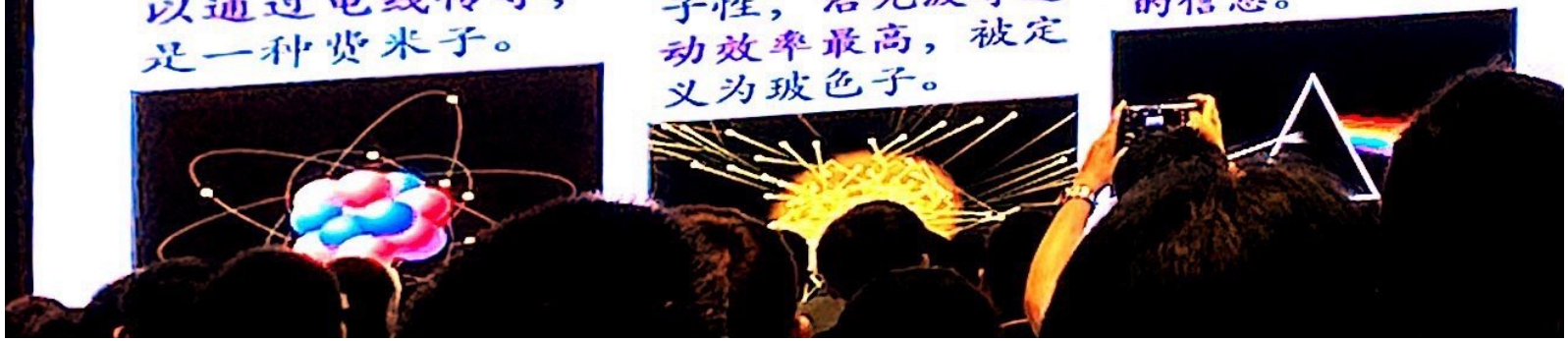
SPM

信息技术的基本要素：
电子，光子，光谱

电子是构成物质的基本粒子之一。它绕原子核运动，可以通过电线传导，是一种货米子。

光子是一种电磁波的量子状态。它同时具有波动性和粒子性，沿光波导运动效率最高，被定义为玻色子。

光谱表达光波的不同频率分布。如可见光中不同颜色对应不同的光谱区，可以分别携带不同的信息。



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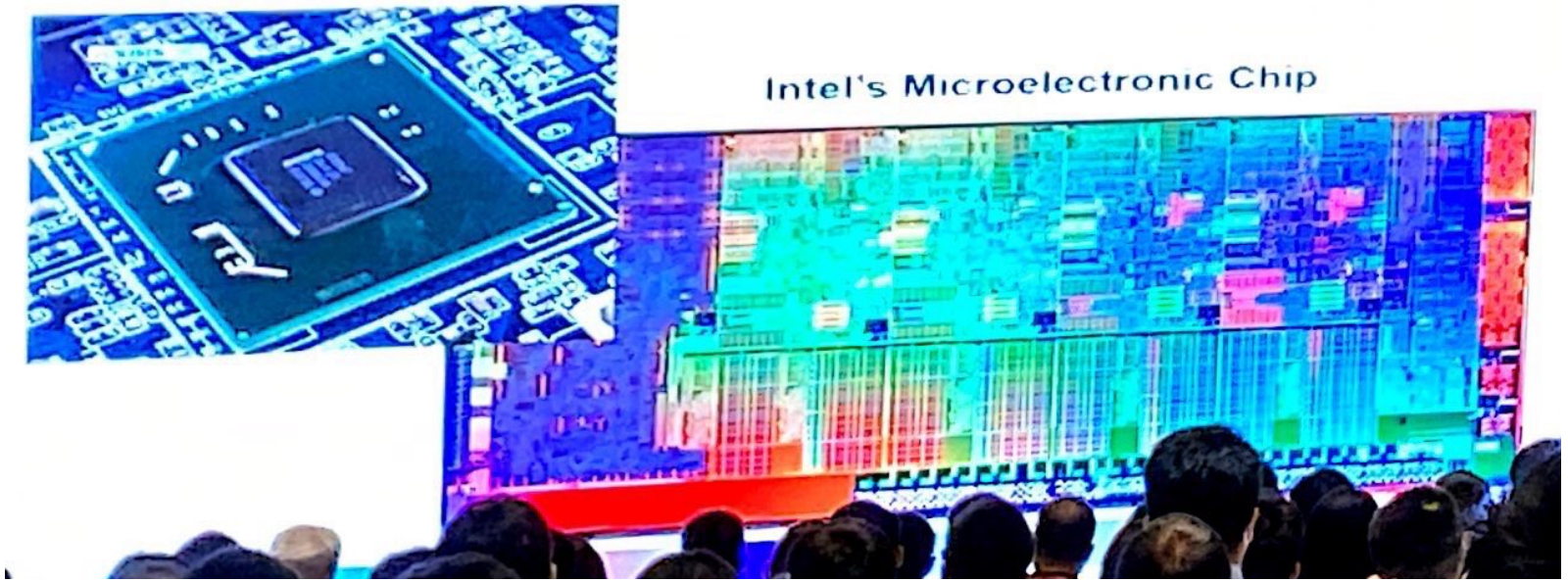
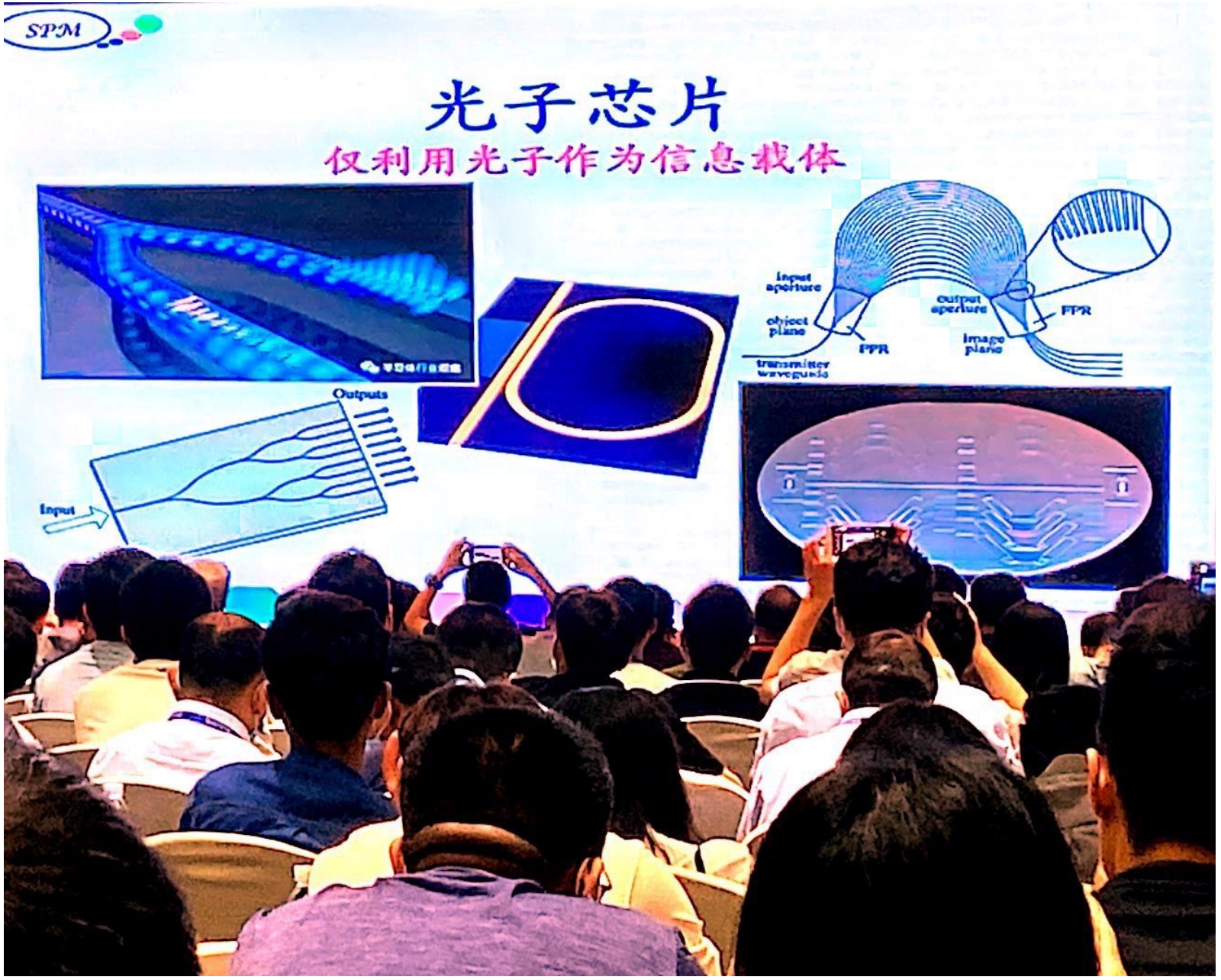
几个学科/芯片的定义和区别

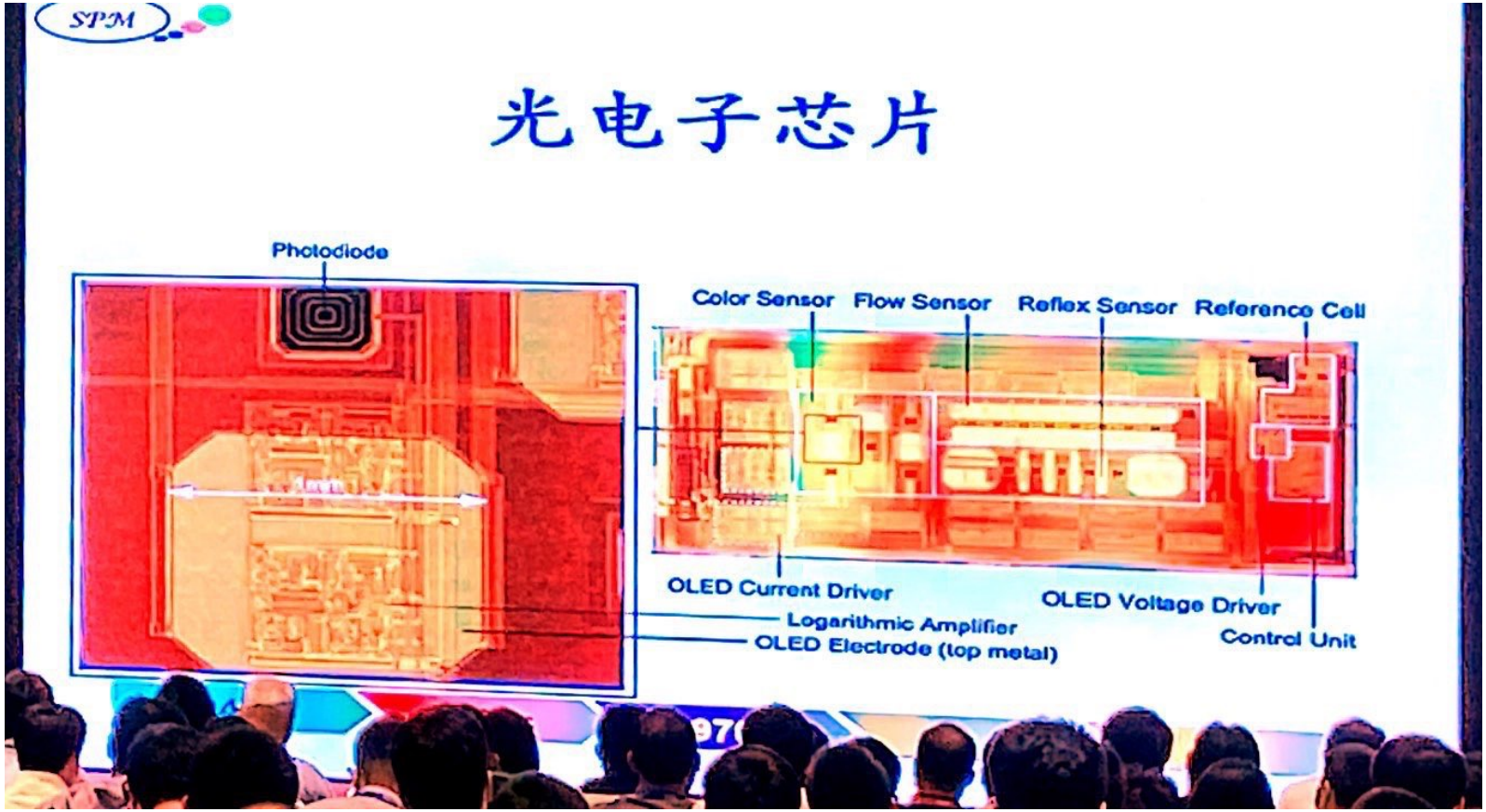
Electronics 电子学	电子芯片/集成电路
Photonics 光子学	光子芯片
Optoelectronics 光电子学	光电子芯片
Silicon Based Optoelectronics 硅基光电子学	硅基光电子芯片

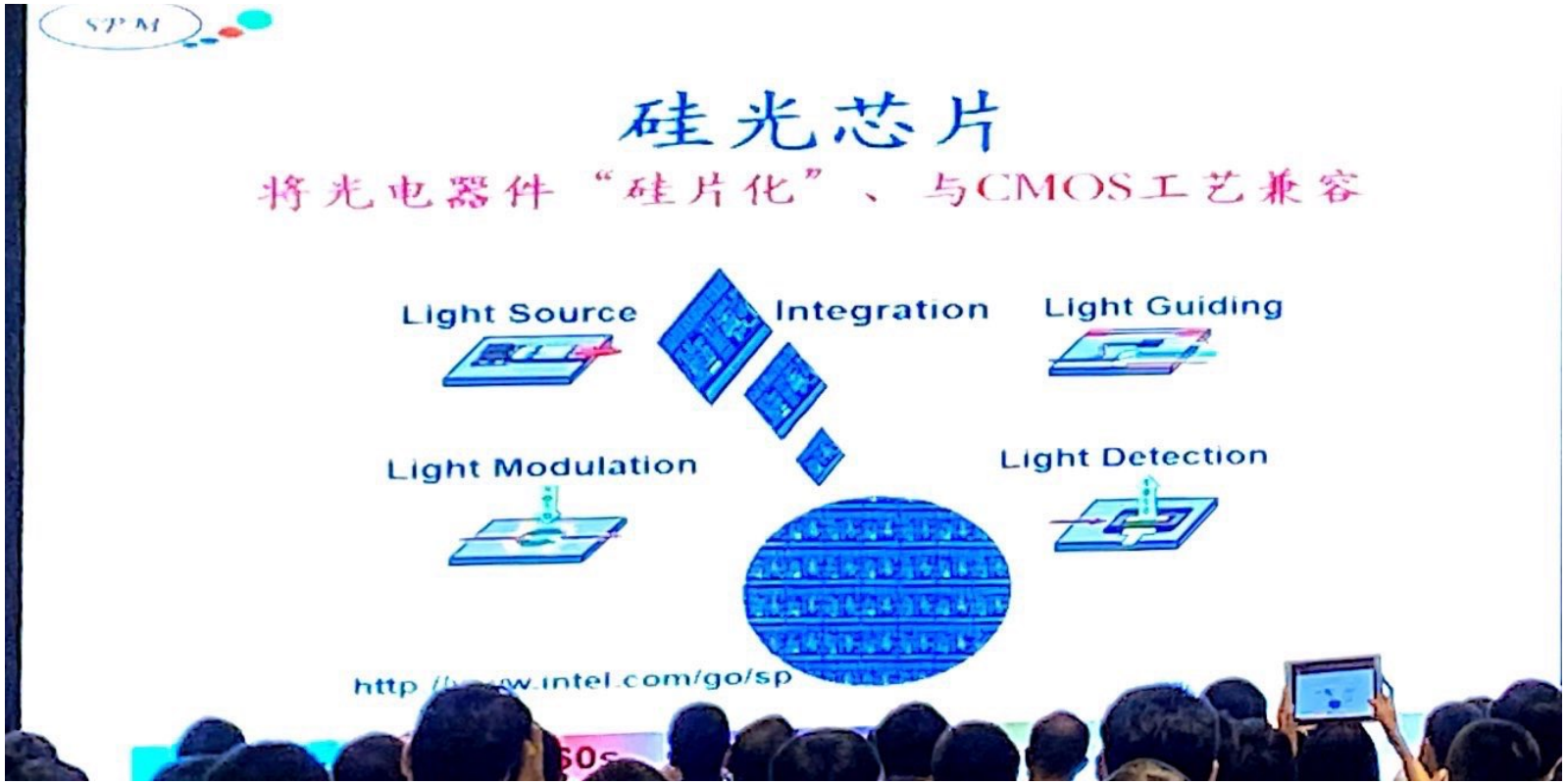
电子芯片

仅利用电子作为信息载体

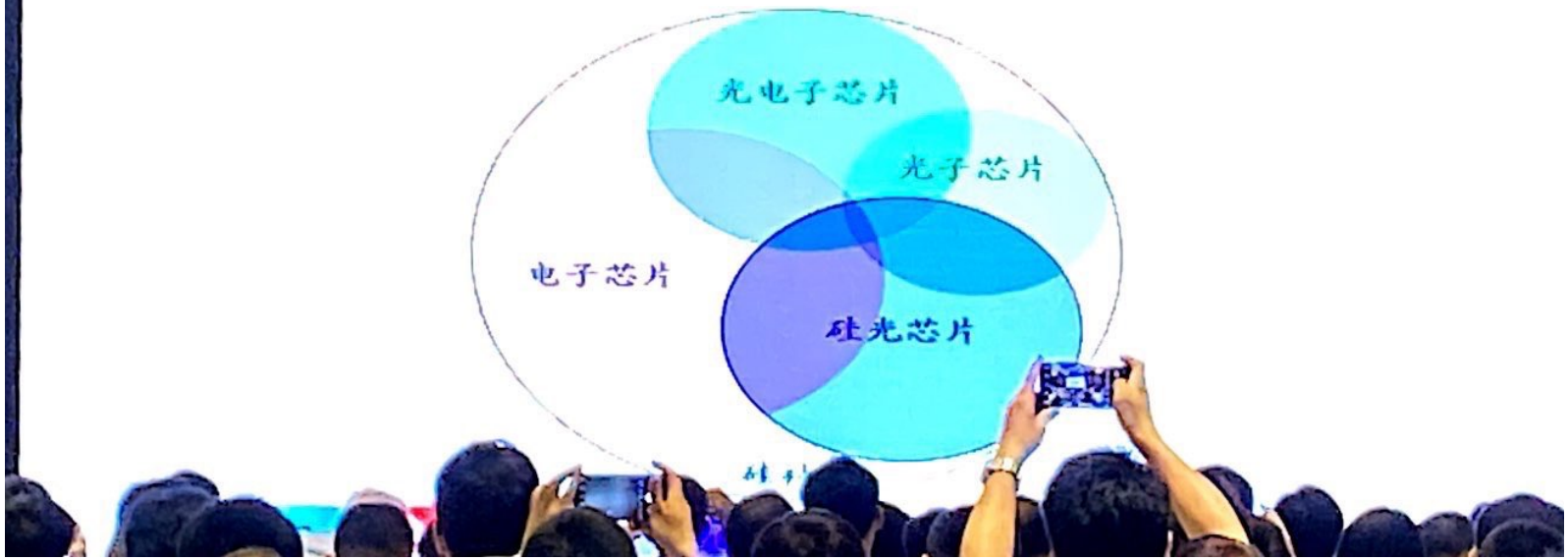



SPM
光子芯片
仅利用光子作为信息载体
Outputs
Input
input aperture
output aperture
object plane
image plane
FPR
FPR
transmitter waveguide


SPM
光电子芯片
Photodiode
Color Sensor
Flow Sensor
Reflex Sensor
Reference Cell
OLED Current Driver
OLED Voltage Driver
Logarithmic Amplifier
OLED Electrode (top metal)
Control Unit

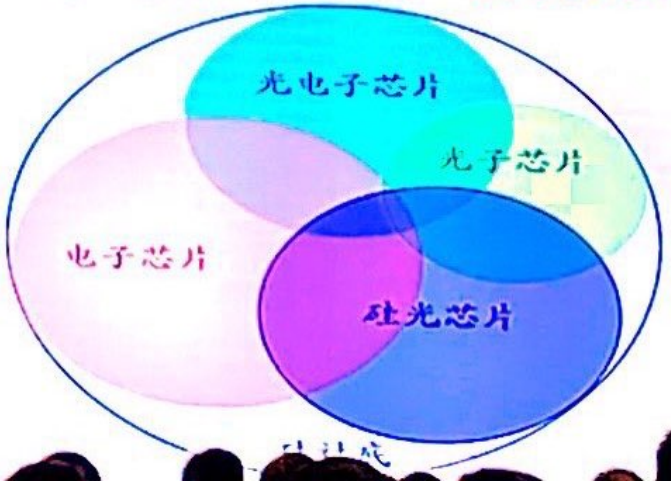

硅光芯片
将光电器件“硅片化”、与CMOS工艺兼容
Light Source
Integration
Light Guiding
Light Modulation
Light Detection
http

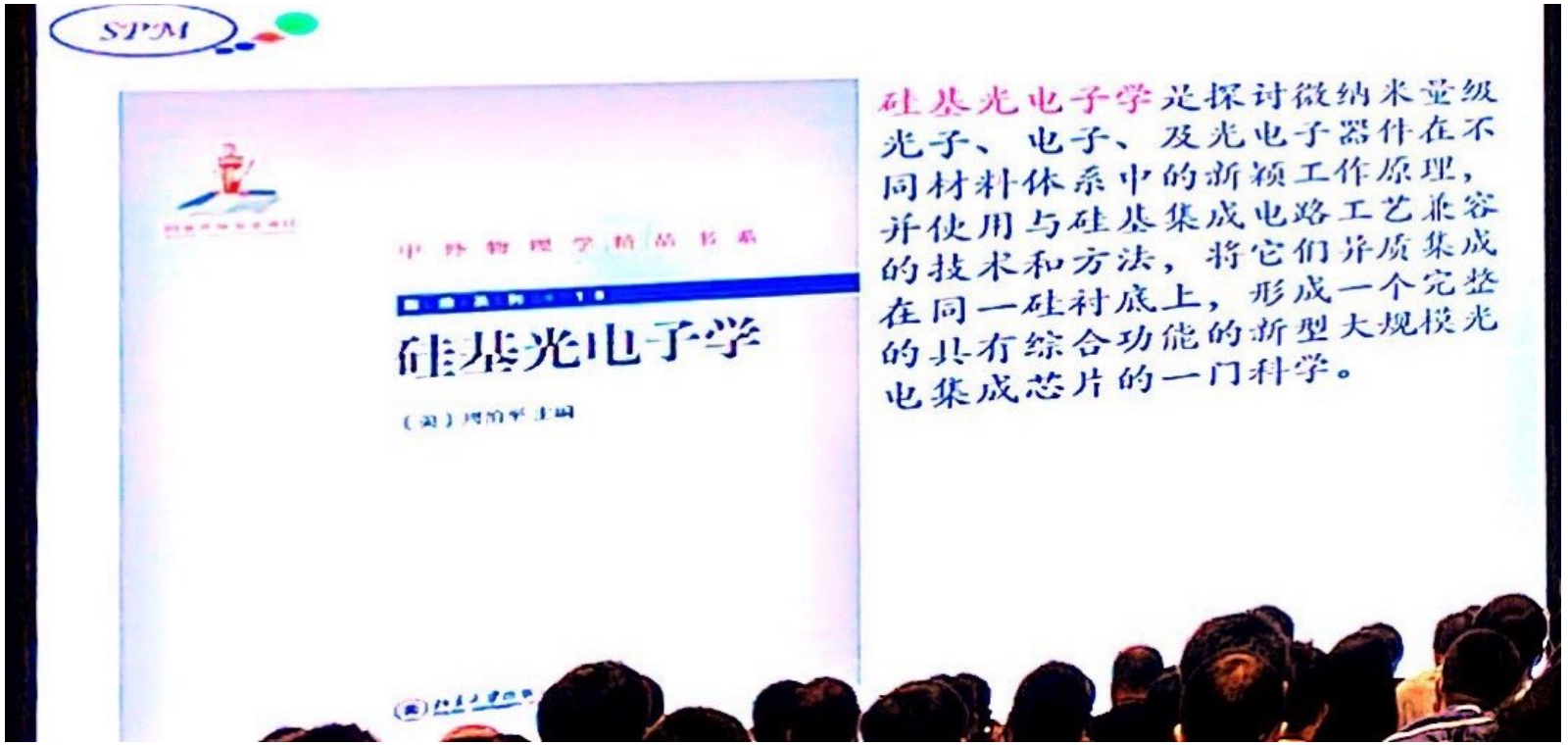
硅基光电子芯片



硅基光电子芯片

以硅材料为平台，包含前述4种芯片，
注重光子和电子的相互作用，强调大规模异质集成




SPM
中外物理学精品书系
硅基光电子学
硅基光电子学是探讨微纳米量级光子、电子、及光电子器件在不同材料体系中的新颖工作原理，并使用与硅基集成电路工艺兼容的技术和方法，将它们异质集成在同一硅衬底上，形成一个完整的具有综合功能的新型大规模光电集成芯片的一门科学。

SPM

电子和光子的产业应用

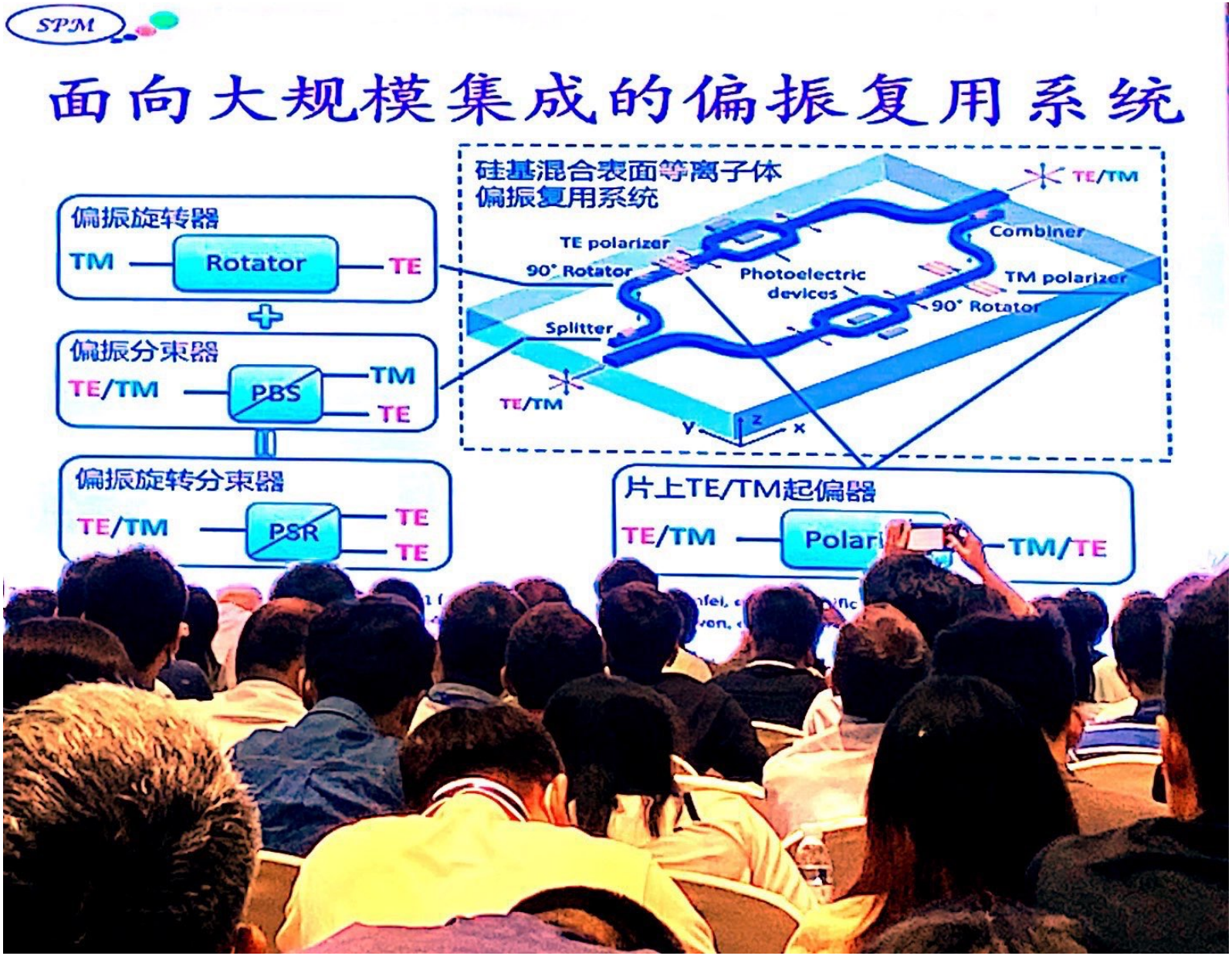
电子之间有强相互作用，因此形成了“电子产业”；光子之间基本上没有互动，也就无法形成自己的产业。

目前与光相关的产品，除了光波导，基本上都是光电共同作用的产物。“光电产业”也已经广泛应用于消费市场。

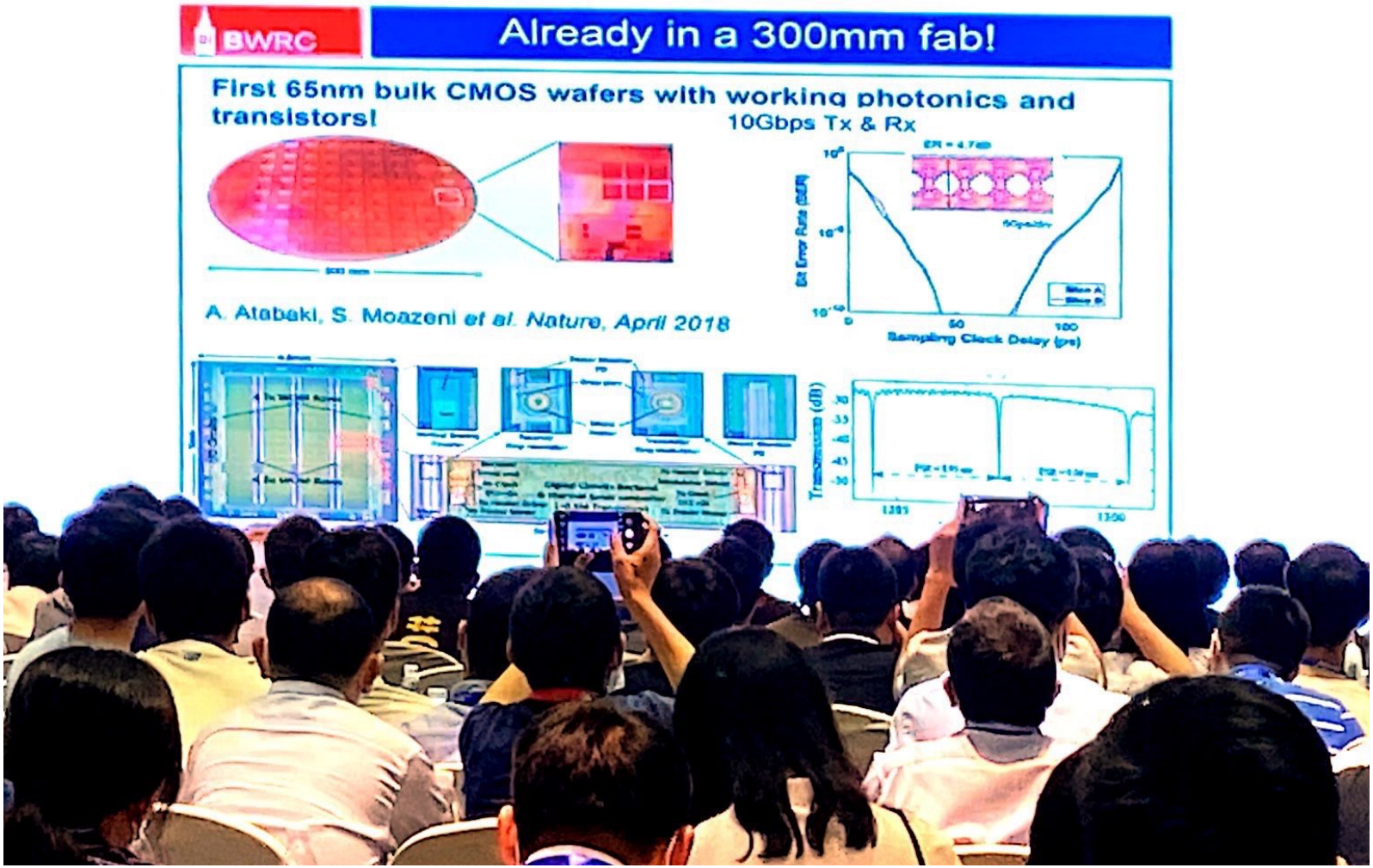
“光子产业”只是个概念，根本无法进入消费市场，除非把“光电产业”改名为“光子产业”。

SPM

面向大规模集成的偏振复用系统

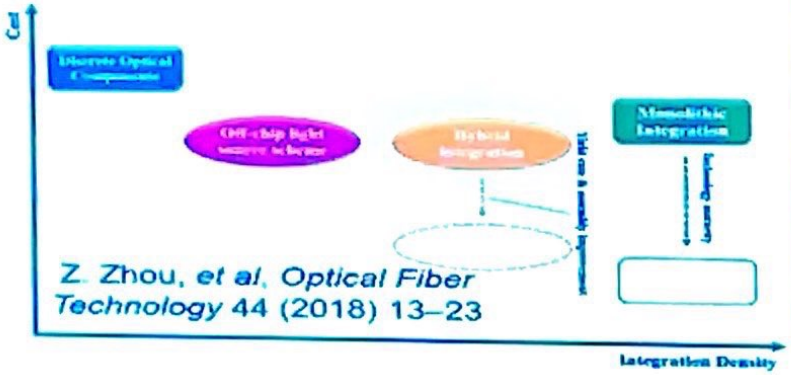


硅基大规模光电集成芯片

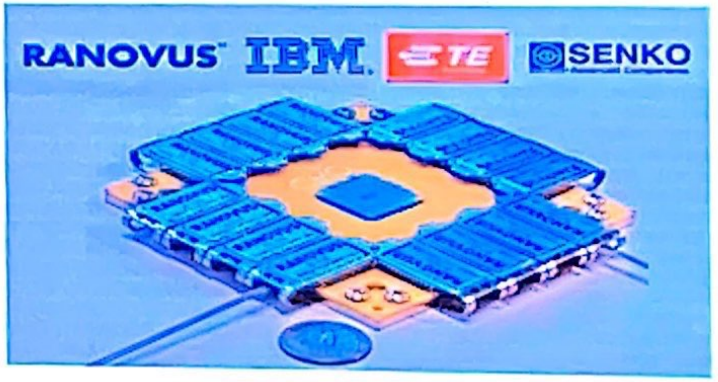


SPM

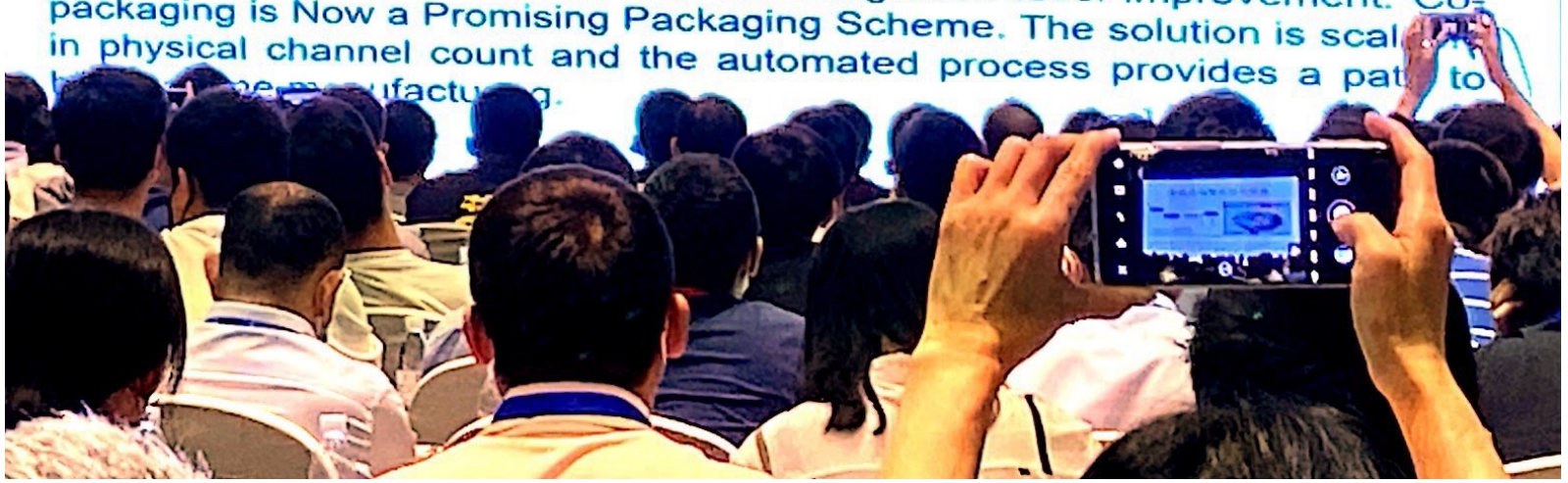
硅基光电集成芯片封装



Z. Zhou, *et al*, *Optical Fiber Technology* 44 (2018) 13–23



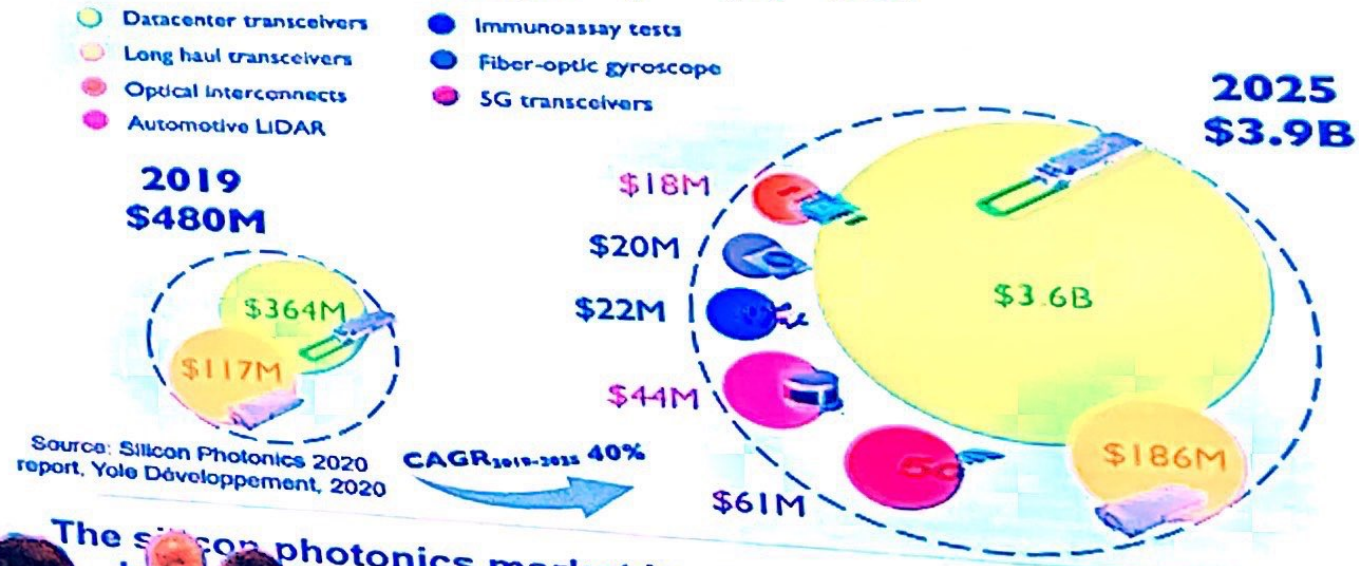
The cost generally decreases with the integration level improvement. Co-packaging is Now a Promising Packaging Scheme. The solution is scal in physical channel count and the automated process provides a pat to



SPM

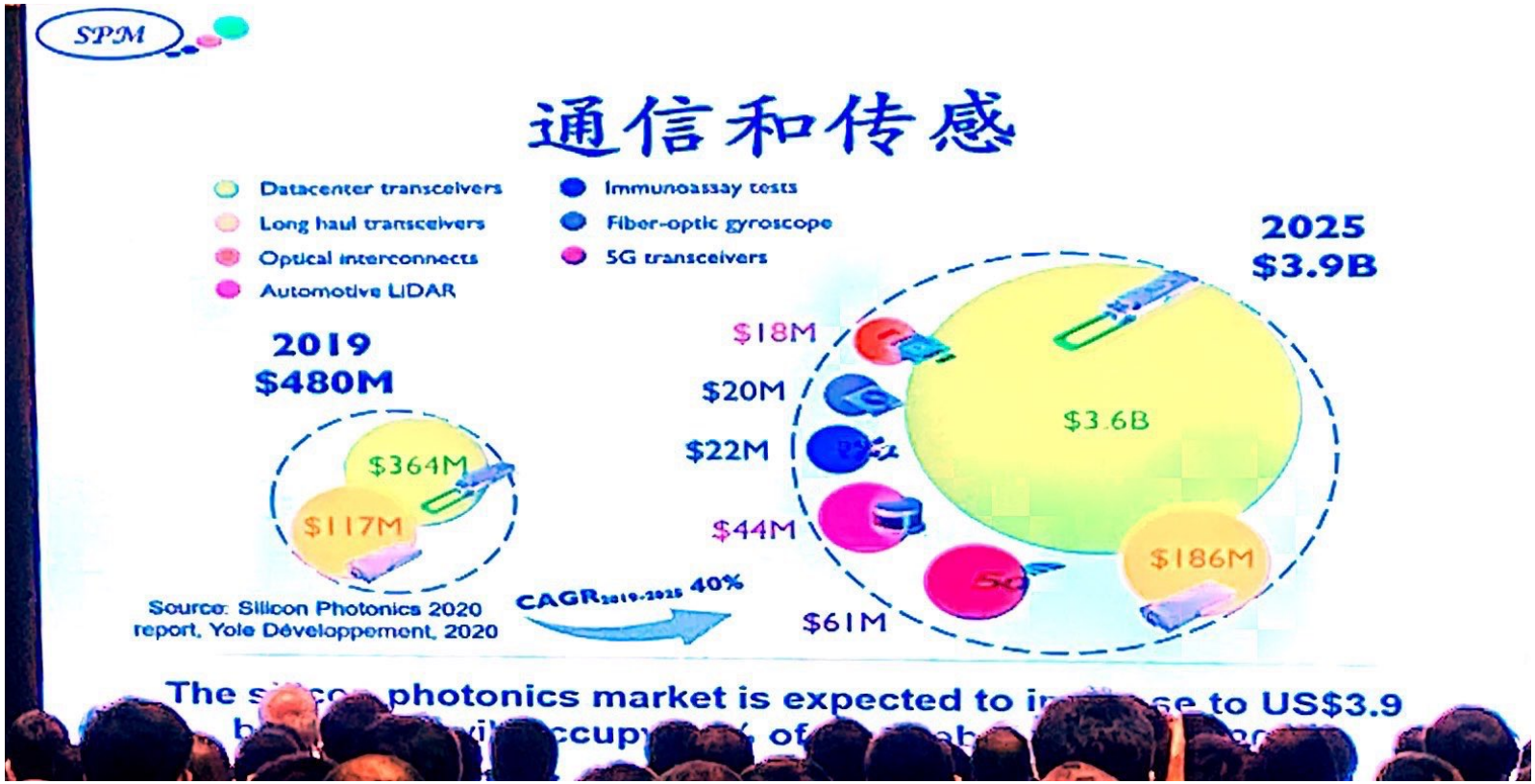
通信和传感

- Datacenter transceivers
- Long haul transceivers
- Optical interconnects
- Automotive LIDAR
- Immunoassay tests
- Fiber-optic gyroscope
- 5G transceivers



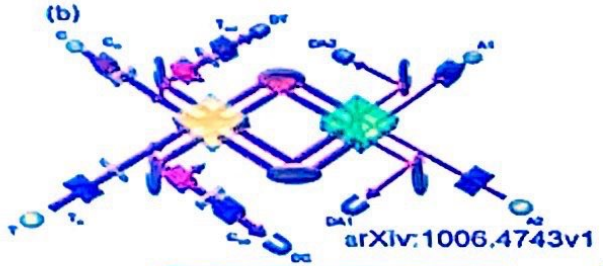
Source: Silicon Photonics 2020 report, Yole Développement, 2020

The si[illegible]con photonics market is expected to inc[illegible]


SPM
通信和传感
Datacenter transceivers
Long haul transceivers
Optical interconnects
Automotive LIDAR
Immunoassay tests
Fiber-optic gyroscope
5G transceivers
2019
$480M
$364M
$117M
2025
$3.9B
$18M
$20M
$22M
$44M
$61M
$3.6B
$186M
CAGR2019-2025 40%
Source: Silicon Photonics 2020 report, Yole Développement, 2020
photonics market is expected to

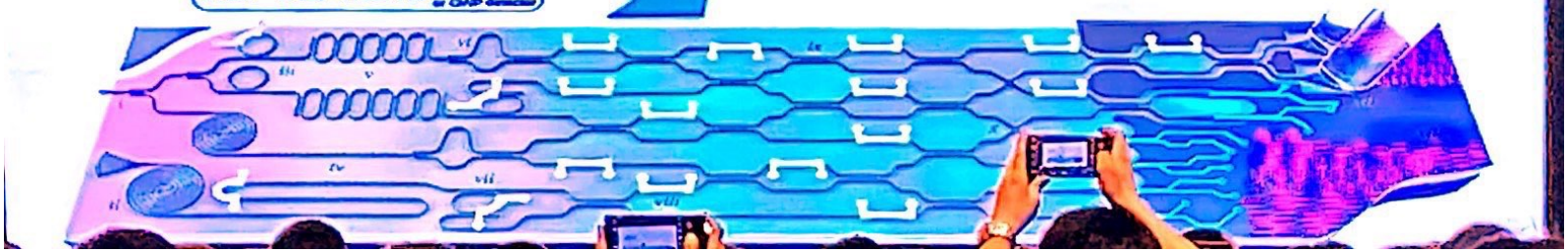
SPM

量子技术



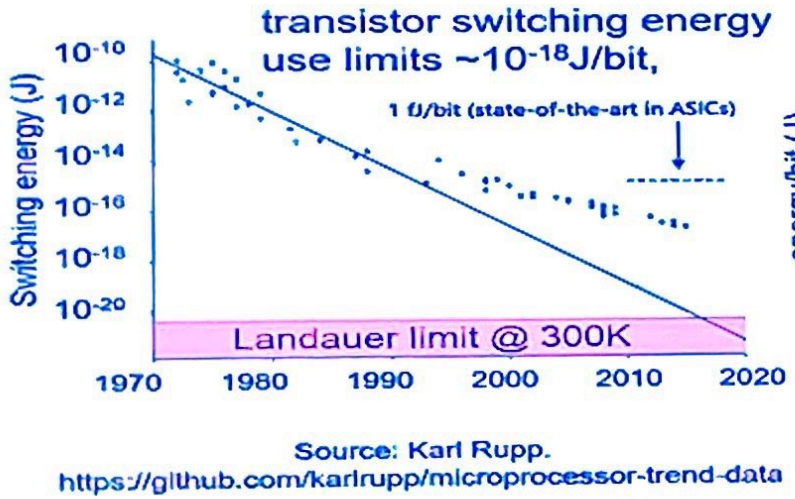
Silicon photonics has the potential to achieve on-chip quantum photonic system with all components integrated.

i. pump input and splitter,
ii~iii. photon-pair source,
iv~v. pump removal filter,
vi~vii. WDM,
viii. thermal phase tuner,
ix. MMI coupler,
x. waveguide crossing,
xi. single-photon detector,
xii. Grating coupler,
xiii. control and logic IC.

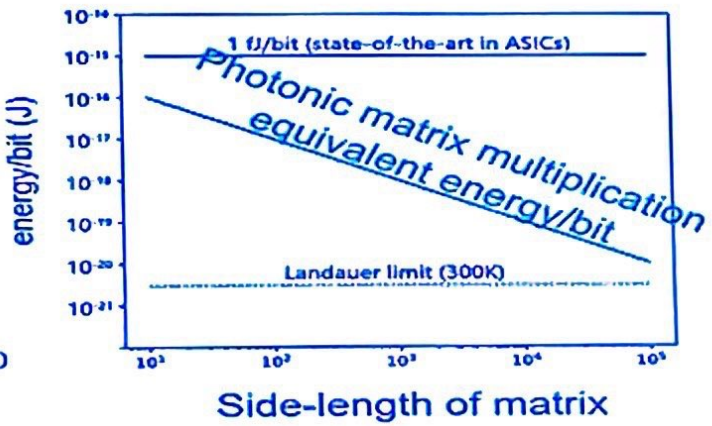


SPM

高速计算/人工智能



Source: Karl Rupp.
https://github.com/karlrupp/microprocessor-trend-data

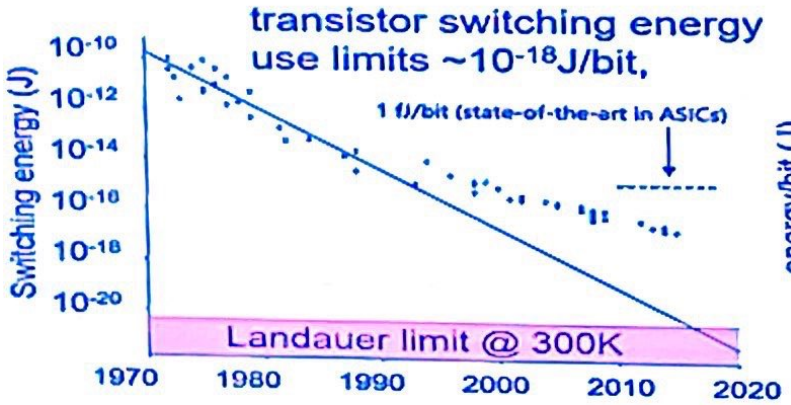


Physical Review X, 9(2), 1–12. (2019).

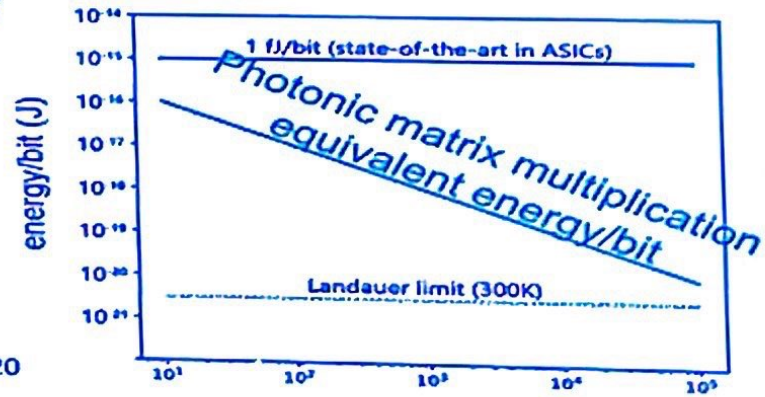
Large-scale photonic matrix multiplication:

SPM

高速计算/人工智能



Source: Karl Rupp.
https://github.com/karlrupp/microprocessor-trend-data



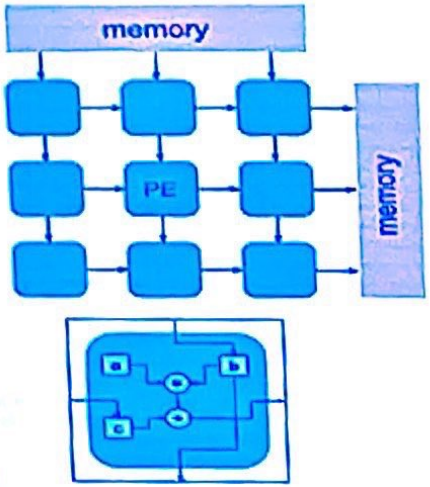
Physical Review X, 9(2), 1–12. (2019).

Large-scale photonic matrix multiplication:

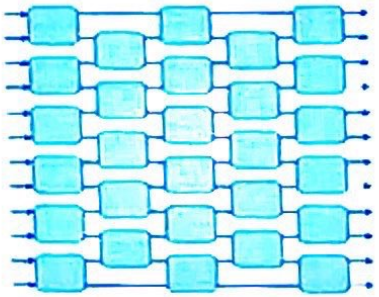
SPM

高速计算/人工智能

Systolic Arrays



MZI network



MAC Unit Cell Comparison

	Silicon Photonics	Electronics	Improvement
latency	100ps	100ns	10^3
bandwidth	20GHz	2GHz	10
Power	1uW	1mW	10^3
Area	2500 μm^2	2500 μm^2	1

C. Ramey, In 2020 IEEE HotChips 32 Symposium (HCS), Palo Alto, CA, USA, 2020

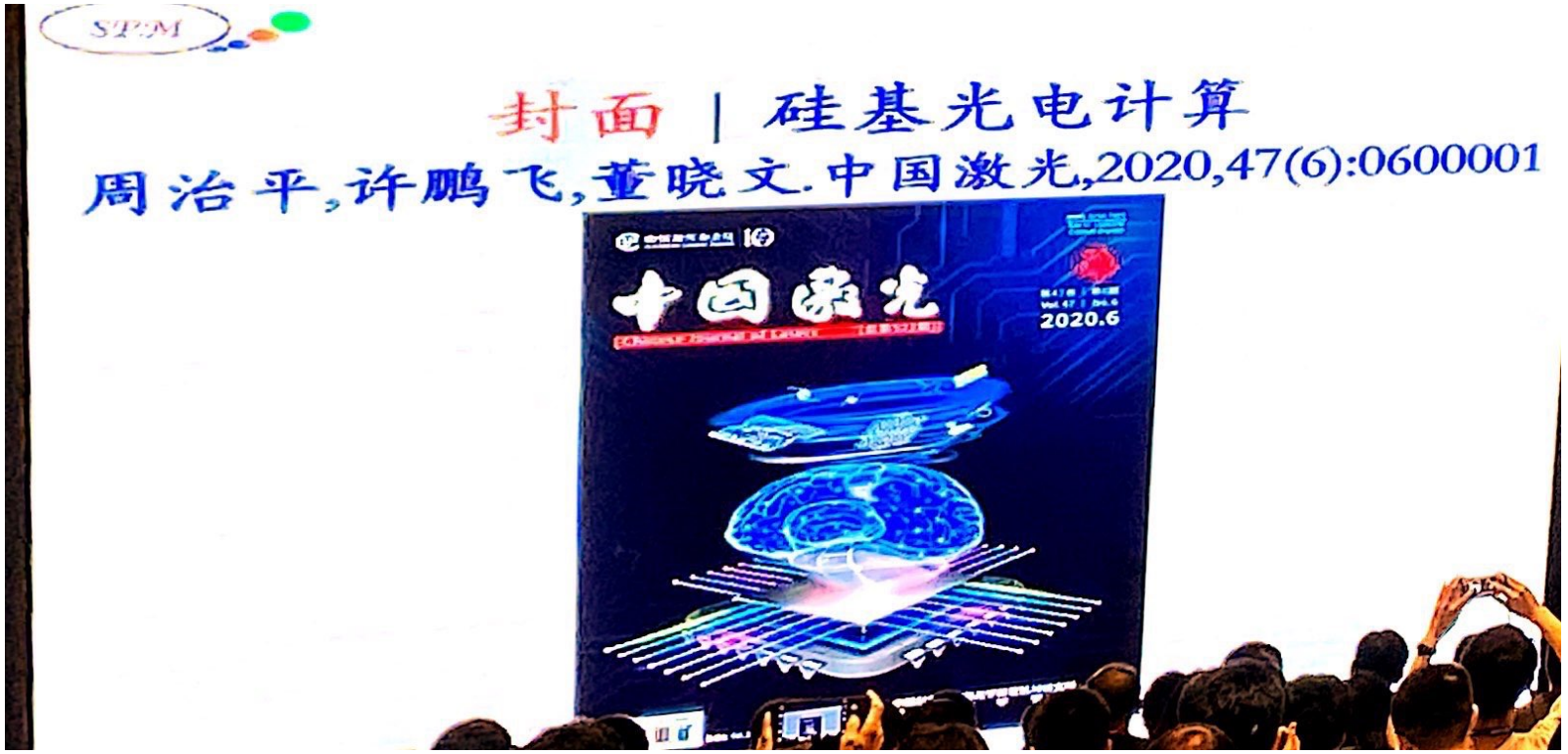
Electronics

Silicon Photonic

MAC: Multiply and Accum ate

封面 | 硅基光电计算

周治平，许鹏飞，董晓文. 中国激光，2020，47(6)：0600001



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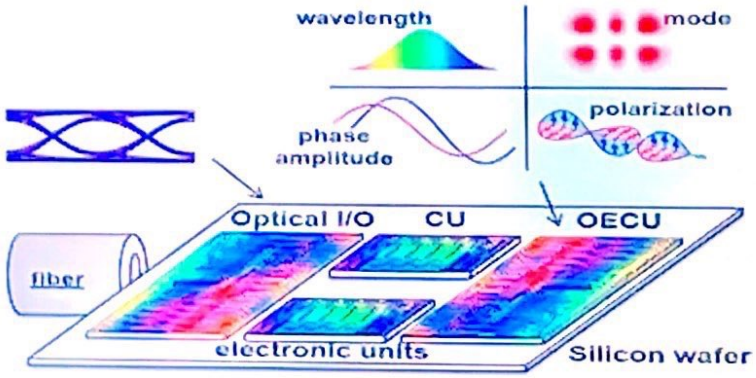
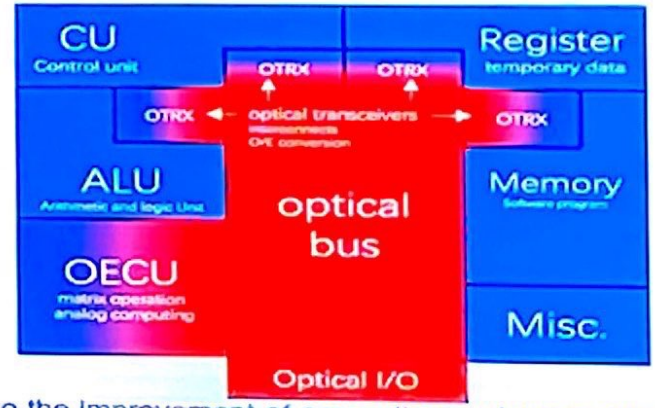
硅基光电计算





1. The Opto-Electronic Computing Unit (OECU) is the key to the improvement of computing and processing performance to achieve high-speed matrix operations.
2. Some calculation operations that are inconvenient in the optical domain, such as signal delay, data buffering, and logic operations, still need to be implemented in the electronic ng unit.