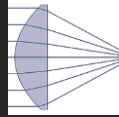
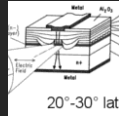


Lectures & Labs by Donn Silberman



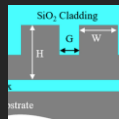
Introduction to Optics (1st lecture was today)



Photonics Industry & Technologies (2nd lecture, NOW)



Fiber Based Photonics (3rd lecture on Monday)



Integrated Photonics (4th lecture also next Monday)



Labs – IPEK Demo Wed. 29th & Quantum Demos Fri. 31st

Start stopwatch on phone to monitor pace

**High
Speed**

**Power
Efficiency**



Photonics Industry & Technologies

**High
Bandwidth**

**Enabler
for Future
Technologies**

**Instructor: Donn Silberman,
Founder QOISC**

www.qoisc.org

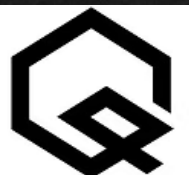
Overview of Photonics

The science of photonics includes investigation of the emission, transmission, amplification, detection, and modulation of light.



Why Photonics Matters

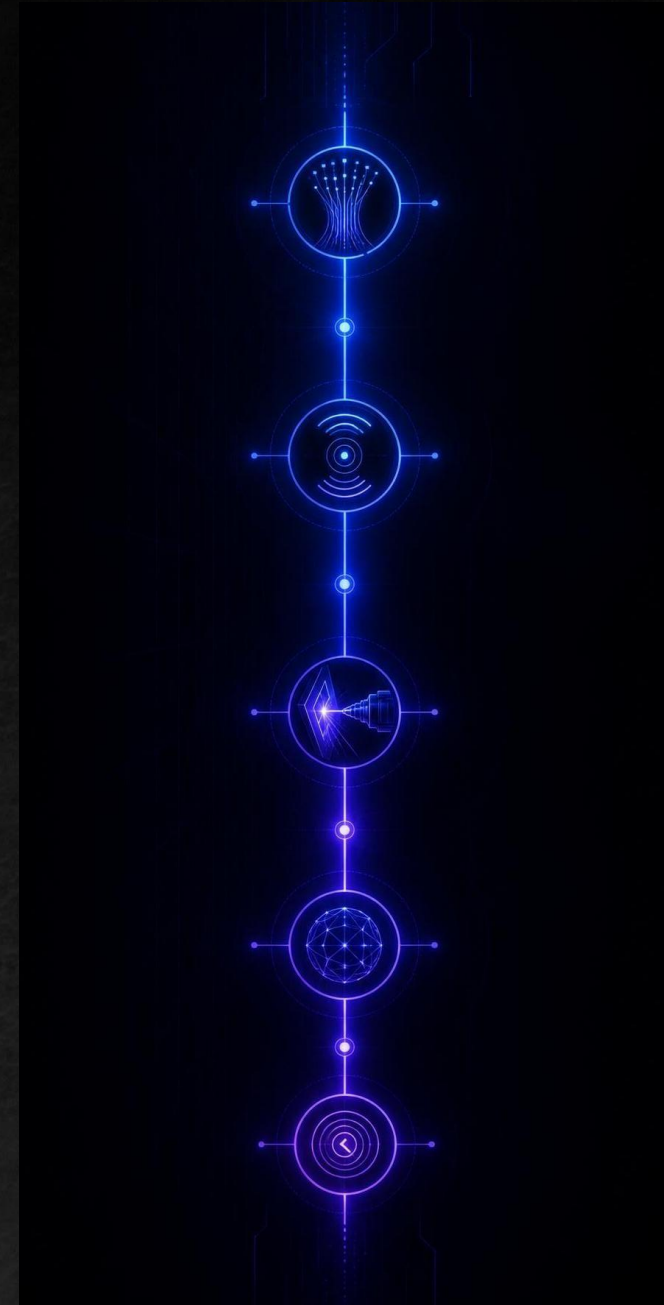
- Faster data transmission
- Precision sensing
- Advanced manufacturing



Topics:

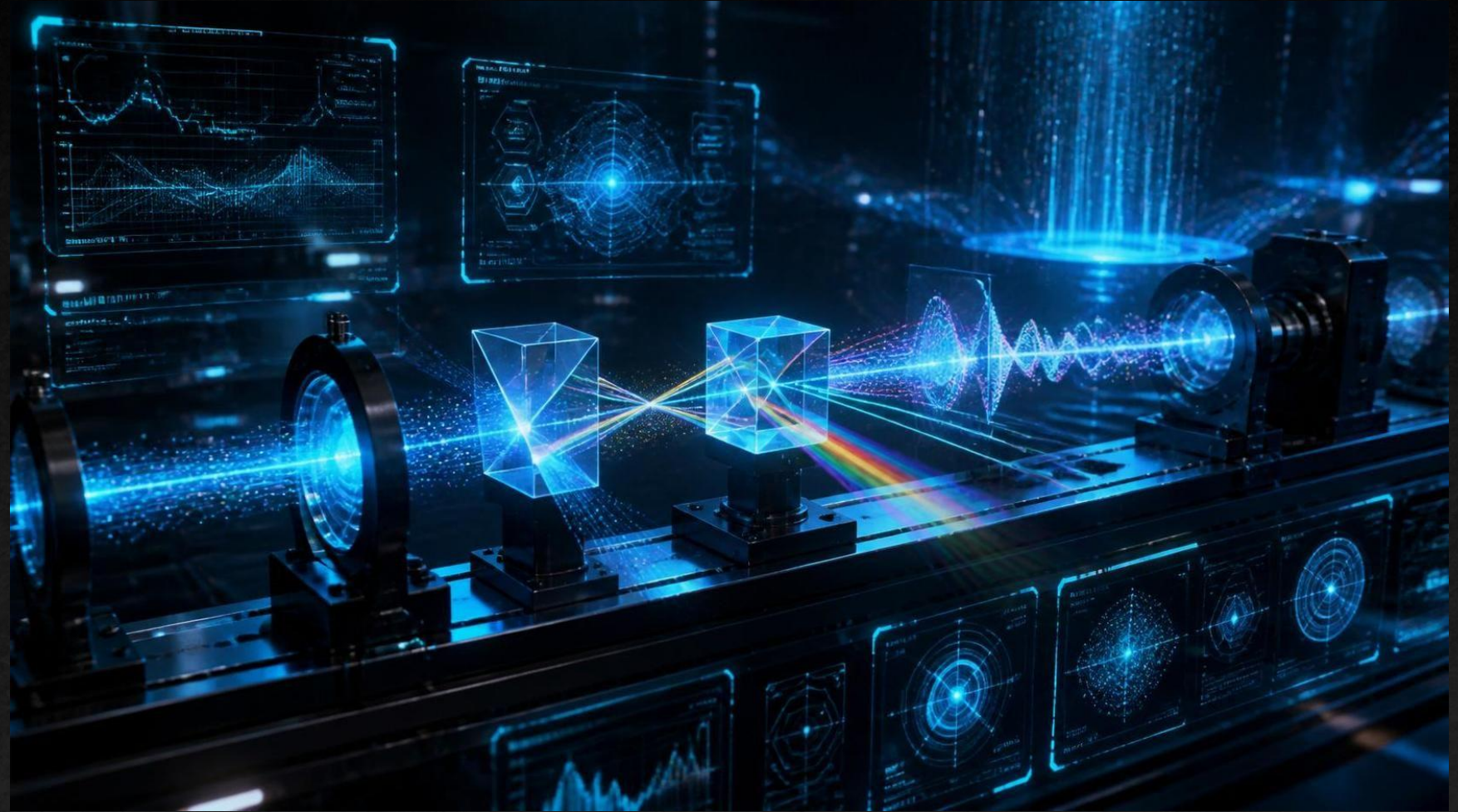
- **Photonics Basics**
- **Industry Landscape**
- **Core Technologies**

- **Photonics Applications**
- **Industry Challenges**
- **Future Outlook**



What Is Photonics?

Photonics is the practical use of light as a tool for communication, measurement, imaging, and processing. If electronics is about controlling electrons, photonics is about controlling photons.

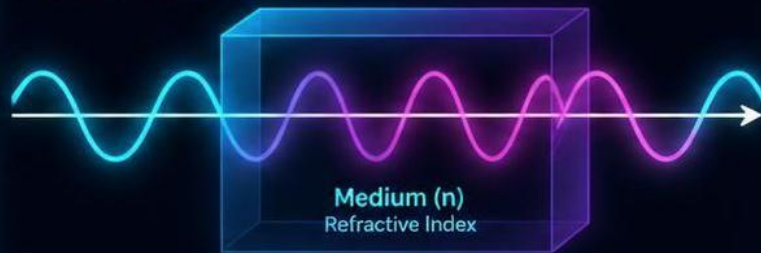


Photonics = Optics + Electronics

OPTICS

1. LIGHT WAVES

Sinusoidal electromagnetic waves traveling through a medium



2. LIGHT INTERACTION

REFLECTION

Angle in = Angle out



REFRACTION

Snell's Law
 $n_i \sin \theta_i = n_r \sin \theta_r$



DISPERSION

Prism splits white light



PRISM



LENS



MIRROR



BEAM SPLITTER

NEON COMPARISON: LIGHT WAVES

VS

SIGNAL CONTROL

ELECTRONICS

1. ELECTRICAL SIGNAL

Voltage vs. time (waveform)



2. CIRCUIT COMPONENTS

TRANSISTOR (NPN)



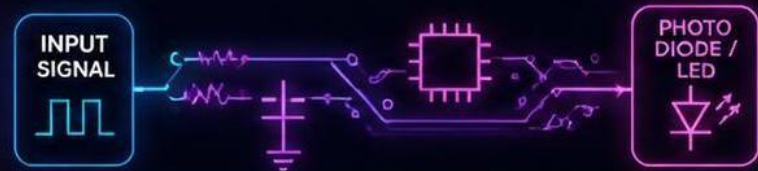
LED



RESISTOR



3. SIGNAL PATH ON PCB



DIGITAL
0 / 1



ANALOG
CONTINUOUS



PROCESS
CONTROL



FEEDBACK
SYSTEMS



Light waves carry energy through space.

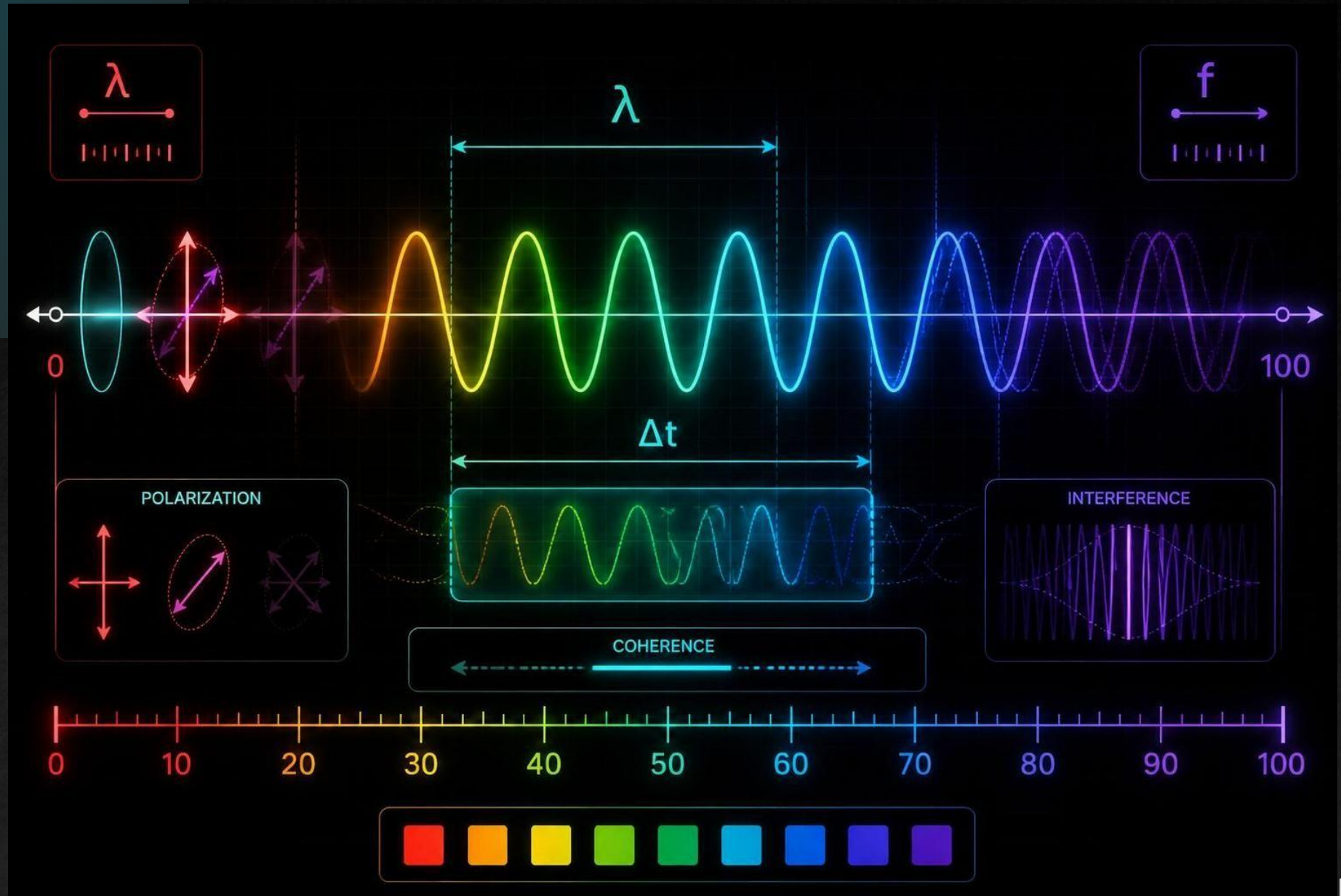


Electrical signals control systems and devices.



Properties of Light

Wavelength
Frequency
Power
Polarization
Coherence



A Photonic System: From Light to Information

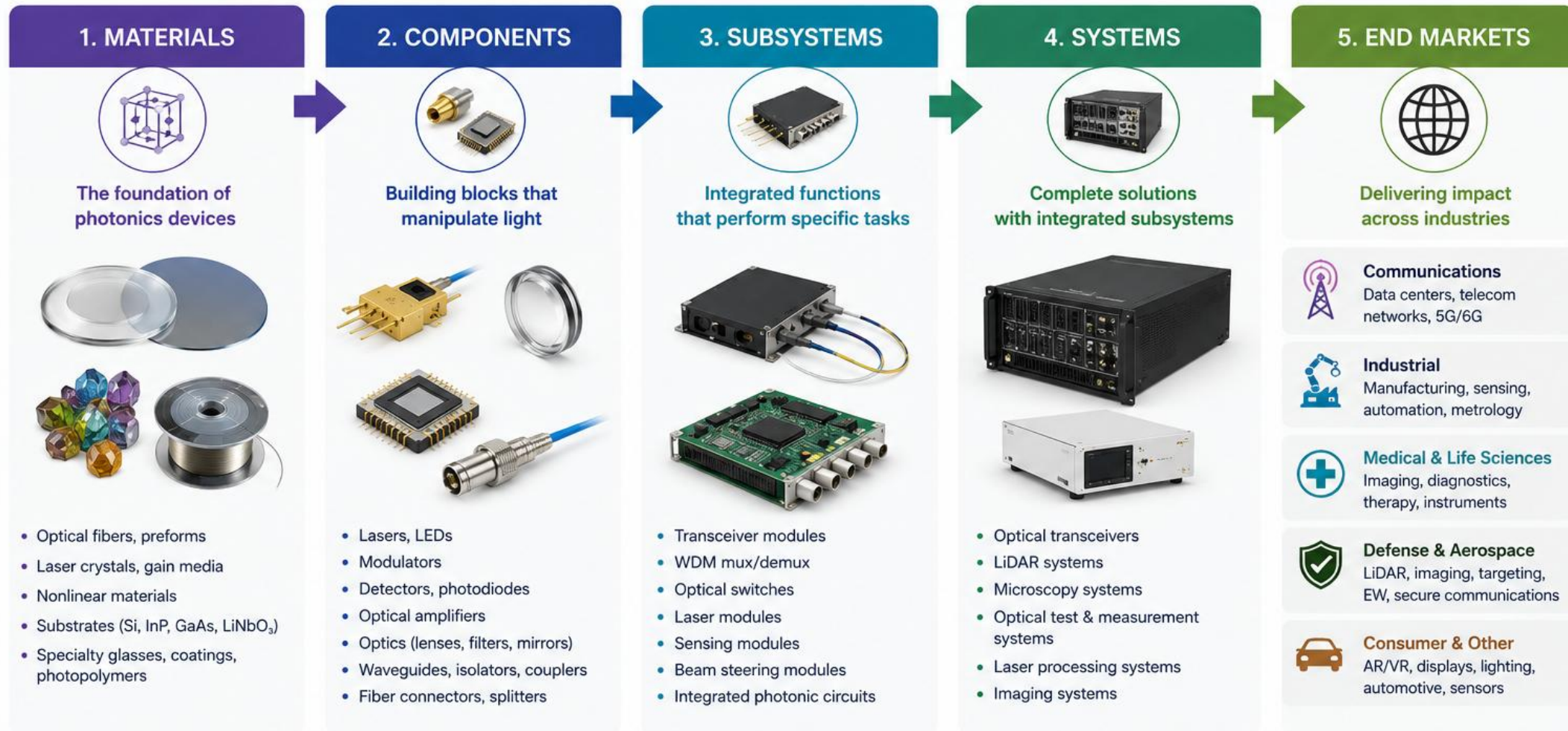
A photonic system typically starts with a light source, modifies that light with a modulator, sends it through a medium like fiber or a waveguide, detects it at the destination, and converts it into usable information.



In Summary: Light carries data. Photonics controls, guides, and detects that light—enabling fast, efficient, and high-bandwidth communication and sensing.

Photonics Industry Value Chain

The industry has multiple layers. Some firms focus on materials or components, others on integrated subsystems, and others on full systems sold into communications, industrial, medical, or defense markets.



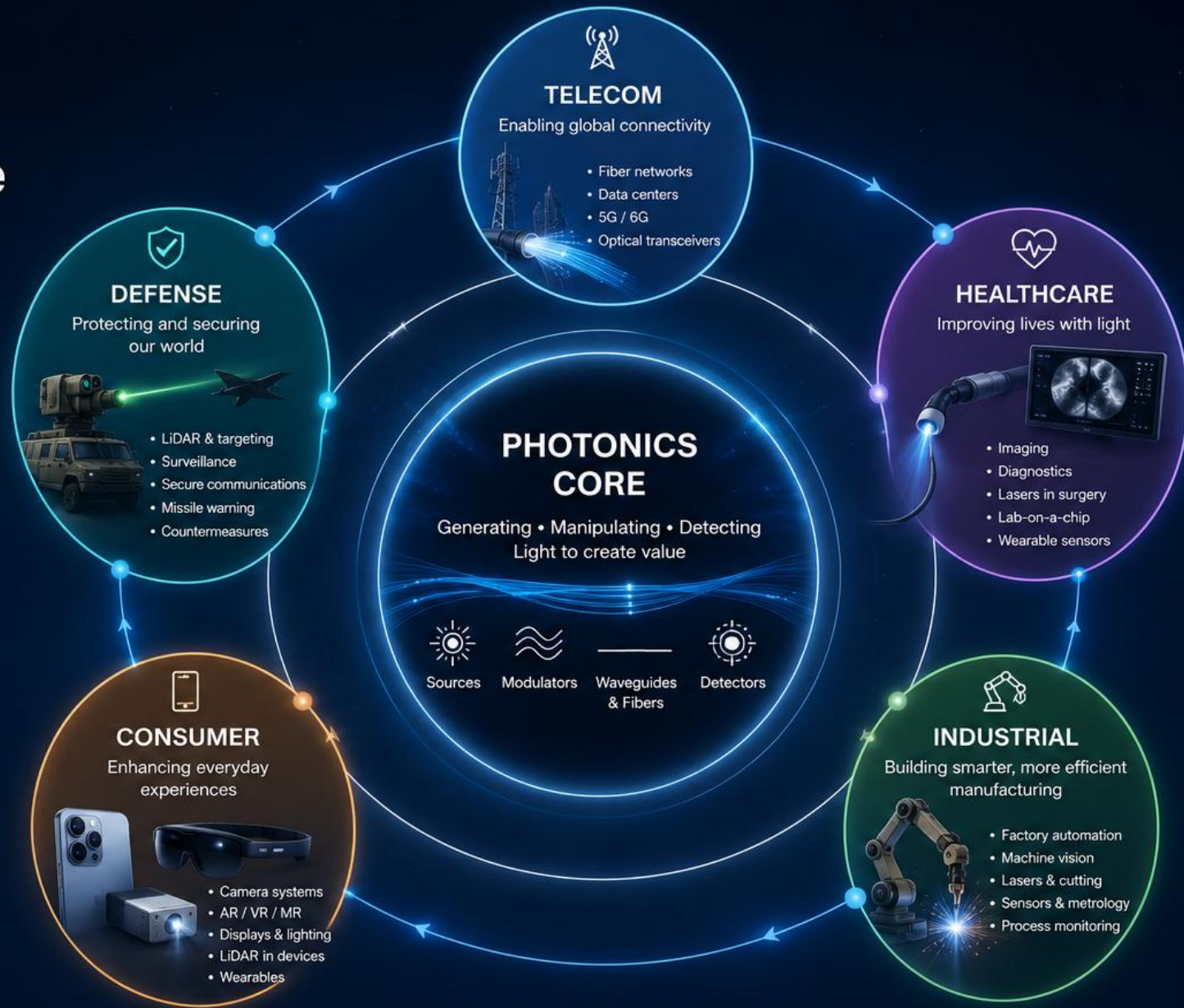
VALUE CREATION ACROSS THE CHAIN

Each layer enables the next—transforming raw materials into innovative photonic solutions that power modern technologies and improve lives.

Photonics Industry Structure

Photonics is broad. It spans telecom infrastructure, medical devices, defense systems, factory automation, consumer products, and research equipment. The same underlying physics serves many different businesses.

-  Light is the enabler
-  Shared technologies
-  Many applications
-  Broad economic impact



ONE CORE TECHNOLOGY. LIMITLESS POSSIBILITIES.

Photonics is a platform technology—versatile, scalable, and essential across a wide range of industries and applications.

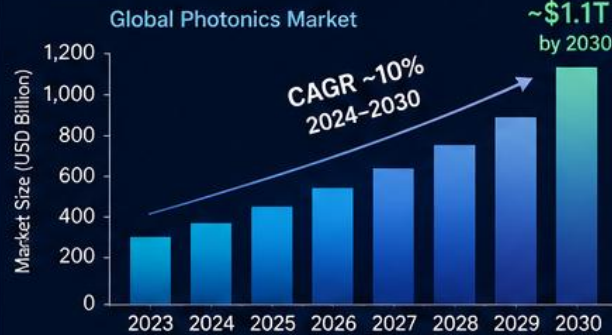


PHOTONICS INDUSTRY MARKET OVERVIEW

Growth driven by data, automation, and precision technologies

The industry is expanding because the world keeps demanding more bandwidth, more sensing, and more precision. That makes photonics strategically important across both digital and physical industries.

MARKET SIZE & GROWTH



Source: MarketsandMarkets, Fortune Business Insights, Verified Market Research

WHY PHOTONICS, WHY NOW?



EXPLOSIVE DATA GROWTH

Cloud, AI, and 5G/6G driving unprecedented demand for bandwidth



AUTOMATION & SMART INDUSTRY

Photonics enables faster, more precise, and more reliable automation



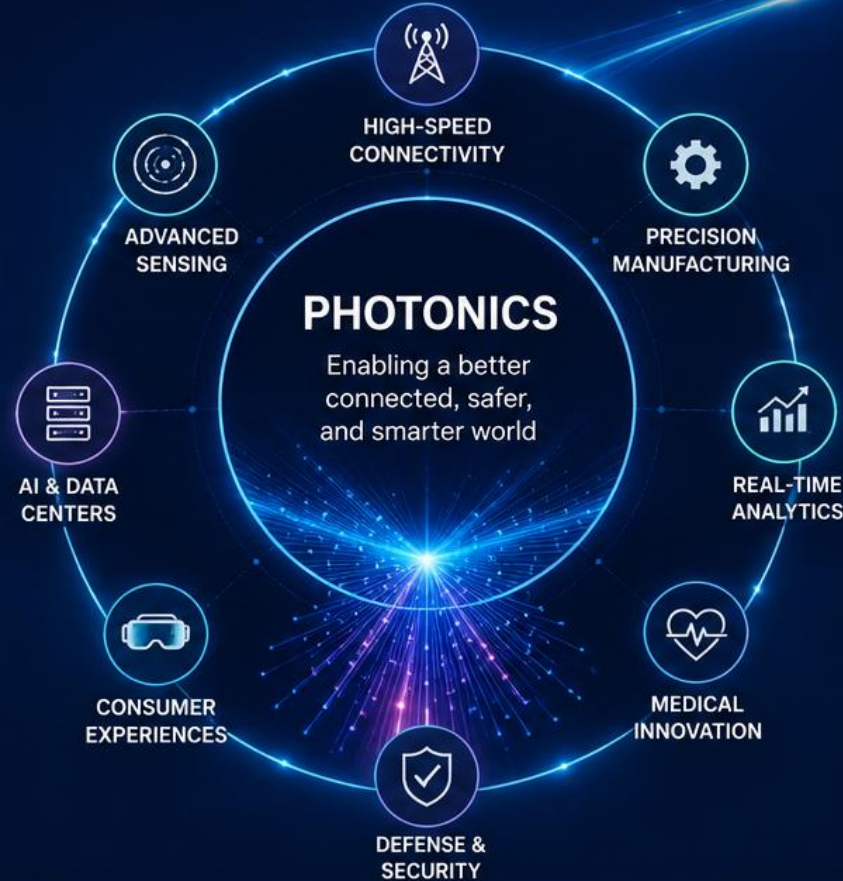
PRECISION & PERFORMANCE

Light delivers unmatched accuracy, speed, and sensitivity



ENERGY & SUSTAINABILITY

Photonics improves efficiency in communications, sensing, and manufacturing



STRATEGIC TAKEAWAY

Photonics is a key enabler of the digital transformation and the next wave of industrial and societal innovation.

KEY GROWTH DRIVERS



DATA EXPLOSION

Surging use of cloud, streaming, AI, and connected devices



INDUSTRIAL AUTOMATION

Need for speed, accuracy, and reliability in manufacturing



ADVANCED SENSING DEMAND

From autonomous systems to health monitoring and environmental sensing



TECHNOLOGY CONVERGENCE

Integration with electronics, AI, and advanced materials

MARKET OUTLOOK



Strong, long-term growth
~10% CAGR through 2030



Expanding across multiple end markets and geographies



Increasing investments, innovation, and strategic partnerships



From components to systems, value moving up the stack

A STRATEGIC INDUSTRY



Critical to digital infrastructure



Enabling smarter industries



Improving life and well-being



Strengthening security and resilience



PHOTONICS INDUSTRY KEY GROWTH DRIVERS

These drivers are shaping demand across the sector. AI and cloud expand data-center optics; EVs and autonomy increase sensing needs; diagnostics and automation push optical measurement into more workflows.



1. AI AND CLOUD

Exponential data growth drives demand for high-speed, high-capacity optical connectivity in data centers and across networks.



More bandwidth
for the AI era



2. EVS AND AUTONOMY

Photonics powers LiDAR, in-cabin sensing, and high-speed communications—enabling safer autonomous systems and efficient electric vehicles.



More sensing.
Safer mobility.



3. DIAGNOSTICS

Advanced optical imaging and spectroscopy enable earlier detection, precise analysis, and better treatment outcomes.



Better insights.
Better outcomes.



4. AUTOMATION

Optical sensors and systems drive precision, quality, and efficiency in smart factories and next-generation manufacturing.



Measure. Monitor.
Optimize.



5. MINIATURIZATION

Advances in materials and integration shrink size, reduce power, and unlock new applications across industries.



Smaller. Faster.
More capable.



**ONE TECHNOLOGY.
MANY APPLICATIONS. LIMITLESS IMPACT.**

Photonics is at the core of the technologies transforming how we connect, move, diagnose, build, and innovate.



PHOTONICS INDUSTRY COMMUNICATIONS SEGMENT

Fiber optics • Telecom networks • Data centers

Communications remains a core photonics market.

Fiber optics carry massive amounts of data over long distances, and data centers rely increasingly on optical links for speed and efficiency.



TELECOM NETWORKS
Connecting the world



DATA CENTERS
Powering cloud and AI workloads



GLOBAL CONNECTIVITY
Linking cities, countries, and continents



FIBER OPTICS

High-capacity, long-distance data transmission with low loss and high reliability.



Global connectivity backbone



TELECOM NETWORKS

Optical technology powers 5G/6G, metro, long-haul, and submarine networks.



5G/6G and beyond ultra-fast networks



DATA CENTERS

Optical interconnects enable higher bandwidth, lower power, and greater scalability.



AI, cloud, and big data demand optical speed



HIGHER BANDWIDTH

More data.
Faster speeds.



LOWER POWER

Optics use less energy than copper.



GREATER RELIABILITY

Immune to EMI.
Built for scale.



SCALABLE FUTURE

Ready for the next wave of data growth.

OPTICAL LINKS AT THE CORE



Optical Fiber



Optical Transceivers



Optical Switching



High-Speed Connections



PHOTONICS INDUSTRY INDUSTRIAL SEGMENT

Laser cutting • Welding • Marking • Additive manufacturing

In industrial settings, lasers provide precision, repeatability, and automation compatibility. They are used to cut, weld, drill, mark, and build parts layer by layer.



LASER CUTTING

High-speed, precise cutting of metals and complex geometries.



LASER WELDING

Strong, clean welds with deep penetration and minimal distortion.



LASER MARKING

Permanent, high-contrast marking for traceability and brand protection.



ADDITIVE MANUFACTURING

Building parts layer by layer with high precision and control.



HIGH PRECISION
Micron-level accuracy for complex parts.



HIGH SPEED
Faster processing and higher throughput.



AUTOMATION READY
Seamless integration with robotic systems.



COST EFFECTIVE
Lower waste, less rework, better ROI.

INDUSTRIES SERVED



AUTOMOTIVE



AEROSPACE



ELECTRONICS



MEDICAL DEVICES



ENERGY



HEAVY EQUIPMENT



CONSUMER GOODS



BUILT FOR THE FUTURE

Photonics-driven manufacturing enables smarter factories, better products, and a more sustainable world.



PHOTONICS INDUSTRY HEALTHCARE SEGMENT

Imaging • Diagnostics • Surgery • Therapy

In healthcare, photonics supports both diagnosis and treatment. Optical methods can reveal structures inside the body and enable highly targeted procedures.



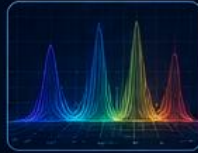
IMAGING

High-resolution optical imaging reveals physiological structures with exceptional clarity and non-invasive methods.



DIAGNOSTICS

Advanced spectroscopy and optical sensing enable earlier, more accurate detection of disease at the molecular level.



SURGERY

Laser and fiber-based tools enable minimally invasive procedures with higher precision, control, and faster recovery.



THERAPY

Light-based therapies target diseased tissues, stimulate healing, and treat conditions with minimal side effects.



KEY APPLICATIONS



PATHOLOGY



CARDIOLOGY



OPHTHALMOLOGY



ONCOLOGY



DENTISTRY



ORTHOPEDICS

BENEFITS OF PHOTONICS



HIGH PRECISION
Targeted diagnosis
and treatment



MINIMALLY INVASIVE
Less trauma,
faster recovery



EARLIER DETECTION
Better outcomes
through early insight



IMPROVED OUTCOMES
Personalized care
and monitoring



SAFE & EFFECTIVE
Reduced side effects,
better quality of life



PHOTONICS INDUSTRY

AUTOMOTIVE SEGMENT

LiDAR • ADAS • SENSING • LIGHTING

Automotive photonics is tied to safety and autonomy. LiDAR and optical sensing help vehicles perceive their surroundings, while advanced lighting improves visibility and design.



LiDAR

High-resolution 3D mapping and object detection for autonomous navigation.



ADAS

Advanced driver-assistance systems use optical sensors to enhance safety and prevent collisions.



SENSING

Cameras, ToF, and infrared sensors detect, classify, and track objects in all conditions.



LIGHTING

Laser headlights and adaptive lighting improve visibility, safety, and vehicle design.



SAFETY FIRST

Improved perception reduces accidents and saves lives.



AUTONOMY ENABLER

Critical for self-driving vehicles and advanced mobility.



ALL-WEATHER

Optical sensors work day or night, in rain, fog, and low light.



EV OPTIMIZED

Photonics enhances efficiency and design in electric vehicles.



KEY APPLICATIONS



AUTONOMOUS
DRIVING



COLLISION
AVOIDANCE



LANE KEEPING &
TRAFFIC MONITORING



PARKING
ASSIST



PEDESTRIAN &
CYCLIST DETECTION



SIGN RECOGNITION &
ENVIRONMENT MAPPING

PHOTONICS TECHNOLOGIES



LiDAR
3D scanning



CAMERAS
Image sensing
& vision



INFRARED
Thermal & night
vision



ToF SENSORS
Distance
measurement



LASER LIGHTING
Adaptive &
high intensity



PHOTONICS INDUSTRY

CONSUMER ELECTRONICS SEGMENT

Displays • Cameras • AR/VR • Sensing

Consumer products rely on photonics more than people often realize. Displays, smartphone cameras, facial sensing, and immersive headsets all use light-based components.



DISPLAYS

Mini LED, microLED, and OLED technologies deliver brighter, more efficient, and more immersive visual experiences.



CAMERAS

Advanced optical lenses and image sensors capture more light for stunning detail, even in low light.



AR/VR

Light engines, waveguides, and microdisplays enable immersive augmented and virtual reality experiences with incredible clarity.



SENSING

LiDAR, structured light, and ToF sensors power face unlock, gestures, and environment awareness.



FRONT CAMERA
Face recognition and selfies



MULTI-LENS SYSTEM
Ultra-wide, wide, telephoto, depth

MICRODISPLAYS
High resolution, low power



OPTICAL ENGINES
Light delivery and image projection



BIOMETRIC SENSORS
Health monitoring and wellness

EVERYDAY IMPACT



SMARTPHONES
Better photos, faster unlock, longer battery life



LAPTOPS & TABLETS
Brighter displays, slimmer designs, power efficiency



AR GLASSES
Immersive overlays, contextual info, hands-free



GAMING
Realistic visuals, quick response, deeper immersion



WEARABLES
Health tracking, noise cancellation, smart sensing

PHOTONICS INSIDE



MICRO-LED / OLED
Light emission



IMAGE SENSORS
Capture light



LENSES & FILTERS
Shape & refine light



WAVEGUIDES
Direct light efficiently



VCSEL / LASERS
High-speed light sources



PHOTODETECTORS
Convert light to data



LIGHT. ENGINEERING. EXPERIENCE.

Photonics makes consumer electronics smarter, more immersive, and more connected—enhancing the way we live every day.



PHOTONICS INDUSTRY DEFENSE & AEROSPACE SEGMENT

Targeting • Surveillance • Secure communications • Navigation

Defense and aerospace applications demand performance in difficult environments. Photonics supports precision targeting, surveillance, communications, and navigation systems.



TARGETING

High-precision laser systems enable accurate targeting, rangefinding, and designation in any conditions.



SURVEILLANCE

Advanced optical sensors deliver real-time situational awareness day or night, through haze, smoke, or clouds.



SECURE COMMUNICATIONS

Laser communication links provide high bandwidth, low probability of intercept, and jam-resistant connectivity.



NAVIGATION

Photonics-based systems deliver precise positioning, inertial navigation, and star tracking in GPS-denied environments.



LASER RANGEFINDERS
Long-range detection and measurement



EO/IR SENSORS
High-resolution imaging in all conditions



OPTICAL LINKS
Secure, high-speed data transfer



PHOTONIC RF
Low SWaP, high performance communication systems



STAR TRACKERS
Precision attitude and navigation



HARDENED SYSTEMS
Built for extreme environments

MISSION CRITICAL. PERFORMANCE DRIVEN.

Photonics delivers the speed, precision, and reliability modern defense and aerospace missions demand.



AIR



SEA



LAND



SPACE



PHOTONICS INDUSTRY SCIENTIFIC & RESEARCH SEGMENT

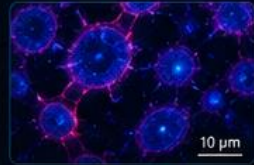
Microscopy • Spectroscopy • Instrumentation

Research labs use photonics to see and measure things at very small scales. Many commercial breakthroughs begin as scientific instrumentation.



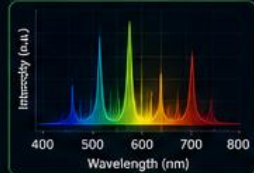
MICROSCOPY

Advanced optical microscopes reveal the micro- and nano-scale world with exceptional resolution and contrast.



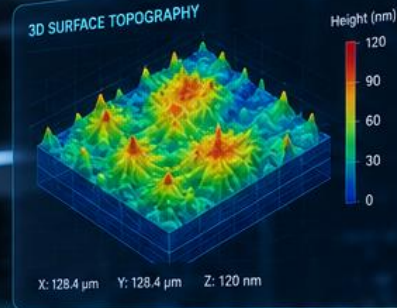
SPECTROSCOPY

Light-matter interaction measured across wavelengths provides deep chemical and structural information.

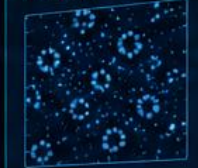


INSTRUMENTATION

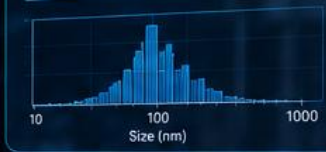
High-performance photonic instruments enable precise measurement, analysis, and discovery across disciplines.



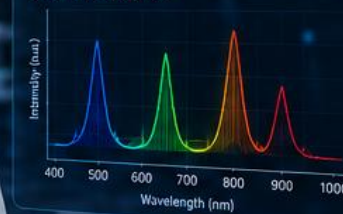
PARTICLE ANALYSIS



Count: 15284
Mean Size: 87.3 nm
Std Dev: 12.1 nm



SPECTRAL ANALYSIS



INTERFEROMETRY



ENABLING DISCOVERY ACROSS DISCIPLINES



LIFE SCIENCES
Cell imaging, biophotonics, genomics



MATERIALS SCIENCE
Structure, composition, and properties



PHYSICS
Quantum optics, fundamental research



NANOTECHNOLOGY
Nanofabrication, characterization



ENVIRONMENTAL SCIENCE
Remote sensing, chemical detection

PHOTONICS IMPACT



HIGH PRECISION MEASUREMENT



NON-CONTACT ANALYSIS



MULTI-SCALE INSIGHT



ENABLING INNOVATION



DRIVING FUTURE BREAKTHROUGHS



SEEING MORE. MEASURING BETTER. DISCOVERING THE FUTURE.

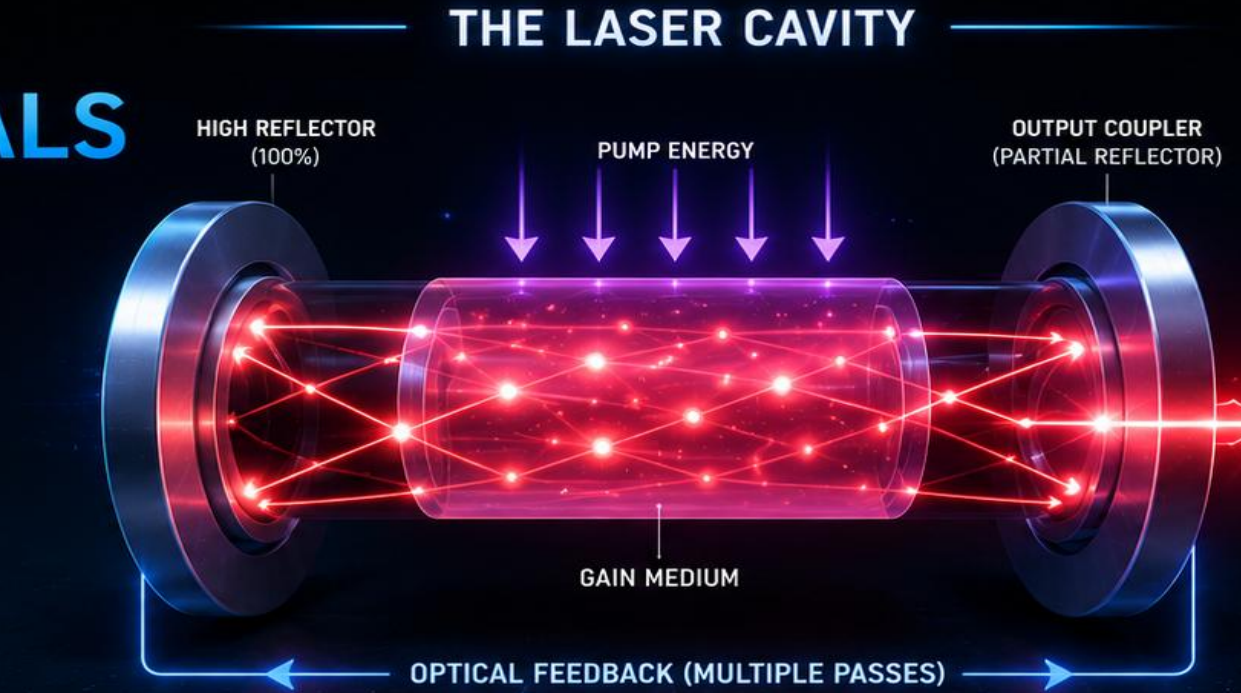
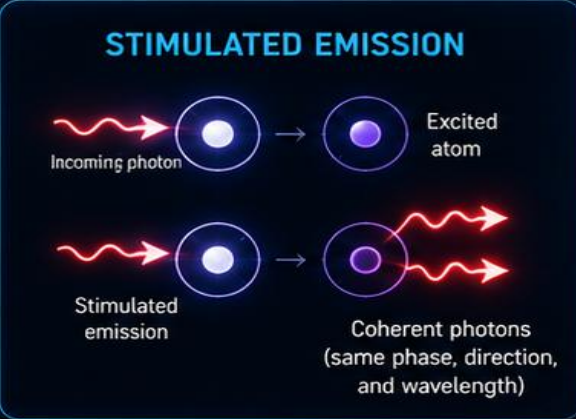
Photonics instrumentation is the foundation of modern science and innovation.



LASER FUNDAMENTALS

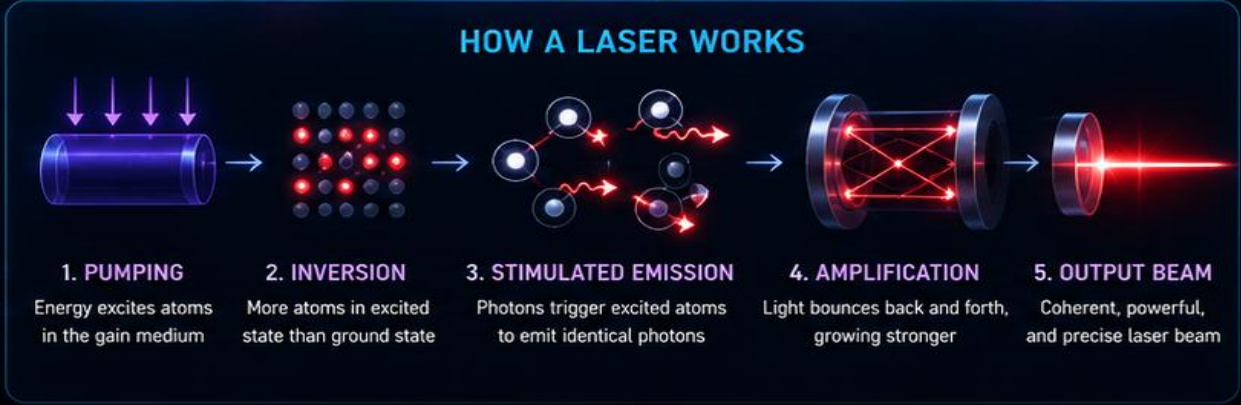
Stimulated emission and coherent light generation

Lasers work by producing coherent light with a narrow beam and stable wavelength. That makes them extremely useful where precision and power concentration matter.



KEY CHARACTERISTICS

- COHERENCE**
Light waves are in phase with each other
- MONOCHROMATIC**
Narrow wavelength (high spectral purity)
- DIRECTIONAL**
Highly collimated and focused
- HIGH BRIGHTNESS**
High intensity in a small area



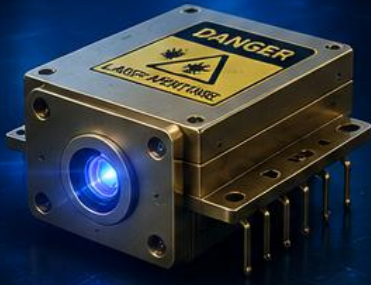
WIDE-RANGING APPLICATIONS

 MANUFACTURING	 MEDICAL	 COMMUNICATIONS
 RESEARCH	 SENSING	 DEFENSE

MAJOR LASER TYPES

Different lasers are optimized for different wavelengths, power levels, materials, and cost structures. No single laser type is best for every application.

DIODE LASER



WAVELENGTH
780 nm – 1550 nm

POWER RANGE
mW – Multi-kW

BEAM QUALITY
Good

EFFICIENCY
High

SIZE / FOOTPRINT
Compact

COST
Low – Medium

TYPICAL APPLICATIONS



FIBER LASER



WAVELENGTH
1030 nm – 1090 nm, 1550 nm

POWER RANGE
W – Multi-kW+

BEAM QUALITY
Excellent ($M^2 < 1.3$)

EFFICIENCY
Very High

SIZE / FOOTPRINT
Compact

COST
Medium

TYPICAL APPLICATIONS



SOLID-STATE LASER



WAVELENGTH
355 nm – 1064 nm

POWER RANGE
mW – Multi-kW

BEAM QUALITY
Excellent

EFFICIENCY
High

SIZE / FOOTPRINT
Medium

COST
Medium – High

TYPICAL APPLICATIONS



CO₂ LASER



WAVELENGTH
10.6 μ m

POWER RANGE
10 W – Multi-kW

BEAM QUALITY
Good

EFFICIENCY
Moderate

SIZE / FOOTPRINT
Large

COST
Low – Medium

TYPICAL APPLICATIONS



EXCIMER LASER



WAVELENGTH
193 nm – 351 nm (UV)

POWER RANGE
mW – 100s of W (avg.)

BEAM QUALITY
Excellent

EFFICIENCY
Low

SIZE / FOOTPRINT
Large

COST
High

TYPICAL APPLICATIONS



RIGHT LASER. RIGHT APPLICATION. MAXIMUM IMPACT.

Understanding the strengths of each laser type helps engineers select the best tool for the job.



MANUFACTURING



LASER CUTTING
High-precision cutting of metals and materials



LASER WELDING
Strong, clean welds with minimal heat distortion



LASER MARKING
Permanent, high-contrast identification and traceability



ADDITIVE MANUFACTURING
Powder bed fusion and 3D printing with lasers

LASER APPLICATIONS

MANUFACTURING • MEDICINE • COMMUNICATIONS • RESEARCH

Lasers are one of the most versatile tools in photonics. They support cutting, therapy, sensing, alignment, imaging, and scientific experiments.

THE POWER OF LIGHT
ENABLING
INNOVATION

MEDICINE



LASER SURGERY
Minimally invasive precision procedures



LASER THERAPY
Targeted treatment of tissues and conditions



DIAGNOSTIC IMAGING
High-resolution imaging and optical coherence tomography



LASER DENTISTRY
Gentle, precise, and effective dental care



FIBER OPTIC COMMUNICATIONS
High-speed data transmission over long distances



FREE-SPACE OPTICAL COMMUNICATIONS
Wireless data links using laser beams



LASER ALIGNMENT & SENSING
Precise alignment and positioning of systems



DATA CENTER INTERCONNECTS
High-bandwidth, low-latency optical connections



COMMUNICATIONS

CROSS-INDUSTRY APPLICATIONS



LIDAR & REMOTE SENSING
Mapping, detection, and navigation



LASER LIGHTING & PROJECTION
High-efficiency illumination and display systems



ENVIRONMENTAL MONITORING
Remote sensing of gases, pollutants, and aerosols



SECURE COMMUNICATIONS
Encrypted data transmission with laser links



SPACE & AEROSPACE
Ranging, constellation links, and deep-space communication



LASER MICROSCOPY
High-resolution imaging at micro and nanoscale



SPECTROSCOPY
Material analysis and chemical detection



OPTICAL TRAPPING & MANIPULATION
Manipulating particles and cells with light



QUANTUM & PHOTONICS RESEARCH
Exploring light-matter interactions and quantum phenomena

RESEARCH



ONE TECHNOLOGY. ENDLESS POSSIBILITIES.
POWERING THE FUTURE WITH LIGHT.



LEDs AND OLEDs

Efficient light sources for lighting and displays

LEDs dominate efficient lighting, while OLEDs are important in displays that need thin, bright, flexible emission layers. Both are major light-generation technologies.



LEDs

Efficient. Durable. Versatile.

- High efficiency and long lifetime
- Low power consumption
- Robust solid-state technology
- Wide color range and color tunability
- Ideal for general lighting and backlighting



OLEDs

Thin. Bright. Flexible.

- Self-emissive pixels – no backlight needed
- Ultra-thin and lightweight
- High contrast with deep blacks
- Vibrant colors and wide viewing angles
- Ideal for premium displays and flexible devices



OLED DISPLAY

Deep blacks, high contrast, and vibrant colors

LED LIGHTING

Energy-efficient, long life, and reliable performance

POWERING A BRIGHTER FUTURE



ENERGY EFFICIENT
Lower power,
lower impact



LONG LIFETIME
Built to last,
less maintenance



HIGH BRIGHTNESS
More light,
better performance



RICH COLORS
Accurate, vibrant,
and tunable



SUSTAINABLE
Mercury-free and
environmentally friendly

WHERE LIGHT MATTERS



**HOME & OFFICE
LIGHTING**



**MOBILE & TV
DISPLAYS**



**AUTOMOTIVE
LIGHTING**



**WEARABLE &
FLEXIBLE DEVICES**



**SIGNAGE &
ARCHITECTURAL
LIGHTING**



OPTICAL FIBERS

Low-loss long-distance transmission

Optical fiber is the backbone of global communications. It carries data as light pulses through glass with very low loss compared with electrical transmission over long distances.



LIGHT PULSES CARRY DATA

Data is encoded in light pulses that travel through the fiber core.



ULTRA-LOW LOSS

Typical loss: ~0.2 dB/km at 1550 nm
Enables long-distance transmission with fewer repeaters.



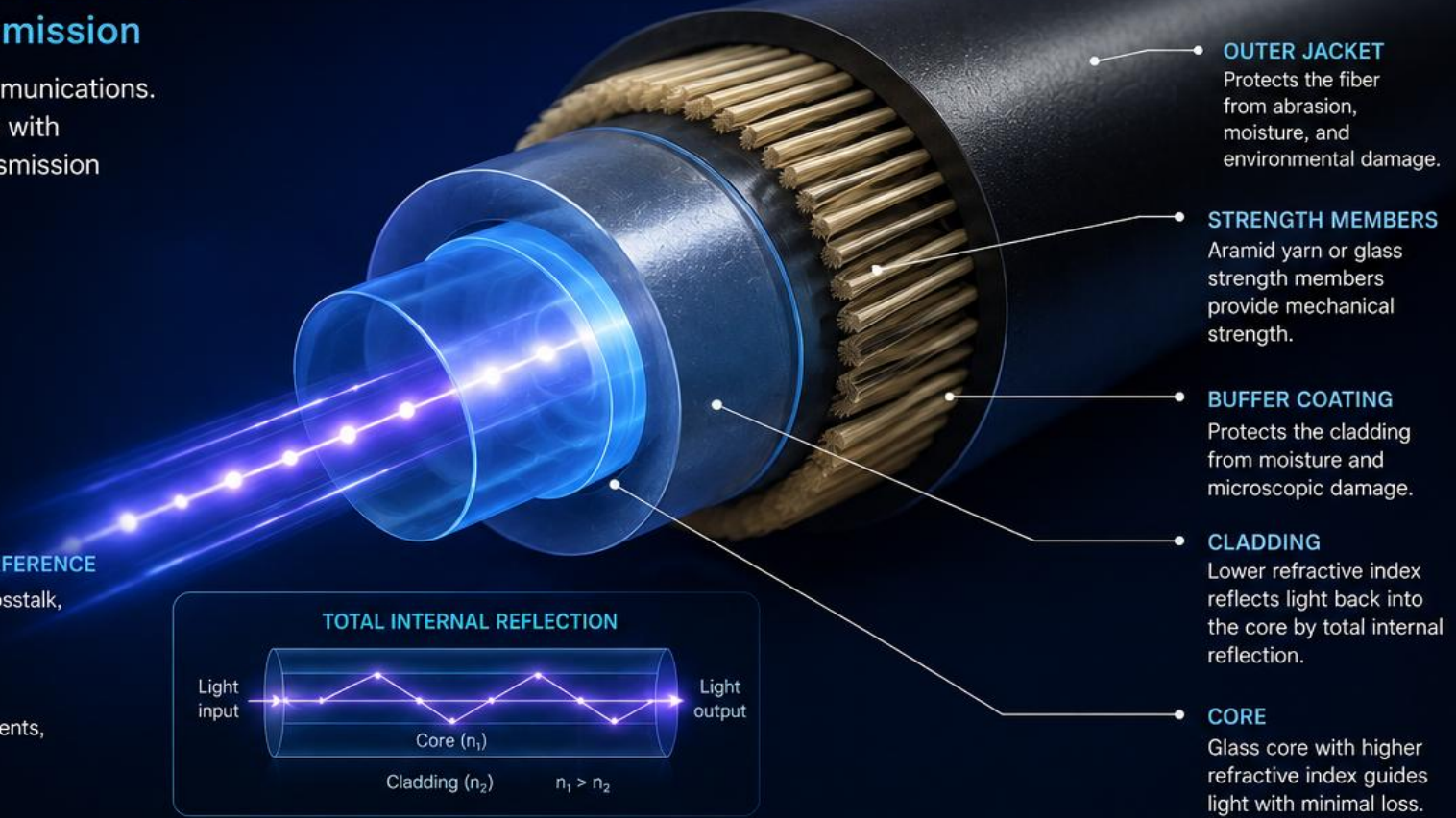
IMMUNE TO ELECTROMAGNETIC INTERFERENCE

Light signals are not affected by EMI or crosstalk, ensuring high signal integrity.



HIGH BANDWIDTH, GLOBAL REACH

Supports massive data rates across continents, forming the backbone of the internet.



OUTER JACKET

Protects the fiber from abrasion, moisture, and environmental damage.

STRENGTH MEMBERS

Aramid yarn or glass strength members provide mechanical strength.

BUFFER COATING

Protects the cladding from moisture and microscopic damage.

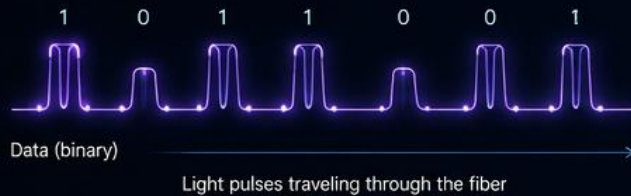
CLADDING

Lower refractive index reflects light back into the core by total internal reflection.

CORE

Glass core with higher refractive index guides light with minimal loss.

DATA TRANSMISSION AS LIGHT PULSES



TYPICAL PERFORMANCE (SINGLEMODE FIBER)

Wavelength	1310 nm / 1550 nm
Attenuation	~0.35 dB/km @ 1310 nm ~0.20 dB/km @ 1550 nm
Bandwidth	> 10 Tb/s per fiber (DWDM)
Distance (without repeater)	80 – 120 km typical
Core Diameter	8 – 10 μ m

ENABLING THE CONNECTED WORLD



TELECOMMUNICATIONS
NETWORKS



DATA CENTERS



INTERNET
BACKBONE



SMART CITIES
& IoT



SUBMARINE
CABLES



FIBER COMPONENTS

CABLES • CONNECTORS • AMPLIFIERS • SPLITTERS • TRANSCEIVERS

A fiber network is more than just the fiber itself. It requires supporting components that maintain signal quality, distribute light, and convert between optical and electrical domains.



HOW THEY WORK TOGETHER



Each component plays a critical role in delivering high-performance, reliable, and scalable optical networks.

KEY BENEFITS



LOW LOSS
Minimize signal degradation



HIGH RELIABILITY
Ensure stable connections



SCALABILITY
Support growing bandwidth demands



LONG DISTANCE
Extend reach with amplification



FLEXIBILITY
Adapt to diverse network architectures



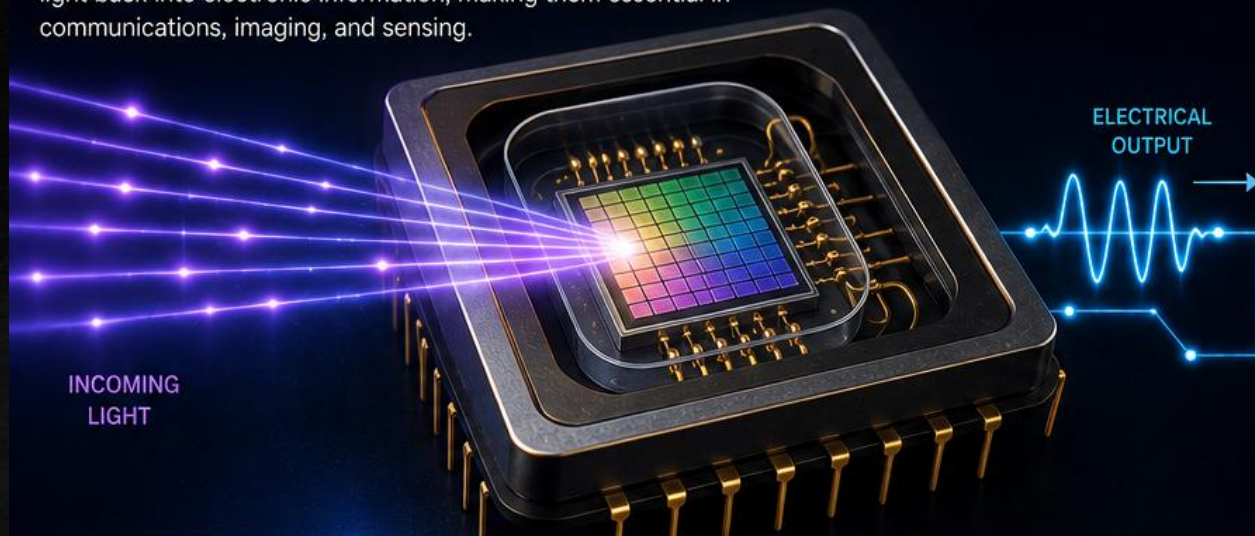
HIGH PERFORMANCE
Enable fast, efficient data transmission



PHOTODETECTORS

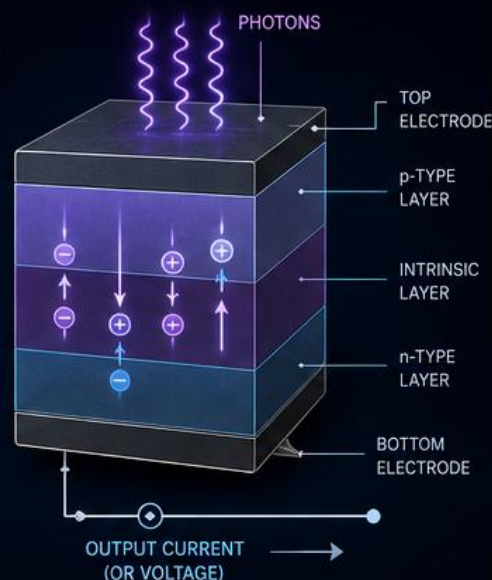
Convert light into electrical signals

Detection is the reverse of generation. Photodetectors translate light back into electronic information, making them essential in communications, imaging, and sensing.

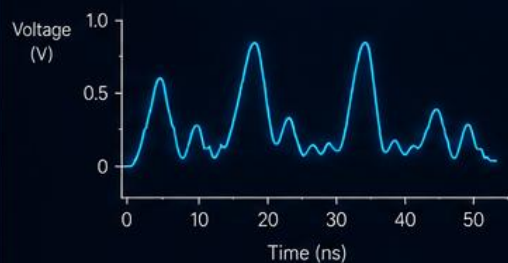


HOW IT WORKS

- 1 PHOTONS ABSORBED**
Photons enter the detector and are absorbed in the photosensitive layer.
- 2 GENERATE CARRIERS**
Absorbed photons create electron-hole pairs.
- 3 SEPARATE CHARGES**
An electric field separates the charges and drives them to the electrodes.
- 4 MEASURE CURRENT**
The collected charge produces a current or voltage proportional to the light intensity.



OUTPUT SIGNAL



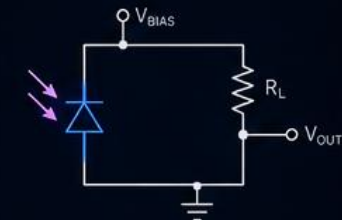
KEY PERFORMANCE METRICS

- | | |
|---|--|
| Responsivity (A/W)
How much current per unit of light. | Quantum Efficiency (%)
How many photons are converted to charge. |
| Bandwidth (Hz)
How fast the detector can respond. | Noise Equivalent Power (NEP)
The minimum detectable signal. |
| Dark Current (A)
The noise floor in the absence of light. | Dynamic Range (dB)
The range between weak and strong signals. |

COMMON MATERIALS

- Si**
Silicon
(400 – 1100 nm)
- InGaAs**
Indium Gallium Arsenide
(800 – 1700 nm)
- Ge**
Germanium
(800 – 1800 nm)
- InP**
Indium Phosphide
(900 – 1650 nm)
- HgCdTe (MCT)**
Mercury Cadmium Telluride
(1 – 12 μm)

TYPICAL OUTPUT CIRCUIT



- Photocurrent generated by light
- Converted to voltage across R_L
- V_{OUT} proportional to light intensity

WIDE RANGE OF APPLICATIONS



FIBER OPTIC
COMMUNICATIONS



IMAGING &
CAMERAS



LIDAR & 3D
SENSING



BIOPHOTONICS
& MEDICAL



INDUSTRIAL
INSPECTION



ENVIRONMENTAL
MONITORING



ASTRONOMY &
SPACE

THE ESSENTIAL EYE OF PHOTONICS SYSTEMS

From high-speed data links to deep-space telescopes, photodetectors enable systems to see, measure, and understand the world with light.



SENSORS AND IMAGING

Optical measurement and machine vision

Photonics enables non-contact measurement with high speed and accuracy. That is why it is so valuable in inspection, automation, and machine vision.



NON-CONTACT MEASUREMENT

Measure without touching the part, reducing wear and contamination.



HIGH SPEED

Capture and analyze images at high frame rates.



HIGH ACCURACY

Detect fine details and small defects with precision.

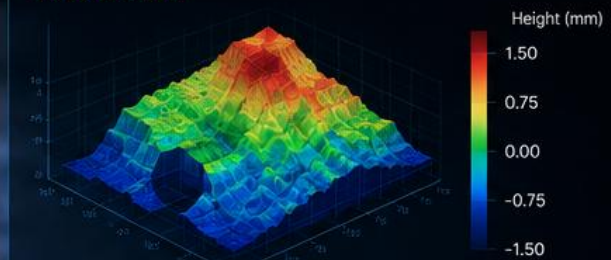


AUTOMATION READY

Seamlessly integrate into modern manufacturing and robotic systems.



3D PROFILE MAP



DIMENSIONAL MEASUREMENTS



DEFECT DETECTION



TYPICAL APPLICATIONS



AUTOMATED
INSPECTION



ROBOT GUIDANCE
& ALIGNMENT



DIMENSIONAL
MEASUREMENT



READING & CODE
VERIFICATION



QUALITY CONTROL
IN MANUFACTURING



SORTING &
IDENTIFICATION

DATA INSIGHTS

PASS RATE



CYCLE TIME



THROUGHPUT

Parts / min



287

TREND ANALYSIS

Dimensional Drift (mm)



0.0023



WAVEGUIDES AND INTEGRATED OPTICS

Light guided on a chip

Waveguides confine and direct light in a controlled path. This allows optical functions to be miniaturized and integrated into compact devices.

WAVEGUIDES

Confine and guide light with low loss and high precision.

RING RESONATOR

Enables filtering, modulation, and wavelength selection.

PHASE SHIFTER

Precisely controls the phase of light for advanced functions.

LIGHT IN

LIGHT OUT (λ_1)

LIGHT OUT (λ_2)

KEY BENEFITS



HIGH INTEGRATION
Many optical functions on a single chip.



LOW POWER
Efficient guiding and compact footprints.



SCALABLE
CMOS-compatible manufacturing.



HIGH PERFORMANCE
Low loss, high speed, and stable operation.

EDGE COUPLER

Efficiently couples light between optical fiber and waveguide.

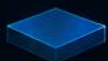
SURFACE GRATING COUPLER

Couples light vertically on and off the chip—ideal for testing and dense packaging.

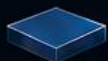
BEAM SPLITTER

Divides optical power into multiple paths with low loss.

TYPICAL MATERIALS



SILICON (Si)
High index contrast
CMOS compatible



SILICON NITRIDE (Si₃N₄)
Low loss, wide bandgap,
broad applications



INDIUM PHOSPHIDE (InP)
Active devices, high speed,
modulators & lasers



LITHIUM NIOBATE (LiNbO₃)
Electro-optic modulation,
high bandwidth

COMMON FUNCTIONS ON A CHIP



ROUTING



SPLITTING



FILTERING



MODULATION



DETECTION



MUX / DEMUX

APPLICATIONS



DATA
COMMUNICATIONS



SENSING



QUANTUM
PHOTONICS



LIDAR



MEDICAL
DIAGNOSTICS



SILICON PHOTONICS

Optics integrated with semiconductor fabrication

Silicon photonics uses semiconductor manufacturing methods to build optical functions at scale. It is especially important for data-center interconnects and high-speed links.

KEY ADVANTAGES



HIGH BANDWIDTH

Supports Tb/s data rates for next-generation links.



CMOS COMPATIBLE

Leverages advanced semiconductor foundries and processes.



COST EFFECTIVE

Wafer-scale manufacturing lowers cost per port.



SCALABLE

Enables dense integration and high-volume production.

WAFER SCALE INTEGRATION



High volume manufacturing



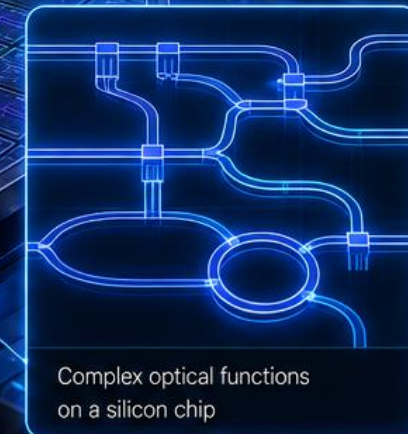
CMOS compatibility



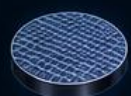
Low loss, high speed



Scalable and cost efficient



TYPICAL SILICON PHOTONICS FABRICATION FLOW



WAFER START



THIN FILM DEPOSITION



LITHOGRAPHY



ETCH



DOPING / IMPLANT



PLANARIZATION



METALIZATION



DICE & TEST

ENABLING APPLICATIONS



DATA CENTER INTERCONNECTS



AI / ML CLUSTERS



TELECOM NETWORKS



HIGH PERFORMANCE COMPUTING



PHOTONIC INTEGRATED CIRCUITS

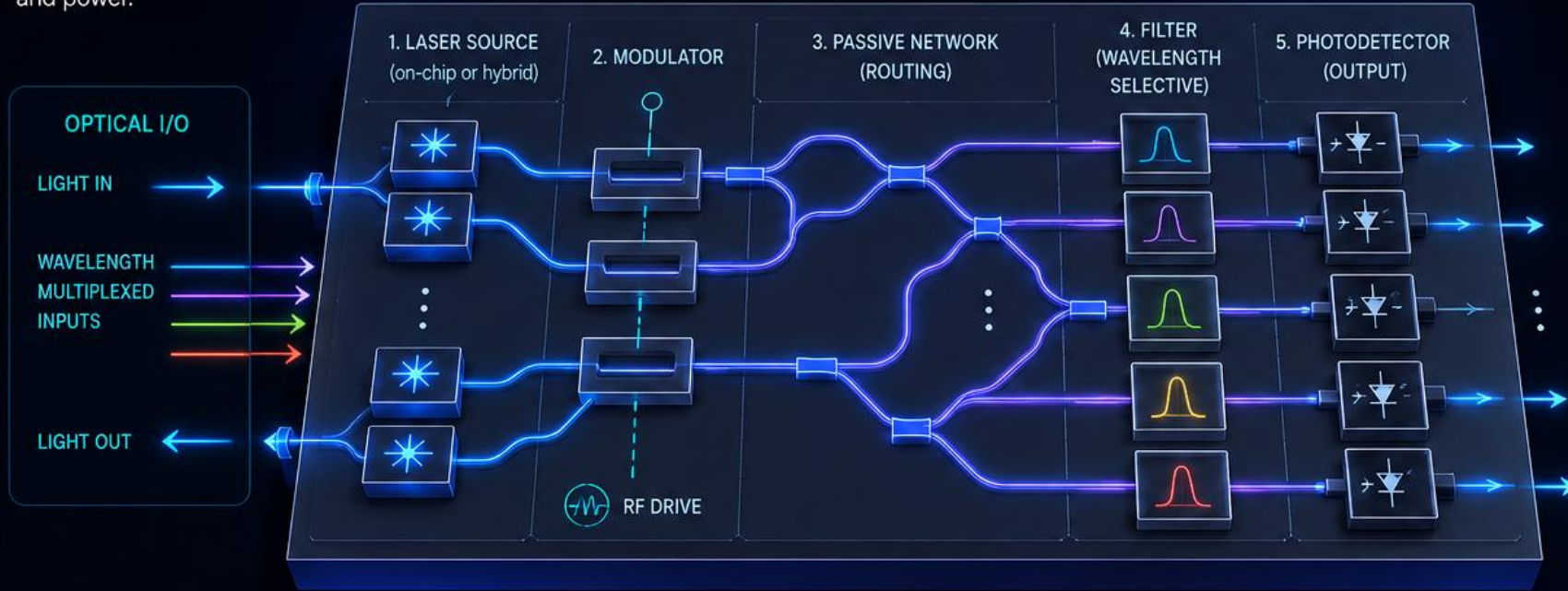
Multiple optical functions on one chip

PICs combine several photonic elements on a single platform, similar to how electronic integrated circuits combine transistors. Integration can reduce size, cost, and power.



KEY BENEFITS OF INTEGRATION

- HIGH INTEGRATION**
Many functions on a single chip
- BETTER PERFORMANCE**
Shorter interconnects, lower loss, higher speed
- LOWER POWER**
Reduced drive voltages and optical loss
- SCALABLE**
Manufactured using mature semiconductor processes



COMMON PHOTONIC BUILDING BLOCKS



TYPICAL PIC APPLICATIONS



OPTICAL INTERCONNECTS

Faster data movement, lower power

As computing systems become more data-hungry, optical interconnects help reduce bandwidth bottlenecks and power consumption associated with moving data electrically.

KEY BENEFITS



HIGHER BANDWIDTH

Scales to Tb/s and beyond to handle growing data demands.



LOWER POWER

Significantly reduces energy per bit compared to copper.



LOWER LATENCY

Enables faster, more efficient communication across systems.



BETTER SCALABILITY

Supports longer distances and higher densities with ease.



OPTICAL INTERCONNECT APPLICATIONS



DATA CENTERS &
CLOUD INFRASTRUCTURE



AI / ML
CLUSTERS



HPC
SYSTEMS



STORAGE AREA
NETWORKS



EDGE & DISTRIBUTED
COMPUTING

OPTICAL vs. ELECTRICAL INTERCONNECTS

METRIC	OPTICAL INTERCONNECTS	ELECTRICAL INTERCONNECTS
BANDWIDTH DENSITY	Very High	Limited
POWER CONSUMPTION	Low	High
REACH	Long	Short
SIGNAL INTEGRITY	Excellent	Degrades



DATA CENTER PHOTONICS

Optical networking for AI and cloud workloads

AI and cloud infrastructure depend on fast east-west traffic inside data centers. Photonics is increasingly critical to linking servers, switches, and accelerators.

KEY BENEFITS



EXTREME BANDWIDTH
Supports massive scale AI and cloud workloads.



LOWER POWER
Much lower power per bit compared to electrical I/O.



HIGH SCALABILITY
Enables flexible, disaggregated, and scale-out architectures.



HIGH RELIABILITY
Robust optical links for mission-critical infrastructure.



EAST-WEST TRAFFIC ACCELERATION
Photonic links move data faster between servers and accelerators, eliminating electrical bottlenecks.

OPTICAL FABRIC NETWORKING
Scalable, non-blocking architectures built with high-radix optical switches and photonic interconnects.

TYPICAL AI DATA CENTER ARCHITECTURE



SERVERS & ACCELERATORS
GPUs / TPUs / AI Compute Nodes



TOP-OF-RACK SWITCHES
Optical Uplinks



SPINE SWITCH FABRIC
High-Radix Optical Switches

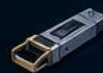


LEAF / SPINE NETWORK
Ultra-High Bandwidth Backbone

OPTICAL TRANSCEIVERS



OSFP / QSFP-DD
800G / 1.6T



COHERENT
800G / 1.6T+



LPO / CPO
Low Power



SILICON PHOTONICS
High Volume

ENABLING NEXT-GENERATION WORKLOADS



GEN AI TRAINING



CLOUD SERVICES



RECOMMENDER
SYSTEMS



REAL-TIME
INFERENCE



VIDEO STREAMING
& CDN



BIG DATA
ANALYTICS

PHOTONICS IMPACT

10X+

MORE BANDWIDTH
vs electrical links

2-5X

LOWER POWER
per bit

SCALE TO
10Ks

OF GPUS
with optics



TELECOM NETWORKS

5G/6G backbone, fronthaul, backhaul

Telecommunications relies on photonics to move traffic through backbone and metro networks. As speeds rise, optical transport remains essential.

KEY BENEFITS



MASSIVE BANDWIDTH

Supports exponential data growth and higher spectral efficiency.



LOWER POWER

Much lower power per bit compared to electrical links.



LONG REACH

Enables long-haul transport with minimal signal loss.



NETWORK AGILITY

Reconfigurable, scalable, and future-ready networks.

CORE / BACKBONE

High-capacity, long-haul optical transport

METRO / REGIONAL

Metro aggregation and interconnect

FRONTHAUL

Timing-sensitive connectivity to radio sites

BACKHAUL

High-capacity links from cell sites to aggregation points

NETWORK LAYERS



CORE / BACKBONE

Long-haul DWDM networks connecting cities and countries.



METRO / REGIONAL

Metro networks linking data centers, sites, and exchanges.



BACKHAUL

High-capacity links from aggregation nodes to base stations.



FRONTHAUL

Low-latency, high-precision connectivity to radio units.

KEY PHOTONIC TECHNOLOGIES



DWDM
High-capacity wavelength multiplexing



COHERENT OPTICS
Long-haul, high spectral efficiency



OPTICAL AMPLIFIERS
Extend reach and boost signal



OPTICAL SWITCHING
Dynamic, agile network routing



SILICON PHOTONICS
Compact, efficient, and scalable

ENABLING THE FUTURE



5G / 6G
EVERYWHERE



EDGE CLOUD
CONNECTIVITY



IoT MASSIVE
CONNECTIONS



IMMERSIVE
EXPERIENCES



SMART CITIES
& INDUSTRY

Building the high-speed, high-capacity networks that connect the world.

**FASTER. FARTHER.
ALWAYS ON.**



INDUSTRIAL LASER PROCESSING

Precision cutting and welding

Lasers excel at controlled energy delivery. That makes them ideal for high-throughput production environments where accuracy and repeatability are essential.

KEY BENEFITS



EXCEPTIONAL PRECISION

Achieves intricate geometries and tight tolerances with minimal thermal impact.



HIGH THROUGHPUT

Fast processing speeds increase productivity and reduce cycle times.



RELIABLE & REPEATABLE

Consistent results with excellent repeatability and process stability.



VERSATILE APPLICATIONS

Cutting, welding, drilling, marking, and surface treatment of a wide range of materials.

IDEAL FOR



Automotive



Aerospace



Electronics



Battery Manufacturing



Medical Devices



General Manufacturing

LASER PROCESSING CAPABILITIES



CUTTING



WELDING



DRILLING

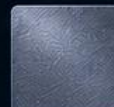


MARKING

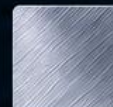


SURFACE
TREATMENT

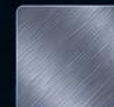
MATERIALS



STEEL



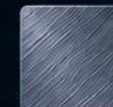
STAINLESS
STEEL



ALUMINUM



COPPER



TITANIUM



NICKEL
ALLOYS



GLASS



PLASTICS



HIGH BEAM QUALITY

Small spot size for fine detail



ADVANCED MOTION CONTROL

Complex 2D/3D processing



REAL-TIME MONITORING

In-process feedback for quality assurance



SCALABLE SOLUTIONS

From standalone systems to integrated lines



ADDITIVE MANUFACTURING

Laser-based 3D printing

Laser-based additive manufacturing builds parts one layer at a time. It enables complex geometries and advanced materials that are hard to produce conventionally.

KEY BENEFITS



DESIGN FREEDOM

Create complex, lightweight geometries impossible with traditional methods.



MATERIAL EFFICIENCY

Add material only where needed, reducing waste and cost.



HIGH PERFORMANCE

Produce parts with excellent mechanical properties and dense microstructures.



FASTER TIME TO MARKET

Rapid iteration and on-demand production accelerate innovation.

PRECISION POSITIONING
(POWDER FEEDER)

Sub-micron accuracy
motion control

PRECISION POSITIONING
(LASER HEAD)

Sub-micron accuracy
motion control

POWDER
DEPOSITION
FEEDER

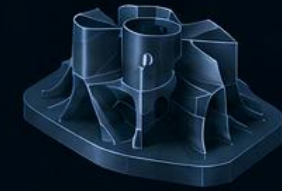
LASER HEAD

POWDER AND LASER
INTERACTION POINT

BUILD IN PROGRESS

LAYER 1250 / 2480

66%



MATERIAL	Ti-6Al-4V
LASER POWER	370 W
SCAN SPEED	1250 mm/s
LAYER THICKNESS	30 μ m
ATMOSPHERE	Argon
BUILD TIME	02:45:18

ADDITIVE MANUFACTURING PROCESS



1. 3D MODEL
Digital design
(CAD)



2. SLICING
Model is sliced
into layers



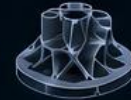
3. POWDER DEPOSITION
Thin layer of metal
powder is deposited



4. LASER EXPOSURE
Laser selectively melts
powder at the surface



5. LAYER REPEAT
Platform lowers and
process repeats



6. FINISHED PART
Part is complete after
all layers are built

ADVANCED MATERIALS



TITANIUM
ALLOYS



NICKEL
SUPERALLOYS



STAINLESS
STEEL



ALUMINUM
ALLOYS



COBALT
CHROME



TOOL
STEELS



INCONEL
ALLOYS



COMPLEX GEOMETRIES

Internal channels, lattices,
and organic shapes



LIGHTWEIGHTING

Optimize performance
with less weight



CONSOLIDATION

Reduce part count by
integrating features



SUSTAINABILITY

Less waste, lower energy,
responsible production



INDUSTRY IMPACT

Aerospace, medical, automotive,
energy, and beyond



METROLOGY AND INSPECTION

Non-contact measurement and quality control

Photonic metrology systems can measure defects, dimensions, and surfaces without touching the part. That improves both accuracy and throughput.



NON-CONTACT

Measure without touching to avoid part distortion or contamination.



HIGH ACCURACY

Detect micron-scale features and subtle surface deviations with high precision.



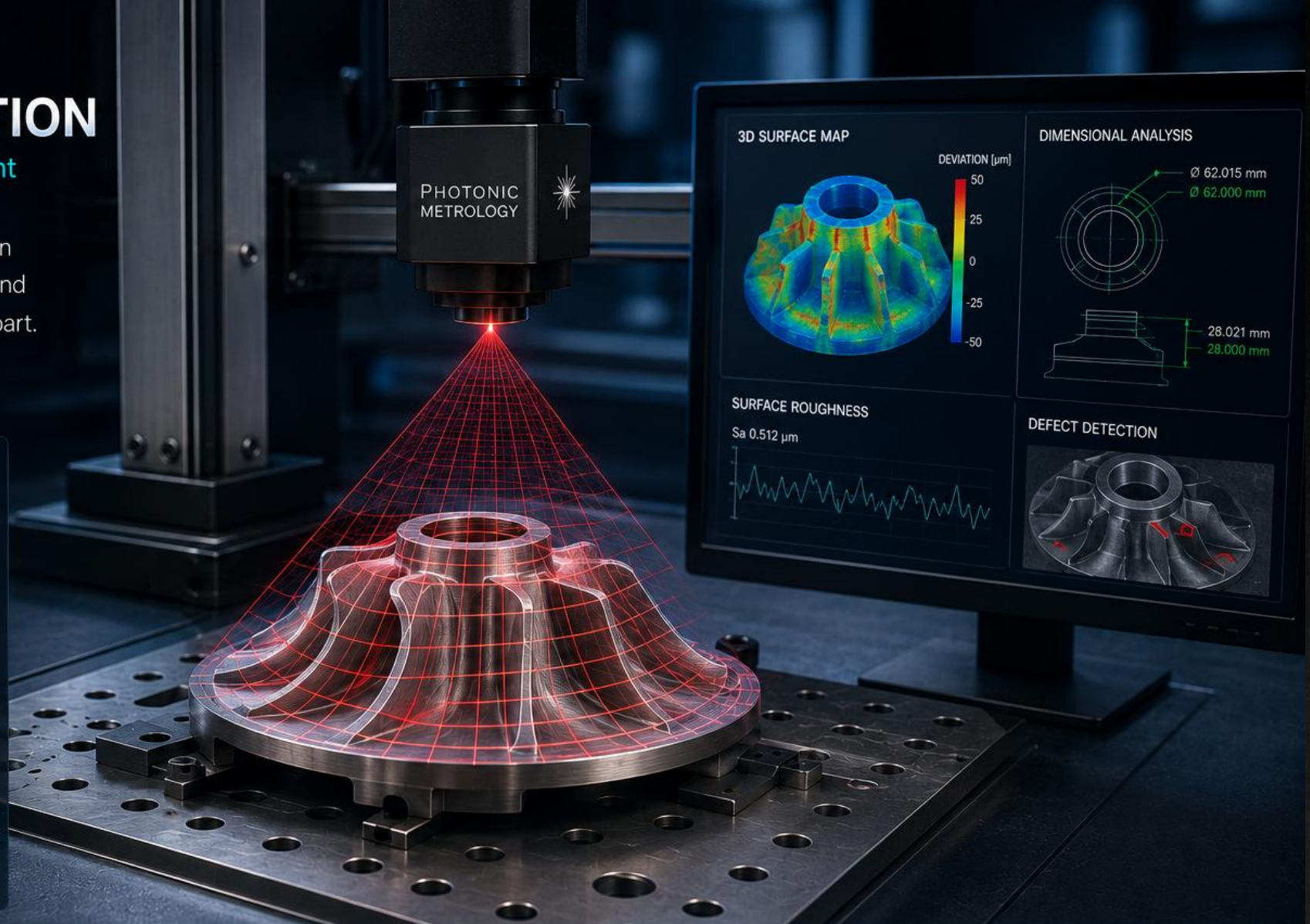
FULL-FIELD INSPECTION

Capture complete surface data in seconds with scanning laser or structured light.



FASTER QUALITY CONTROL

Automate inspection to improve throughput and ensure consistent quality.



AEROSPACE

Tight tolerance inspection



AUTOMOTIVE

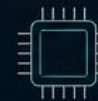
Inline quality assurance



KEY APPLICATIONS

MEDICAL DEVICES

Precision component verification



ELECTRONICS

Micro-feature and surface inspection



GENERAL MANUFACTURING

Defect detection and process control

MEDICAL IMAGING

OCT • Endoscopy • Fluorescence • Microscopy

Optical imaging reveals structures with high resolution and often without invasive procedures. This is one of photonics' most impactful healthcare roles.



NON-INVASIVE
Many optical techniques require no incisions or ionizing radiation.



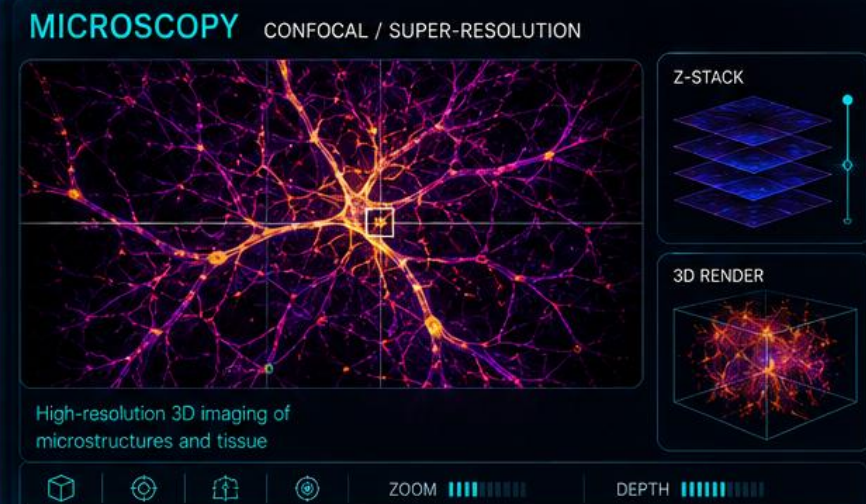
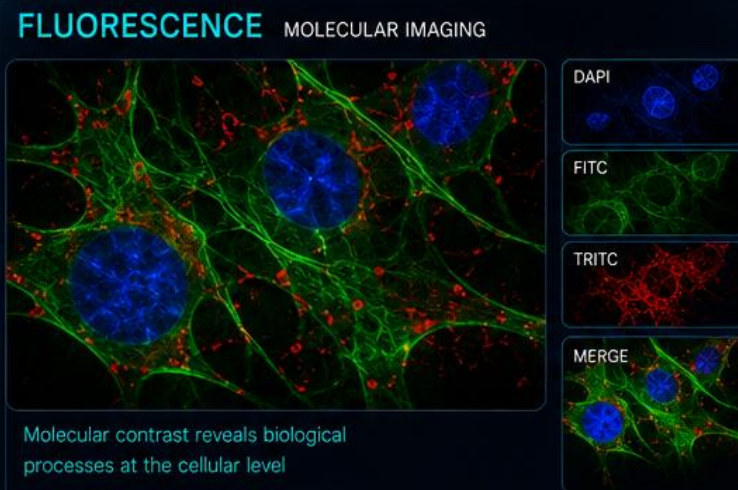
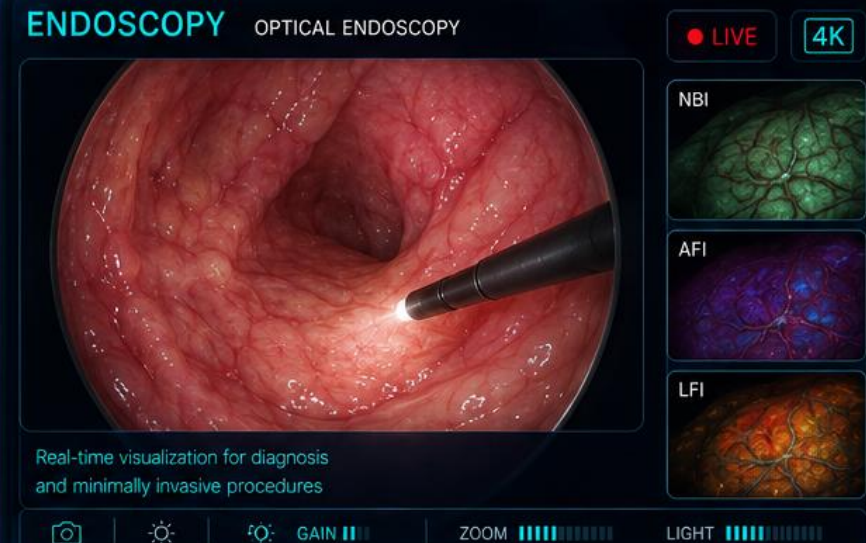
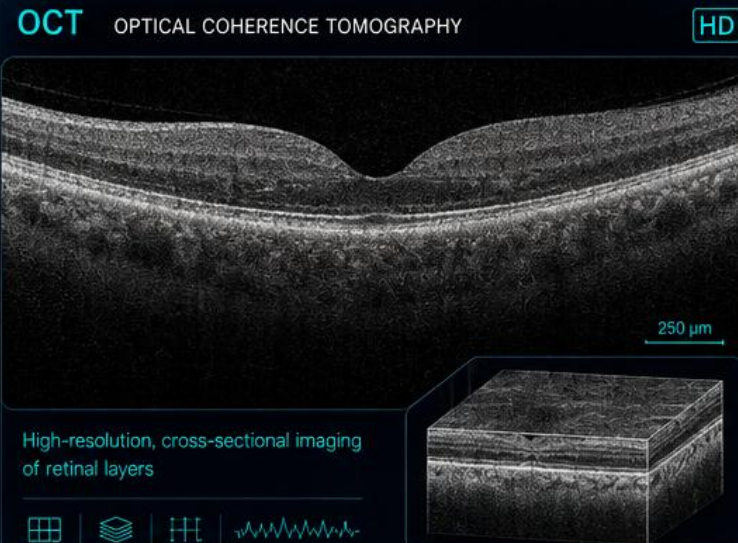
HIGH RESOLUTION
Reveal microstructures and subtle contrasts at cellular scales.



REAL-TIME IMAGING
Enable fast visualization for guidance and decision-making.



MULTI-MODAL
Complementary contrasts provide more complete diagnostic information.



TRANSFORMING HEALTHCARE



OPHTHALMOLOGY
Retinal imaging, glaucoma, AMD



GASTROENTEROLOGY
Early detection and lesion assessment



NEUROLOGY
Neurosurgery guidance and brain mapping



ONCOLOGY
Tumor margin detection and drug response



PATHOLOGY
Digital histology and cellular analysis



IMAGE-GUIDED THERAPY
Real-time guidance for better patient outcomes



MEDICAL THERAPY AND SURGERY

Lasers and optical systems for precise, targeted treatment

Lasers and related optical systems enable targeted treatment. They are widely used in eye care, skin treatment, and procedures that benefit from precision.



HIGH PRECISION

Focused energy targets only the tissue of interest, sparing surrounding areas.



MINIMALLY INVASIVE

Small incisions, less trauma, faster recovery, reduced risk of complications.



BETTER OUTCOMES

Improved safety, accuracy, and consistency lead to better patient results.



WIDE APPLICABILITY

Used across many specialties and procedures.

OPHTHALMOLOGY

Vision care with laser precision



LASIK

Vision correction



YAG CAPSULOTOMY

After cataract surgery



RETINAL LASER

Retinal repair

DERMATOLOGY

Advanced laser skin treatments



LASER RESURFACING

Skin rejuvenation



VASCULAR LESIONS

Redness and vessels



PIGMENT LESIONS

Sun spots and tattoos

MINIMALLY INVASIVE PROCEDURES

Precision inside the body



ENDOSCOPIC LASER

Tissue ablation



LITHOTRIPSY

Stone fragmentation



FIBER LASER PROBE

Targeted treatment



TARGETED TREATMENT

Precisely delivers energy exactly where needed



MINIMAL DAMAGE

Preserves healthy surrounding tissue



FASTER RECOVERY

Less pain and downtime for patients



ENHANCED SAFETY

Real-time control and advanced monitoring



PROVEN TECHNOLOGY

Trusted, widely adopted in modern medicine



BIOSENSING AND DIAGNOSTICS

Rapid detection and lab-on-chip systems

Photonic biosensors can detect biological signals quickly and with high sensitivity. This supports point-of-care testing and decentralized diagnostics.



HIGH SENSITIVITY

Detects low concentrations of biomarkers with excellent limit of detection.



RAPID RESULTS

Real-time optical readout enables results in minutes.



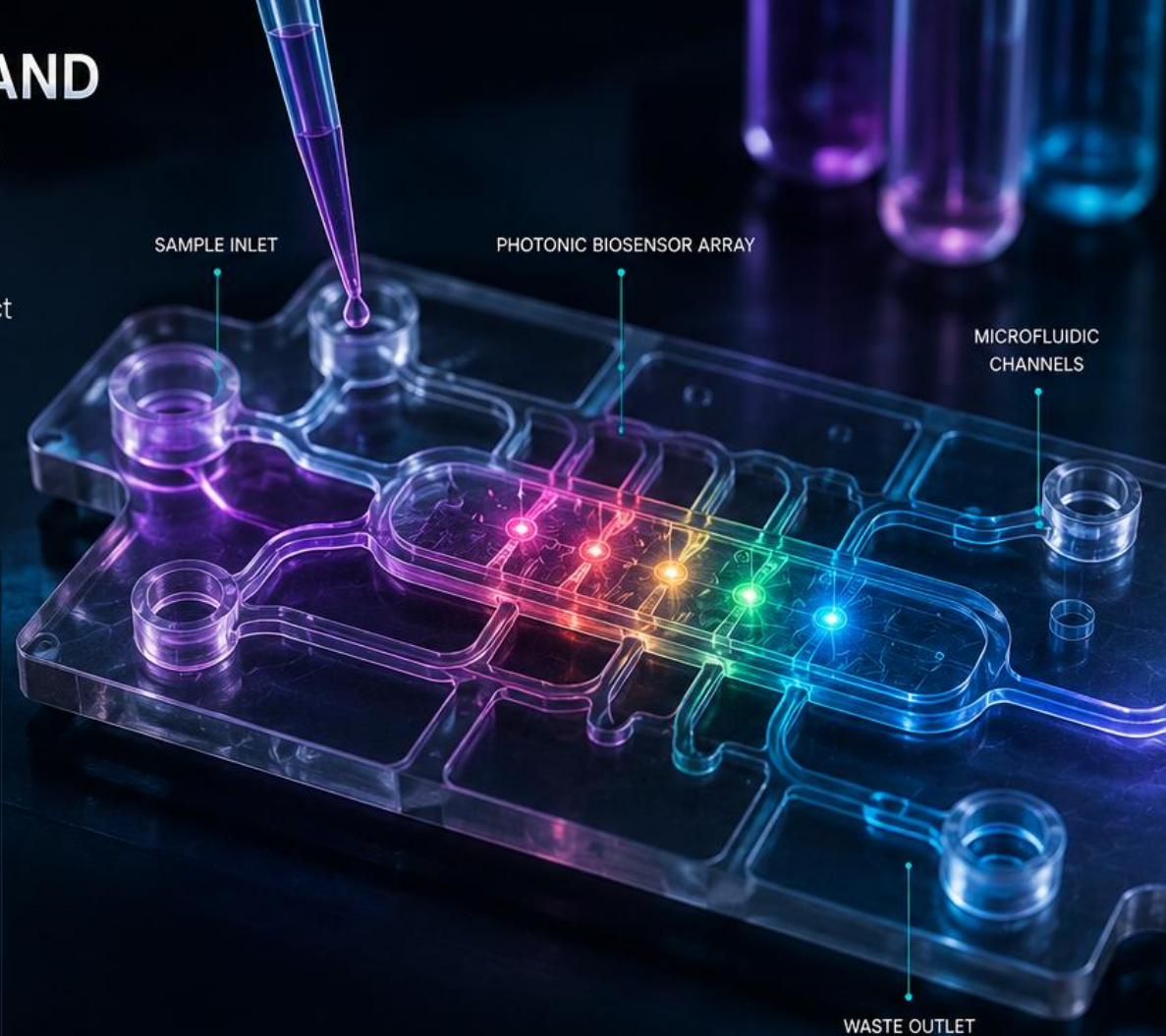
MINIATURIZED

Integrated photonic circuits and microfluidics reduce sample and reagent volumes.



POINT-OF-CARE READY

Portable, easy-to-use platforms for decentralized diagnostics.

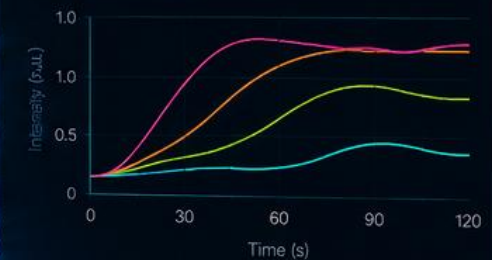


REAL-TIME READOUT

BIOMARKER DETECTION

Protein A	125.7 pg/mL
Protein B	78.3 pg/mL
miRNA-21	32.6 pg/mL
CRP	15.4 pg/mL

SIGNAL RESPONSE



ANALYSIS

POSITIVE



FROM SAMPLE TO RESULT



1. SAMPLE COLLECTION

Small sample volume (blood, saliva, urine, etc.)



2. MICROFLUIDIC DELIVERY

Sample flows through engineered channels



3. BIOMOLECULAR RECOGNITION

Targets bind to functionalized sensor surfaces



4. PHOTONIC DETECTION

Optical signal changes measured in real time



5. DATA ANALYSIS

Quantification and result interpretation



6. DIAGNOSTIC RESULT

Fast, accurate decision at the point of care

APPLICATIONS



INFECTIOUS DISEASE TESTING



CANCER BIOMARKER DETECTION



CARDIOVASCULAR MONITORING



METABOLIC AND HORMONAL ANALYSIS



ENVIRONMENTAL TOXIN DETECTION



LIDAR AND AUTONOMOUS SYSTEMS

Ranging • Mapping • Object detection

LiDAR sends pulses of light to measure distance and build 3D environmental maps. It is central to many autonomy and advanced sensing platforms.



PRECISE 3D PERCEPTION

High-resolution point clouds for accurate depth and mapping.



REAL-TIME DETECTION

Identify and track vehicles, pedestrians, and objects.



ROBUST IN ALL CONDITIONS

Works day or night, in rain, fog, and low light.



SAFE AND RELIABLE

Enables smarter decisions for autonomous navigation.



3D POINT CLOUD VIEW



REAL-TIME OBJECT DETECTION

	Vehicle	18.6 m
	Pedestrian	7.3 m
	Cyclist	12.4 m
	Traffic Sign	23.1 m
	Lane Marking	—



LIDAR SENSOR



- Laser pulses
- High precision
- 360° field of view

AUTONOMOUS VEHICLES



Safe navigation in complex environments

ROBOTICS & DRONES



Mapping and obstacle avoidance

SMART INFRASTRUCTURE



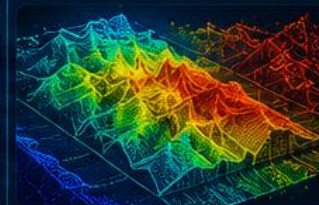
Traffic monitoring and environmental mapping

INDUSTRIAL AUTOMATION



Inventory, safety, and process optimization

AERIAL MAPPING



High-resolution 3D mapping from air and ground

MARITIME & NAVIGATION



Port navigation, monitoring, and situational awareness



AR/VR AND CONSUMER SENSING

Displays • Tracking • Interaction

Immersive devices use optical systems for projection, tracking, and interaction. Photonics helps make experiences more responsive and realistic.



HIGH-RESOLUTION DISPLAYS

Advanced microdisplays and optical engines deliver crisp, vibrant visual experiences.



PRECISE TRACKING

Optical tracking systems monitor position and movement with millimeter accuracy.



NATURAL INTERACTION

Hand, eye, and gesture tracking enable intuitive and immersive user interactions.



REAL-WORLD AWARENESS

Depth sensing and environmental mapping integrate virtual content with the physical world.

DISPLAYS



MICRODISPLAY LENS OPTICAL WAVEGUIDE EYE

Compact, efficient optical engines enable lightweight, high-performance AR/VR devices.

TRACKING TECHNOLOGIES



INSIDE-OUT TRACKING OUTSIDE-IN TRACKING DEPTH & LIDAR SENSING

Advanced optical sensors provide robust tracking in any environment or lighting.

INTERACTION METHODS



HAND TRACKING EYE TRACKING GESTURE RECOGNITION

Multi-modal interaction creates more natural and engaging user experiences.

SYSTEM INTEGRATION



PHOTONIC INTEGRATION OPTICAL CALIBRATION SENSOR FUSION

Integrated photonic systems deliver precise performance with low latency and power.

APPLICATIONS



GAMING & ENTERTAINMENT SOCIAL EXPERIENCES EDUCATION & TRAINING RETAIL & SHOPPING

Photonics powers immersive applications across entertainment, productivity, and everyday life.



LOW LATENCY

Faster response for comfortable experiences.



HIGH FIDELITY

Sharp visuals and accurate depth perception.



LIGHTWEIGHT DESIGN

Optical efficiency reduces size and weight.



POWER EFFICIENCY

Optimized photonics extend battery life.



PRIVACY BY DESIGN

On-device processing keeps data secure.



QUANTUM PHOTONICS

Photons for quantum communication, sensing, and computing

Quantum photonics harnesses the unique properties of light at the quantum level to enable secure communication, ultra-precise sensing, and the next generation of computing.

ENTANGLED PHOTONS
CORRELATED QUANTUM STATES

QUANTUM STATES



SUPERPOSITION

Qubits exist in multiple states simultaneously.



ENTANGLEMENT

Particles become linked and share a common state.



INTERFERENCE

Probability patterns reveal quantum information.



QUANTUM COMMUNICATION

Entangled photons enable unconditionally secure data transfer over any distance.



QUANTUM SENSING

Quantum states of light achieve unprecedented precision and sensitivity.



QUANTUM COMPUTING

Photons process and transmit quantum information with high speed and low noise.



SCALABLE & INTEGRATED

On-chip photonic platforms bring quantum technologies closer to real-world impact.

TRANSFORMATIVE APPLICATIONS



QUANTUM KEY DISTRIBUTION

Information-theoretically secure encryption for a quantum-safe future.



QUANTUM LIDAR

High-resolution imaging and sensing beyond classical limits.



ATOM CLOCKS & TIMING

Ultra-precise timing for navigation, geodesy, and fundamental science.



QUANTUM SIMULATION

Model complex systems for materials, chemistry, and physics breakthroughs.

PHOTONIC QUANTUM PLATFORM



QUANTUM
LIGHT SOURCE



STATE
PREPARATION



ON-CHIP
PROCESSING



ENTANGLEMENT
DISTRIBUTION



DETECTION &
MEASUREMENT



HIGH SPEED
Operate at the speed
of light.



ULTRA SECURE
Security guaranteed
by quantum laws.



EXTREME PRECISION
Sensitivity beyond
classical limits.



LOW NOISE
Photons are robust
and interference-free.



FUTURE READY
Enabling the next era
of technology.



QUANTUM HARDWARE CHALLENGES

Loss • Stability • Scalability

The physics is promising, but engineering is hard. Quantum photonic systems must minimize loss, maintain stability, and scale manufacturing.

QUANTUM PHOTONIC SYSTEM

CHALLENGE OVERVIEW



LOSS

Photons are easily lost in components, circuits, and interconnects.



STABILITY

Quantum states are extremely sensitive to environmental fluctuations.



SCALABILITY

Scaling to useful systems requires complex integration and manufacturing precision.

SYSTEM STATUS

LOSS

HIGH

STABILITY

MEDIUM

SCALABILITY

LOW

OVERALL HEALTH: CRITICAL

SCALING ROADBLOCKS



LARGE-SCALE FABRICATION
Yield and uniformity are hard to maintain.



INTEGRATION DENSITY
More components increase complexity and loss.



TEST & CHARACTERIZATION
Quantum measurement is slow and resource intensive.



COST
High precision and low yield drive up system costs.



TIME TO MARKET
Long development cycles slow real-world adoption.



COUPLING LOSS

Loss at interfaces reduces photon efficiency.

Impact: HIGH



PROPAGATION LOSS

Scattering, absorption, and imperfections cause loss in waveguides.

Impact: HIGH



DEPHASING

Environmental noise causes loss of quantum coherence.

Impact: HIGH



FABRICATION VARIATION

Nanometer-scale variations lead to performance inconsistencies.

Impact: HIGH



THERMAL DRIFT

Temperature fluctuations change optical path lengths and phases.

Impact: HIGH



DETECTOR EFFICIENCY

Imperfect detectors add noise and reduce fidelity.

Impact: MEDIUM



CROSSTALK

Unwanted coupling between channels reduces fidelity and increases errors.

Impact: HIGH



PACKAGING & INTEGRATION

Packaging stress and misalignment reduce system performance.

Impact: MEDIUM

SYSTEM PERFORMANCE METRICS

TOTAL LOSS

2.7 dB

Target: < 1 dB

VISIBILITY

68 %

Target: > 95%

COHERENCE TIME

12.3 μ s

Target: > 100 μ s

SYSTEM FIDELITY

0.78

Target: > 0.99

ENGINEERING OBJECTIVES



REDUCE LOSS

25%



IMPROVE STABILITY

40%



SCALE INTEGRATION

20%



INCREASE YIELD

35%

ENVIRONMENTAL SENSITIVITY



TEMPERATURE

± 1.2 mK



VIBRATION

± 10 nm



HUMIDITY

± 2.5 %



MAGNETIC FIELD

± 0.1 μ T

TIME

PATH FORWARD



ADVANCED MATERIALS
Lower loss & better stability



PRECISION FABRICATION
Better control at the nanoscale



INTEGRATED PHOTONICS
Higher density, lower footprint



ACTIVE STABILIZATION
Real-time feedback & control



SCALABLE ARCHITECTURES
Modular, manufacturable systems



MATERIALS IN PHOTONICS

THE RIGHT MATERIAL. THE RIGHT PERFORMANCE.

Different materials are chosen for different wavelengths, power levels, and fabrication needs. Material selection is a major system-level decision.

KEY CONSIDERATIONS

Wavelength

Loss

Power Handling

Nonlinearity

Fabrication

Cost & Supply

MATERIAL SELECTION DRIVERS

- **OPTICAL PERFORMANCE**
Transparency range, refractive index, nonlinear response, and loss determine how light behaves.
- **FABRICATION & INTEGRATION**
Compatibility with processes, yield, scalability, and integration with other components.
- **THERMAL & MECHANICAL**
Heat dissipation, thermal expansion, hardness, and reliability under stress.
- **COST & AVAILABILITY**
Material cost, wafer size availability, and supply chain maturity.

REFRACTIVE INDEX (n)

OPTICAL LOSS (Relative)

BANDGAP / TRANSPARENCY RANGE

POWER HANDLING

MATURITY / ECOSYSTEM

RELATIVE COST

GLASS

SiO₂ and Specialty Glasses



Broad transparency, low loss, and excellent uniformity. Ideal for lenses, fiber, and passive components.

LOW LOSS

WIDE BAND

SILICON

Si



Mature platform for photonic integration at scale. Strong foundry ecosystem.

CMOS COMPATIBLE

HIGH INDEX

III-V SEMICONDUCTORS

InP, GaAs, GaN, AlGaAs



Direct bandgap materials for active devices. High speed and efficiency.

HIGH GAIN

HIGH SPEED

POLYMERS

PMMA, SU-8, PS



Low cost, lightweight, and easy to process. Useful for waveguides and packaging.

LOW COST

DESIGN FLEXIBILITY

CRYSTALS

LiNbO₃, KTP, BBO, Quartz



Enable nonlinear, electro-optic, and acousto-optic functions at high performance.

NONLINEAR

HIGH POWER

2D & EMERGING

Graphene, TMDs, Perovskites



Emerging materials for ultra-compact, tunable, and novel photonic devices.

INNOVATIVE

TUNABLE

1.45 – 1.52

★★★★★
(Very Low)

0.2 – 3.5 μm+

★★★★☆

★★★★★

★★★★★

\$

~3.48 (at 1550 nm)

★★★☆☆
(Low)

1.1 – 8 μm

★★★★☆

★★★★★

★★★★★

\$

3.2 – 3.6

★★★☆☆
(Moderate)

0.8 – 1.7 μm

★★★★☆

★★★☆☆

★★★☆☆

\$\$\$

1.5 – 1.6

★★☆☆☆
(Higher)

0.3 – 2.5 μm

★★☆☆☆

★★★☆☆

★★★☆☆

\$

1.6 – 2.3

★★★☆☆
(Low)

0.4 – 5+ μm

★★★★★

★★★★☆

★★★★☆

\$\$ – \$\$\$

Variable

★★☆☆☆
(Early Stage)

0.4 – 10+ μm

★★★★☆

★★☆☆☆

★★☆☆☆

\$\$ – \$\$\$\$

TYPICAL PHOTONIC APPLICATIONS



Fibers, Lenses,
Windows, Isolators



PICs, Modulators,
Detectors, Interposers



Lasers, Modulators,
Detectors, Amplifiers



Waveguides, Optical
Interconnects, Packaging



Frequency Conversion,
Modulators, Q-switches



Ultra-compact Devices,
Sensors, Novel Interactions



THERE IS NO UNIVERSAL MATERIAL. The best systems combine multiple materials to achieve performance, cost, and manufacturability goals.



MANUFACTURING METHODS

PRECISION. REPEATABILITY. PERFORMANCE.

Photonic manufacturing uses many of the same processes as semiconductor production, plus specialized steps for optical alignment and packaging.

KEY PRINCIPLES



NANOMETER PRECISION

Critical dimensions control optical performance and yield.



CLEAN & CONTROLLED

Ultra-clean environments and process control ensure device reliability.



ALIGNMENT MATTERS

Sub-nanometer alignment enables low-loss, high-performance coupling.



TEST EARLY, TEST OFTEN

Comprehensive testing at every stage improves yield and reduces cost of failure.

1



LITHOGRAPHY

Define photonic circuits with deep-UV or e-beam lithography.

2



ETCHING

Transfer patterns into materials with high selectivity and control.

3



DEPOSITION

Add or modify thin films (Dielectrics, Metals, Semiconductors).

4



BONDING

Wafer or chip bonding for 3D integration and low-loss optical coupling.

5



PLANARIZATION (CMP)

Achieve ultra-flat surfaces for low-loss waveguides and reliable stacking.

6



PACKAGING

Protect devices and enable optical/electrical interconnects.

7



TESTING

Electrical, optical, and functional test at wafer and package level.

8



INSPECTION & RELIABILITY

Inspect, qualify, and stress test for long-term reliability.

KEY ENABLERS



ADVANCED LITHOGRAPHY

High-resolution patterning for complex photonic circuits.



PRECISE ALIGNMENT

Sub-nanometer alignment for low-loss coupling and integration.



MATERIAL INNOVATION

Engineered materials for specific wavelengths and performance.



AUTOMATION & DATA

Advanced metrology and process control for high yield.

QUALITY & TEST



OPTICAL TEST
(IL, PD, XR)



ELECTRICAL TEST
(IV, CV)



WAFER PROBE TEST



RELIABILITY TEST
(HAST, TCT)

TYPICAL APPLICATIONS



DATACOM
TRANSCIVERS



LIDAR &
SENSORS



QUANTUM
PHOTONICS



MEDICAL
IMAGING

MANUFACTURING METRICS



CD UNIFORMITY
< 3%



OVERLAY ACCURACY
< 2 nm



WAVEGUIDE LOSS
< 0.1 dB/cm



PACKAGING YIELD
> 95%



PHOTONICS MANUFACTURING: WHERE LIGHT MEETS PRECISION ENGINEERING.

Advanced processes. Rigorous control. Exceptional performance.



LOWER LOSS



HIGHER YIELD



SCALABLE
PRODUCTION



REAL-WORLD
RELIABILITY



PACKAGING AND ASSEMBLY CHALLENGES

ALIGNMENT • THERMAL CONTROL • COST • YIELD

Packaging is one of the hardest parts of photonics. Small alignment errors can reduce performance, and thermal behavior affects reliability and cost.

KEY CHALLENGES



ALIGNMENT SENSITIVITY

Sub-micron misalignment can cause significant optical loss and crosstalk.



THERMAL MANAGEMENT

Heat affects wavelength, phase, and reliability. Efficient thermal control is critical.



COST PRESSURE

Complex assembly, materials, and test steps drive up cost and limit scalability.



YIELD AND VARIABILITY

Process variation and assembly defects reduce yield and system performance.

ALIGNMENT MONITOR



X: +0.18 μm
Y: -0.22 μm
 θ : 0.03°

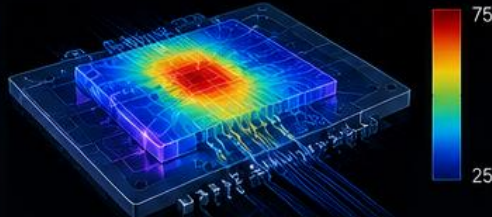
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ACTIVE ALIGNMENT

Real-time feedback minimizes loss and maximizes coupling.

THERMAL EFFECTS

TEMPERATURE MAP (°C)



WAVELENGTH SHIFT

$\Delta\lambda \propto \Delta T$

+0.08 nm/°C



INSERTION LOSS

↑ with temperature

+0.15 dB/°C



RELIABILITY IMPACT

Higher temps accelerate aging and failure

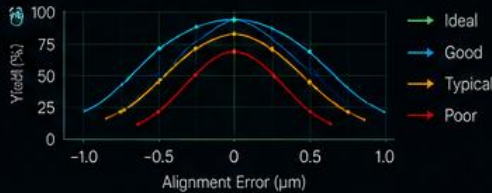
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COST DRIVERS



Assembly Complexity	35%
Materials	25%
Testing & Inspection	20%
Yield Loss	15%
Design & Overhead	5%

YIELD IMPACT ANALYSIS



CRITICAL CONTROLS



SUB-MICRON ALIGNMENT



VIBRATION ISOLATION



CLEAN ENVIRONMENT



THERMAL CONTROL



REAL-TIME MONITORING

BEST PRACTICES

- ✓ Design for alignment tolerance
- ✓ Use active alignment and in-situ metrology
- ✓ Optimize thermal path and materials
- ✓ Standardize processes and interfaces
- ✓ Implement rigorous test and screening

PERFORMANCE SUMMARY

ALIGNMENT TOLERANCE



±0.25 μm

TARGET

THERMAL RESISTANCE



1.8 °C/W

TARGET

COUPLING EFFICIENCY



> 85%

TARGET

PACKAGE COST



-15%

TARGET (YoY)

YIELD



> 90%

TARGET



PHOTONICS INDUSTRY ECOSYSTEM

COLLABORATE. INNOVATE. TRANSFORM.

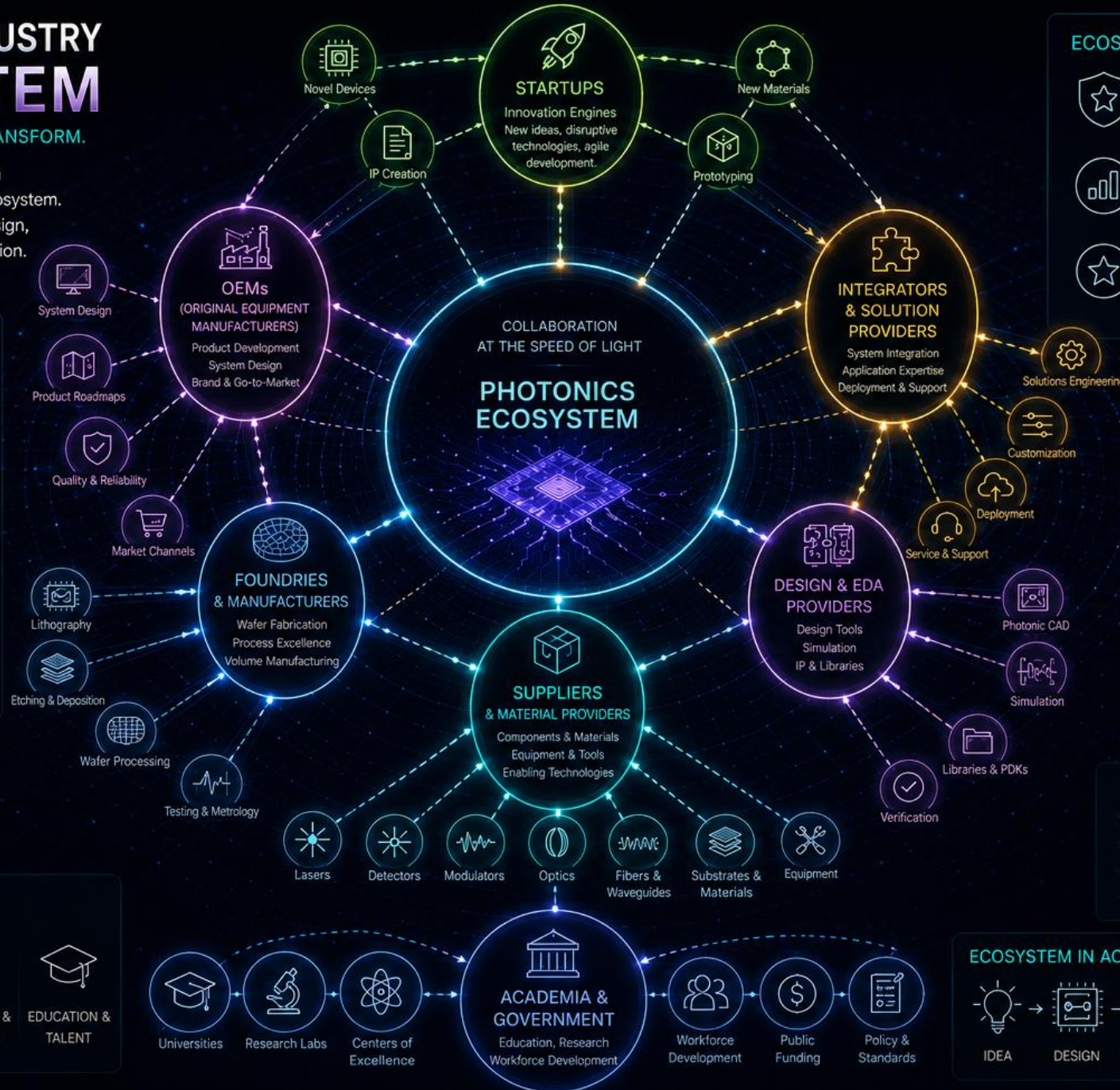
The photonics industry depends on collaboration across a complex ecosystem. Success often requires aligning design, manufacturing, and market integration.

ECOSYSTEM BENEFITS

- ACCELERATED INNOVATION**
Shared knowledge and IP partnerships drive breakthroughs.
- OPTIMIZED SUPPLY CHAINS**
Diverse suppliers and foundries improve resilience and scalability.
- TIME TO MARKET**
End-to-end collaboration reduces risk and cycle time.
- MARKET EXPANSION**
Integrators and OEMs bring solutions to global markets.

CROSS-CUTTING ENABLERS

- STANDARDS & CONSORTIA
- GOVERNMENT & POLICY
- INVESTORS & FUNDING
- EDUCATION & TALENT



ECOSYSTEM OUTCOMES

- COMPETITIVE ADVANTAGE**
Stronger solutions through collaborative strengths.
- SCALABLE GROWTH**
Ecosystem alignment enables sustainable scaling.
- TECHNOLOGY LEADERSHIP**
Collective investment drives the future of photonics.

DATA & IP FLOWS

- COLLABORATION
- SUPPLY CHAIN
- TECHNOLOGY FLOW
- MARKET FLOW

ECOSYSTEM IN ACTION



PHOTONICS INDUSTRY GLOBAL GEOGRAPHY

INNOVATION. COLLABORATION. GLOBAL IMPACT.

Photonics innovation and production are globally distributed. Different regions have strengths in research, fabrication, system design, and manufacturing scale.



**RESEARCH
& INNOVATION**
Universities, Labs,
R&D Centers



**DESIGN
& INTEGRATION**
System Design, PICs,
Software, IP



**FABRICATION
& PRODUCTION**
Wafer Fabs, Assembly,
Test, Scale



**MARKETS
& APPLICATIONS**
Aerospace, Data Comm,
Healthcare, Sensing

NORTH AMERICA

Strengths:

R&D leadership, innovative startups,
system design, advanced applications

- **Silicon Valley, USA**
Integrated Photonics, VC,
Startup Ecosystem
- **Southern California, USA**
Optics, Photonics, Medical,
Aerospace
- **Boston, USA**
Research, Quantum, Biophotonics
- **Rochester, USA**
Imaging, Lasers, Optics
- **Toronto, Canada**
Quantum, Communications
- **Mexico**
Manufacturing, Assembly

EUROPE

Strengths:

Strong research base, photonics
components, industrial automation

- **Eindhoven, Netherlands**
Integrated Photonics, PICs
- **Berlin, Germany**
Research, Sensing, Quantum
- **Munich, Germany**
Lasers, Manufacturing, Systems
- **Paris, France**
Optics, Imaging, Aerospace
- **Cambridge, UK**
Research, Quantum
Technologies

ASIA

Strengths:

Manufacturing scale, supply chain,
cost efficiency, fast innovation

- **Shenzhen, China**
Manufacturing, Components,
Supply Chain
- **Shanghai, China**
Optoelectronics, Lasers,
Market Scale
- **Tokyo, Japan**
Precision Optics, Sensors,
Advanced Materials
- **Seoul, South Korea**
Displays, VCSELs, 5G/6G
- **Singapore**
PICs, R&D, Global Hub
- **Hsinchu, Taiwan**
Semiconductors, Packaging,
Foundries

GLOBAL COLLABORATION



International Partnerships
Accelerate Innovation



Shared Infrastructure
Reduces Time to Market



Open Ecosystems
Drive Standards



Global Markets
Drive Growth

DISTRIBUTED, CONNECTED, STRONGER TOGETHER



2,000+
Universities &
Research Institutions



1,000+
Photonics
Companies



100+
Silicon Photonics
Foundries



50+
Countries with Active
Photonics Programs



\$1T+
Addressable Market
by 2030*



A GLOBAL INDUSTRY POWERED BY LIGHT

Uniting talent, technology, and investment across borders to shape a brighter future.

* Source: Industry reports and market analysis



PHOTONICS INDUSTRY CHALLENGES

OVERCOMING BARRIERS. UNLOCKING POTENTIAL.

Adoption is not limited by physics alone. Cost, manufacturing scale, interoperability, supply chain resilience, and skilled labor remain major challenges.

CHALLENGE IMPACT OVERVIEW



RISK LEVEL LEGEND

- HIGH RISK**
Critical impact on adoption and growth
- MEDIUM RISK**
Moderate impact requires mitigation
- LOW RISK**
Manageable with current strategies
- MONITOR**
Ongoing attention recommended

INDUSTRY READINESS



01



COST

High material, fabrication, and packaging costs limit adoption in price-sensitive markets.



RISK LEVEL

HIGH

KEY CONCERNS

- Expensive materials & epiwafers
- Complex fabrication processes
- Low volume = high unit cost
- Packaging & test costs

02



SCALE-UP

Moving from lab to high-volume manufacturing is complex and capital intensive.



RISK LEVEL

HIGH

KEY CONCERNS

- Yield and repeatability
- Equipment & facility investment
- Process transfer & uniformity
- Ramp-up time to scale

03



STANDARDS

Lack of universal standards hampers interoperability and slows ecosystem growth.



RISK LEVEL

MEDIUM

KEY CONCERNS

- Different interfaces & formats
- Testing & measurement variation
- IP and compliance fragmentation
- Long cycles for standardization

04



SUPPLY CHAIN

Fragile supply chains create risk for critical materials, components, and capacity.



RISK LEVEL

HIGH

KEY CONCERNS

- Single-source dependencies
- Geopolitical & trade risks
- Long lead times
- Logistics & capacity constraints

05



TALENT

Shortage of skilled photonics engineers and technicians limits innovation and scale.



RISK LEVEL

MEDIUM

KEY CONCERNS

- Limited specialized talent pool
- Competition with other industries
- Training & retention challenges
- Aging workforce

SUCCESS REQUIRES ACTION



Reduce Cost
Drive cost-out through innovation and volume



Scale Manufacturing
Invest in tools, fabs, and process maturity



Align on Standards
Collaborate across industry to enable interoperability



Strengthen Supply Chain
Diversify sources and build resilient supply networks



Develop Talent
Invest in education, training, and inclusion



THE PATH FORWARD

Addressing these challenges together will accelerate adoption and unlock the full potential of photonics technologies.



PHOTONICS INDUSTRY FUTURE OUTLOOK

LIGHT. CONNECTED. INTELLIGENT. LIMITLESS.

The next phase of growth will likely be driven by AI data movement, more integrated photonic platforms, better sensors, and new quantum applications.

\$1.3T+

PHOTONICS MARKET
OPPORTUNITY BY 2030*

Fueling the future of technology
and society.

POWERING THE NEXT WAVE OF INNOVATION



EXPLOSIVE DATA
GROWTH FROM AI



CLOUD
EVERYWHERE



HYPERCONNECTED
WORLD



SUSTAINABLE
FUTURE



HUMAN POTENTIAL
UNLEASHED

TRANSFORMING INDUSTRIES



COMMUNICATIONS



COMPUTING



HEALTHCARE



MOBILITY



DEFENSE & SECURITY



ENERGY

01 AI INFRASTRUCTURE



- Massive data movement
- Photonic interconnects for scale
- Lower power, higher bandwidth
- Enabling the AI revolution

02 INTEGRATED PHOTONICS



- More integration, smaller form factors
- Heterogeneous photonic platforms
- Lower cost through volume
- Ubiquitous photonic solutions

03 HEALTHCARE



- Advanced imaging & diagnostics
- Minimally invasive therapies
- Lab-on-a-chip & photonic biosensors
- Personalized, precise, predictive

04 SENSING



- Real-time, high-resolution sensing
- LiDAR, environmental, industrial
- Chemical & biological detection
- Smarter, safer, more aware world

05 QUANTUM



- Photonics for quantum computing
- Quantum communication networks
- Ultra-secure information
- Solving tomorrow's impossible



THE PATH FORWARD

Continued innovation, collaboration, and investment will unlock the full potential of light technologies—driving economic growth and improving lives around the world.



TODAY
Building the
Foundations



2025+
Acceleration
& Adoption



2027+
Breakthrough
Applications



2030+
Transforming
Industries



BEYOND
A Brighter
Future



PHOTONICS INDUSTRY CONCLUSION & Q&A

KEY TAKEAWAYS AND DISCUSSION



FOUNDATIONAL TECHNOLOGY

Photonics underpins the future of computing, communications, sensing, healthcare, and more.



RAPID GROWTH & OPPORTUNITY

Strong market momentum driven by AI, data growth, and new applications across every industry.



GLOBAL & COLLABORATIVE ECOSYSTEM

A diverse ecosystem of innovators, manufacturers, and partners is essential to scale impact.



CHALLENGES TO OVERCOME

Addressing cost, scale, standards, supply chain, and talent will unlock the next wave of adoption.



A BRIGHT FUTURE AHEAD

Photonics will continue to drive innovation, improve lives, and shape a brighter future.

Q&A

YOUR QUESTIONS.
OUR DISCUSSION.

Let's explore ideas, share perspectives,
and shape the future of photonics—together.

