SWTEST

PROBE TODAY, FOR TOMORROW

2025 CONFERENCE

Enabling the Semiconductorization of Photonics

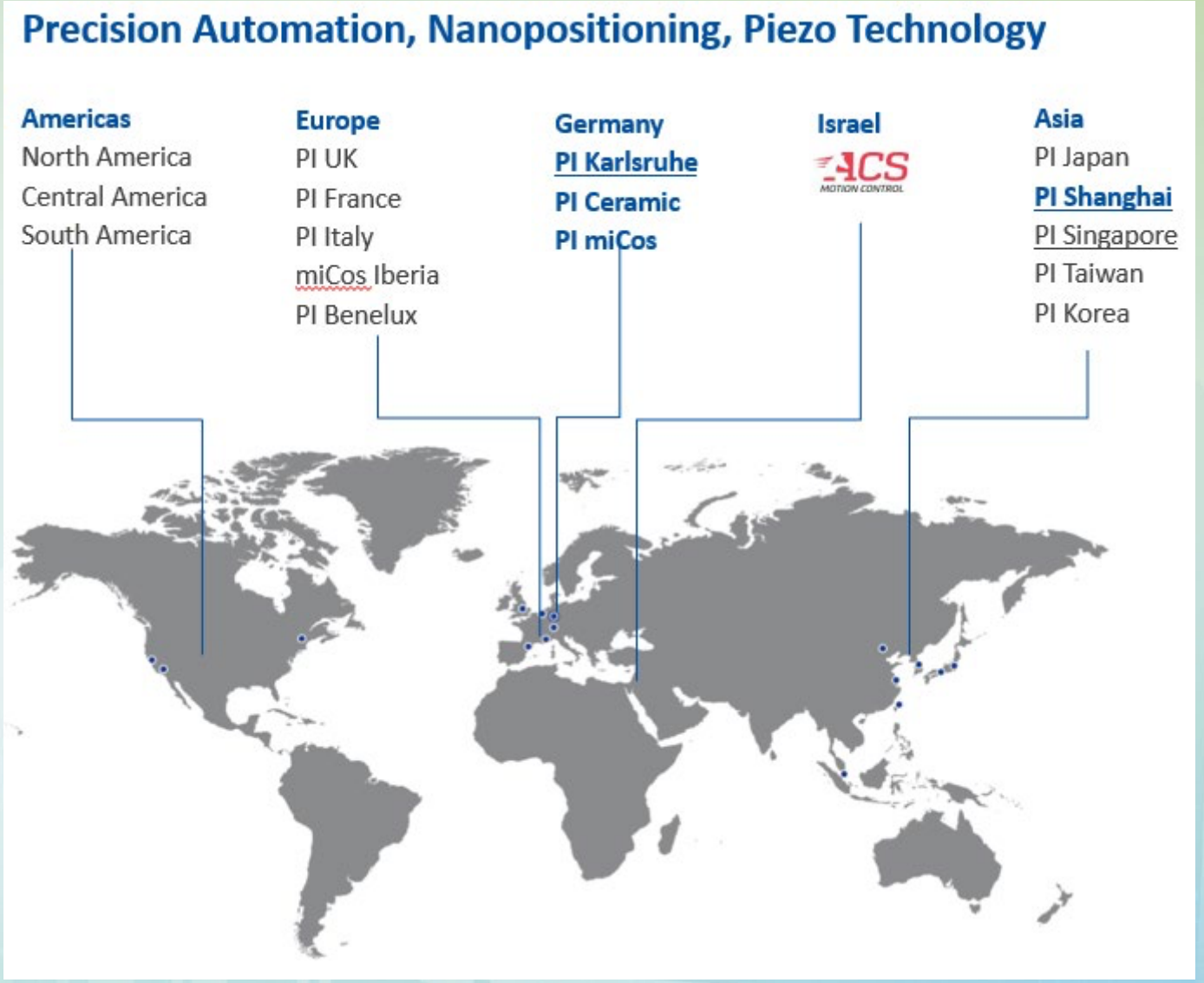
Scott Jordan

PI

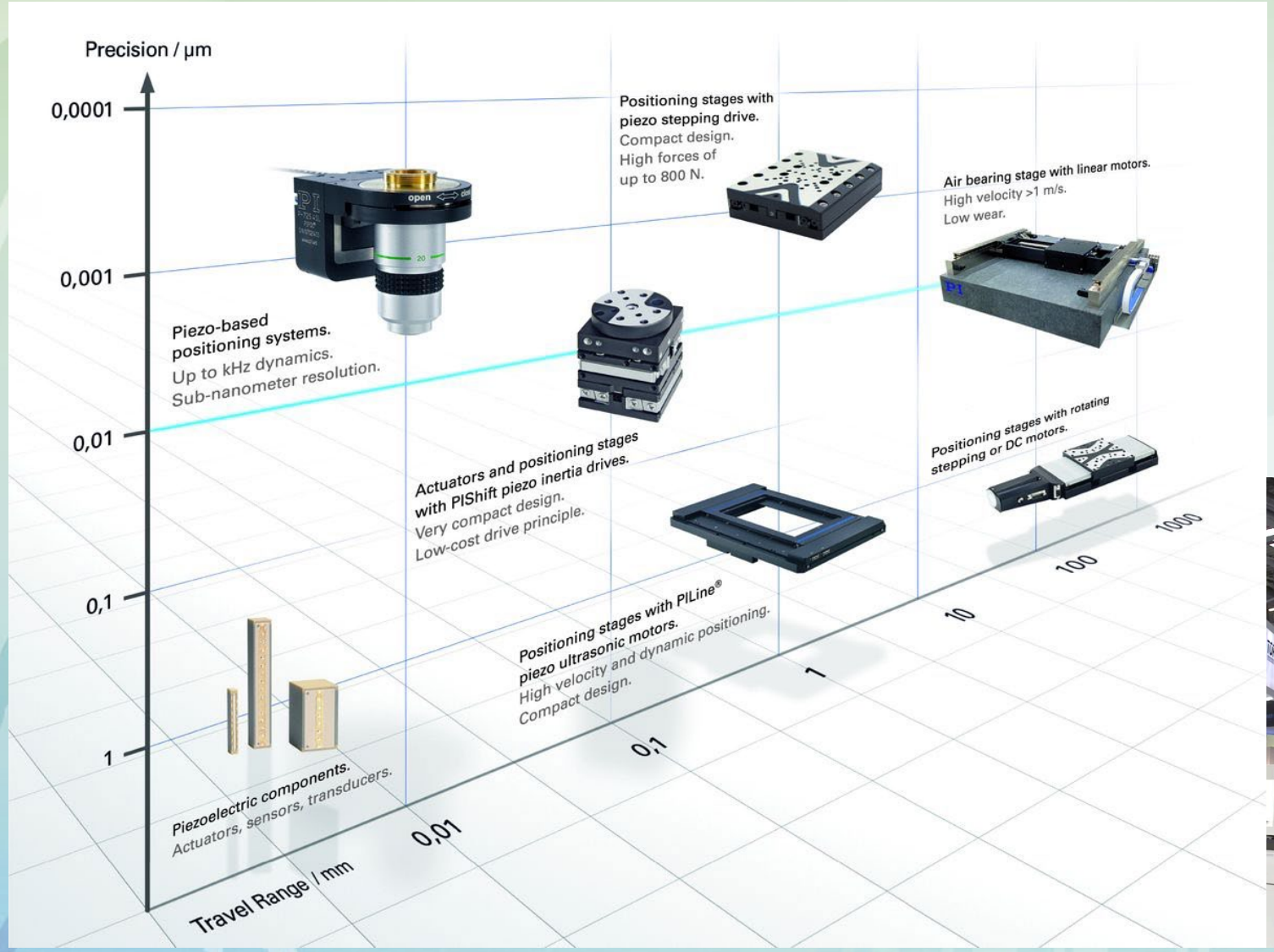
The PI Group

- ~1700 Employees
- 15 Subsidiaries
- Design & Service Centers in USA, Asia, Europe
- >100 man Years of Alignment Expertise

- Privately Owned – Not Driven by Quarterly Results
- Focused on Long Term Relationships w/Customers & Suppliers

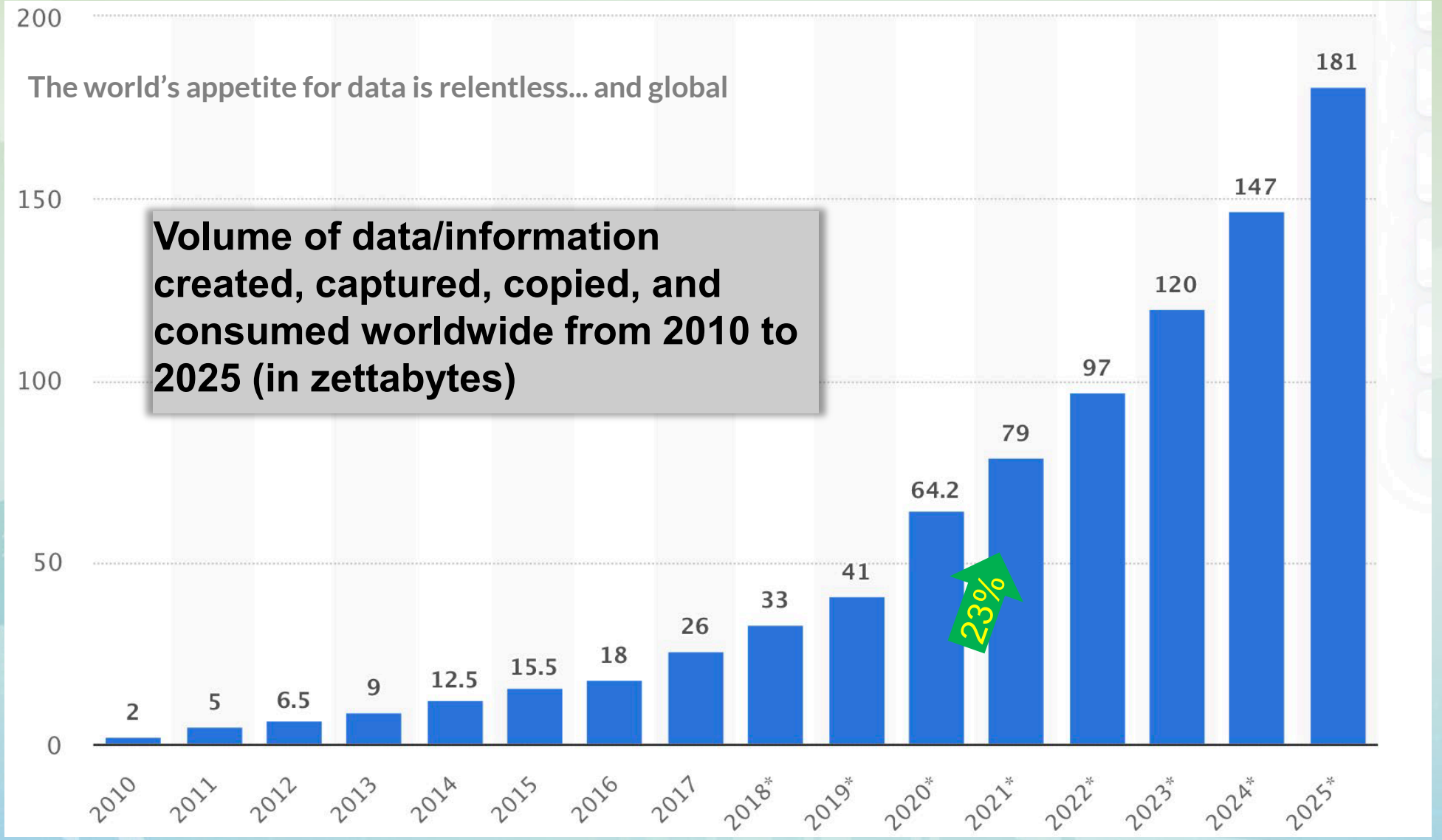


The PI Group



PI's Engineered Systems Group Builds World-Class Automation Platforms

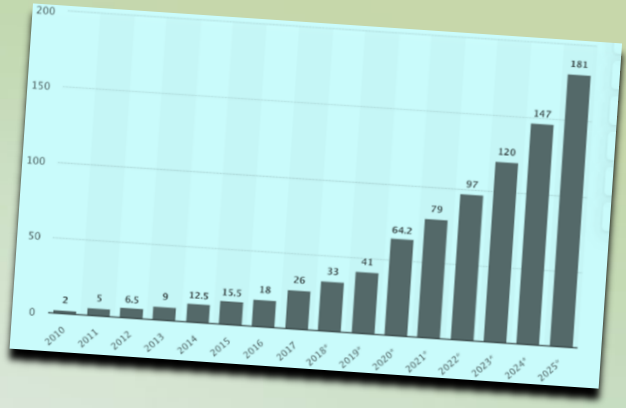
There's really only *one* trend…

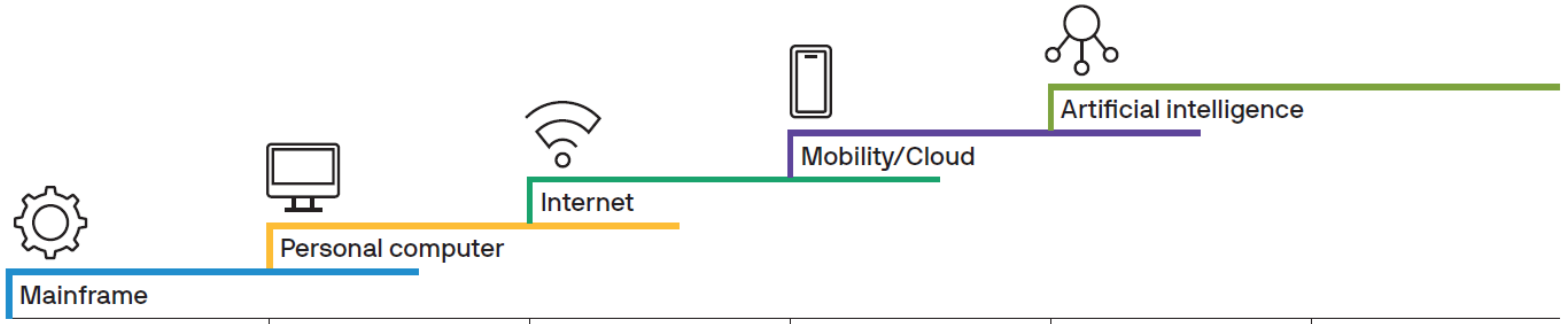


Throughout: Latest available data from credible sources, with links to source

https://www.statista.com/statistics/871513/worldwide-data-created/

AI: The new accelerant



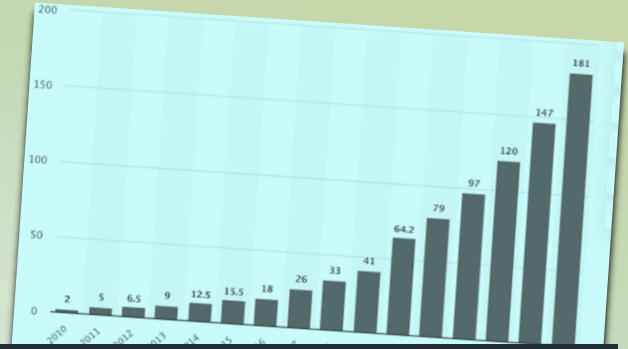


1980		1990		2000		2010		2020		2030	
Company	Mkt cap (USD bn)	Company	Mkt cap (USD bn)	Company	Mkt cap (USD bn)	Company	Mkt cap (USD bn)	Company	Mkt cap (USD bn)	Company	Mkt cap (USD bn)
IBM	38	IBM	54	Microsoft	604	Microsoft	269	Apple	2,232		
Eastman Kodak	8	Panasonic	33	Cisco Systems	355	Google	197	Microsoft	1,682		
Xerox	5	Toshiba	27	Intel	274	Apple	191	Amazon	1,634		
Hewlett-Packard	4	NEC	19	Lucent Technologies	238	IBM	171	Alphabet	1,185		
Emerson Electric	2	Fujitsu	19	Nokia	210	Cisco Systems	138	Facebook	778	?	
Texas Instruments	2	Mitsubishi Electric	16	IBM	193	Oracle	123	Tencent	698		
Motorola Solutions	2	Eastman Kodak	13	Oracle	158	Hewlett-Packard	122	Tesla	669		
Nortel Networks	2	Sanyo Electric	13	Nortel Networks	139	Intel	113	Alibaba	649		
Intel	1	FUJIFILM Holdings	12	Sun Microsystems	135	Samsung	88	Samsung	501		
Harris	1	Hewlett-Packard	11	Dell	130	QUALCOMM	77	TSMC	489		

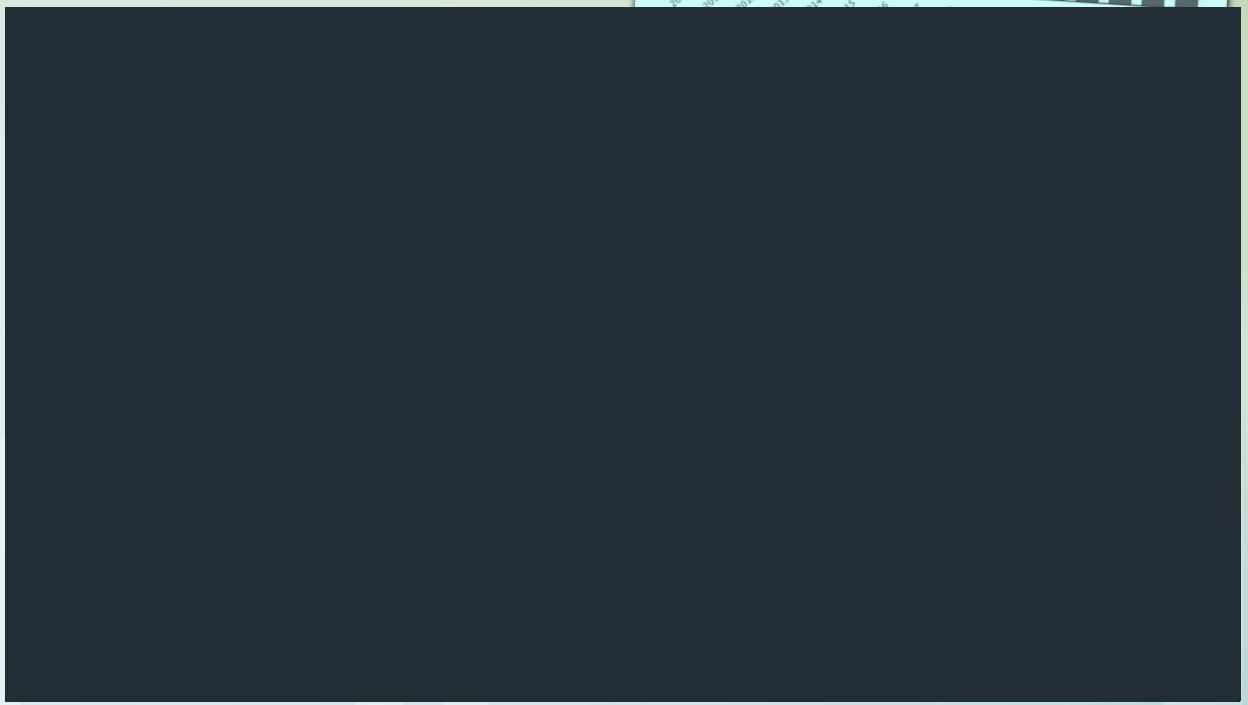
"Often, when a major platform shift occurs – think mainframes to minicomputers, PCs to mobile devices, CPUs to GPUs (central processing units to graphics processing units) – it creates entirely new pools of demand. In the next few years, we expect a record pace of new, densely packed, high powered data center builds. These will be filled with GPUs, custom silicon, advanced memory packages and photonics to support network bandwidth."

--J.P. Morgan Asset Management, 10/2023

mm-scale to planetary scale, humanity's appetite for data drives Photonics



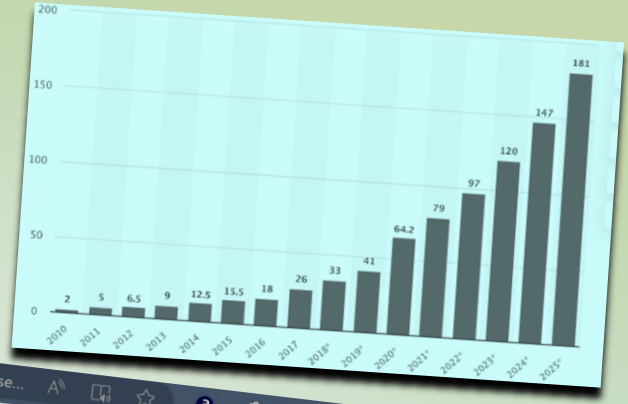
"...a chip maker could build a co-packaged optical transceiver on to the edge of a package, and then use UCIe to connect it to another chiplet..." --*Anandtech*

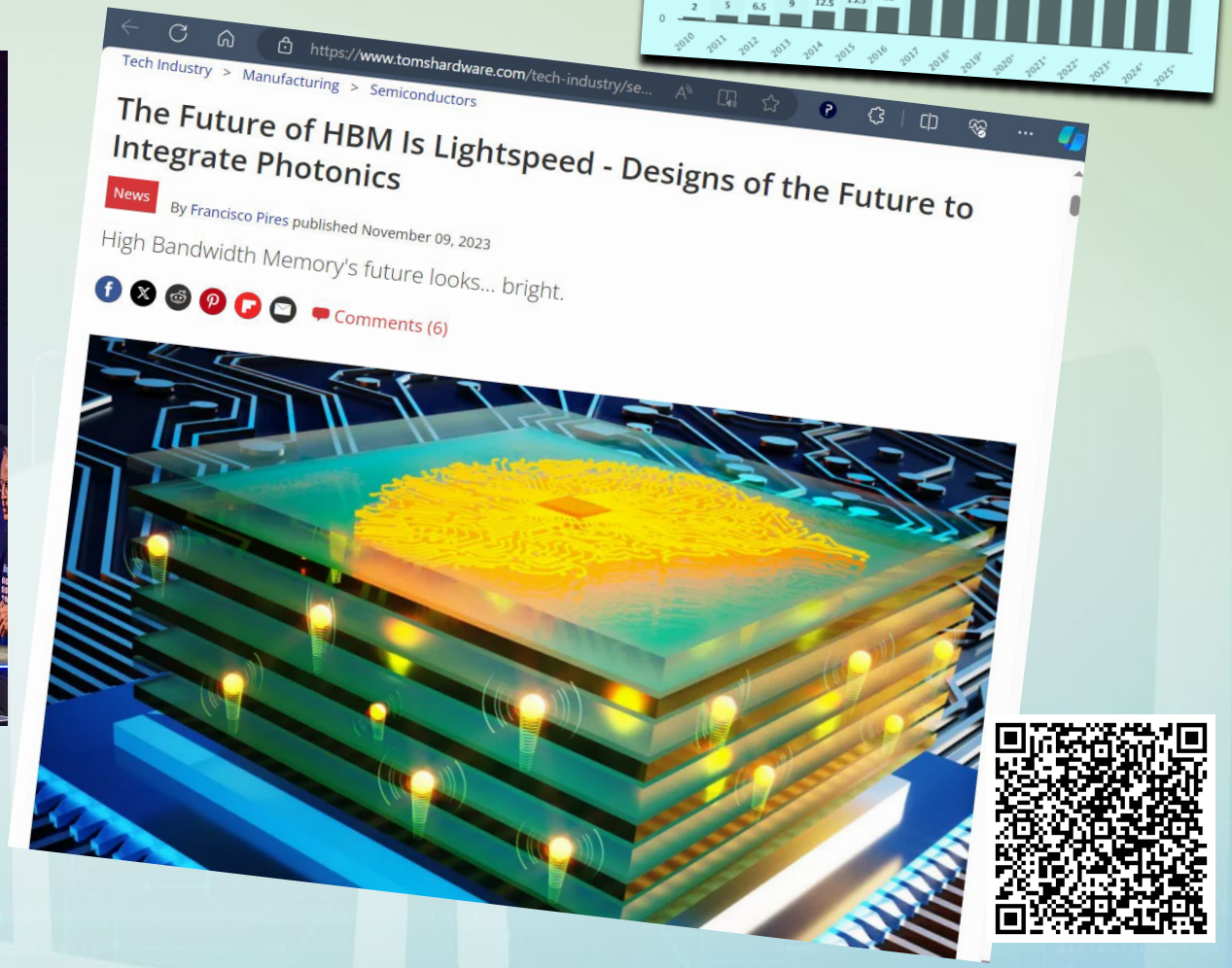


"Good ideas are always crazy until they're not." --*Elon Musk*

Courtesy SpaceX

mm-scale to planetary scale, humanity's appetite for data drives Photonics

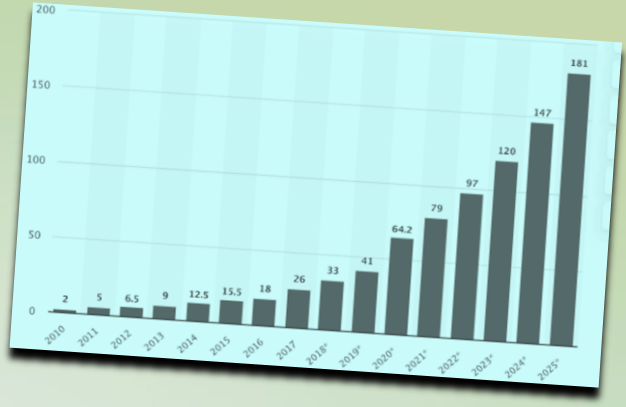




"...a chip maker could build a co-packaged optical transceiver on to the edge of a package, and then use UCIe to connect it to another chiplet..." *--Anandtech*

Observation:

Silicon Photonics is *not just about the data center anymore*



Expanding the Range: Wearables

https://www.photonics.com/Articles/Expanding_the_Range_...

PHOTONICS spectra

Expanding the Range: Wearables Enable the Next Level of Mobile Health Data Monitoring

Deep UV Powers Micro-LED Manufacture

LED arrays, specialized lasers, and a gamut of sensors mark the newes devices, capable of detecting the early onset of cancer and other disease

DOUGLAS FARMER, SENIOR EDITOR DOUG.FARMER@PHOTONIC

The next generation of wearable devices will no longer be created only fo monitor their daily steps or heart rate on a smartwatch. Increasingly sop components such as LED arrays and specialized lasers, as well as a gamu contained within mobile equipment attached to the body, will be able to both the visible and infrared ranges.

spectrum.ieee.org/lidar-on-a-chip-at-l

Aeva Unveils Lidar on a Chip - IEEE Spectrum

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NEWS TRANSPORTATION

Aeva Unveils Lidar on a Chip › Aeva says its high-performance lidar will sell for less than US $500; VW is buying it

BY PHILIP E. ROSS | 11 DEC 2019 | 3 MIN READ

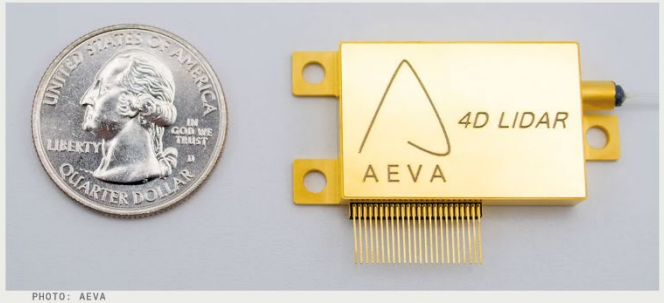

PHOTO: AEVA

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Google says it has created a time crystal in a quantum computer...

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Global Edition Workflow

Deloitte's quantum computing leader on the technology's healthcare future

tum computing offers significant speed and analytics power and ts the ability to track and diagnose disease, modernize supply chains elp with drug discovery, says Scott Buchholz.

Siwicki | August 17, 2021 | 11:44 AM

Buchholz, emergin Deloitte Consulting

Health and Life Sc Experience Surve

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www.marketwatch.com/press-release/ac

Active Optical Cable Market Witness Robust Growth | 3M Company, Amphenol Corporation, Avago Technologies Limited - MarketWatch

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Active Optical Cable Market Witness Robust Growth | 3M Company, Amphenol Corporation, Avago Technologies Limited

Published: July 8, 2021 at 4:00 p.m. ET

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The MarketWatch News Department was not involved in the creation of this content.

Jul 08, 2021 (AB Digital via COMTEX) -- Active Optical Cable Market By

This Chip for AI Works Using Lig

https://www.wired....

WIRED BACKCHANNEL BUSINESS CULTURE GEAR IDEAS POLITICS SCIENCE SECURITY MERCH SIGN

This Chip for AI Works Using Light, Not Electrons

Lightmatter says the computing and power demands of complex neural networks need new technologies like thes

al computer motherboard. COURTESY OF LIGHTMATTER

atabase →

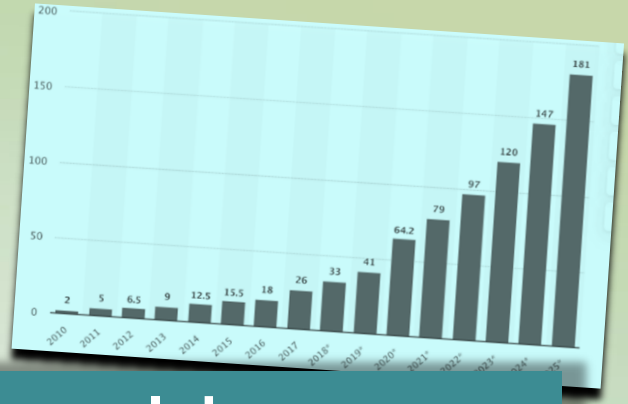
OUD COMPUTING END USER: BIG COMPANY

DUCTORS TECHNOLOGY: PHOTONICS, CHIPS

FOR artificial intelligence grows, so does hunger for power needed to keep AI running.

TRENDING NOW

mm-scale to planetary scale, humanity's appetite for data drives Photonics

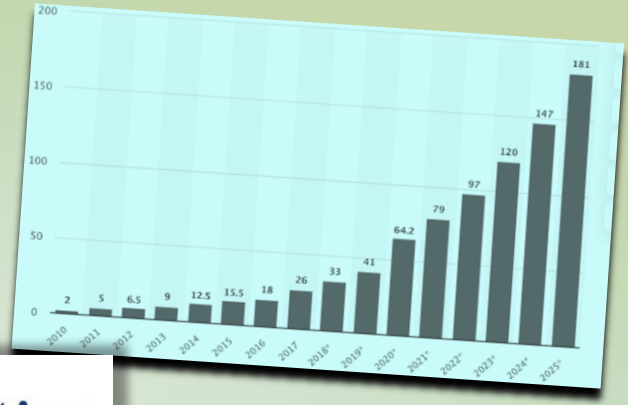


"Introducing inter-chip optical interconnects could obliterate bandwidth and capacity limitations coming from today's copper interconnects, which are hampered by impedance mismatches between the CPU and the dual-inline memory modules."

--Dongjae Shin, Samsung, at PIC 2019

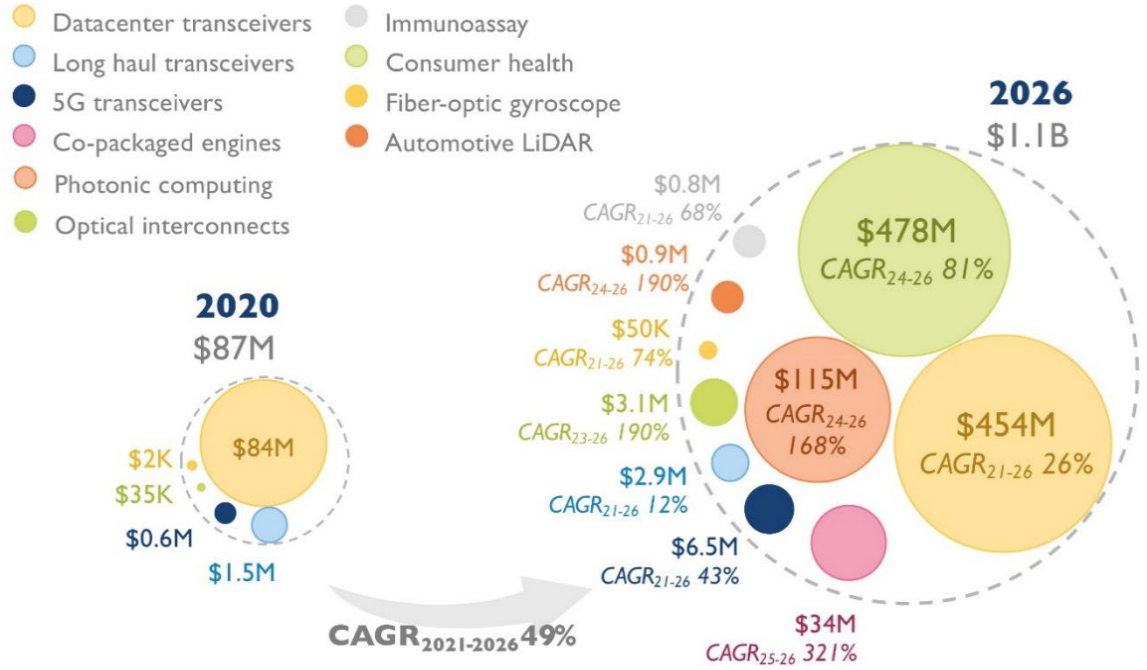
Driving Photonics: New applications

→ *no single point of market failure*



2020-2026 silicon photonics die forecast by application

(Source: Silicon Photonics 2021 report, Yole Développement, 2021)

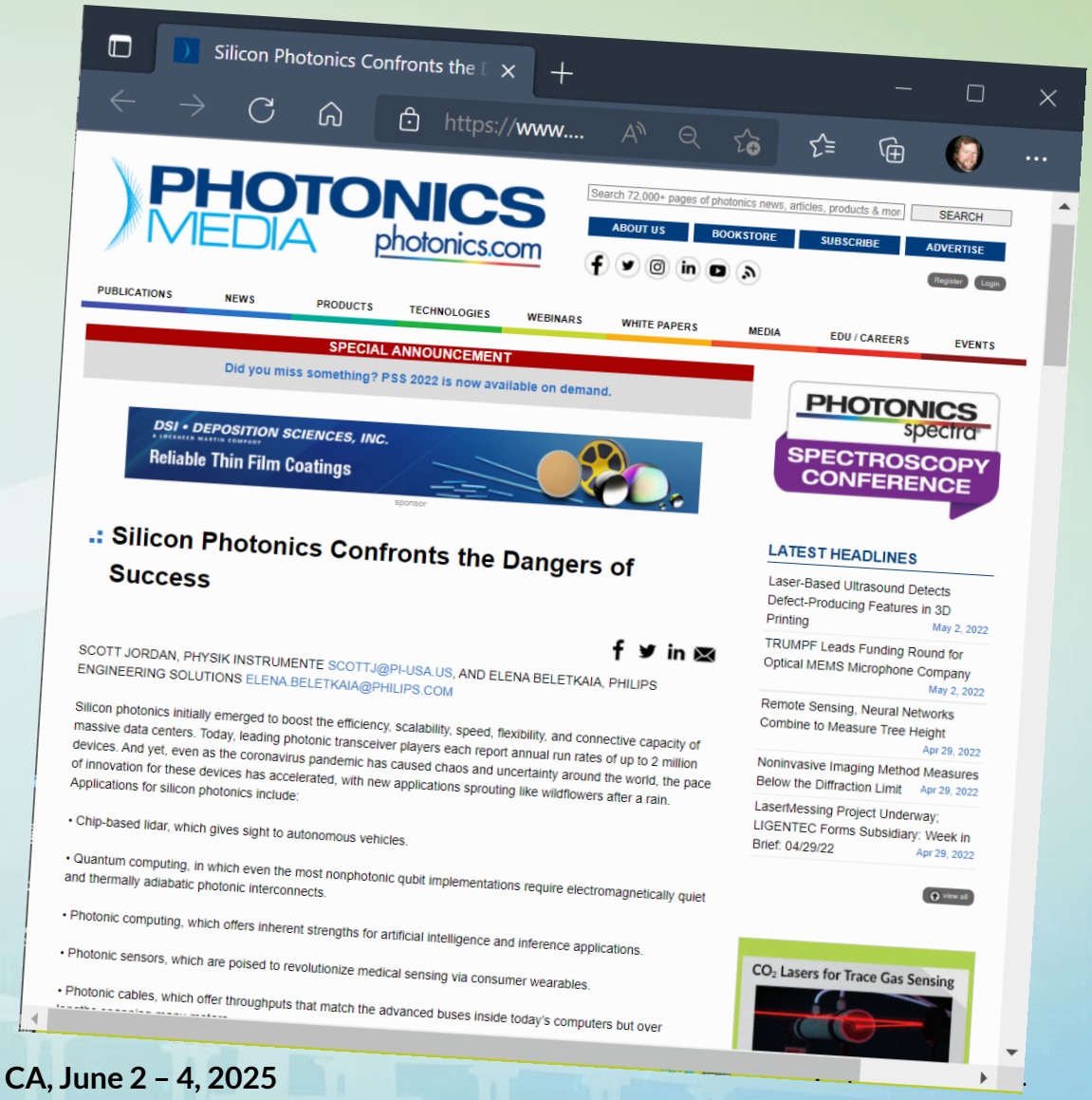


What this means:

Fasten your seatbelts

3-order-of-magnitude ramp!

> *"The photonics industry faces a gut check as its past success drives future demand at a scale and pace that the industry will be challenged to meet."*



What this means:

Fasten your seatbelts

Photonics Spectra

Cover article

> ***"New investments in technology and packaging capacity will be essential before the silicon photonics era can get fully underway."***

PHOTONICS MEDIA photonics.com

Optical solutions at Sensors Converge 2022 — ams OSRAM — Learn more!

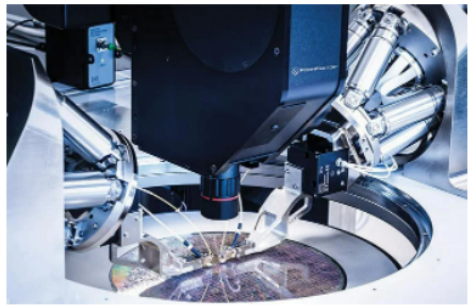
.: As PIC Production Ramps Up, Fabricators Eye Alignment Options

New demand for PICs promises to erupt across multiple end markets over the next few years, forcing fabricators to contemplate options for streamlining the optical alignment of these components.

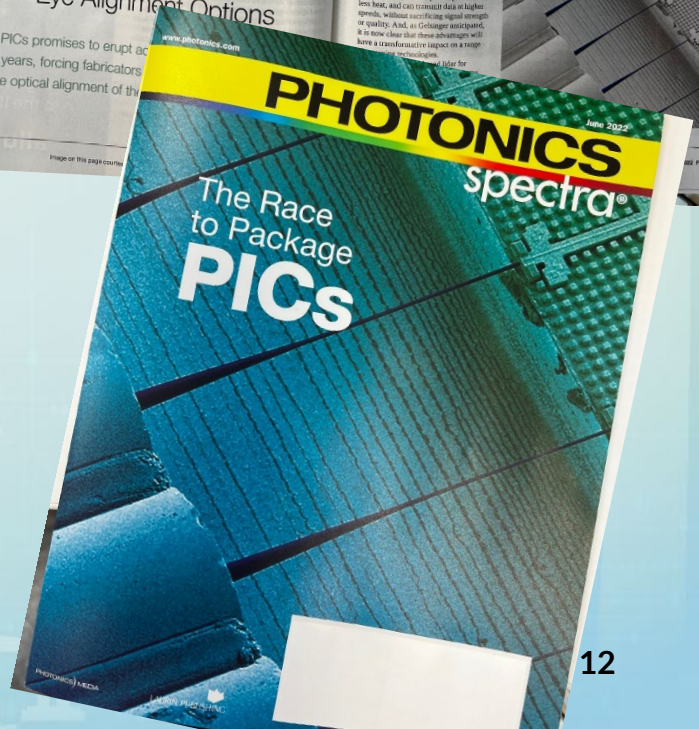
MICHAEL EISENSTEIN, SCIENCE WRITER

The early 2000s saw the rapidly growing global appetite for data collide with the limitations of copper-based wire networks. The performance of these conventional data transmission systems declined dramatically at data bandwidths beyond 10 Gbit/s, imposing a major speed limit on the growth of the internet.

Fortunately, an alternative technology, in which silicon-based photonic devices are coupled to fiber optic cables, was already proving its mettle as a potential replacement. At the time, the technology largely found use along the network backbone. Intel's CEO, Pat Gelsinger, could see the writing on the wall as early as 2005, when he was a senior vice president at the company. "Today, optics is a niche technology," he told *MIT Technology Review*. "Tomorrow, it's the mainstream of every chip that we build."



Active alignment systems have increasingly accelerated the alignment of photonic integrated circuits (PICs) and fiber arrays. PI's (Physik Instrumente's) fast multichannel photonics alignment technology, for example, uses sophisticated parallel-processing scanning and optimization algorithms to simultaneously couple multiple arrayed



These are Early Days

Parallels to 1980s chip industry:

- Ecosystem just being born
- Custom equipment
- In-house and captive integrators

ASML

TEL TOKYO ELECTRON

APPLIED MATERIALS make possible

Lam RESEARCH

KLA

Excerpted from https://www.chiphistory.org/128-an-intel-wafer-fab-cleanroom-circa-1980

Fast forward to today:

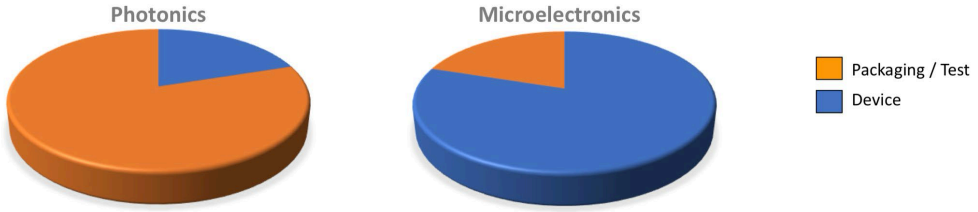
- You can build a fab by writing POs

Alignment: The Repetitive Cost

Cost breakdown

Packaging cost is a big piece of the pie for Photonics

Microelectronic packaging is geared towards low cost



Packaging is key to lower cost of photonics

Leverage the microelectronic industry

IBM

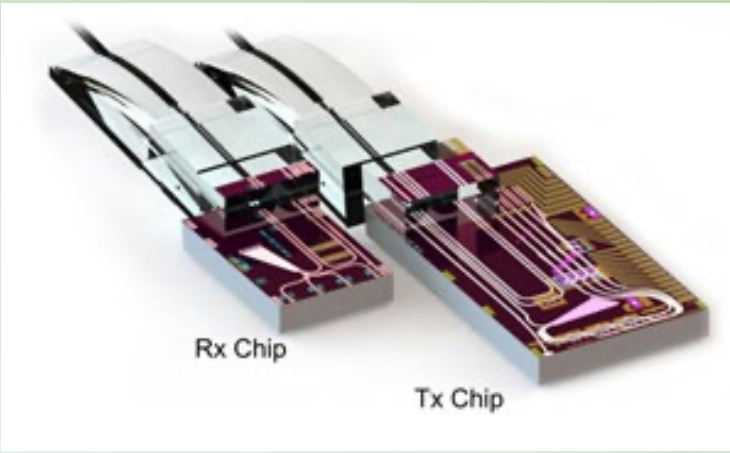
REDEFINING THE LIMITS

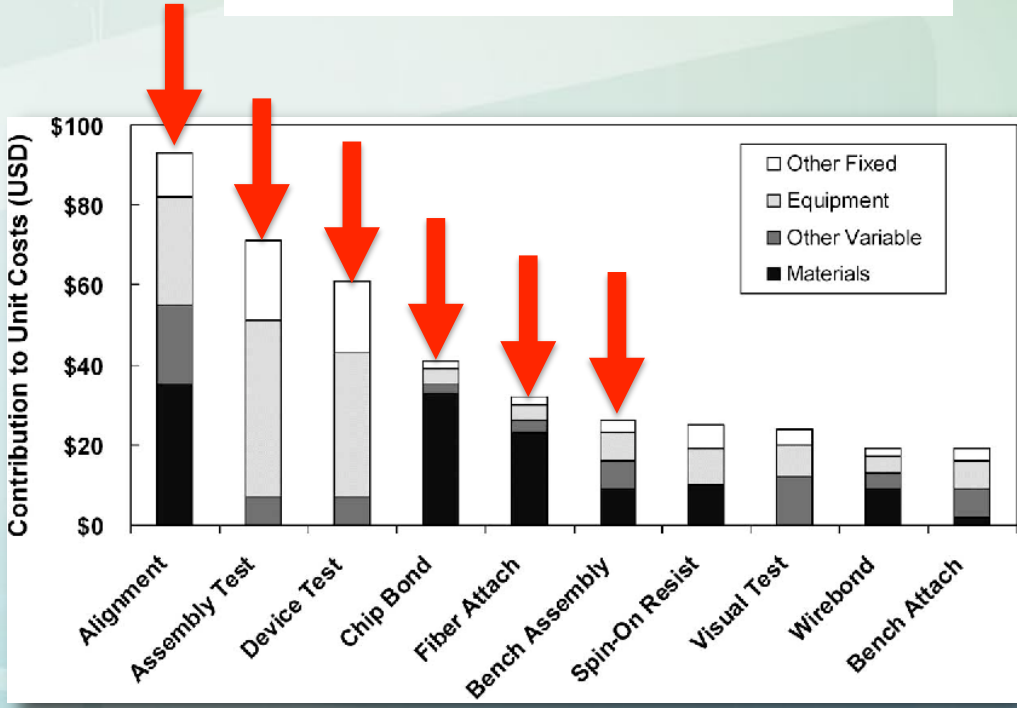
Photonics Summit, Cadence, 6th September 2017, San Jose CA

8

"Automated High-Throughput Assembly for Photonic Packaging", Barwicz et al, *Photonics Summit*, Cadence, 2017, https://www.cadence.com/content/dam/cadence-www/global/en_US/documents/company/Events/summits/photonics/fortier-2017.pdf

"Process-based cost modeling of photonics manufacture…", E. Fuchs et al, J. Lightwave Tech., 2006, https://www.semanticscholar.org/paper/Process-based-cost-modeling-of-photonics-the-cost-a-Fuchs-Bruce/125e24b2e2e71860f088526441ee5ce16e6ce42c





These are Early Days

The way forward:

1. Automation
2. Innovation
3. Cooperation

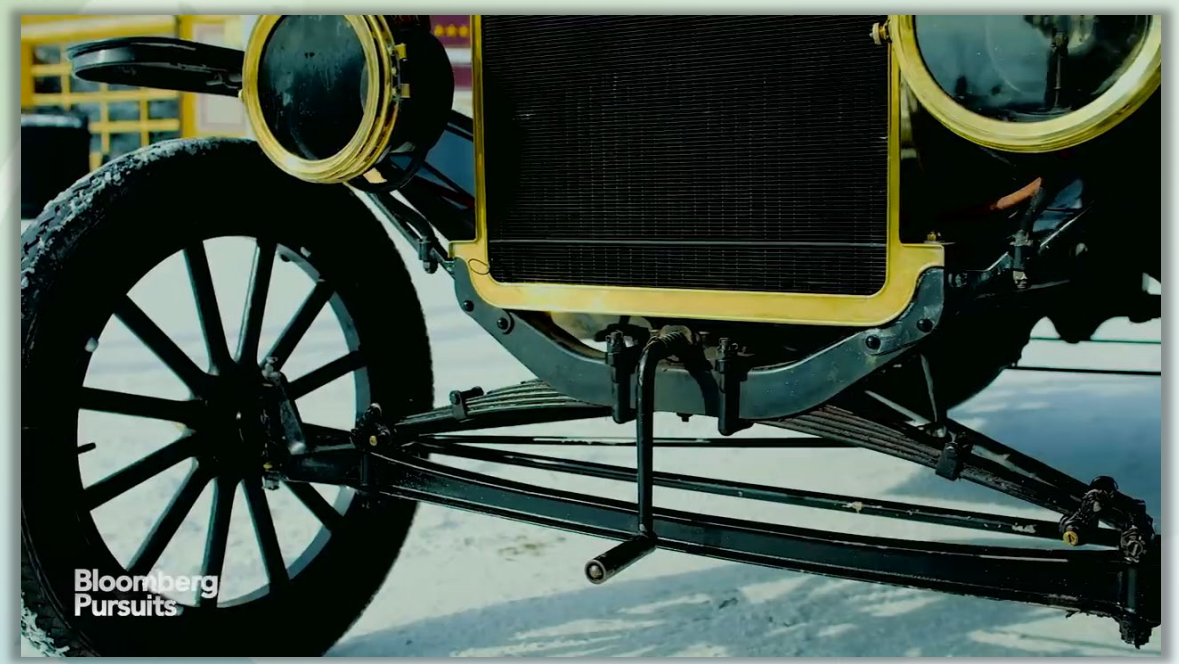
These are Early Days

The way forward:

1. **Automation**
2. Innovation
3. Cooperation

After Motion Control: *Micro-Robotics*

Built-in functionality *and intelligence* mark the future (and not just for motion control)



Courtesy Bloomberg
"Driving a Ford Model T Is a Lot Harder Than You'd Think!"

Courtesy Tesla
"Full Self-Driving"

"Do what I tell you to do"

- Accelerate
- Brake
- Turn…

"Do what I <u>want</u> you to do"

- Go to Aldi

"10 exabytes per month"
--VisualCapitalist.com

A Modular Approach to Meet all Needs

Hexapods

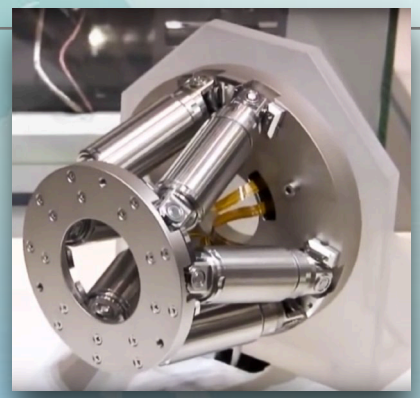
- Trajectory is not defined by bearings
- Compact, 6 degrees-of-freedom, rigid
- No moving cables

Stacks

- Modular
- ACS controls

Both

- Rotate about optical channel, focus, etc.



Use Nanocubes:

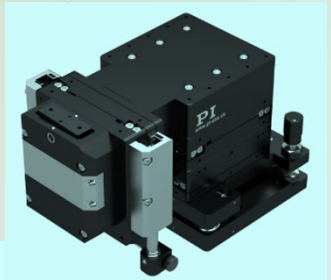
- For speed
- For tracking
- For resolution

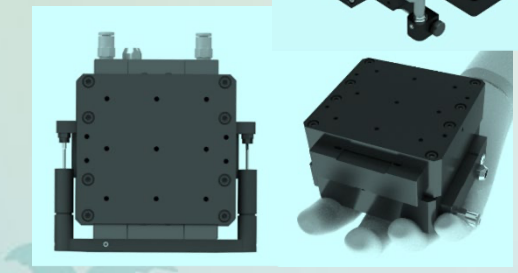
Nanocubes & Air Bearings

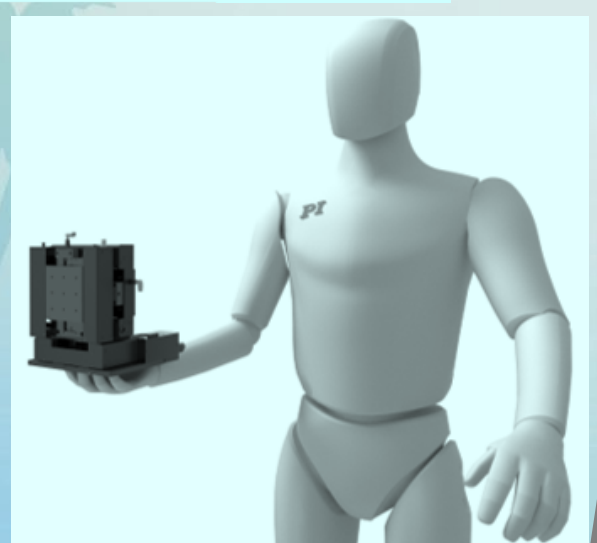
- Long lifetime, zero maintenance, no lubrication, nanometer resolution, high dynamics

All

- Leverage proven technologies
- *Firmware-based alignment*
- *Parallel alignment processes*

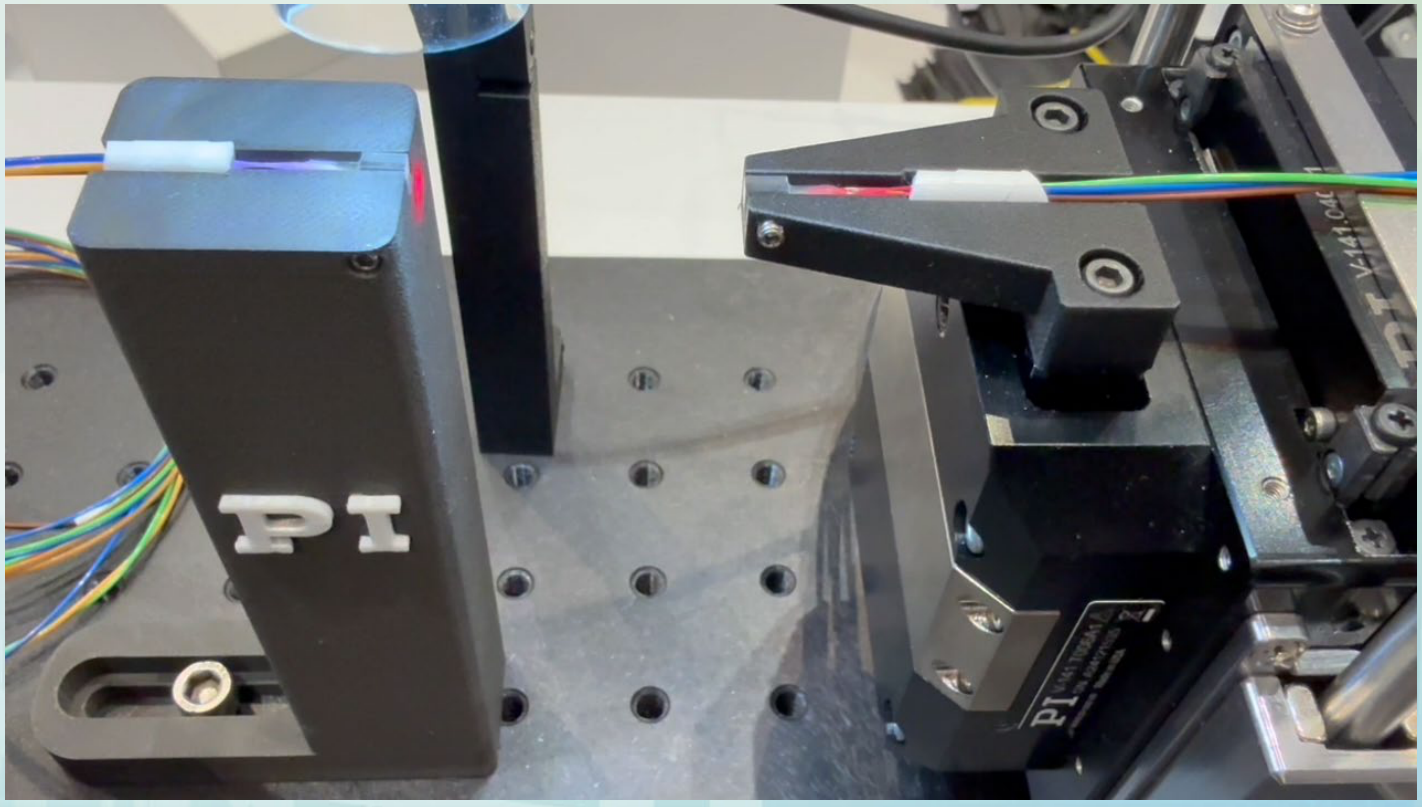






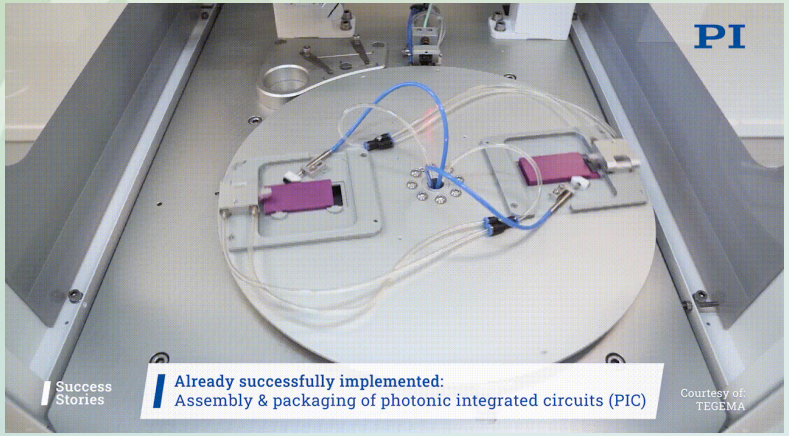
The Solution Spectrum

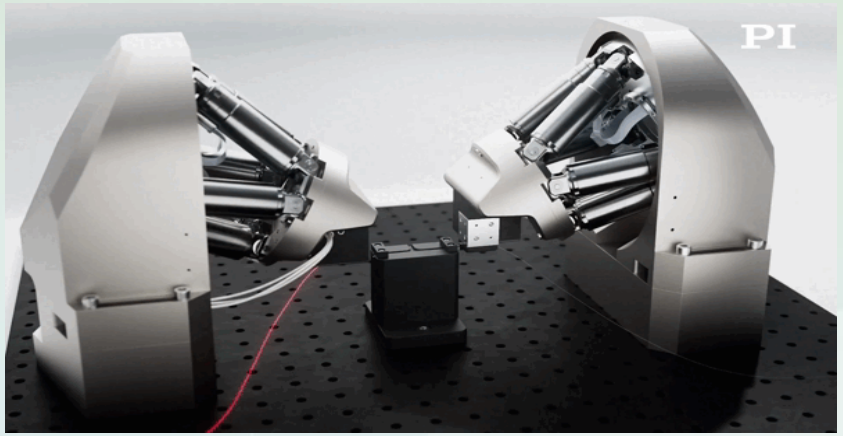
- Hexapod Micro-Robots
- Piezo Nanopositioners
- Wide range of novel mechanical bearing options
- Unique: High-Speed Air Bearing stacks for Alignment
- ***New* NovAlign Fast Compact 4- or 6-DOF aligners**

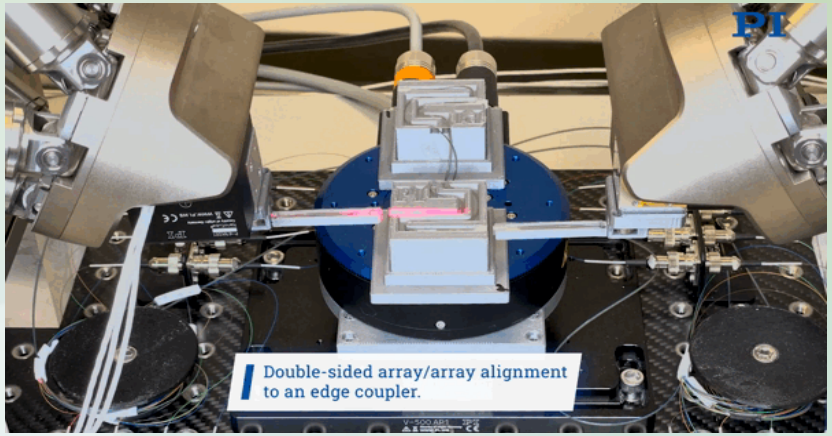


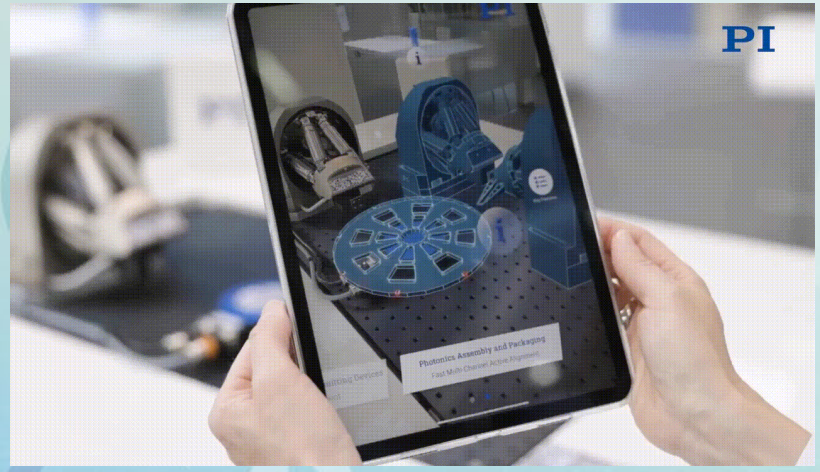
ACS MOTION CONTROL

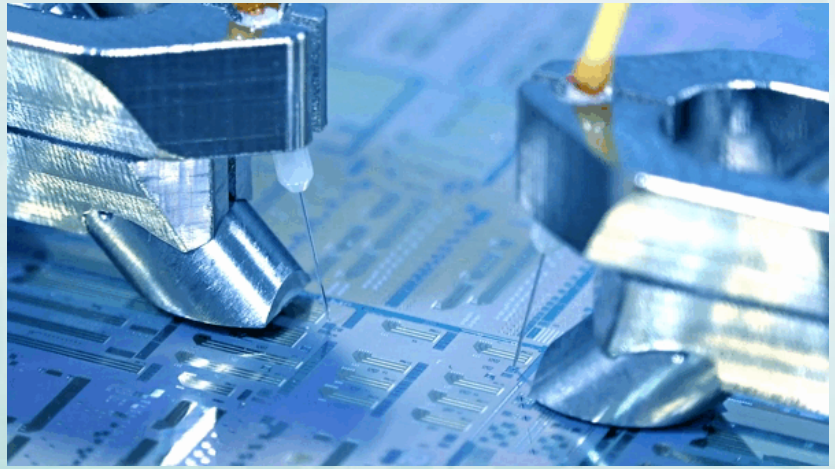
Automation Solutions

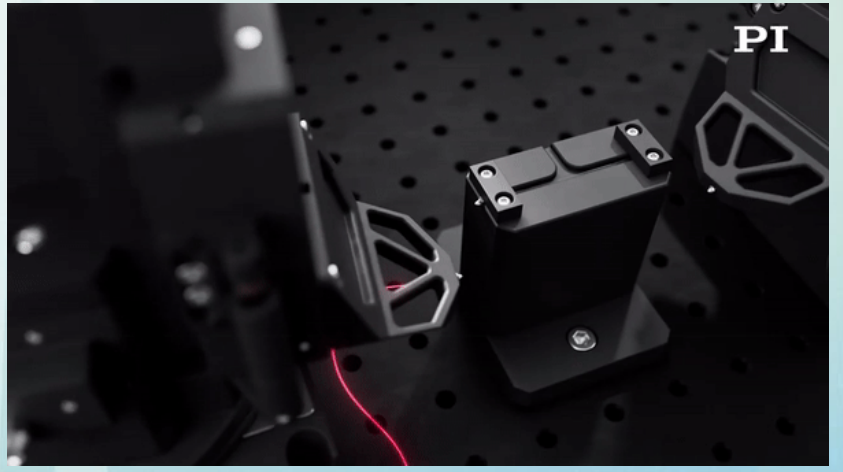










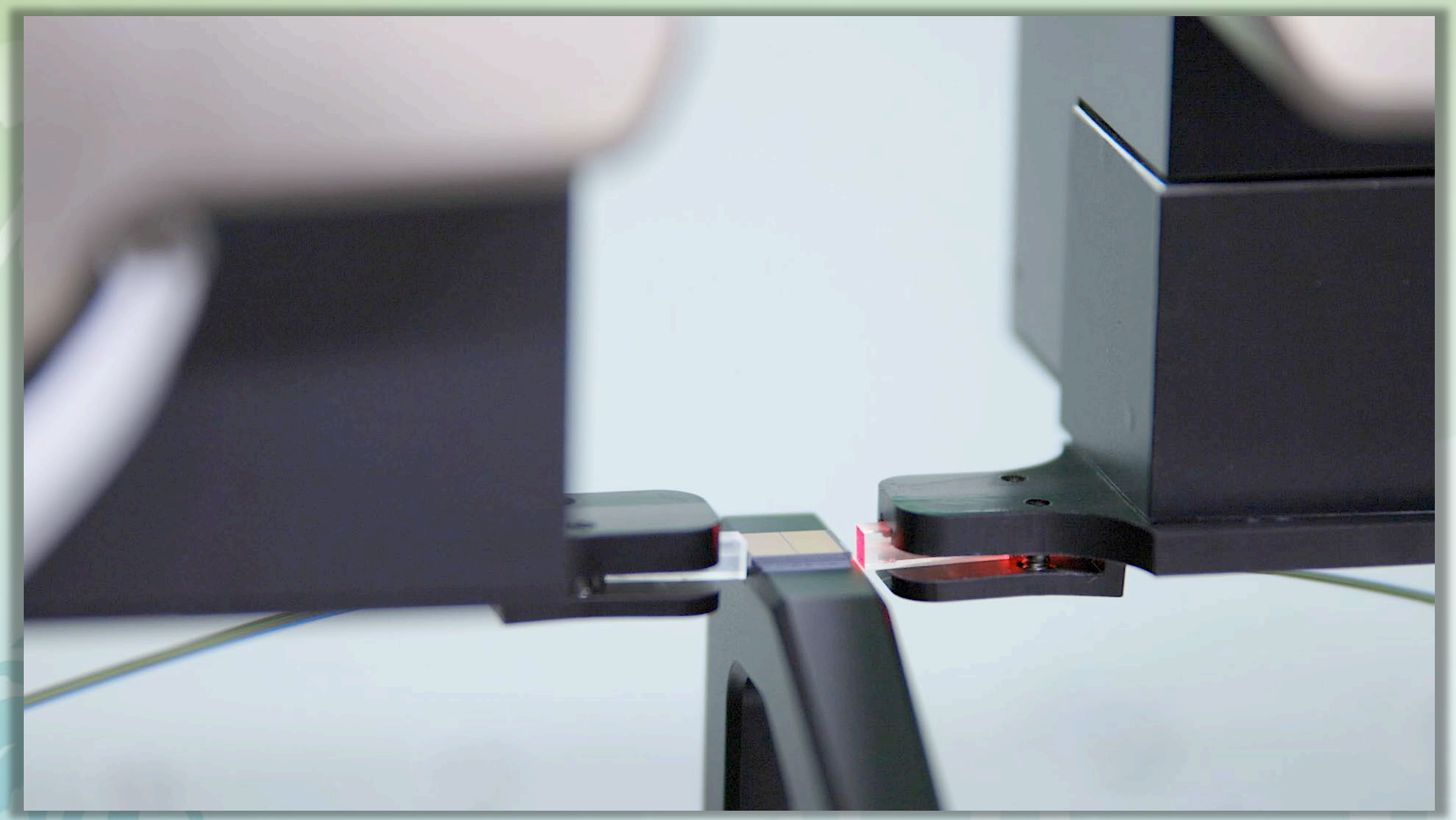


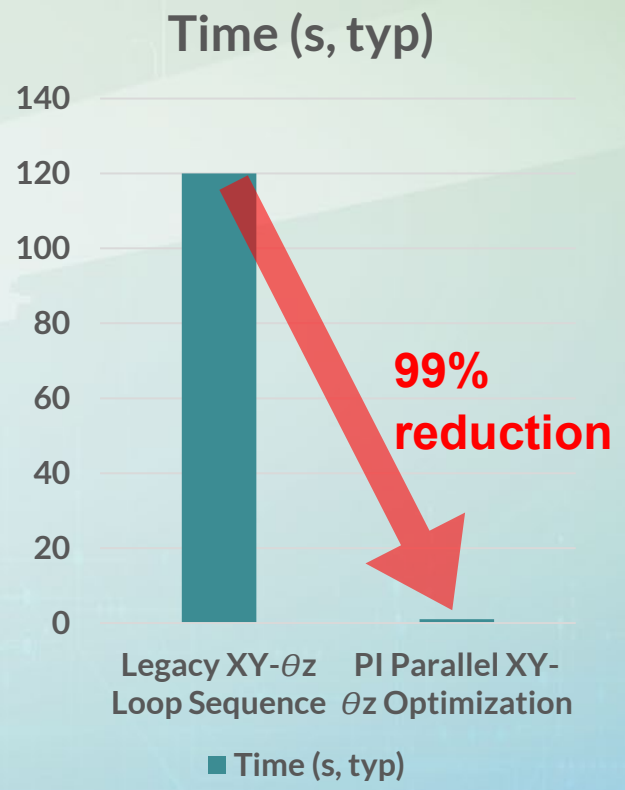
These are Early Days

The way forward:

1. Automation
2. **Innovation**
3. Cooperation

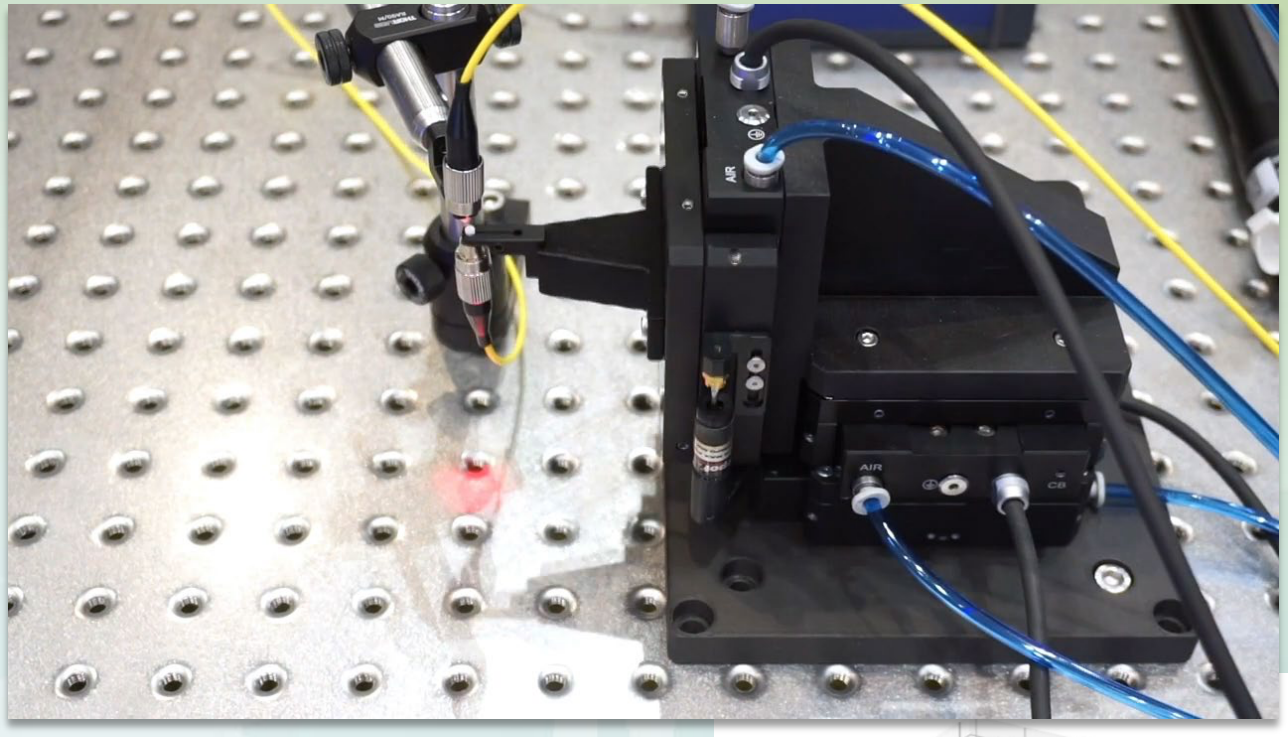
PI's Novel Parallel Multi-DOF Optimization





Unique: Air Bearing Fast Alignment Engines

Super cleanliness
Zero maintenance, Zero wear
Highest MTBF

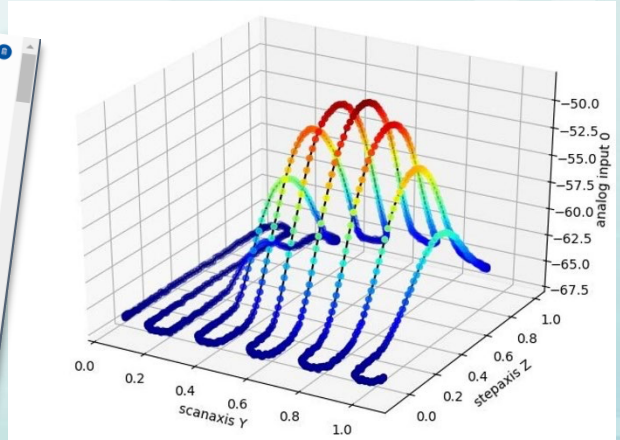


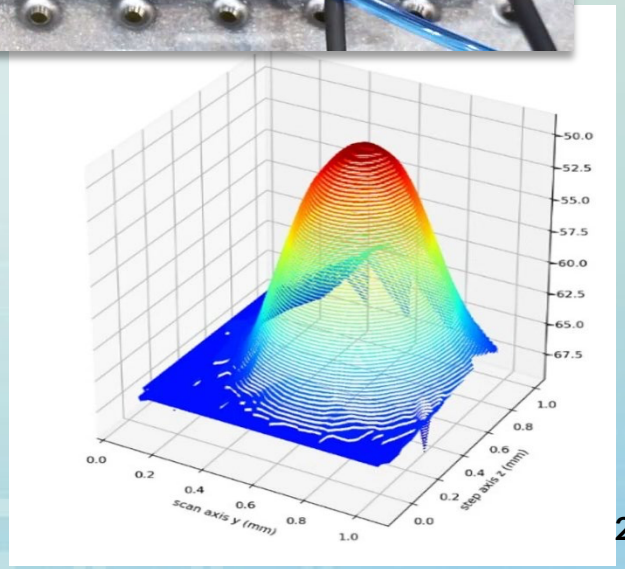
Fast Area Scan

- *First light acquisition*
- *Profiling & characterization*

Parallel Gradient Search

- *Fast Optimization*
- *Real-time tracking across multiple DOFs*
- *Drift compensation*
- *Lock-on*



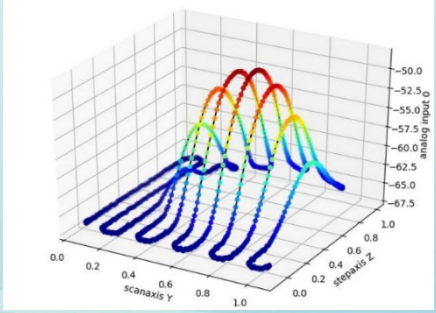


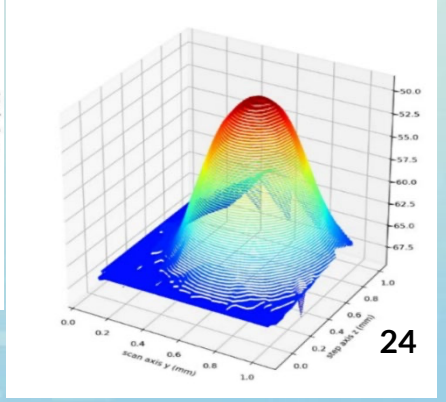
NEW: Revolutionary Fast First-Light Acquisition

PILightning:
Solving the First-Light Problem

Now:

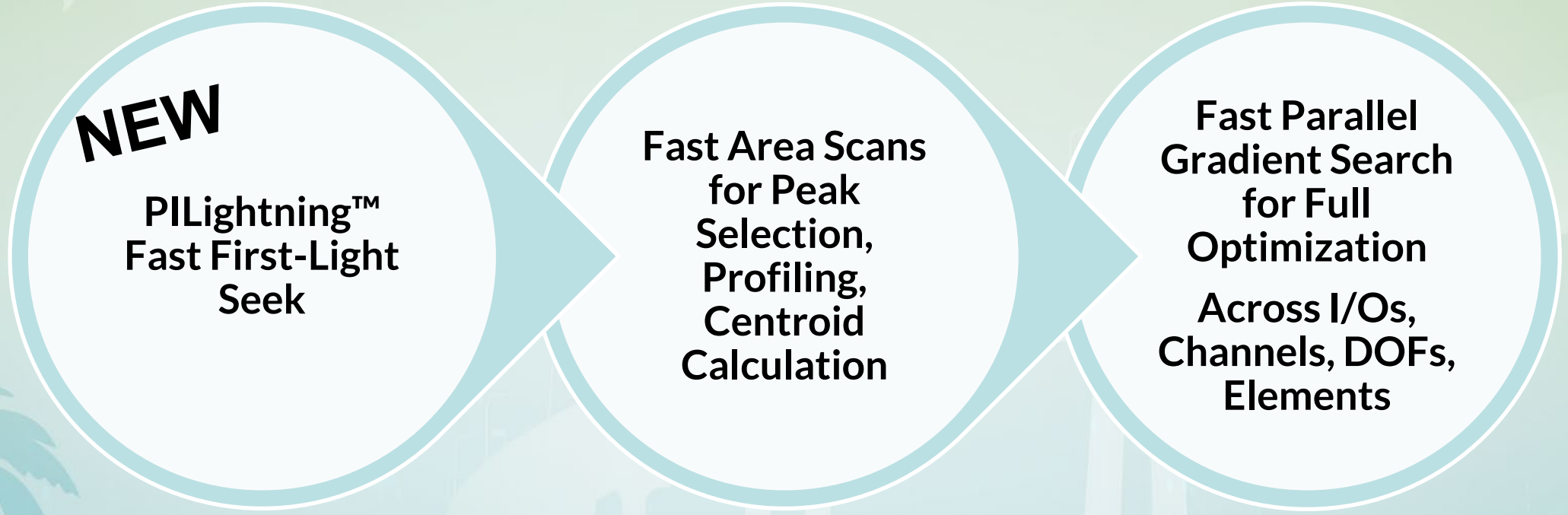
- *Typ. >10X faster first-light acquisition*
- *Even higher gains for double-sided first-light acquisition*
  - *Parallel first-light seek! Typ. <1sec*
- *Single command, fully autonomous, respects soft limits*
- *Integrated with full FMPA alignment suite*





NEW: Revolutionary Fast First-Light Acquisition

PILightning:
Solving the First-Light Problem



These are Early Days

The way forward:

1. Automation
2. Innovation
3. **Cooperation**

The Ecosystem Emerges: Contract Manufacturing

The silent partner

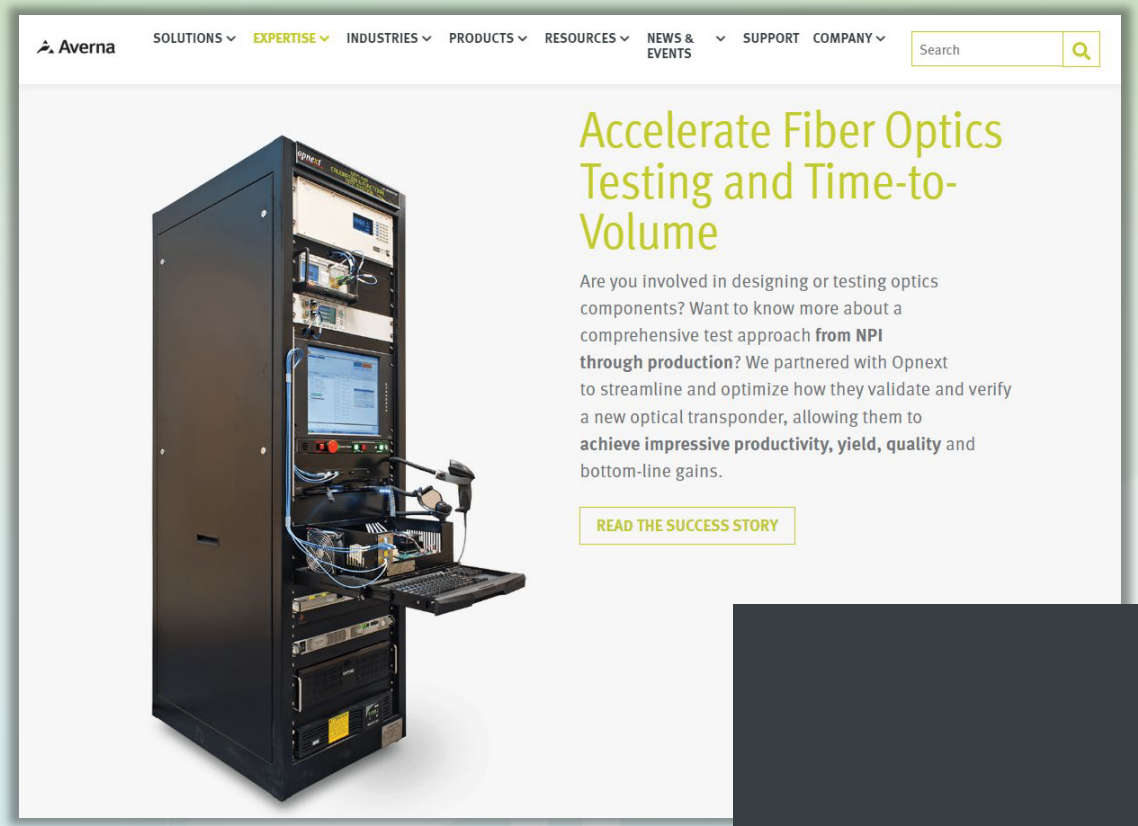
- Photonic-competent players exist
  - Example: Fabrinet →
- Scalability
- Global presence
  - Geographically strategic

Courtesy Fabrinet
Used with permission

The Ecosystem Emerges: Systems Integrators

The builders

- Custom tools to accomplish mission-critical tasks
- From concept to scale
  - Example: Averna →



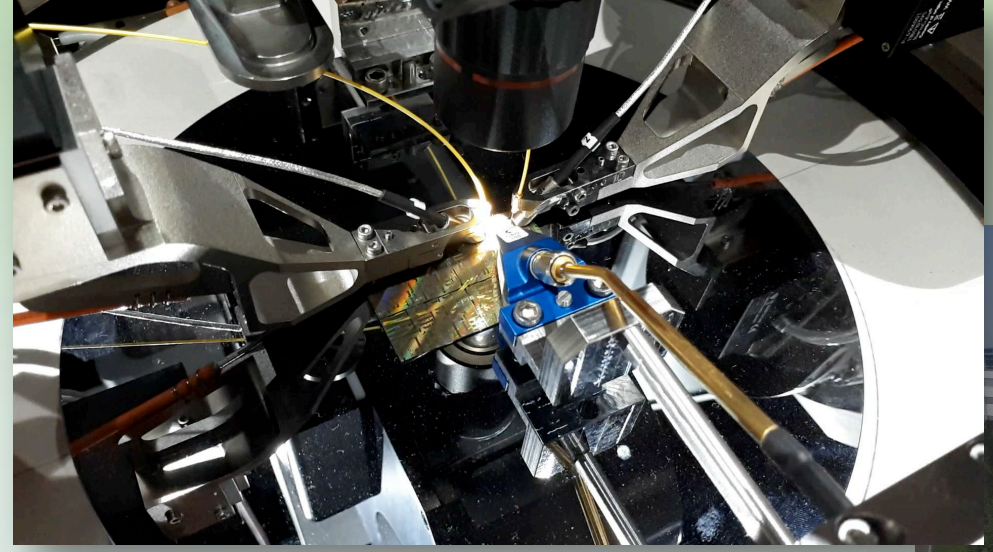
Summary: The Deluge Approaches

- Many, many new applications
- 3 order-of-magnitude volume scaling
  - Consumer applications now in the game
  - Serious challenges to scale
  - Interconnect technology and testing must keep pace
  - Yields must improve
- *"Silicon photonics" is key to to technology's future*

> ***"Today, optics is a niche technology. Tomorrow, it's the mainstream of every chip that we build."***
>
> --Pat Gelsinger, 2005, MIT Technology Review

PI is here to help

- Enabling semiconductor manufacturing since its infancy
- Enabling genomics automation since its infancy
- Enabling silicon photonics since its infancy



Keep in touch!

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