

Co-Packaged Optics: Technical Barriers and the Road to Mass Production

Swissphotonics Lunch Chat
October 14th, 2025

Emma Xu

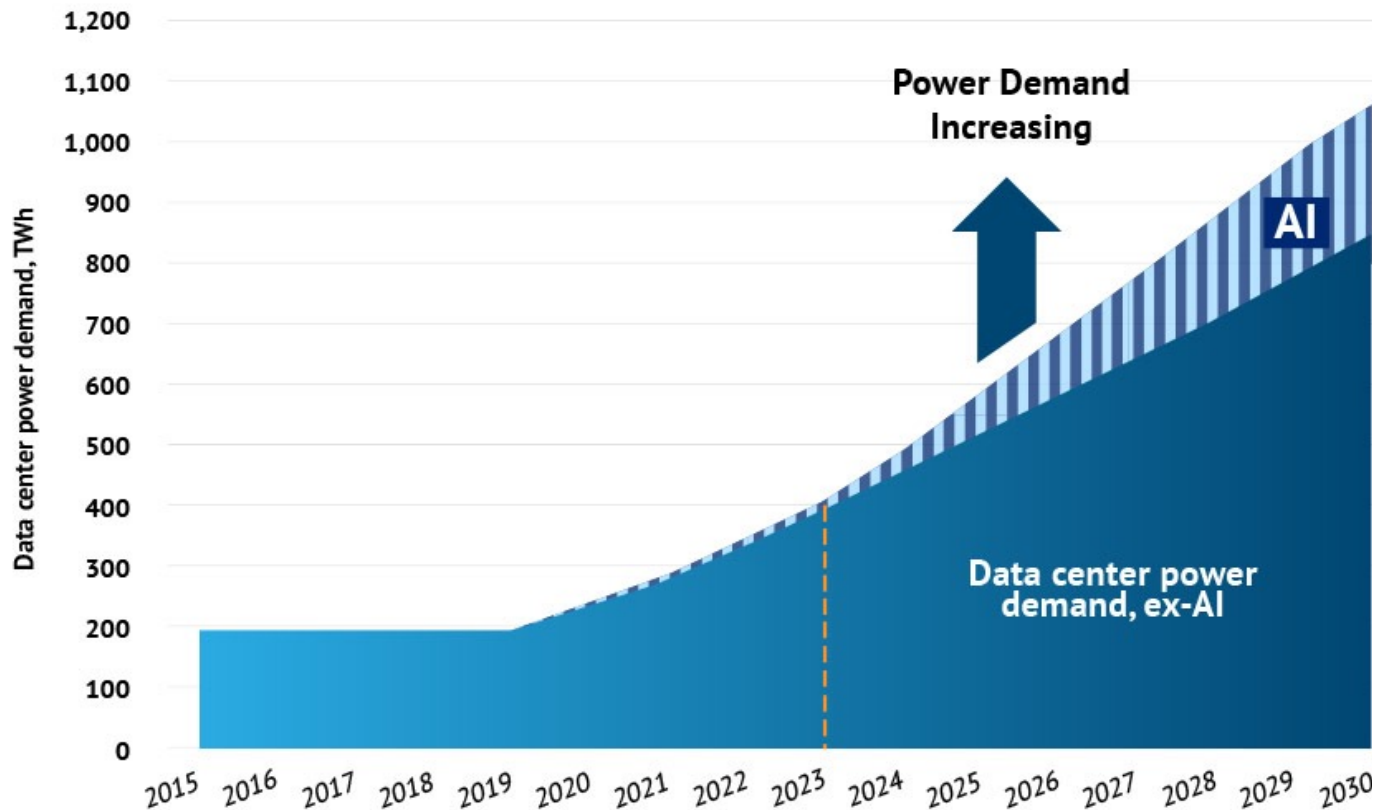
About me

- PhD from Columbia University, research topic: photon upconversion & photon avalanching
- 2 *Nature* publications, 5 patents pending. Former founder; *Forbes* 30 under 30
- Worked in the US & Germany (semiconductor & photonics industries)

Collaborator in Taiwan: Vincent Ho, 30+ years in the semiconductor industry



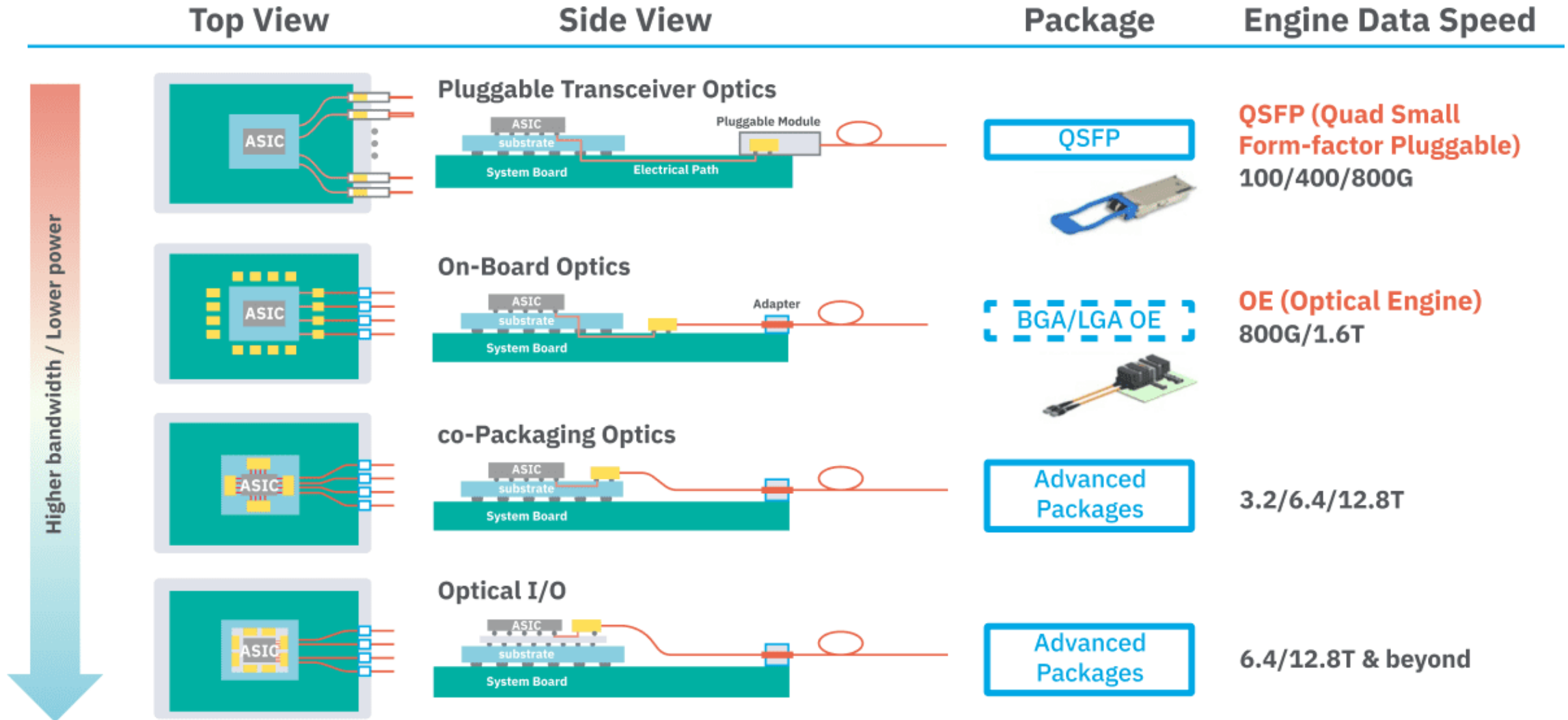
Motivation: Data centers demand high power



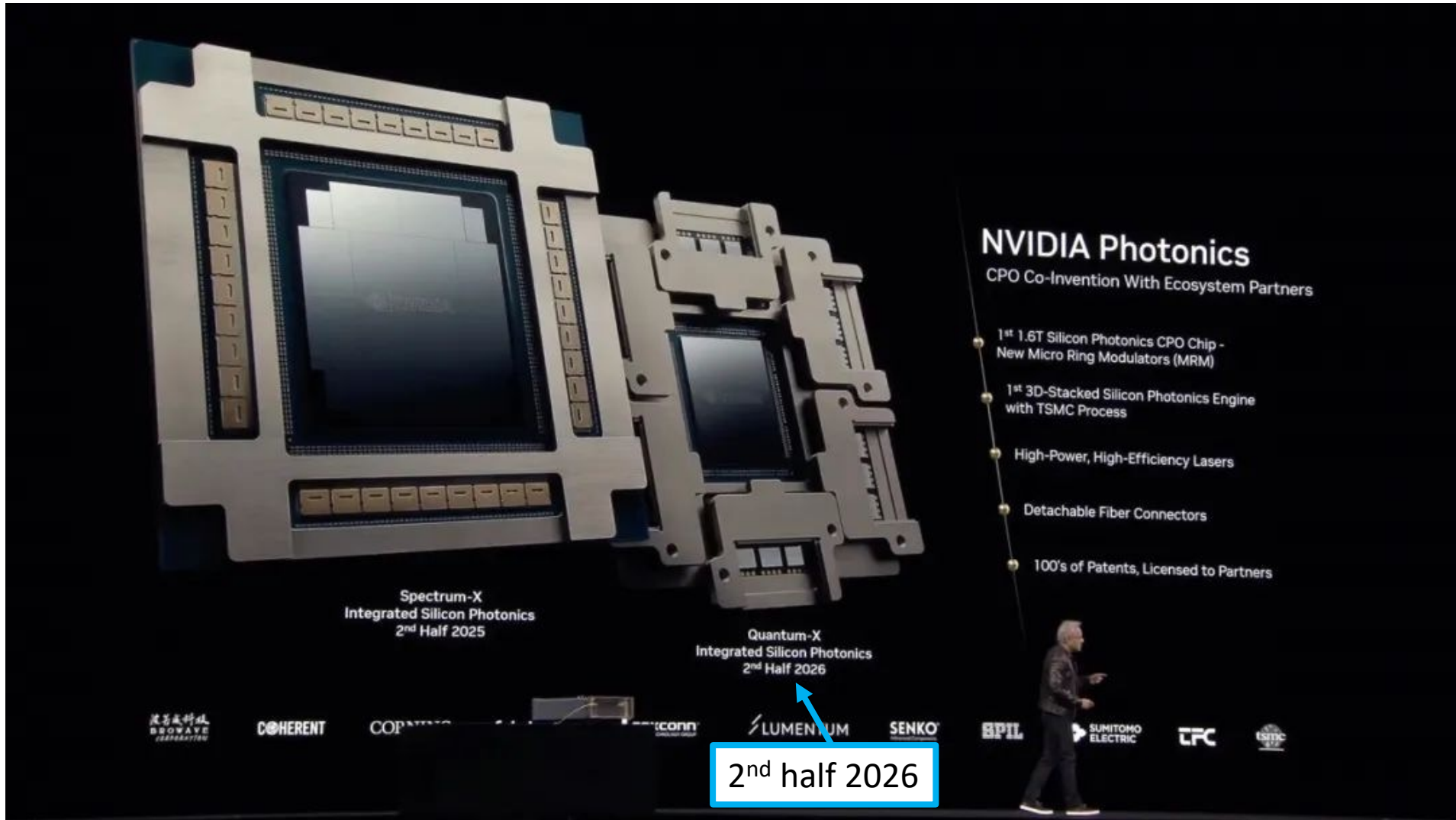
Source: Masanet et al. (2020), Cisco, IEA, Goldman Sachs Global Investment Research

- Current state-of-the-art: data transmitted via copper (electricity)
- With Silicon Photonics:
 - higher data throughput
 - Lower power consumption
 - Mitigate latency

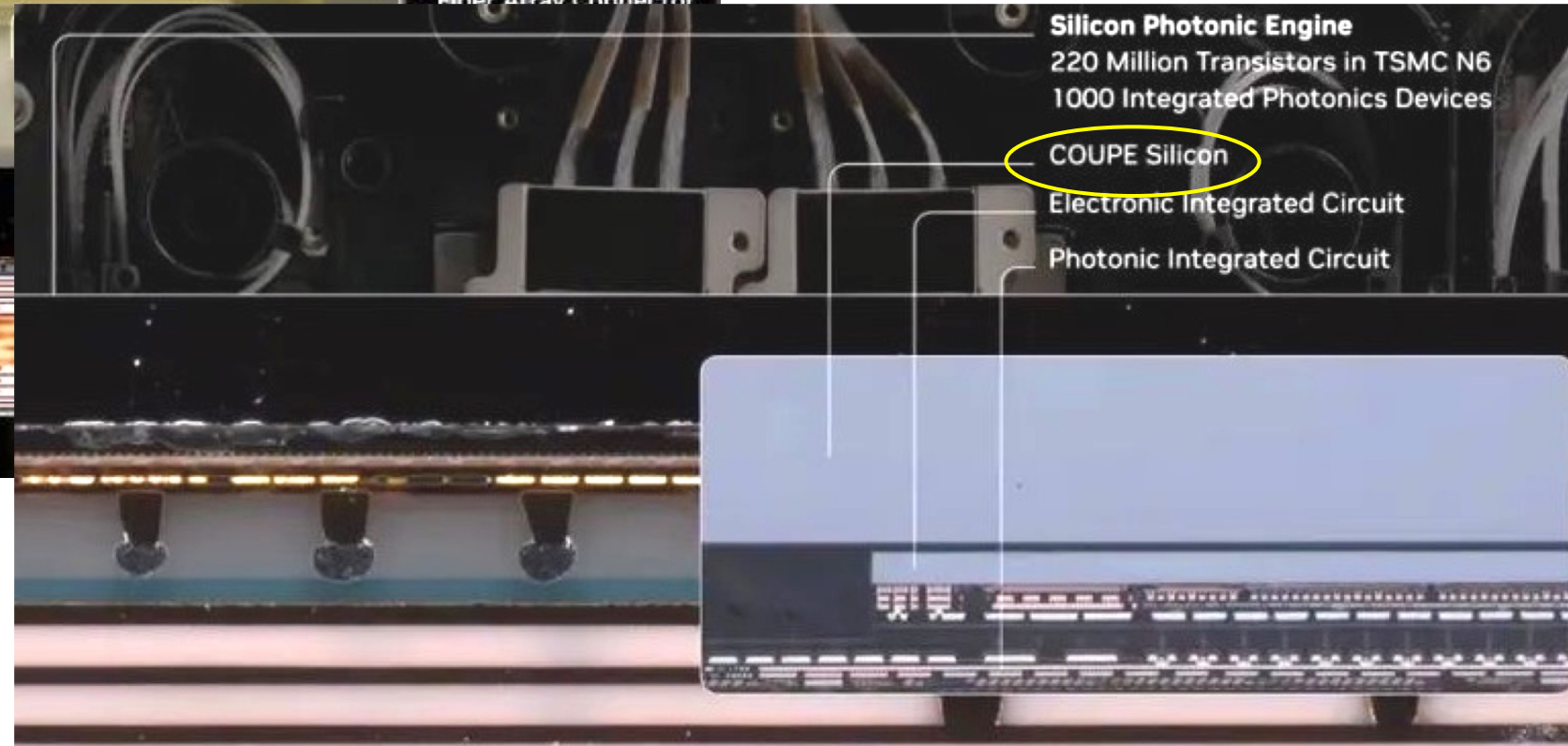
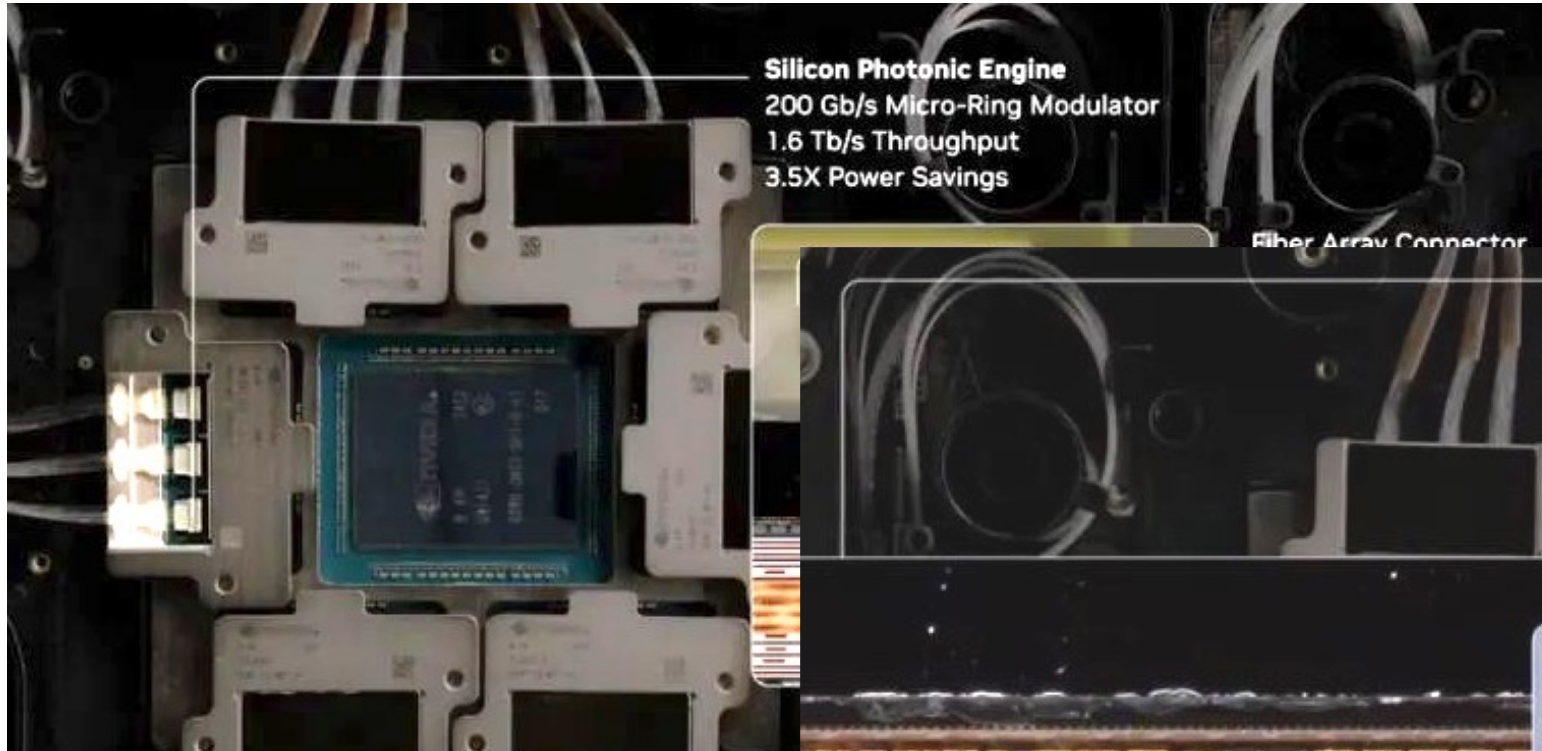
Co-Packaged Optics (CPO)



Nvidia GTC2025 Keynote



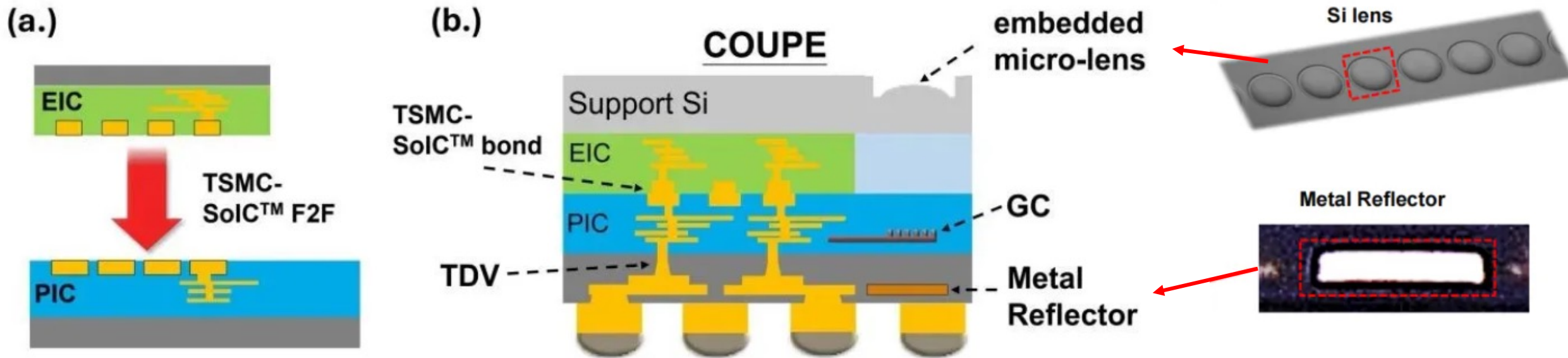
Nvidia CPO-Based Switch



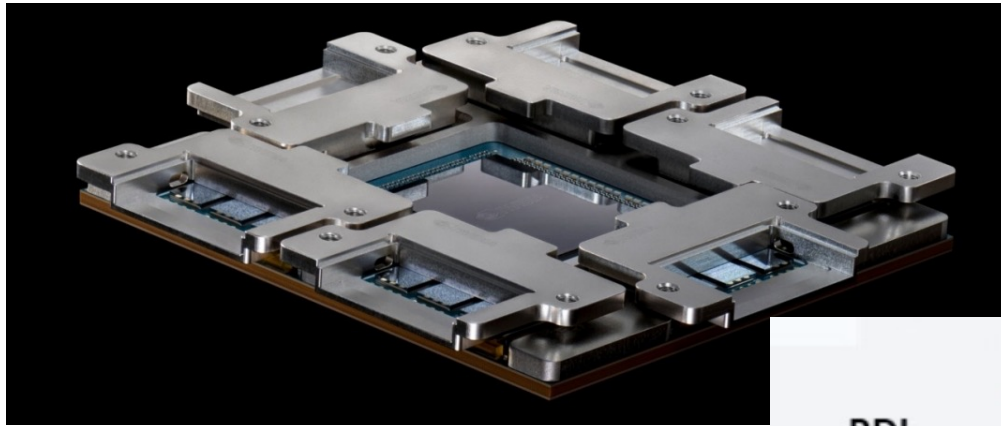
TSMC COUPE

(COUPE: compact universal photonic engine)

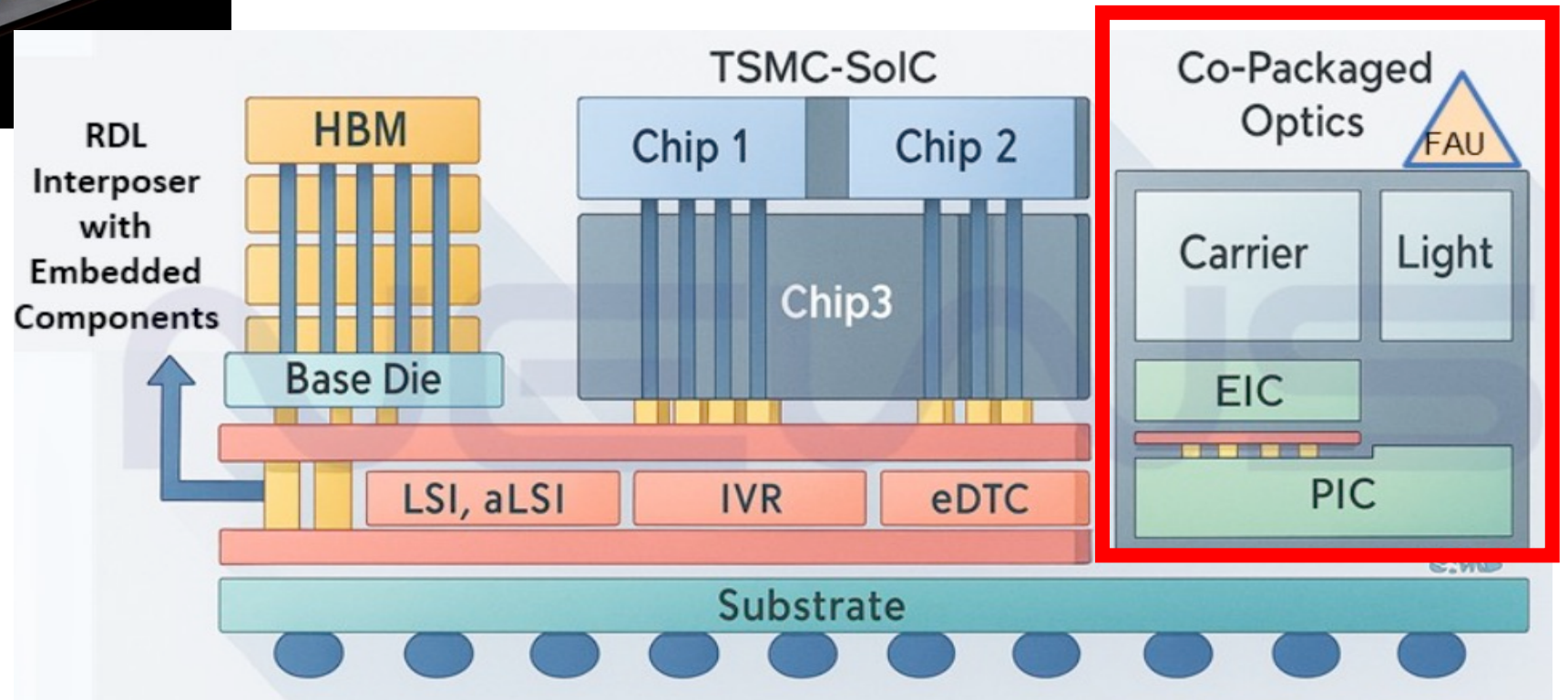
- TSMC-SolC face-to-face (F2F) technology for EIC and PIC bonding.
- critical components of COUPE are the TSMC-SolC™ bond, TDV, embedded micro-lens, and metal reflector



COUPE + COWOS (COWOS: chip on wafer on substrate)



Side-view schematic



COUPE Specs

- High-Performance Silicon Photonics Platform
 - 12-inch 65nm silicon photonics platform
 - 10um alignment tolerance, 0.3dB loss vertical coupling
 - 76GHz micro-ring modulator
 - 4.5nA dark current 110GHz GePD
 - 1.5nm center resonance wavelength drift (wafer-level control)
- Optoelectronic Integrated Chiplet & CPO
 - <1dB/m single-mode SiN waveguide transmission loss
 - 0.1dB broadband edge coupler
 - 2D fiber array with micro-lenses
 - 97% precision in optical beam deflectors
- Parallel Digital Optical Computing Chips
 - 4-layer SiN platform
 - 512x512 optical computing array, 35dB insertion loss
 - 8-bit accuracy computing
 - 0.08 pJ/MAC energy efficiency

Concerns:

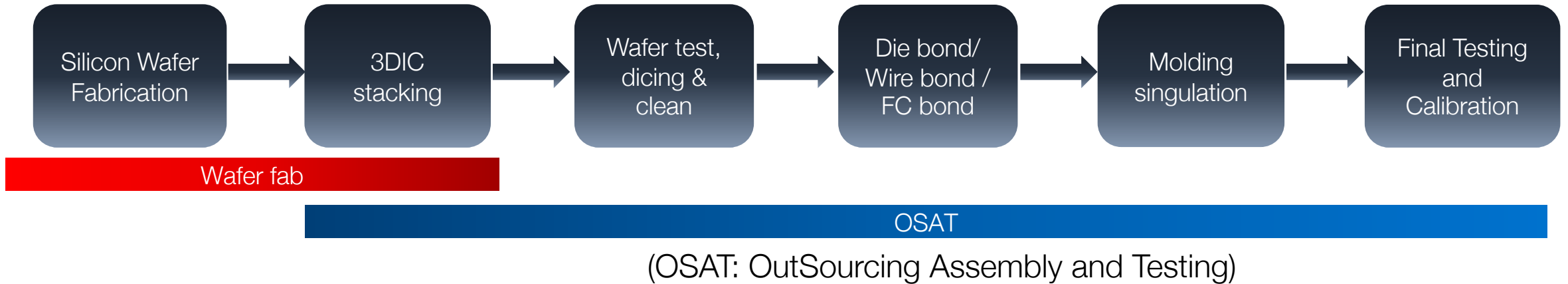
1. Cost
2. Risk
3. Sole supplier

Taiwan semiconductor market

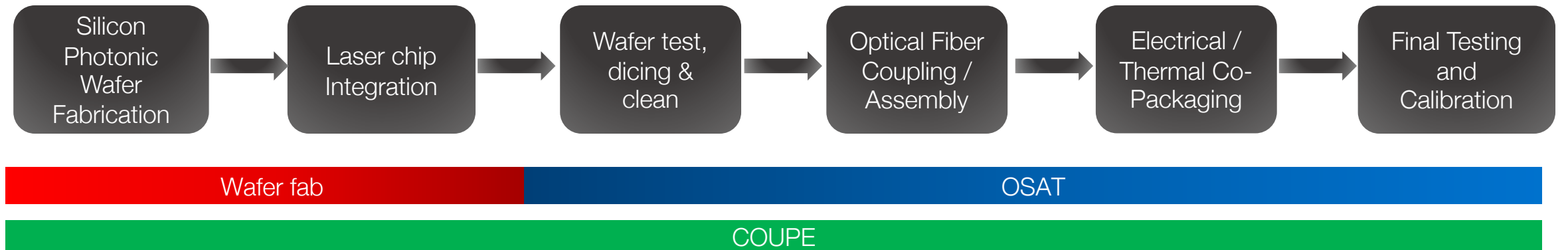
- 2024 Taiwan's semiconductor output value = **165** \$Bn, equivalent to **25%** of the global value
- 2025 Taiwan's output is projected to **191** \$Bn, **28.1%** of global share

Taiwan IC Industry market share (unit: \$Bn)					
	2021	2022	2023	2024	2025
Global	556	604	526.9	655	701
Taiwan	127.1	150	135.2	165.6	197
share	22.9%	24.8%	25.7%	25.3%	28.1%

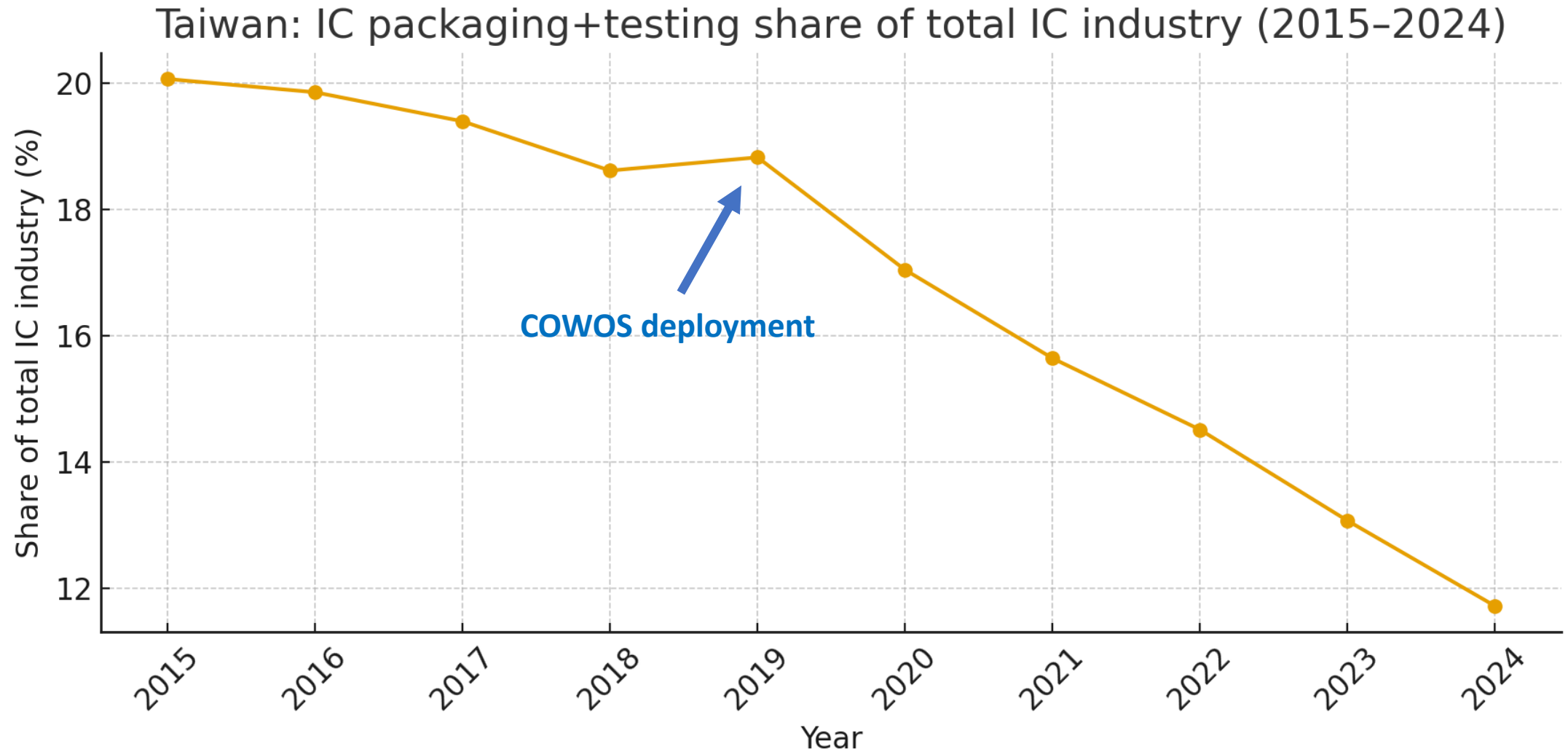
Semiconductor Process



Process from SiPh to CPO



Taiwan OSAT market share trend

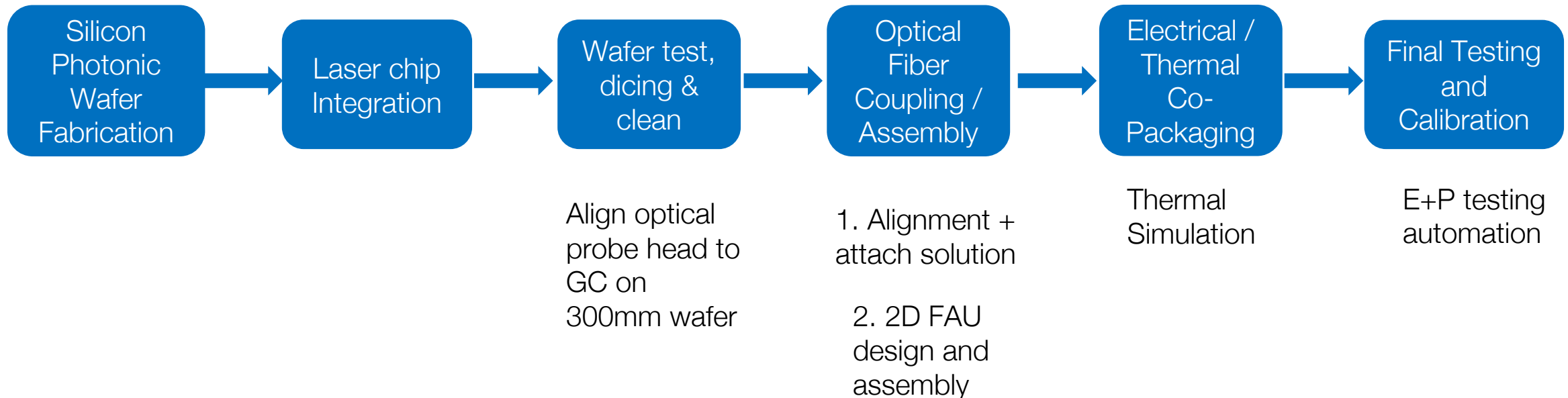


A packaging war?

- 3DIC war lost
 - OSATs invested aggressively in 3D packaging and related technologies but the return was slow
- Taiwan OSATs are leveraging their strengths and pivoting towards the new CPO architectures before COUPE scales
 - Competitive threat
 - Customer pull

Gaps and needs for Taiwan's CPO development

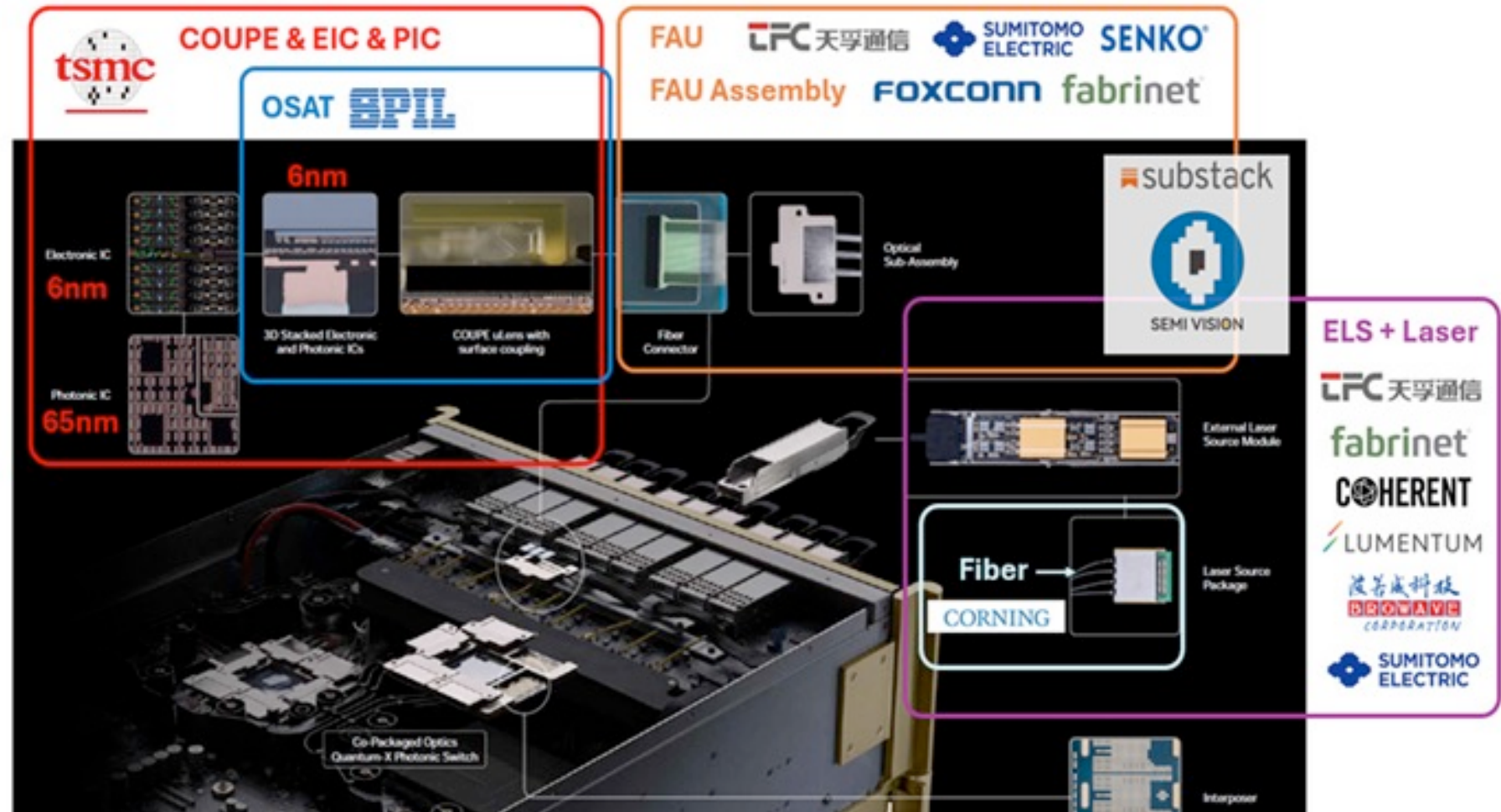
- CPO electrical–optical co-design integration
- High-yield optical coupling & assembly
- Supply chain fragmentation
- Talent and design ecosystem
- Laser integration & heterogeneous bonding
- Testing and yield challenges



Current status in Taiwan

- Silicon photonics chip test yield: 10%–70%
- Fiber-to-silicon chip coupling loss: $> \pm 2.5$ dB
 - Multicore (22–40) fiber module
- Packaging process complexity
 - Active vs. passive alignment
 - Epoxy or solder fixation: Adhesive-induced misalignment
- Limited yield improvement capability (due to lack of optical expertise and proper debugging tools)
- Diverse solutions from vendors, OEMs, and customers prevent OSAT engineering resources from being focused

Nvidia CPO supply chain



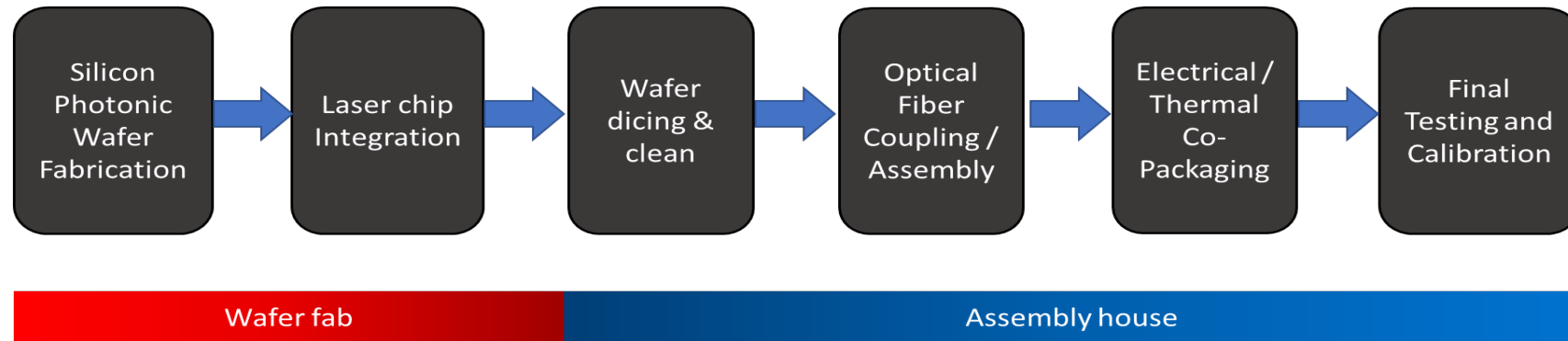
Nvidia CPO supplier locations

Item	Company	Country
Wafer photonics	TSMC	Taiwan
CPO OSAT	SPIL	Taiwan
FAU	TFC	China
	Sumitomo	Japan
	SENKO	Japan
ELS	Fabrinet	USA
	Lumentum	USA
	Coherent	USA
	Browave	Taiwan
System	Foxconn	Taiwan

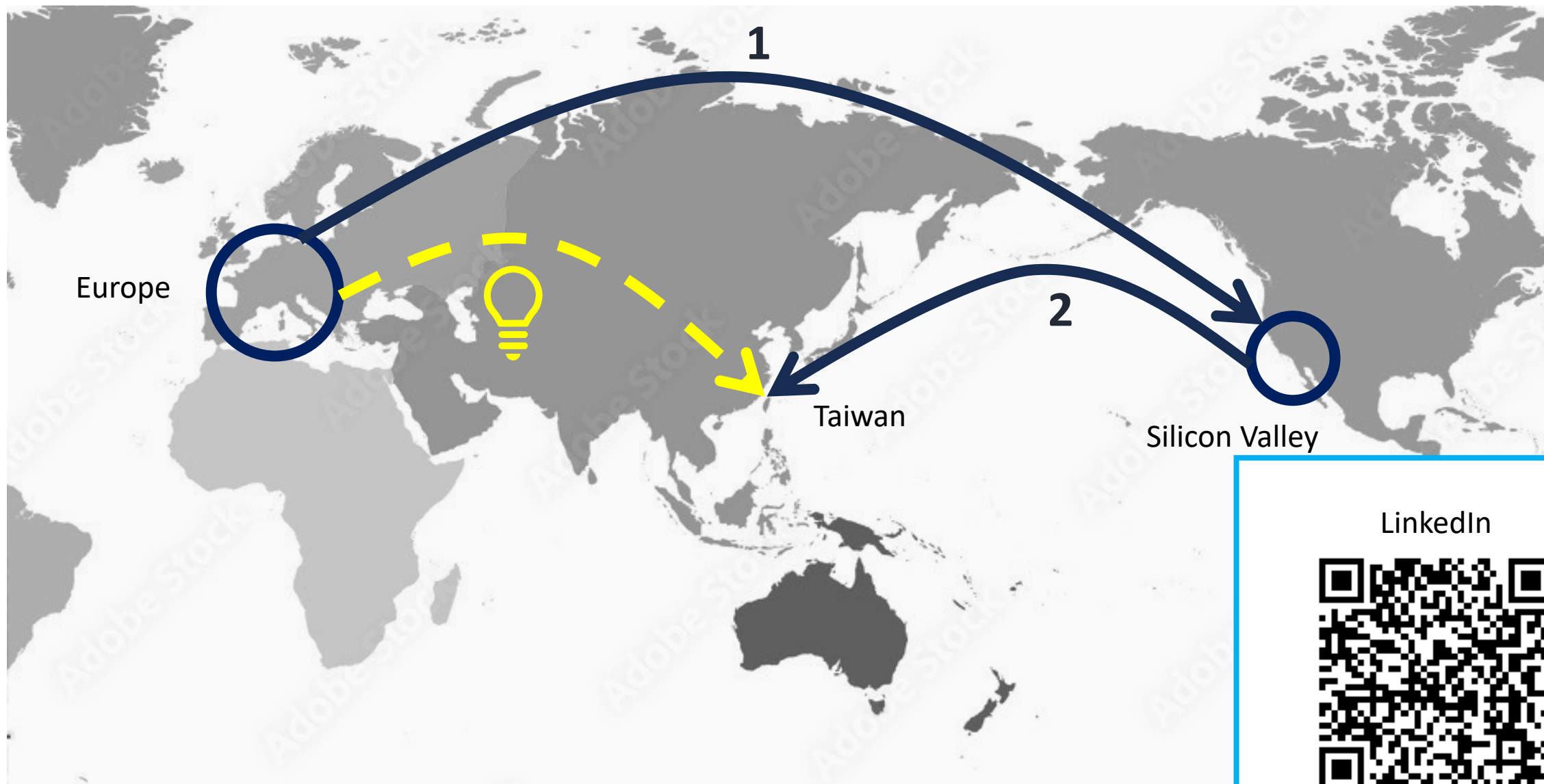
Taiwan : 4
USA : 3
Japan: 2
China : 1
Europe: 0

Advantages of developing business in Taiwan

- Taiwan possesses a comprehensive and fully developed semiconductor manufacturing ecosystem.
- Taiwan has strong momentum and sufficient capacity to drive the development of the CPO industry.



- Taiwan lacks sufficient knowledge and talent in photonics-related technologies, and must leverage external expertise and new technologies to accelerate CPO development and surpass global competitors in this field.



LinkedIn



Email:

emma.xu@Columbia.edu