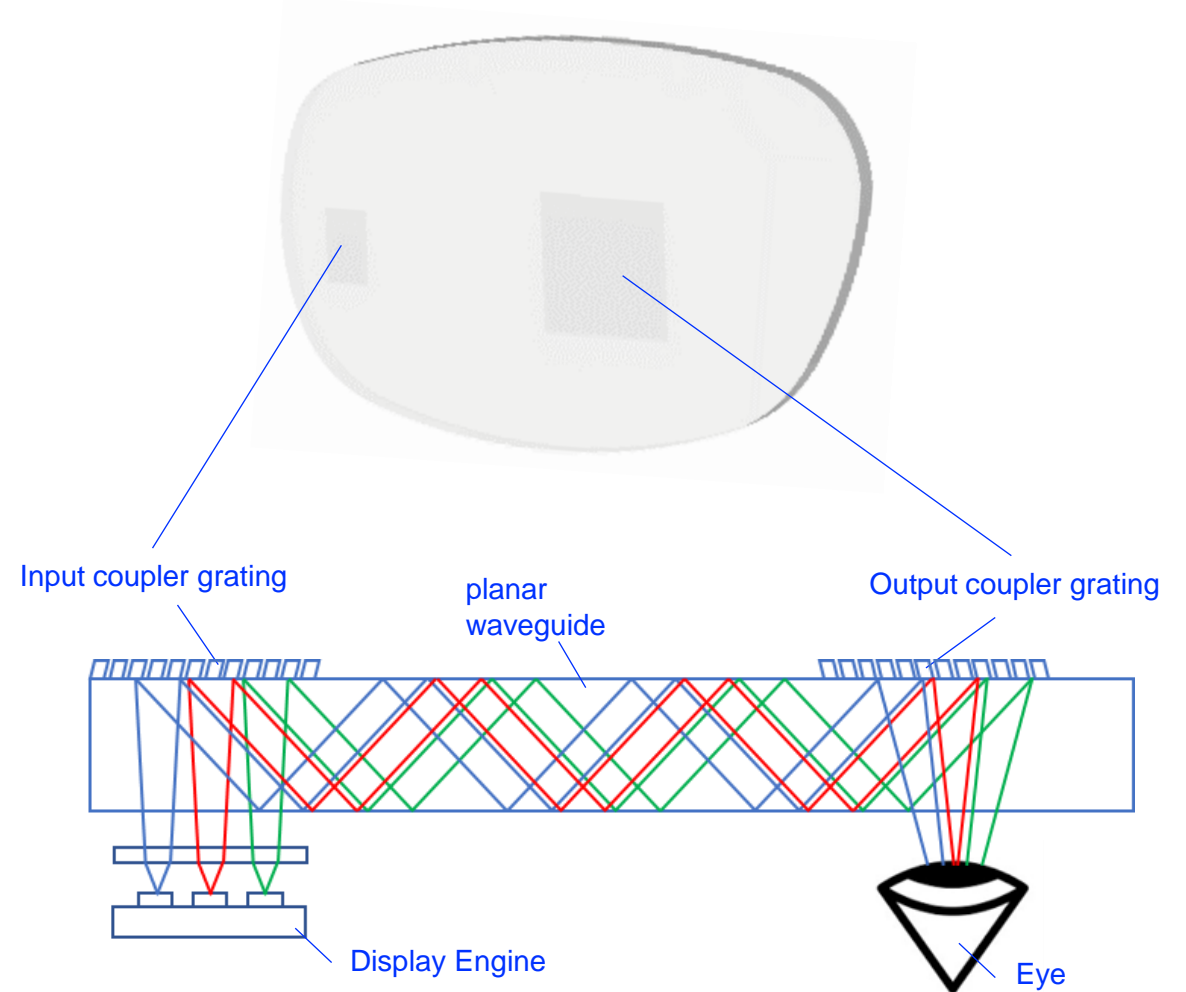
OPTICAL CRYSTAL MATERIALS FOR WAVEGUIDE COMBINERS

Benefits of Lithium-Niobate:

- High refractive index (~ 2.3)
- Transparent in visible spectrum
- High mechanical strength and scratch resistance
- Enables wide field-of-view, up to 70 deg
- Enables single waveguide for all 3 colors

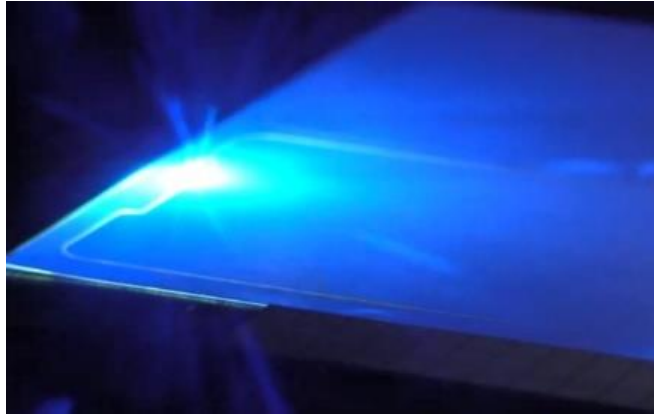
Coherent experience:

- Experience with range of crystal materials: Lithium-Niobate, Zinc-Sulfide, ...
- Scaling crystal growth to large format and high volume



LASER SOLUTIONS FOR DISPLAY MANUFACTURING

FILM AND STACK DISPLAY CUTTING



- Increasing sophistication and functionality of mobile devices require highest cut quality with minimized damages to the cutting kerf
- Ultrashort pulsed lasers are the best choice



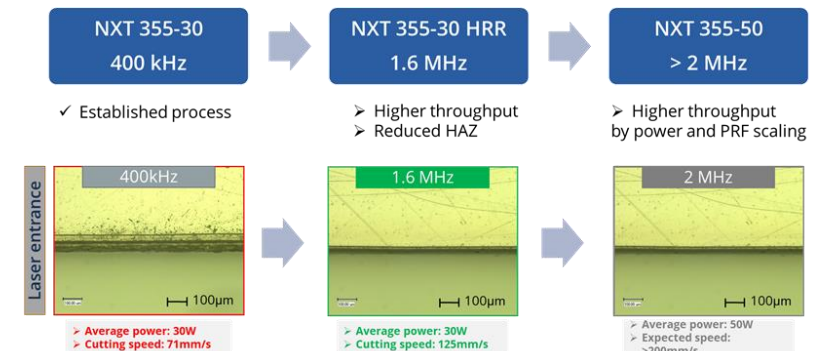
Monaco
fs-Laser with up to 30 W UV

- 30 W / 37.5 μ J / 800 kHz***
- 345 nm, <500 fs pulse width**
- Single pulse and burst mode**



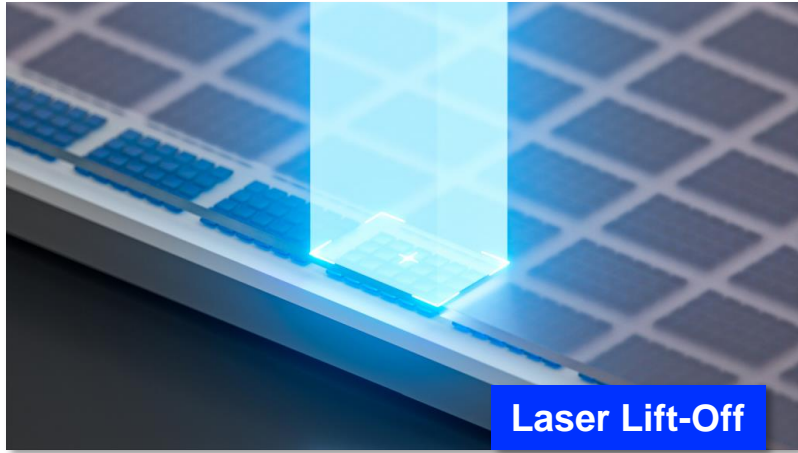
HyperRapid NXT
ps-Laser with up to 50 W UV

- 50 W / 50 μ J / 1 MHz***
- 355 nm, <10 ps pulse width**
- Single pulse and burst mode**

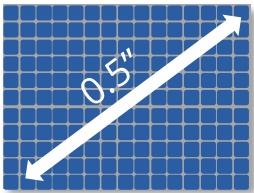


LASER SOLUTIONS FOR RGB MICROLED DISPLAYS

MicroLED Array's



Laser Lift-Off



up to 0.5" can be processed in one step/shot

Most common approach for AR Light Engine

Laser

OEM System

Turn-Key Solution

COHERENT VERTICAL INTEGRATION

- DUV Lasers established for MicroLED processing
- Reliable industrial laser sources at different energy levels
- Scalable power

- Laser + Optics designed on customer requirements
- Standard configurations available
- Mask Imaging and Line Beam systems

- UVtransfer Turn-Key 248 nm System
- Laser, Optics, Stages, Imaging, Software
- Designed for industrial customers



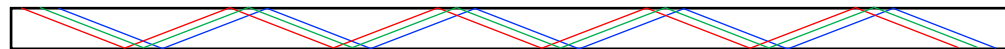
LASER RECORDING OF HOLOGRAPHIC OPTICAL ELEMENTS IN AR

- Writing holographic optical elements using single mode continuous wave laser in a few Watt range
- Photo polymers used in the holographic combiner devices
- Waveguide recording in R, G, B wavelength for color imaging

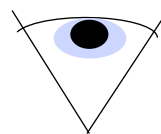
Light Engine
e.g. MicroLED



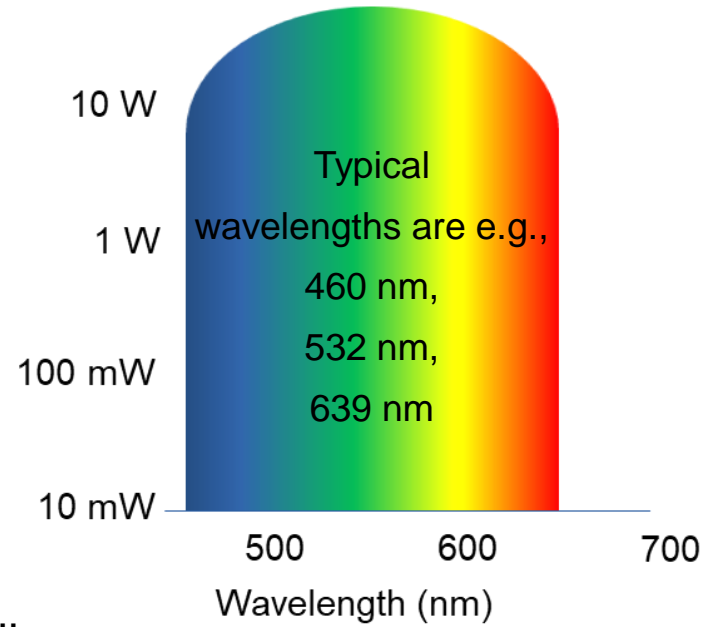
HOE
In Coupling



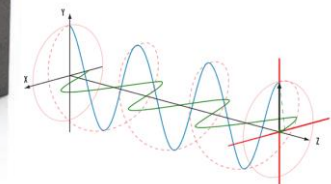
HOE
Out Coupling



Maximum Power (W)



Model	CX-SLM / Low Pwr Verdi G
Lateral Mode	TEM00
Longitudinal Mode	SLM
Bandwidth	<5 MHz
Noise (rms)	<0.1%
Configuration Options	End User or OEM
Wavelength (nm)	
355	100
460	1,000
468	2,000
480	2,000
488	2,000
514	4,000
532	5,000
561	
577	2,000
590	1,000



CONCLUSIONS

- **Coherent offer components for sensing and displays, as well as lasers for display manufacturing**
- **We are convinced AR/VR will become important market.**
- **We look for partnerships throughout the ecosystem**

COHERENT