華南永昌證券 產業趨勢暨企業論壇

矽光子發展趨勢：技術演進與機會

Silicon Photonics：

Technology Evolution and Opportunities

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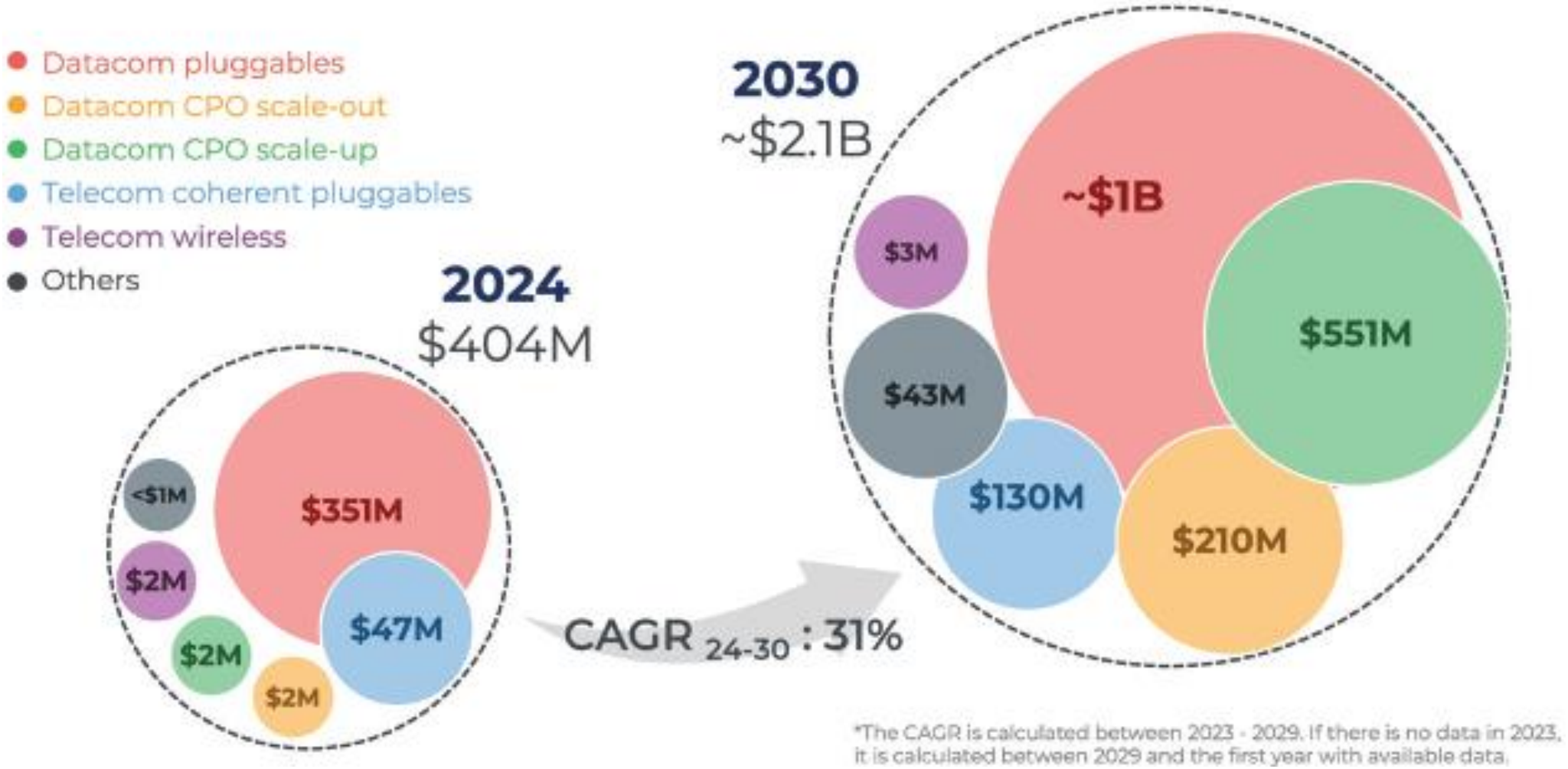
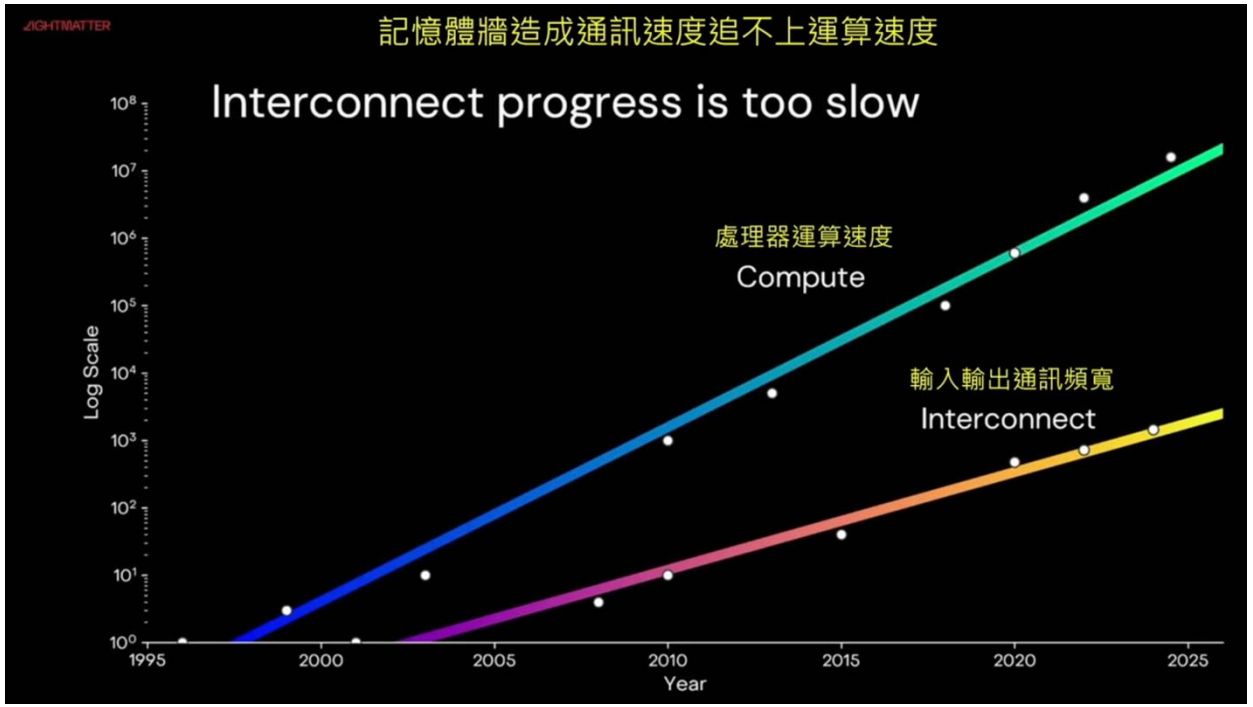
臺灣大學電機工程學系 博士.　大同大學 電機系 助理教授

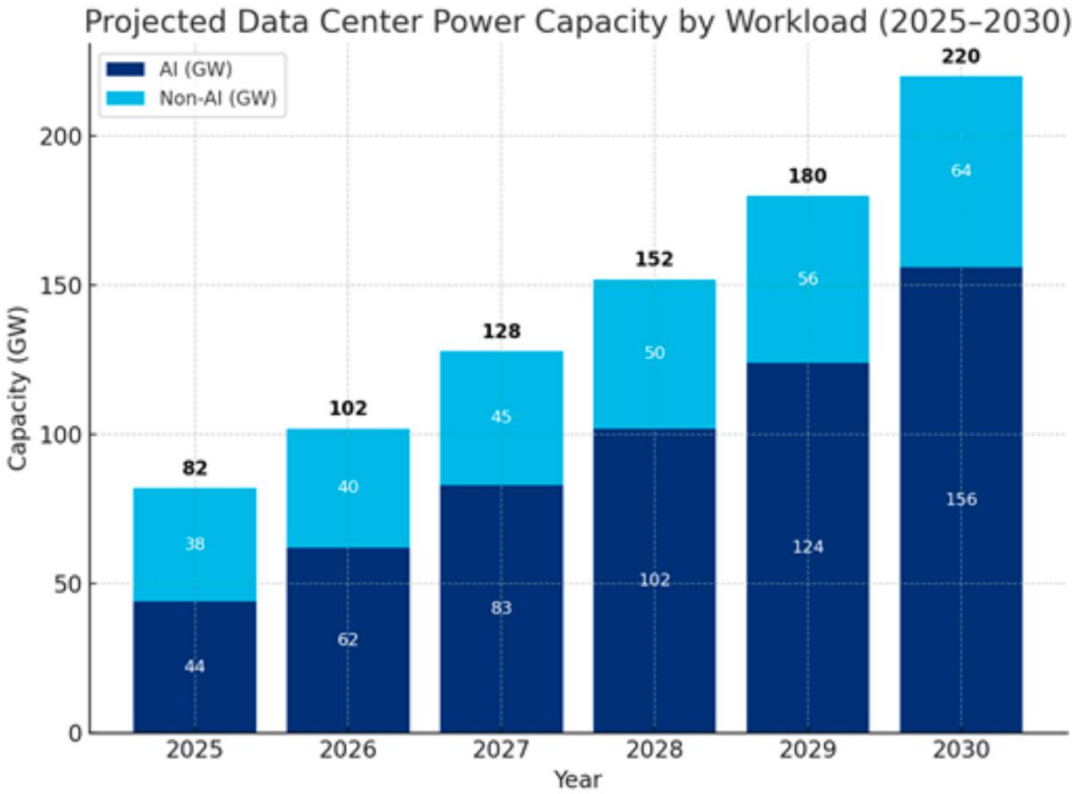
❒ Silicon PIC revenue growth forecast by application



Ref :Yole, Laserfocusworld

❒ "Memory Wall" & Power Crisis

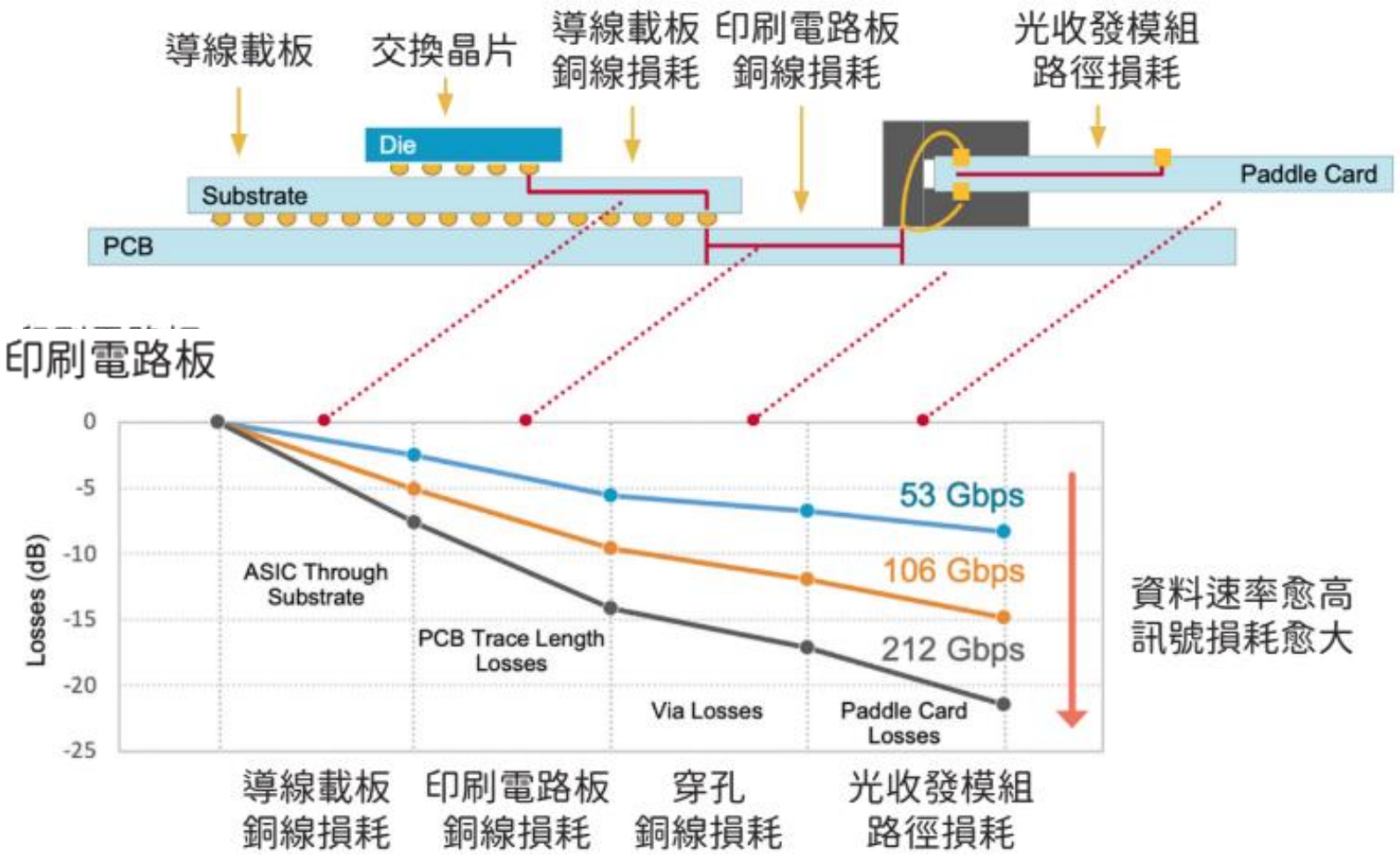




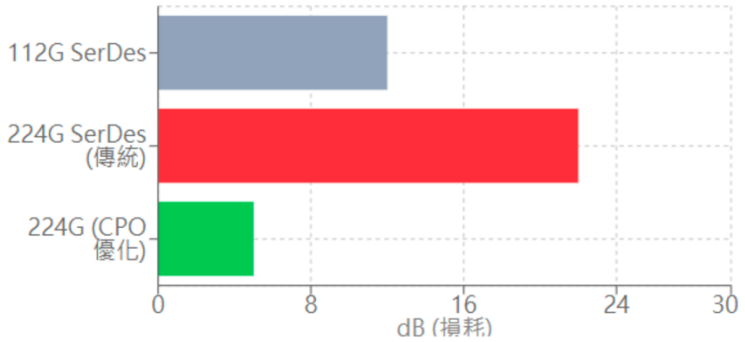
全球資料中心電力負載容量需求

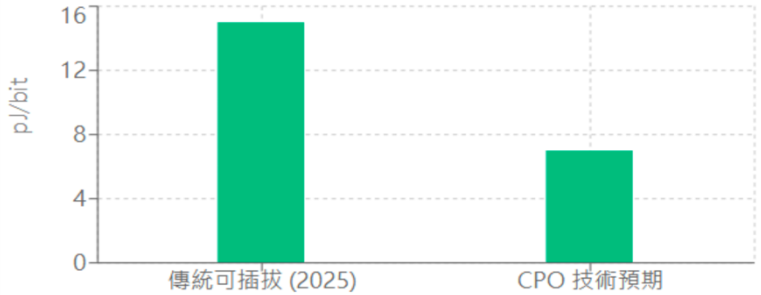
Ref :Lightmatter, 曲博科技教室, 麥肯錫(2025), IEK

❒ Losses of Traditional EO Module



資料速率愈高
訊號損耗愈大

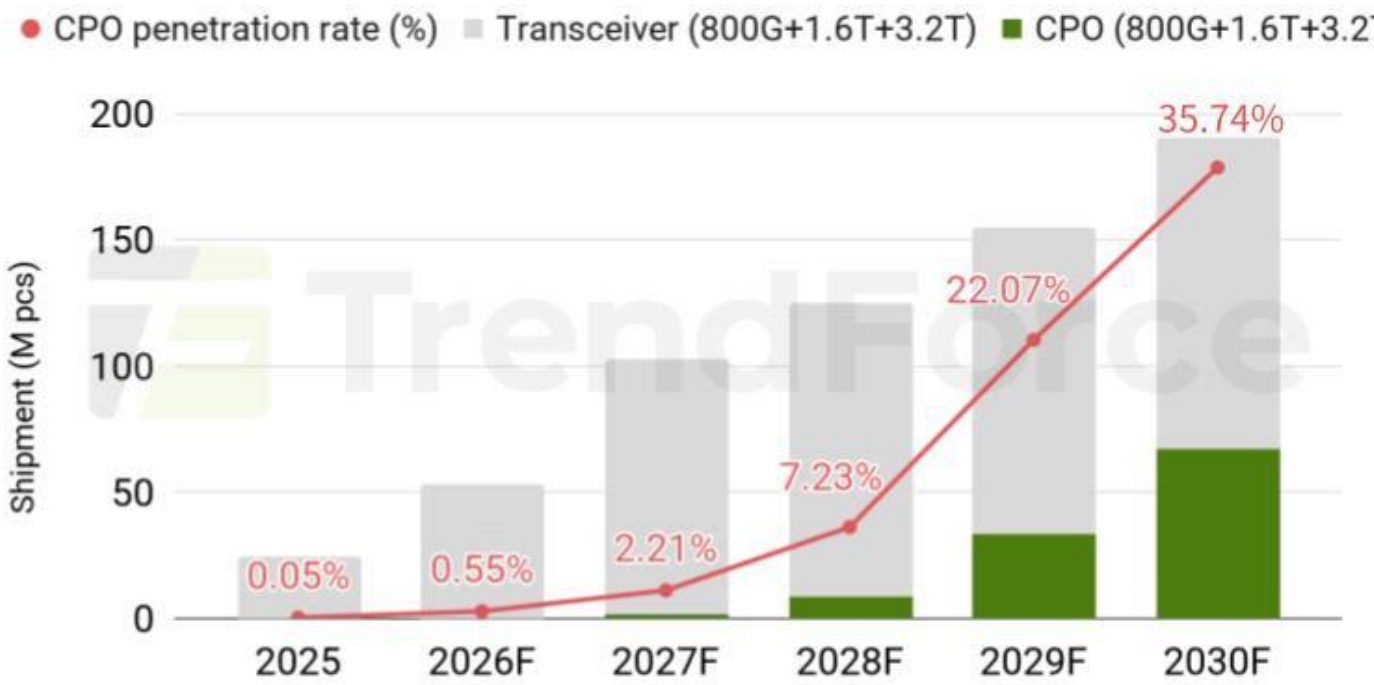




Ref : 博通(Broadcom), Seimens

❒ CPO Penetration Accelerates Towards 2030

2025-2030年CPO於AI資料中心光通訊模組出貨占比預估

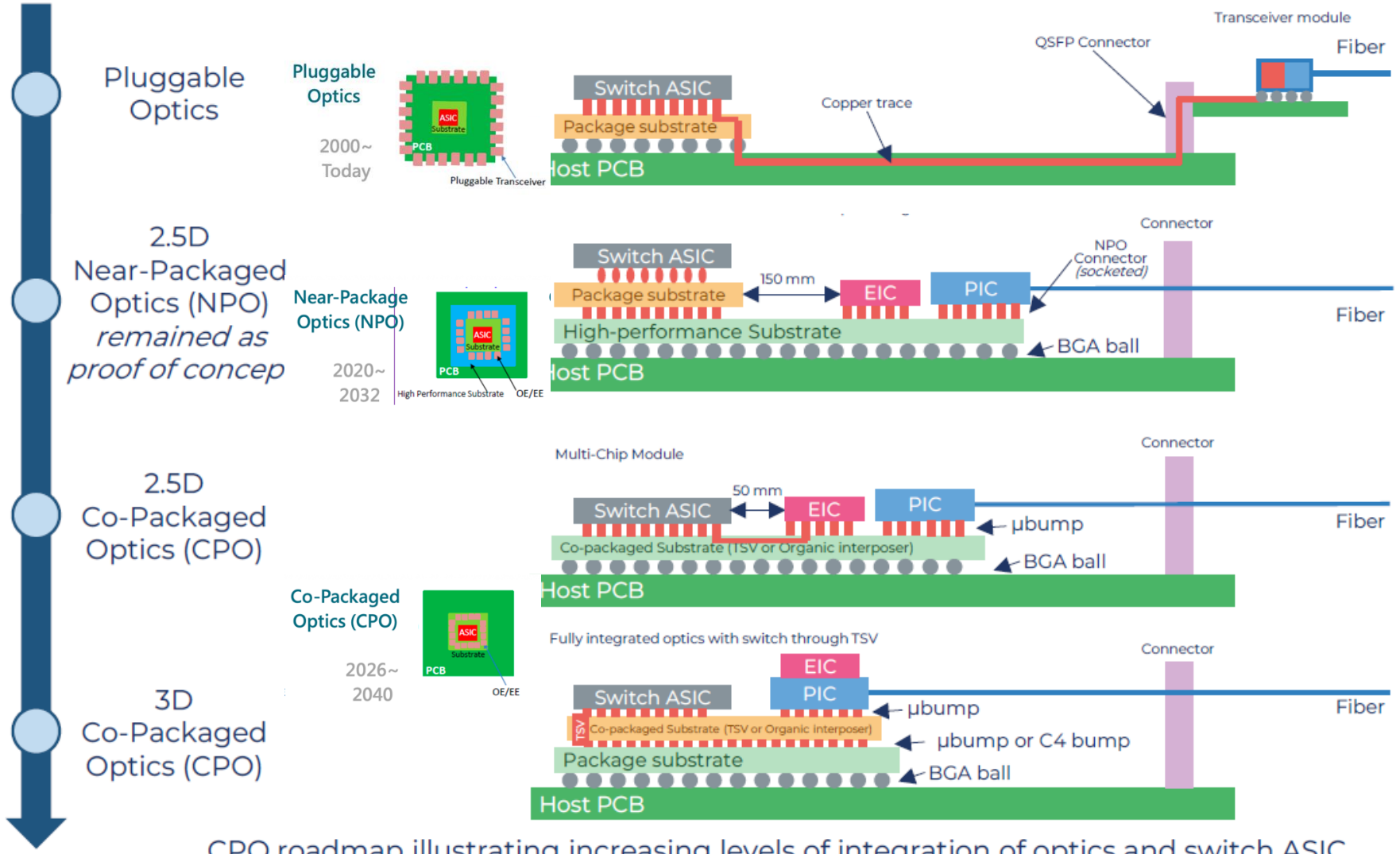


Source: TrendForce, Mar. 2026

TrendForce

Ref : TrendForce, Technews

❒ CPO Roadmap

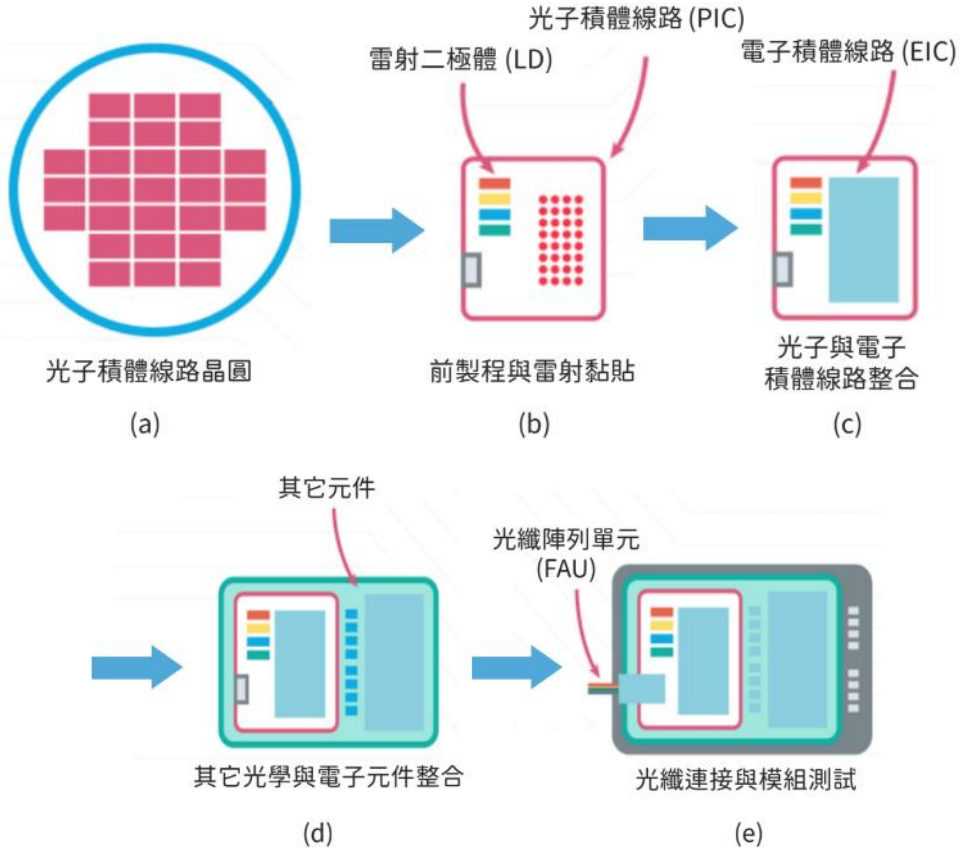


CPO roadmap illustrating increasing levels of integration of optics and switch ASIC

Ref : Yole, Technews

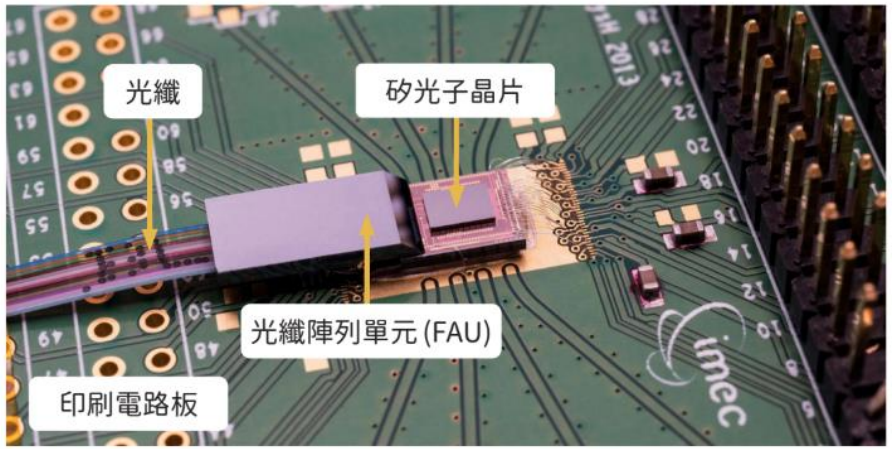
❒ Silicon Photonics & CPO (Co-Packaged Optics)

核心維度	EIC 電子積體電路	PIC 光子積體電路
主要定位	負責運算與邏輯（大腦）	負責互連與傳輸（高鐵）
頻寬速度	受限於 RC 延遲（～ GHz）	多波長 WDM （可達 Tbps）
優勢距離	短距離（< 1 m）	中長距離（> 10 m ～ km）
關鍵封裝	CoWoS（著重熱管理、RDL）	CPO（著重 ±1μm 精準光對位）
最大瓶頸	漏電、短路、RC 延遲	光耦合損耗、測試成本高



Ref :日月光(ASE)

❒ Silicon Photonics



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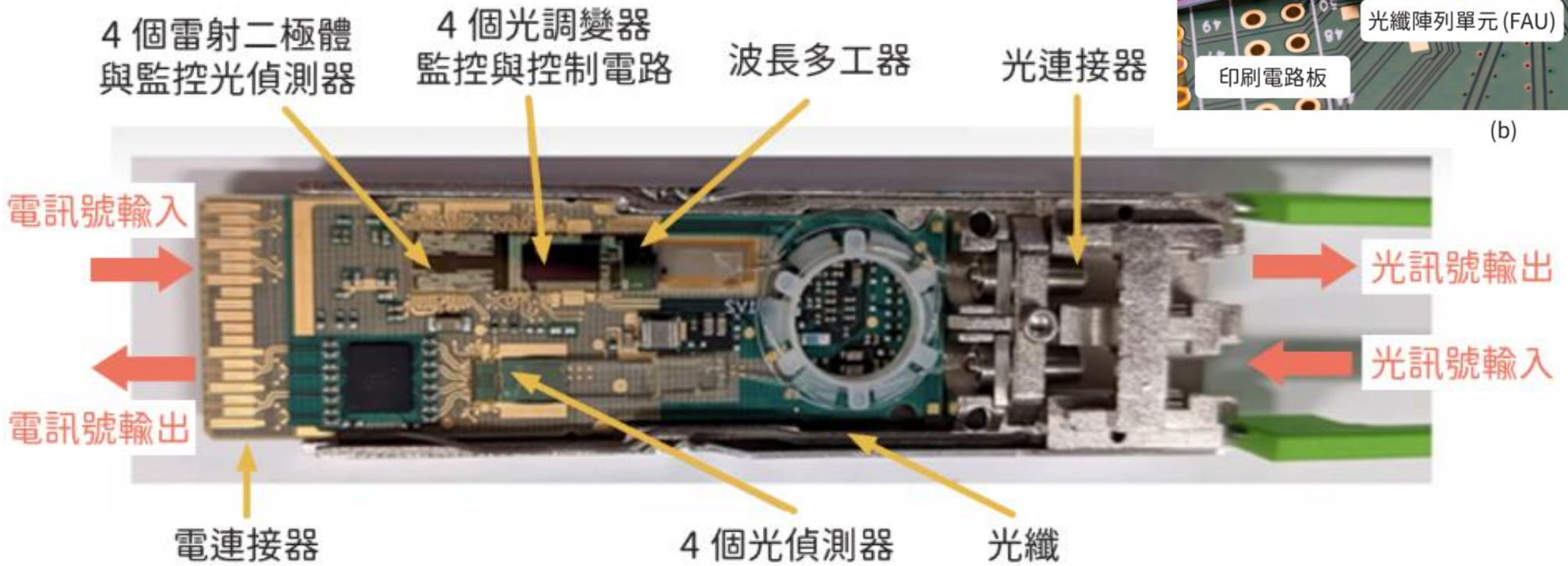
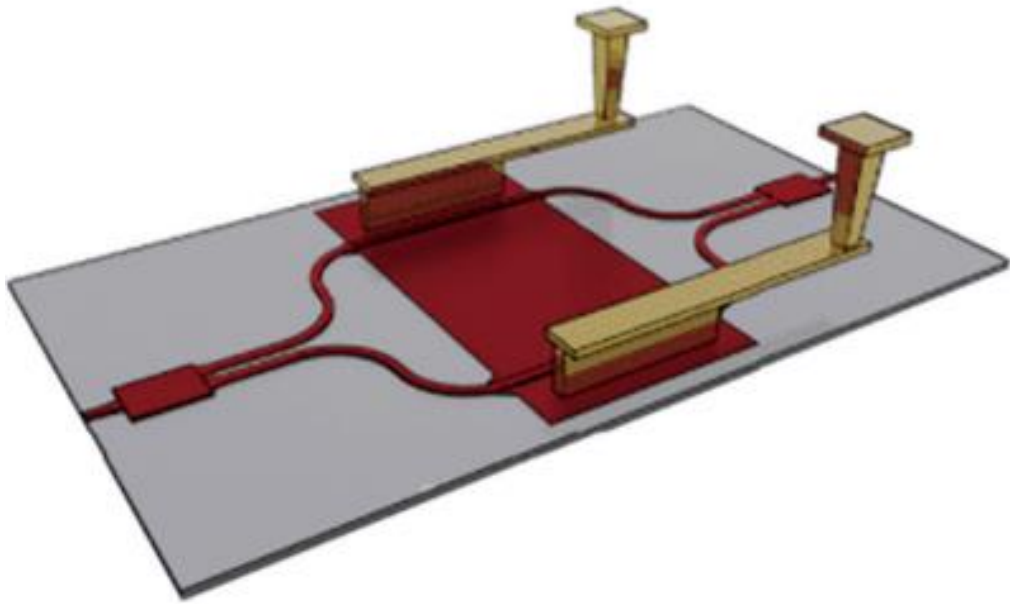
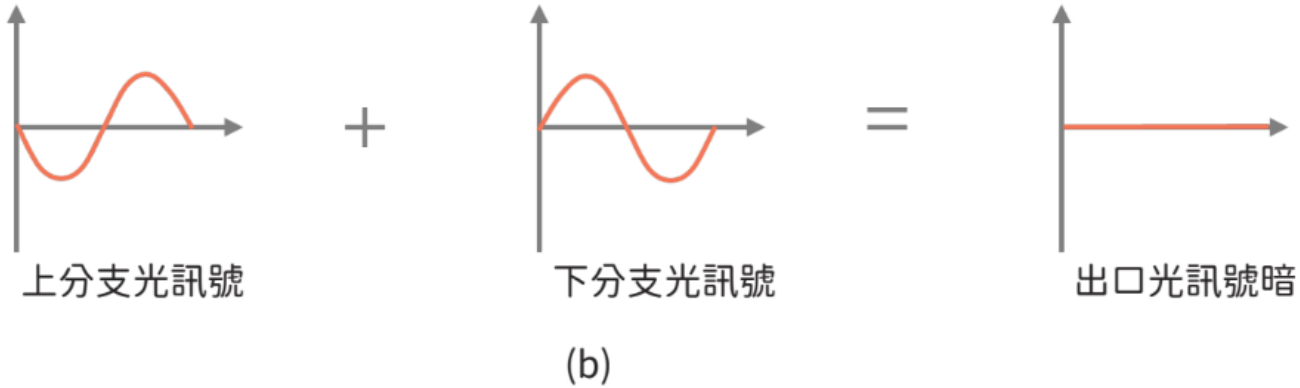


Ref :Intel, IMEC

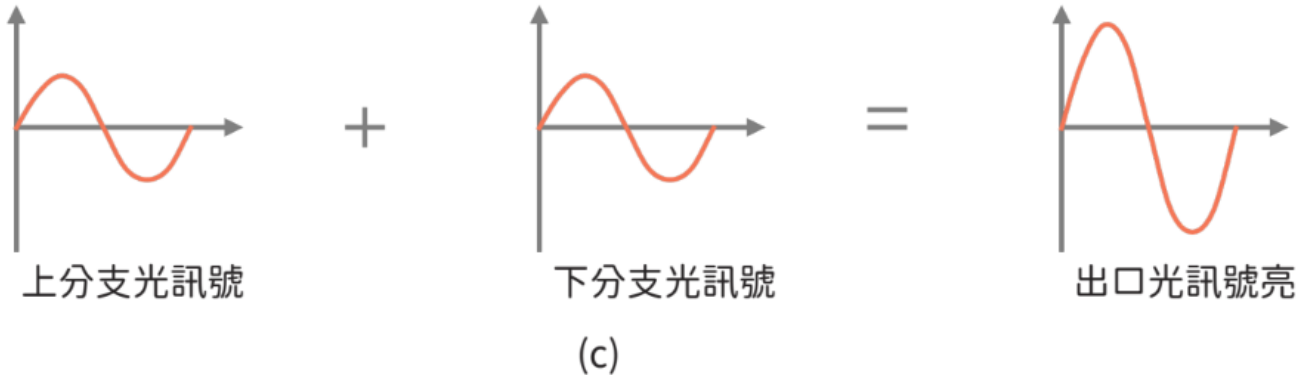
❒ Modulator Battleground: MZM vs. MRM



馬赫任德調變器



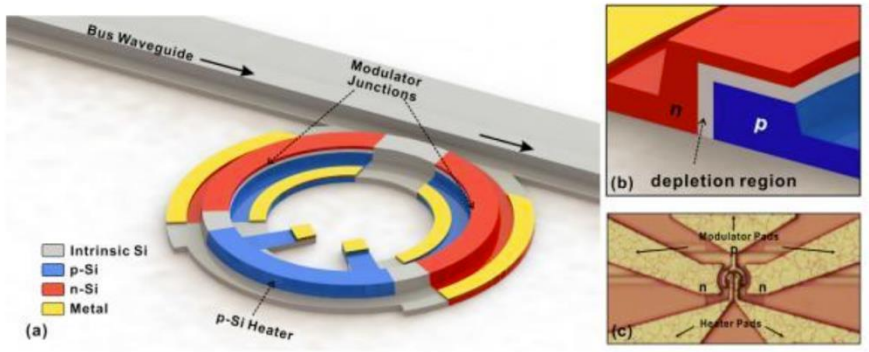
(b)

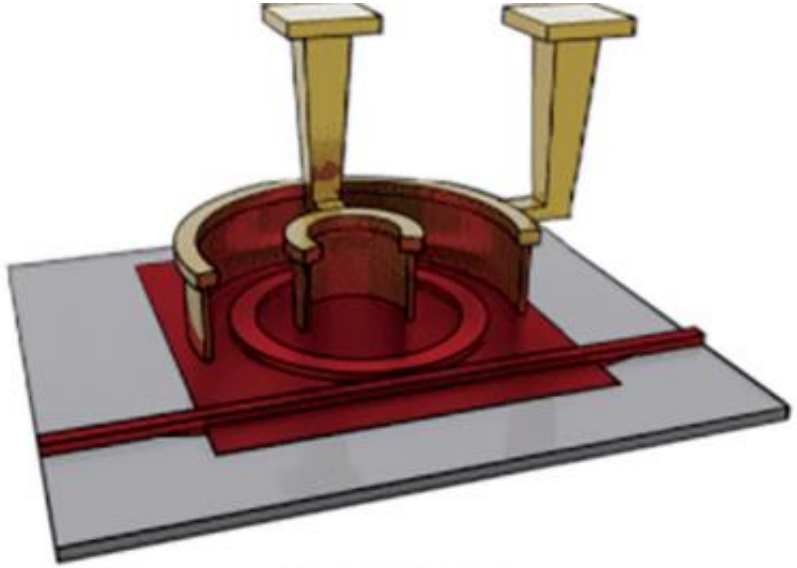


(c)

Ref : WeiSh, etal.Nanophotonics, 曲博科技教室, Intel

❒ Modulator Battleground: MZM vs. MRM





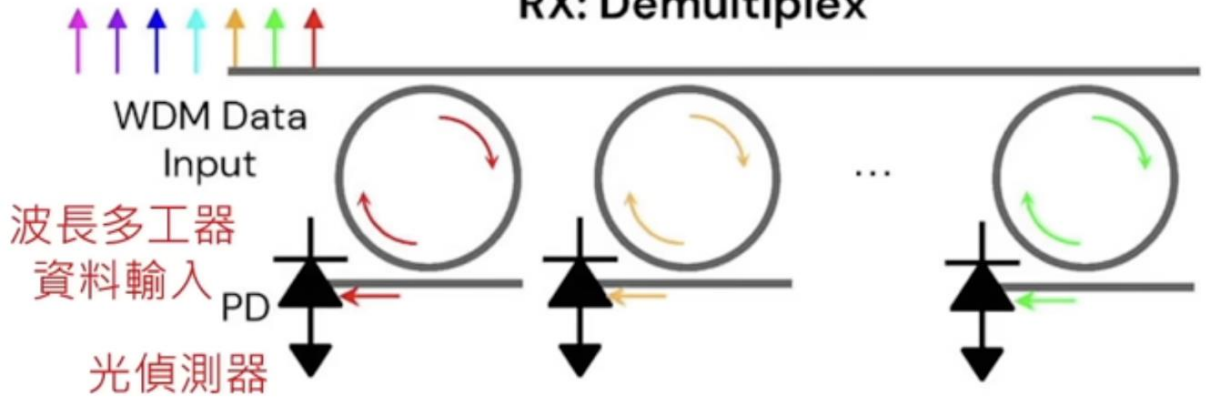
環狀調變器

傳送模組：多工器

TX: Modulate + Multiplex

接收模組：解多工器

RX: Demultiplex



Ref : WeiShi，etal.Nanophotonics, 曲博科技教室, Intel, Lightmatter

LIGHTMATTER

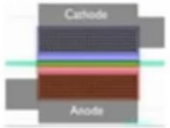
為何微環型調變器是光子學領域的革命性技術？

16

Why rings are revolutionizing photonics

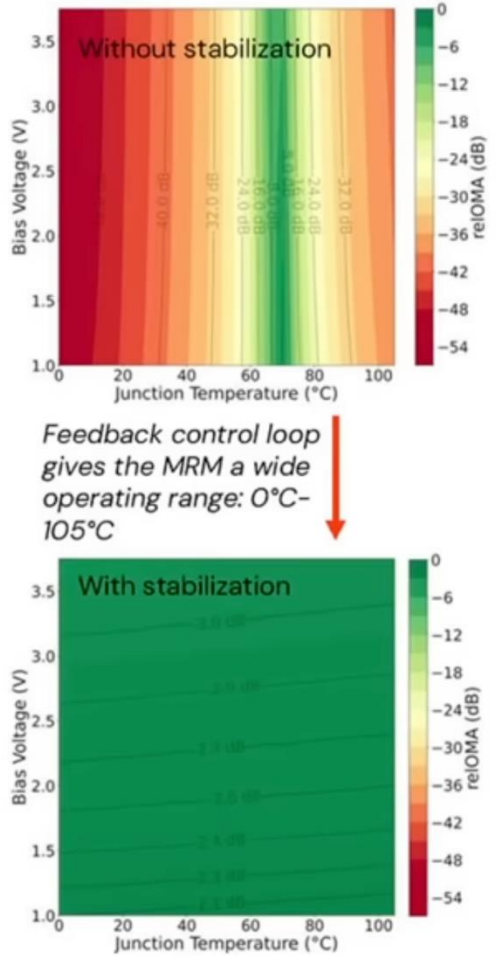
馬赫任德調變器

電致吸收調變器



微環型調變器

Metric	MZM [1]	SiGe/Ge EAM [2, 3]	MRM [4]
3D-CPO compatible?	No, too large. >1000μm	No, too large. 50–100μm	Yes, ~15μm in diameter.
Need another multiplexer?	Yes	Yes	No, already a multiplexer
Thermal stability 熱穩定性	Stable, only thermal gradient between the two arms affect.	Stable with feedback loop. Modulation is temperature dependent.	Stable with feedback loop. Transmission depends on ring resonance.
Power consumption [5]	~50 mW	~10 mW	~1 mW
Transmitter penalty	<5 dB	<10 dB	<5 dB
Optical bands	O-band & C-band	C-band only	O-band & C-band

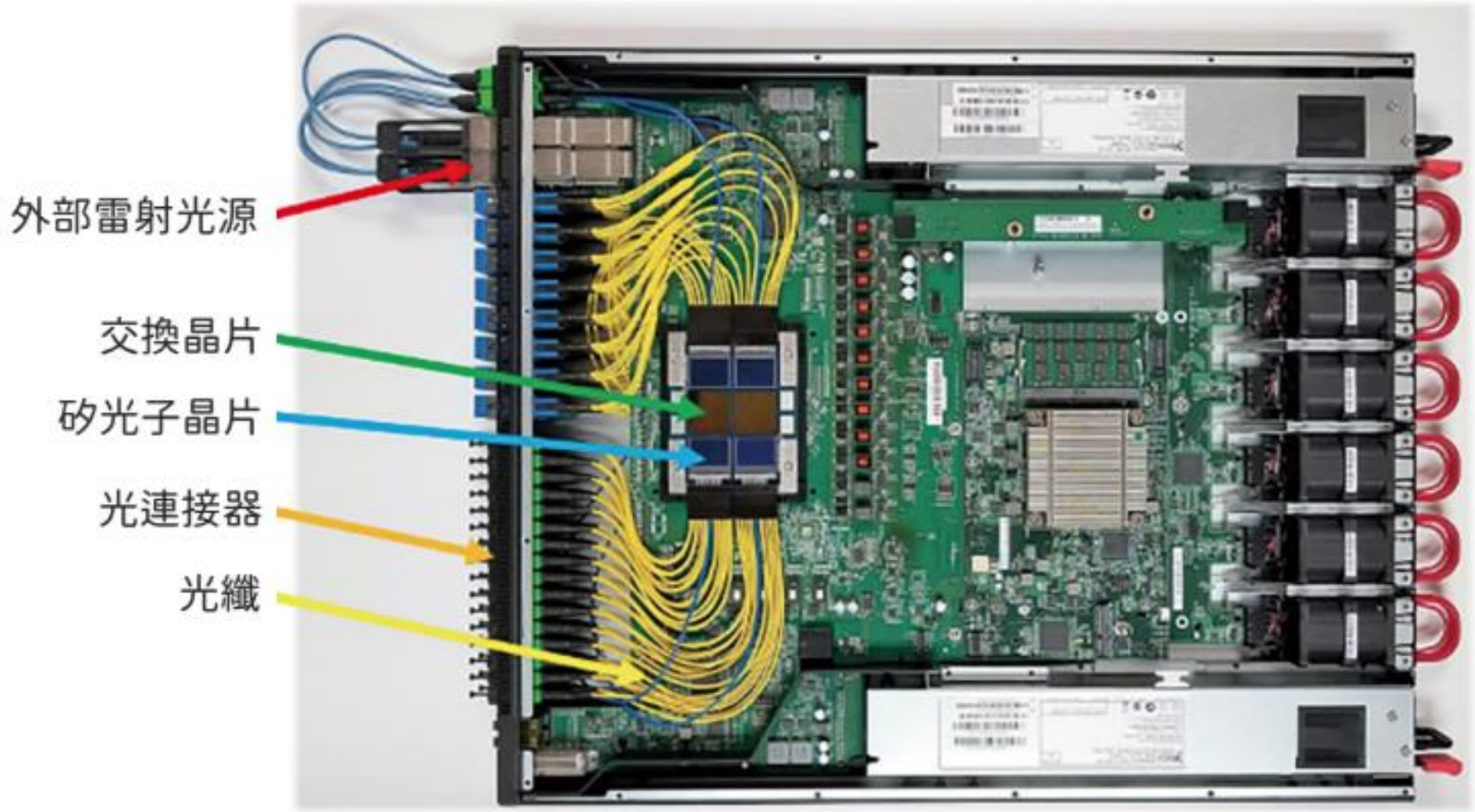


Note: "Relative OMA" (relOMA) is relative to 1 mW laser into the MRM.

[1] M. Streshinsky, et al. Opt. Express 21, 30350-30357 (2013).
[2] J. Fujikata, et al., Opt. Express 31, 10732-10743 (2023).
[3] Y. Liu, et al., PRJ 8, 1474 (2023).
[4] E. Timurdogan, et al. Nature Communications 5, 4008 (2014).
[5] DAB Miller, et al. Opt. Express 20, A293-A308 (2012).

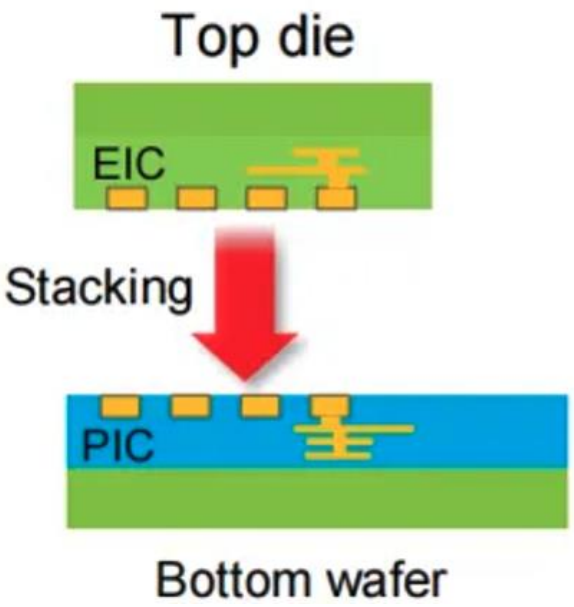
Ref : Lightmatter, 曲博科技教室

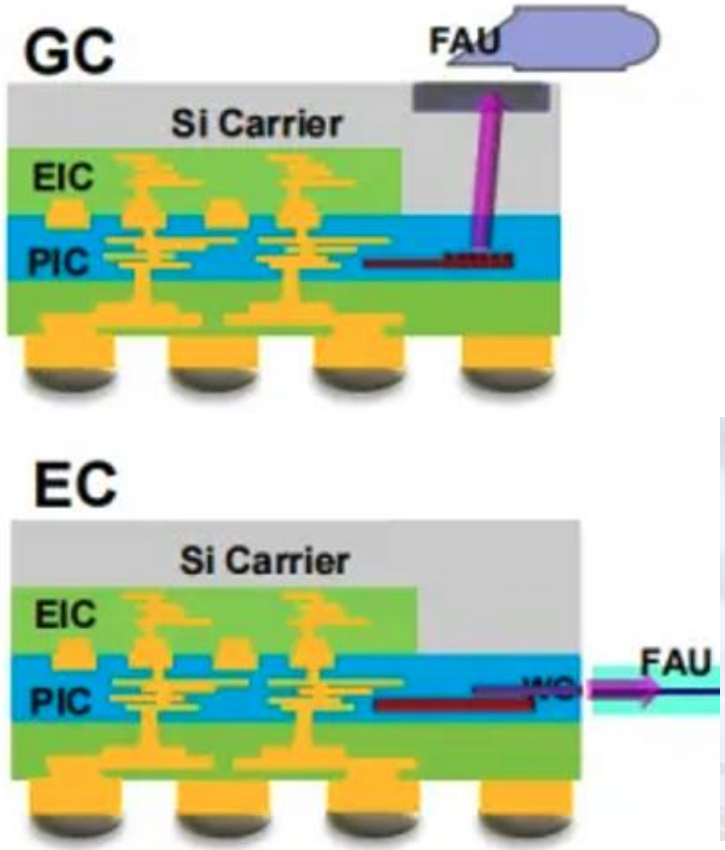
❒ Laser Integration Strategy: External Sources

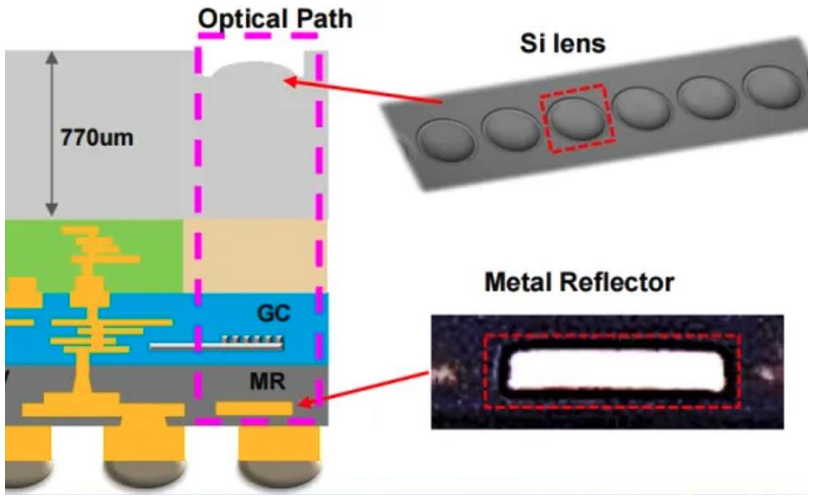


Ref :思科(CISCO), 智邦(Accton), 曲博科技教室

❒ TSMC 緊湊型通用光子引擎
TSMC COUPE （COmpact Universal Photonic Engine）

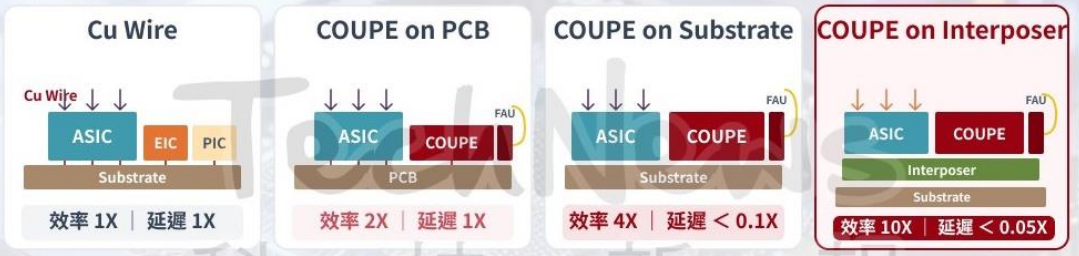






- COUPE on Substrate 較 Cu Wire 提供 4X 電源效率與 10X 延遲改善
- COUPE on Interposer 更進一步達成 10X 電源效率與 20X 延遲改善

封裝剖面示意 | Cross-Section



Ref : TSMC, 鉅亨cnyes, 科技新報Technews

❒ The Silicon Photonics Ecosystem

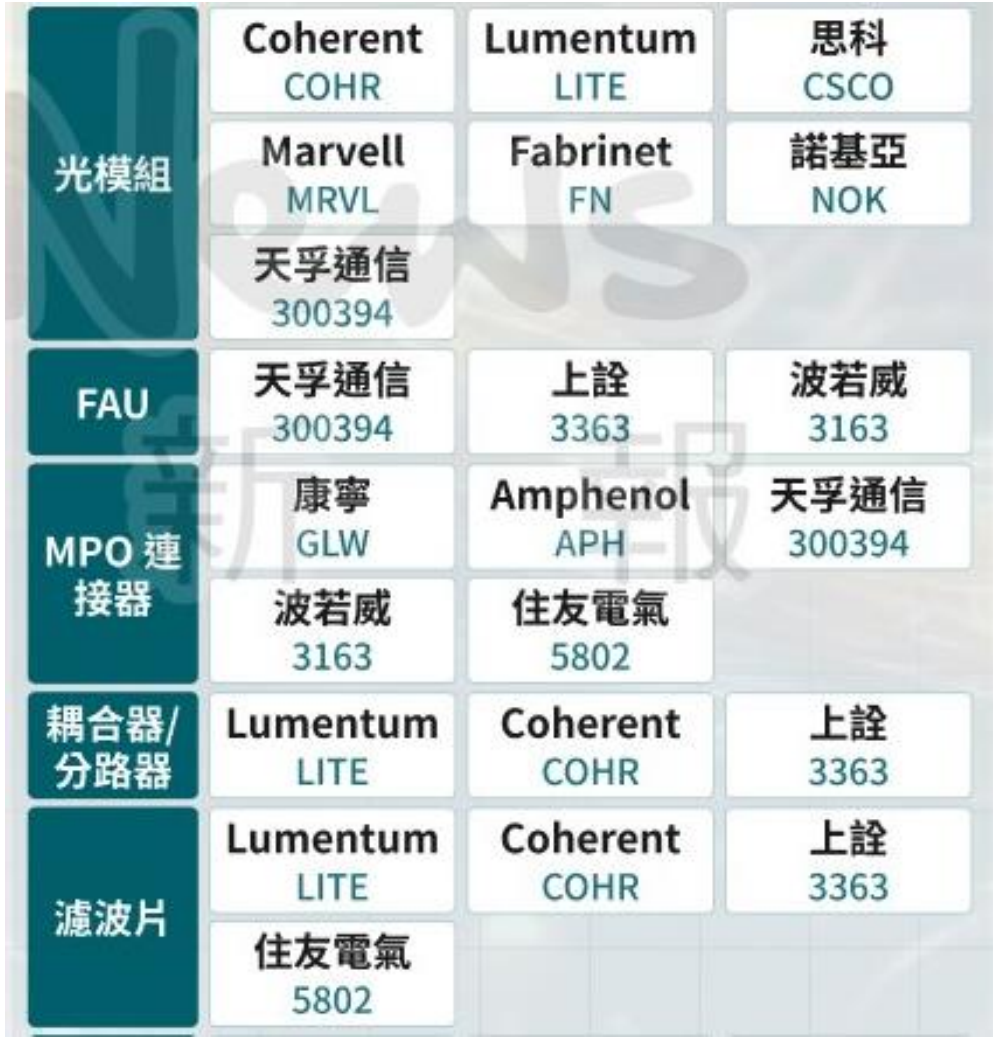
一、IC 設計與製造			
ASIC / xPU	Nvidia NVDA	Marvell MRVL	Broadcom AVGO
	Intel INTC	AMD AMD	聯發科 2454
光子 IC	Nvidia NVDA	Marvell MRVL	Broadcom AVGO
	Lumentum LITE	Coherent COHR	
電子 IC	Nvidia NVDA	Marvell MRVL	Broadcom AVGO
	Lumentum LITE	Coherent COHR	MACOM MTSI
晶圓代工	台積電 TSM	Tower TSEM	GF GFS
	聯電 UMC		

二、材料			
InP 基板	AXT AXTI	住友電氣 5802	
Epi wafer	IQE	全新 2455	IET-KY 4971
	聯亞 3081	住友電氣 5802	
砷化鎵基板	AXT AXTI	住友電氣 5802	
CCL	台光電 2383	台燿 6274	聯茂 6213

Ref :科技新報Technews

❒ The Silicon Photonics Ecosystem

三、光組件			
雷射/光源(矽光)	Lumentum LITE	Coherent COHR	Broadcom AVGO
	祥茂光電 AAOI	聯亞 3081	
雷射/光源(EML)	Lumentum LITE	Coherent COHR	Broadcom AVGO
	天孚通信 300394	上詮 3363	
光模組	Coherent COHR	Lumentum LITE	思科 CSCO
	Marvell MRVL	Fabrinet FN	諾基亞 NOK
	天孚通信 300394		
FAU	天孚通信 300394	上詮 3363	波若威 3163



光模組	Coherent COHR	Lumentum LITE	思科 CSCO
	Marvell MRVL	Fabrinet FN	諾基亞 NOK
	天孚通信 300394		
FAU	天孚通信 300394	上詮 3363	波若威 3163
MPO 連接器	康寧 GLW	Amphenol APH	天孚通信 300394
	波若威 3163	住友電氣 5802	
耦合器/分路器	Lumentum LITE	Coherent COHR	上詮 3363
濾波片	Lumentum LITE	Coherent COHR	上詮 3363
	住友電氣 5802		

Ref :科技新報Technews

❒ The Silicon Photonics Ecosystem

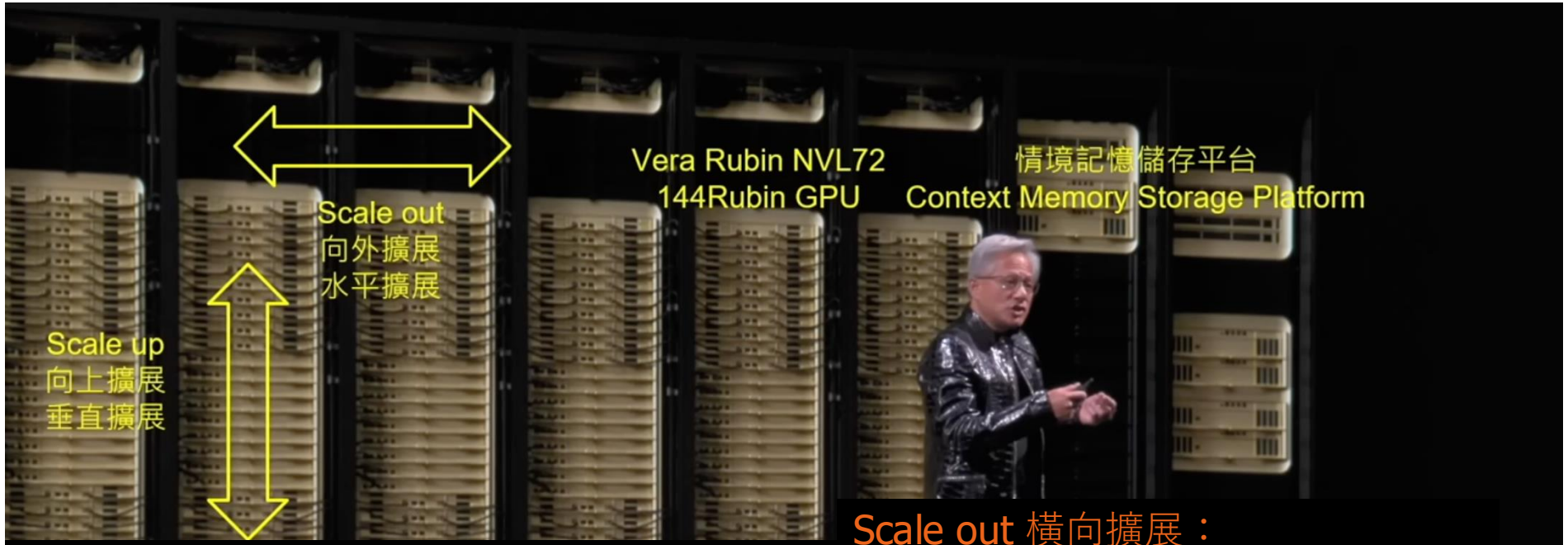
VSFF 連接器	康寧 GLW	Amphenol APH	藤倉 5803
	住友電氣 5802	波若威 3163	
波分復用	Lumentum LITE	Ciena CIEN	光迅科技 002281
	天孚通信 300394	上詮 3363	
光纖	康寧 GLW	住友電氣 5802	藤倉 5803
	古河電工 5801		
衰減器	Lumentum LITE	上詮 3363	

科技新報整理

四、封裝與測試			
測試設備	泰瑞達 TER	Keysight KEYS	FormFactor FORM
	愛德萬 ATEYY	旺矽 6223	致茂 2360
	鴻勁 7769	汎銓 6830	
封測服務	日月光 ASX	Fabrinet FN	Amkor AMKR
	捷普 JBL		
封裝設備	庫力索法 KLIC	萬潤 6187	致茂 2360

Ref :科技新報Technews

❒ Dual Engines for AI Computing: Scale Out & Scale Up



Scale up 縱向擴展：

加速單一伺服器的資料處理效能

- 將光模組與高效能晶片（如GPU）共同封裝，減少I/O瓶頸
- 提供極高頻寬與低延遲的內部互連
- 適合單一節點內部的高速資料交換

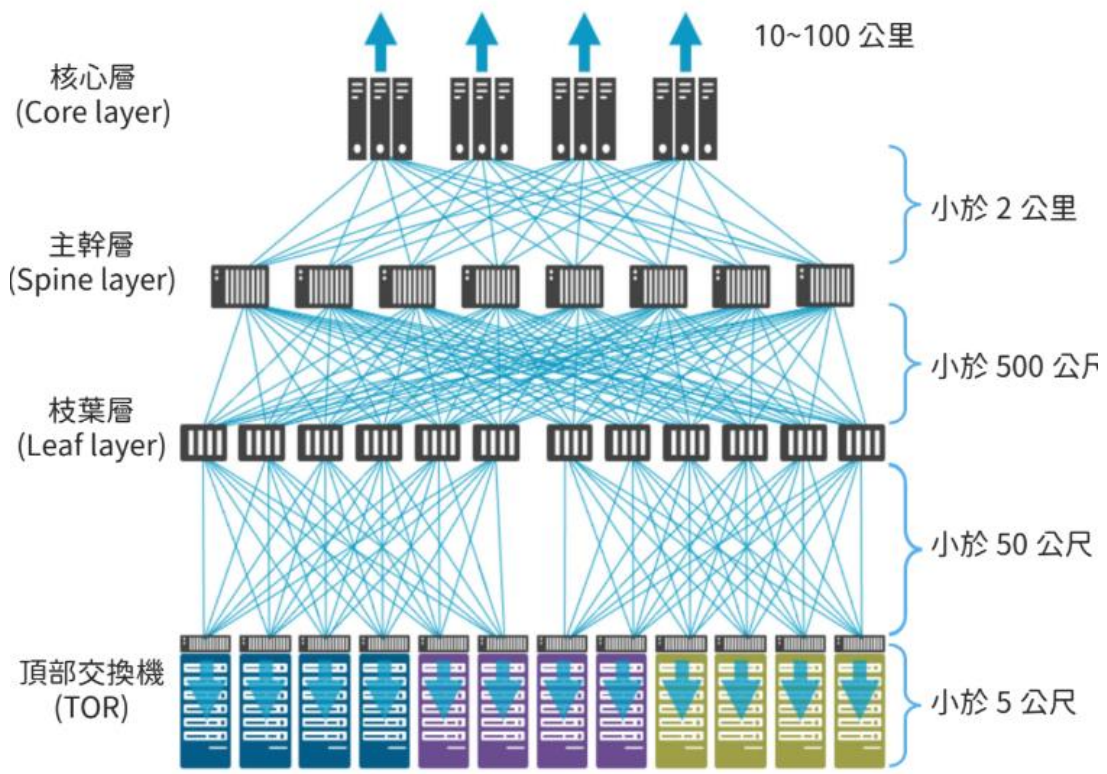
Scale out 橫向擴展：

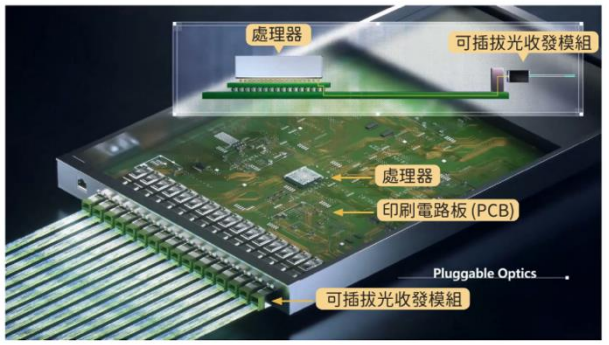
銜接更多節點、提升整體頻寬

- 透過光互連技術實現節點間高速連接
- 降低傳統電纜的功耗與空間限制
- 支援模組化設計，便於節點擴充與維護

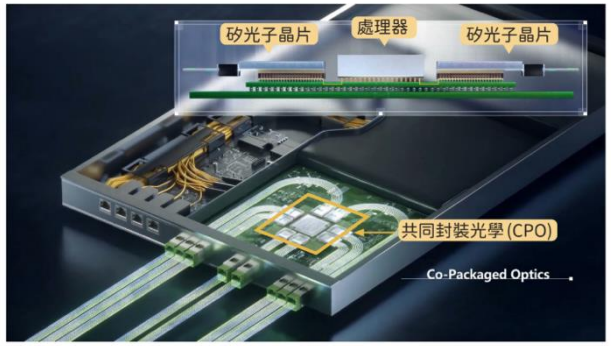
Ref : Nvidia, 工研院產科國際所

❒ Dual Engines for AI Computing: Scale Out & Scale Up

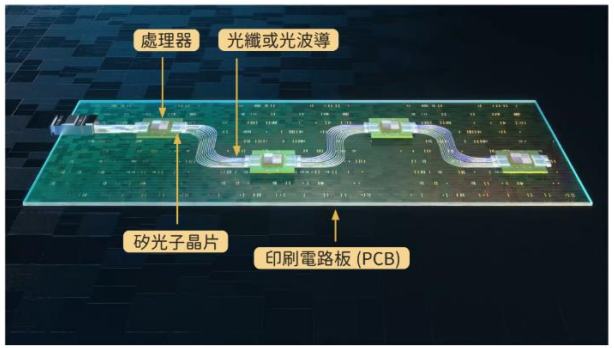




(a)



(b)



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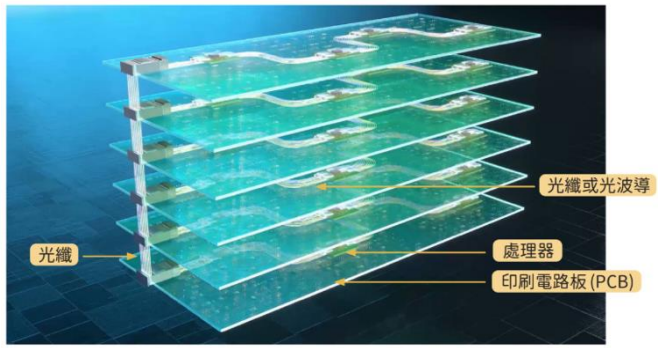
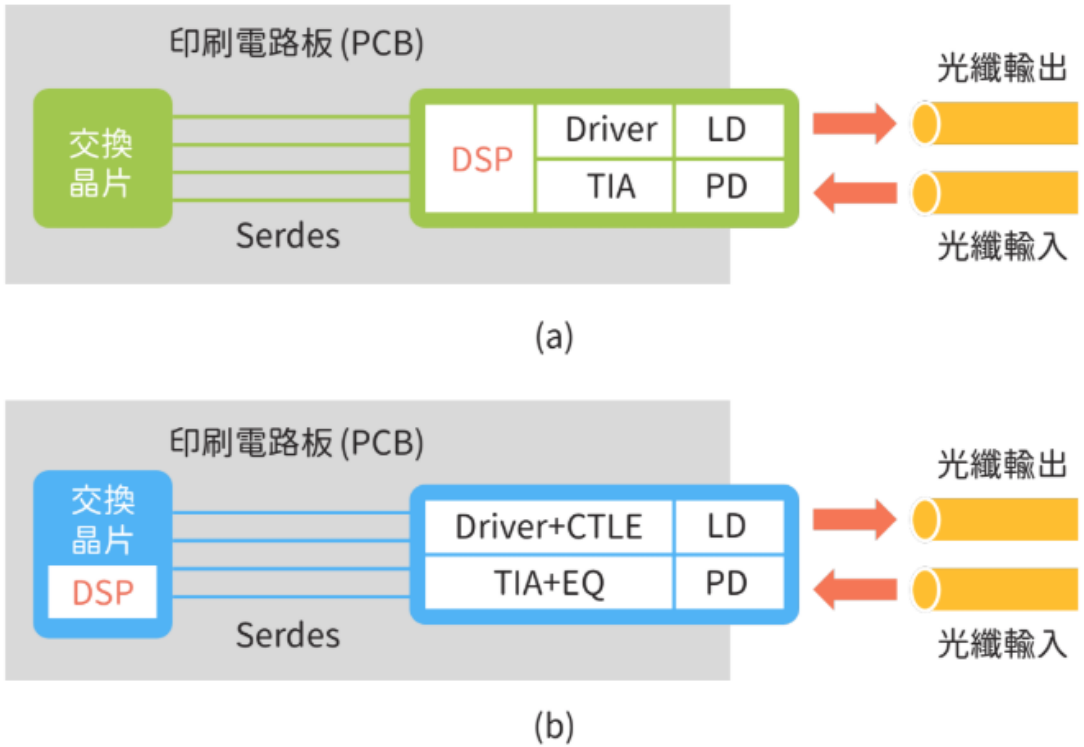


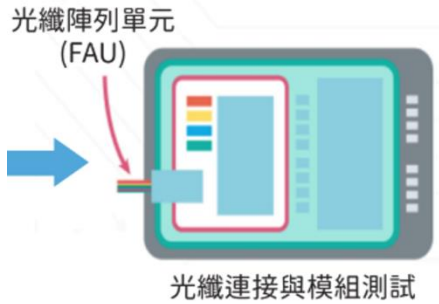
(d)

Ref :日月光(ASE)

❒ Transition Technology: LPO (Linear-drive Pluggable Optics)



❒ Multi-Physics Testing Demand



四、封裝與測試			
測試設備	泰瑞達 TER	Keysight KEYS	FormFactor FORM
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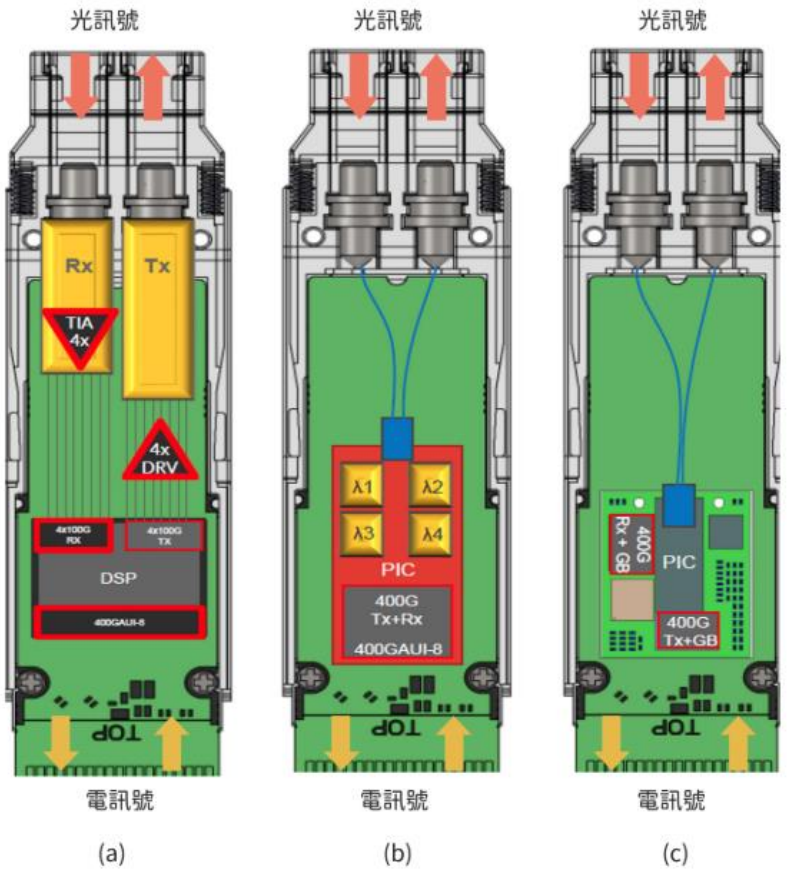
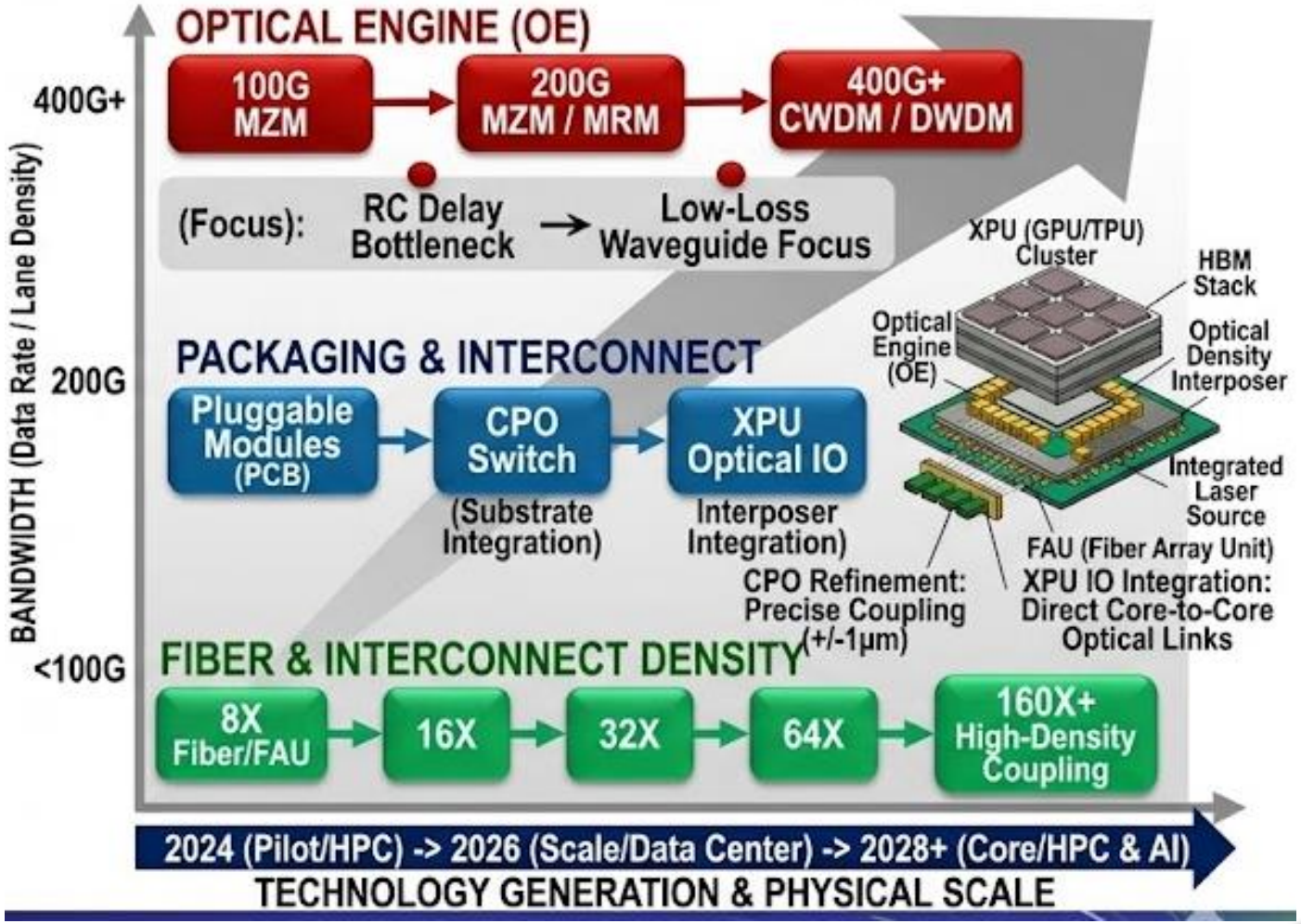
	捷普 JBL		
封裝設備	庫力索法 KLIC	萬潤 6187	致茂 2360

Ref :曲博科技教室, 日月光(ASE), 科技新報Technews

❒ SiPh Roadmap: Bandwidth Growth

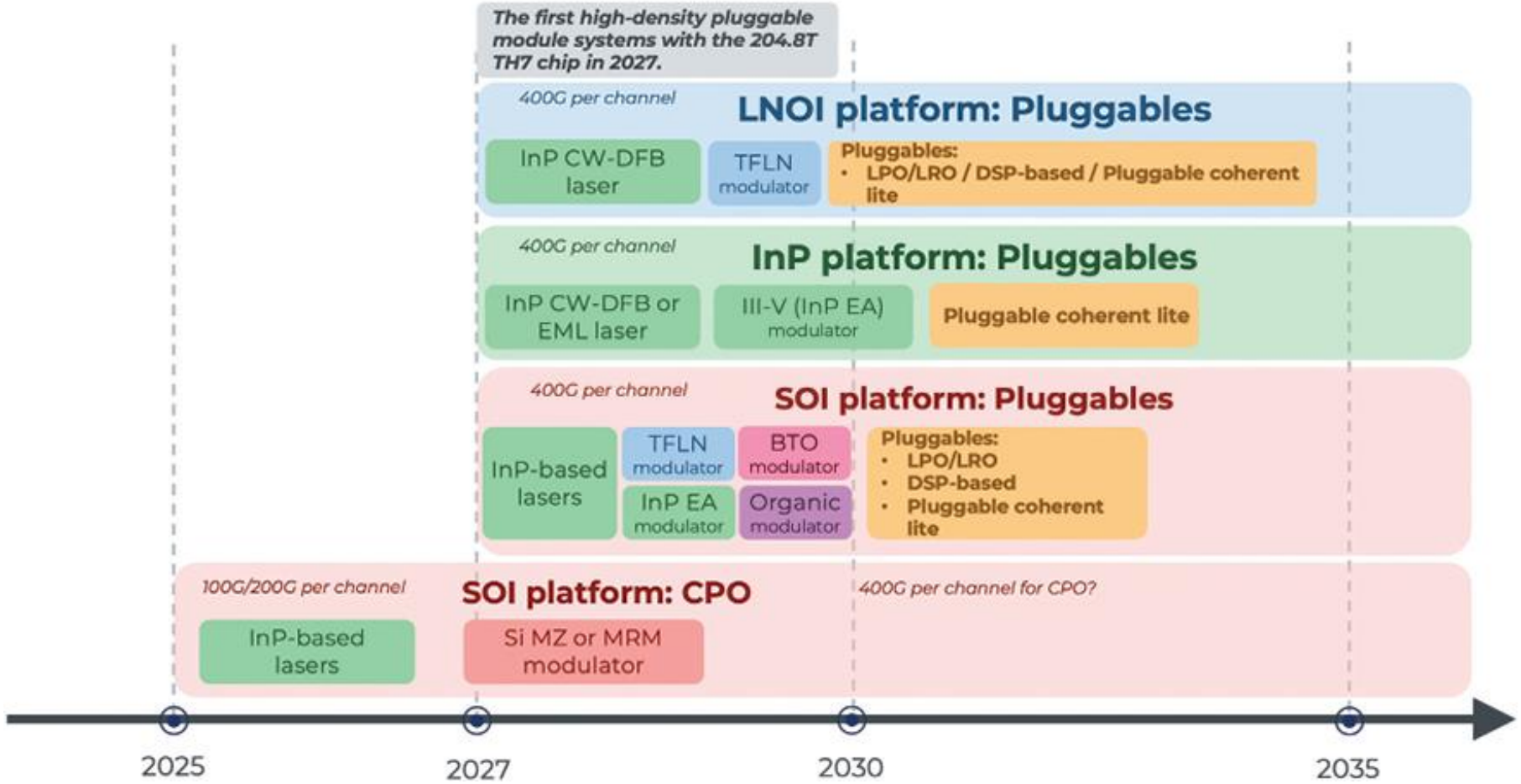




Ref :曲博科技教室, TSMC

❒ SiPh Platform

Source: Silicon Photonics 2025 - Focus on SOI, SiN, LNOI, InP platforms, report Yole Group



Ref :Yole, Laserfocusworld

❒ SiPh Light Source (Micro LED)

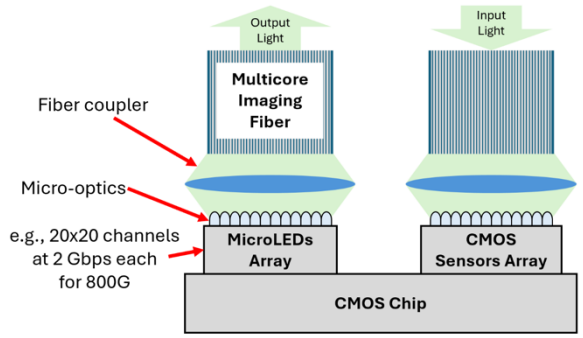


Figure 3: MOSAIC's high-level WaS architecture and key components.

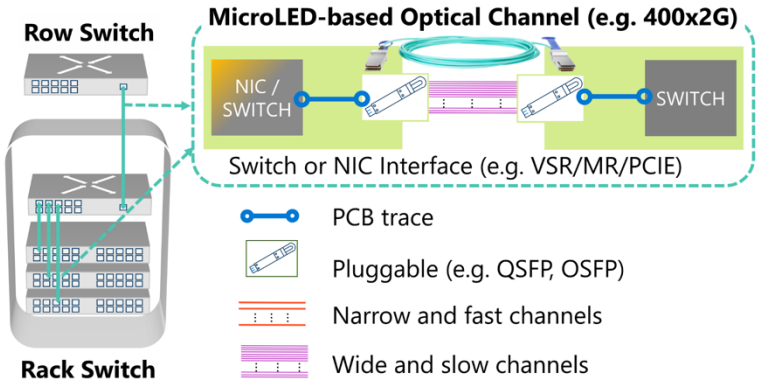


Figure 5: MOSAIC can seamlessly replace existing optical and copper cables without any hardware changes.

Micro LED CPO與矽光子CPO比較

	銅線 (PCIe)	Micro LED	VCSEL	CW雷射 (矽光子CPO)	EML
最大傳輸距離 (公尺)	1	10-50	100	1,000	40,000
傳輸速率 (Gbps/Lane)	4	2-4	10-50	50	100
能耗 (pJ/bit)	>10	1-2	4	5	4.5
最高工作溫度 (°C)	125	125	85	75	85
延遲	低	低	中	中	中
CMOS整合難度	易	易	中	難	中
相對成本 (bit)	低	低	中	高	中

Ref :TrendForce, Microsoft

❒ SiPh Light Source (WDM Laser)

LIGHTMATTER

引導：外部波長多工雷射

Guide™: External WDM laser

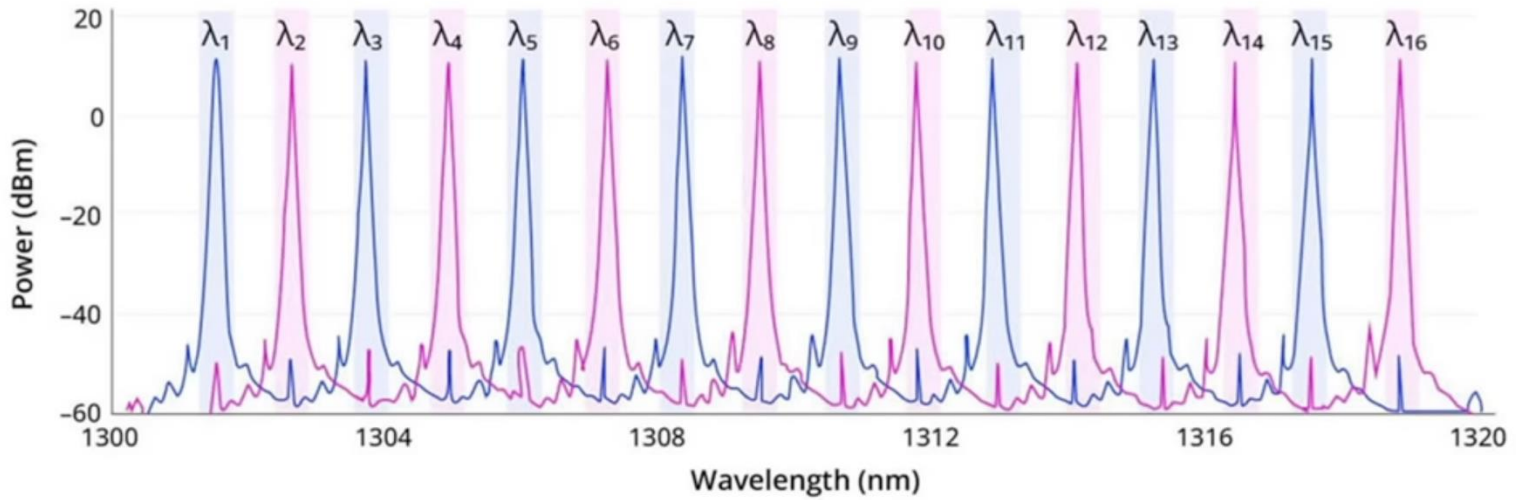
每條光纖最多可以傳輸16個波長200GHz網格

Up to 16 wavelengths per fiber, 200 GHz grid

16 fiber output

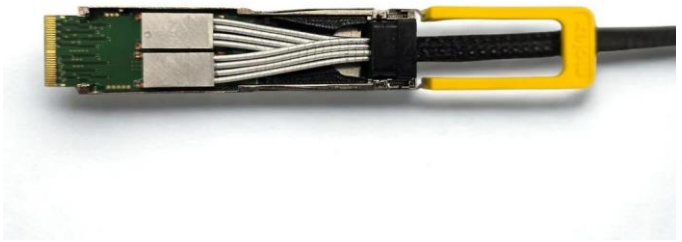
Optimized for microring modulator Tx architectures

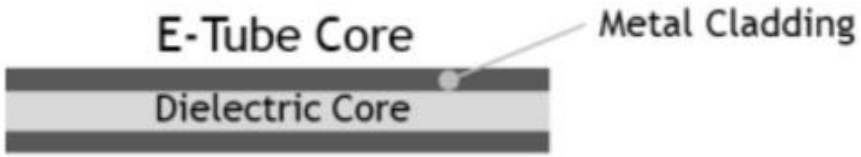
總共16光纖輸出針對微環型調變器傳送器架構進行優化



Ref :Lightmatter, 曲博科技教室

❒ SiPh Transmission (THz waveguide)





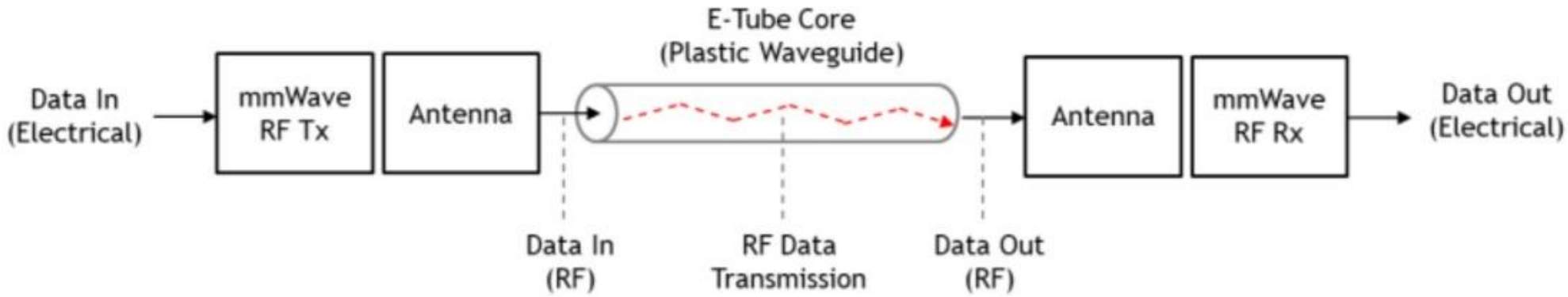
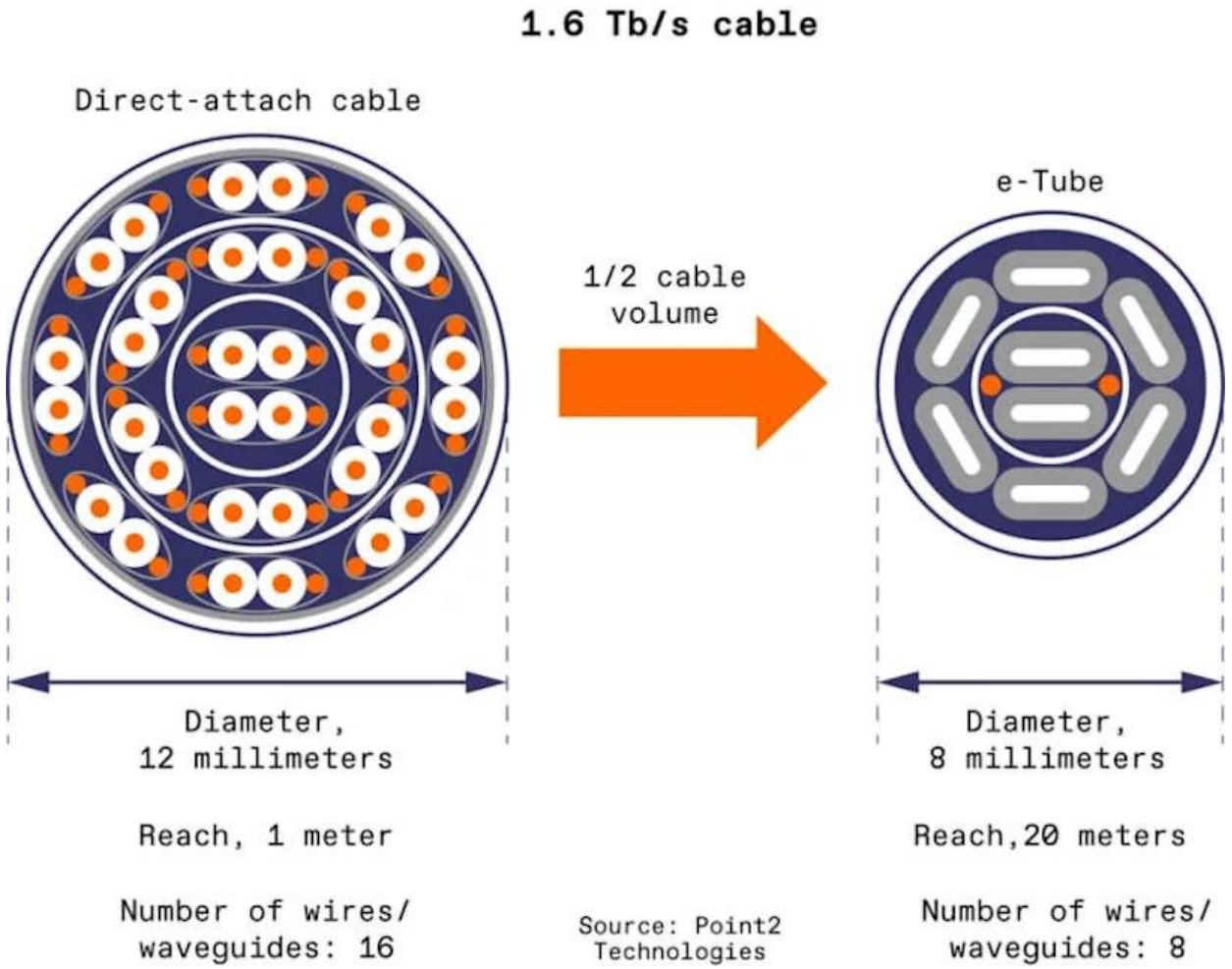
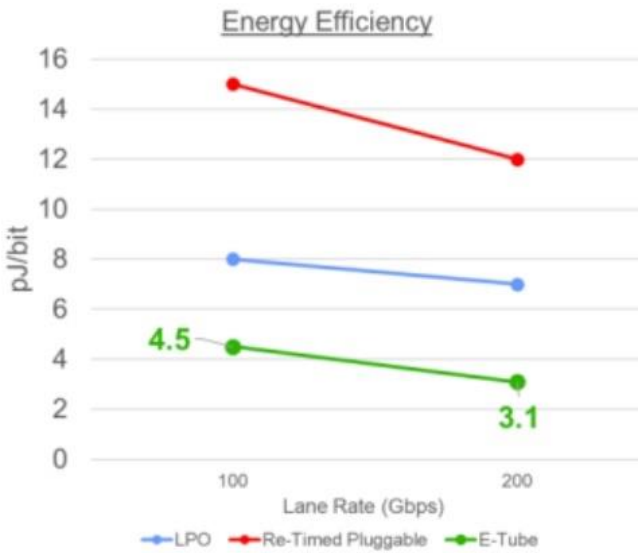


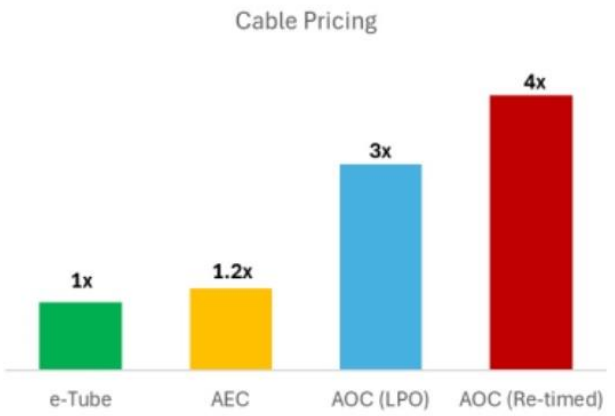
Figure 5: E-Tube Architecture

Ref :AttoTude、Point2, 曲博科技教室

❒ SiPh Transmission (THz waveguide)







Ref :AttoTude、Point2, 曲博科技教室

Thank you for your attention !