

AI超节点高速互连系统方案实践与思考

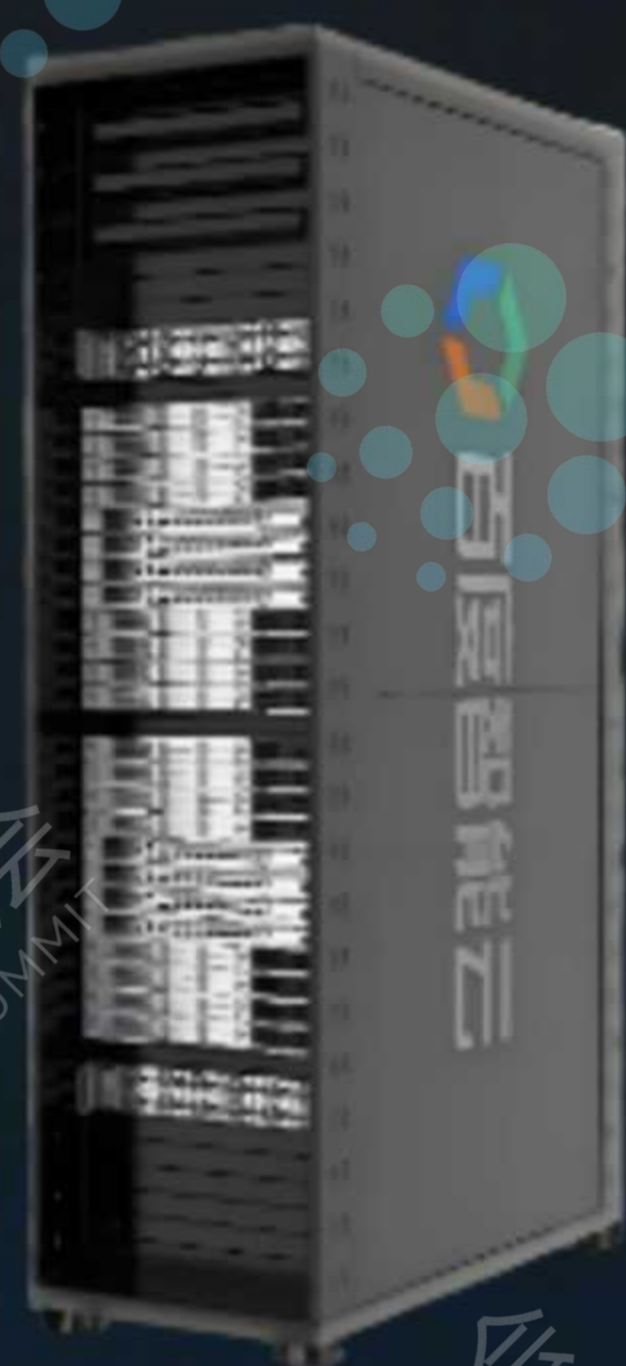
庆虹电子(苏州)有限公司 FAE经理 陈衍冲

AI超节点生态

磐久/方升



天池



银河



大禹



Rubin NVL144



Fusion PoD



Uni-POD



星云



Cloud Matrix
384 / 8192



曙光scaleX640
世界首个单机柜级640卡超节点

ScaleX640
(ScaleX40)

全球AI厂家的激烈竞争与提速

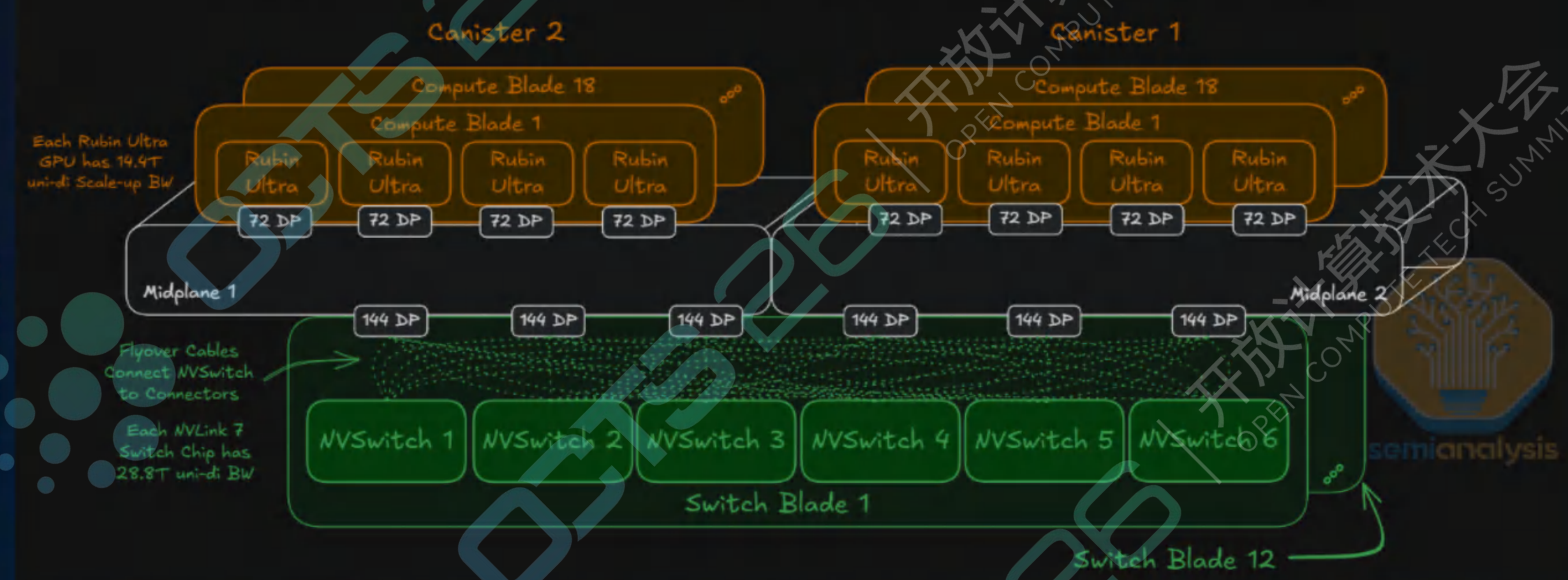
AI芯片头部企业的芯片路标，规划为1年小版本，2年大版本切换，加剧行业竞争

Nvidia Roadmap										
	2024	2025		2026		2027				
Chip and Package Level										
Generation	Blackwell			Rubin						
Accelerator	B200/ GB200	B300/GB300 (Ultra)	B300 (single die, B300A)	Rubin	LP30/LP35	Rubin Ultra				
GPU TDP (W)	700/1,200	1,100/1,400	600	2,300	~600	4,000+				
Foundry Node	4NP			N3P (3NP)	SF4X	N3P (3NP)				
Logic Die Configuration	2 x Reticle Sized GPU			2 x Reticle Sized GPU, 1 C2C I/O Die, 1 NVLink I/O Die	1 x Reticle Sized LPU	4 x Reticle Sized GPU, 2 I/O Die				
FP4 PFLOPs - Dense (per Package)	10	15	4.6	35 ⁽²⁾	-	70				
FP8 PFLOPs - Dense (per Package)	5	5	4.6	17.5	1.2	35				
FP16 PFLOPs - Dense (per Package)	2.5	2.5	4.6	4	0.6	8				
Memory (per Package)	192GB HBM3E	288GB HBM3E	144GB HBM3E	288GB HBM4	500MB SRAM	1,024GB HBM4E				
HBM Stacks	8		4	8	-	16				
Memory Bandwidth	8TB/s		4TB/s	22TB/s	150TB/s	53TB/s				
Packaging	CoWoS-L			CoWoS-L	FC-BGA	CoWoS-L				
SerDes speed (Gb/s uni-di)	224G			224G Bi-di ⁽³⁾	112G	224G Bi-di ⁽³⁾				
System Level and Form Factor										
System	NVL72		NVL16	Rubin NVL8 HGX	Vera Rubin NVL72	Nvidia Groq 3 LPX	Vera Rubin NVL72	Vera Rubin Ultra NVL144	Vera Rubin Ultra NVL288?	Vera Rubin Ultra NVL576
Form Factor	Oberon		HGX	HGX	Oberon	4 racks x 256 Groq 3 LPUs ⁽⁴⁾	Oberon	Kyber	2x Kyber Racks	8x Oberon Racks
# of Logical GPUs	72	72	16	8	72	1,024	72	144	288	576
# of GPU dies / compute chiplets	144	144	16	16	144	1,024	144	576	1,152	2,304
CPU	Grace		Intel or AMD	N/A	Vera	Intel Granite Rapids	Vera			
# of CPU Sockets	36	36	16	2	36	128 FPGAs 64 CPUs	36	72	144	288
Scale up links	Copper Backplane		UBB (PCB)	UBB (PCB)	Copper Backplane	PCB (Intra-node) + Copper Backplane (Inter-node) + AEC/Optics (Inter- rack)	Copper Backplane	PCB Midplane + Flyover Cables	PCB Midplane + Flyover Cables, Copper Cross- Rack?	Within Rack: Copper Backplane Between Racks: Two-tier all-to-all via CPO
Aggregate FP4 PFLOPs (Dense)	720	1,080	74	280 ⁽²⁾	2,520 ⁽²⁾	-	2,520 ⁽²⁾	10,080	20,160	40,320
Aggregate FP8 PFLOPs (Dense)	360	360	74	140 ⁽²⁾	1,260 ⁽²⁾	1,260	1,260 ⁽²⁾	5,040	10,080	20,160
Aggregate FP16 PFLOPs (Dense)	180	180	74	32 ⁽²⁾	288 ⁽²⁾	630	288 ⁽²⁾	1,152	2,304	4,608

NVIDIA Extreme Co-Design Delivering X-Factors Every Year From Chips to Racks to AI Factories



Rubin Ultra NVL144 - All Copper Scale-Up Network

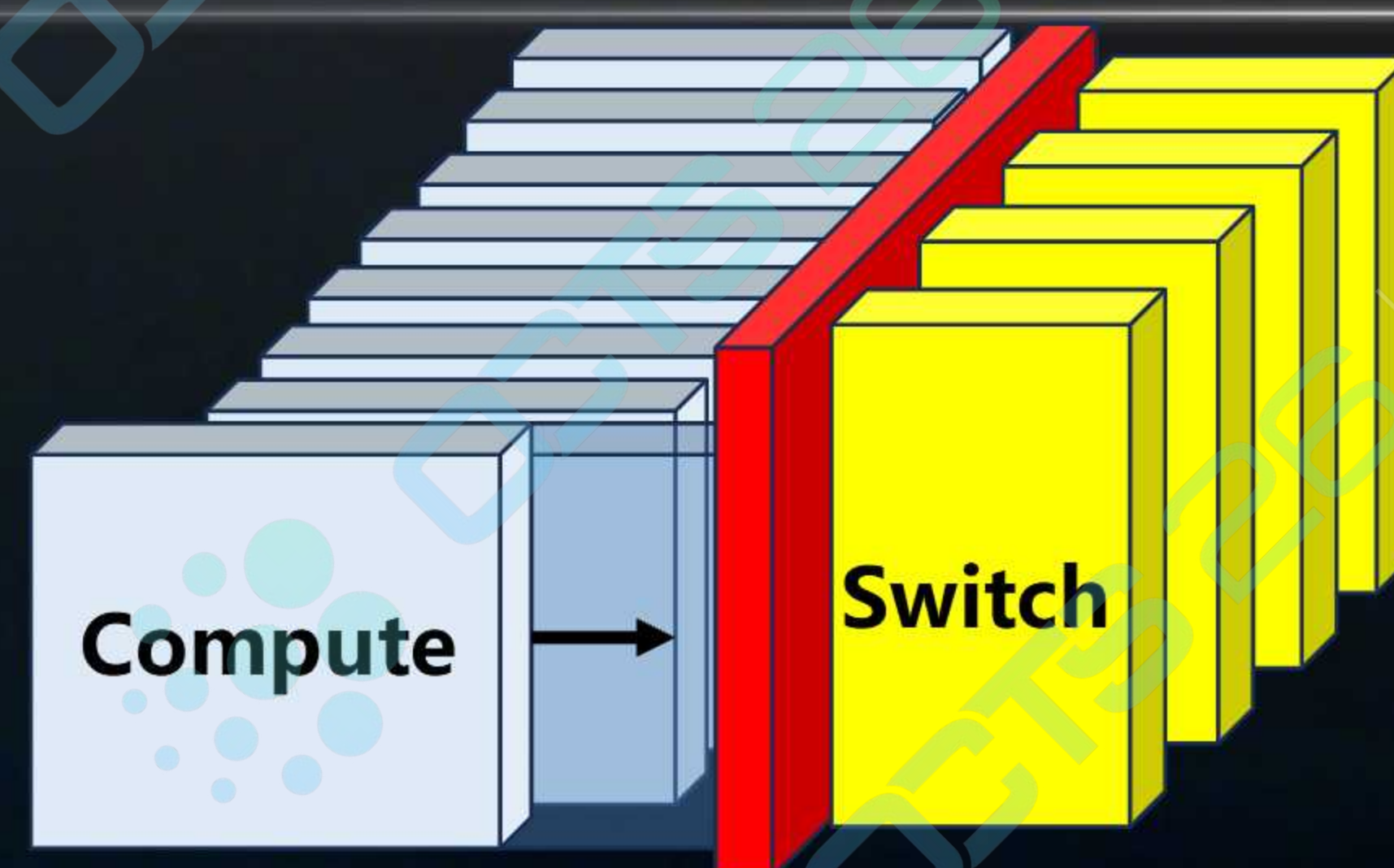


超节点架构形态划分与选择

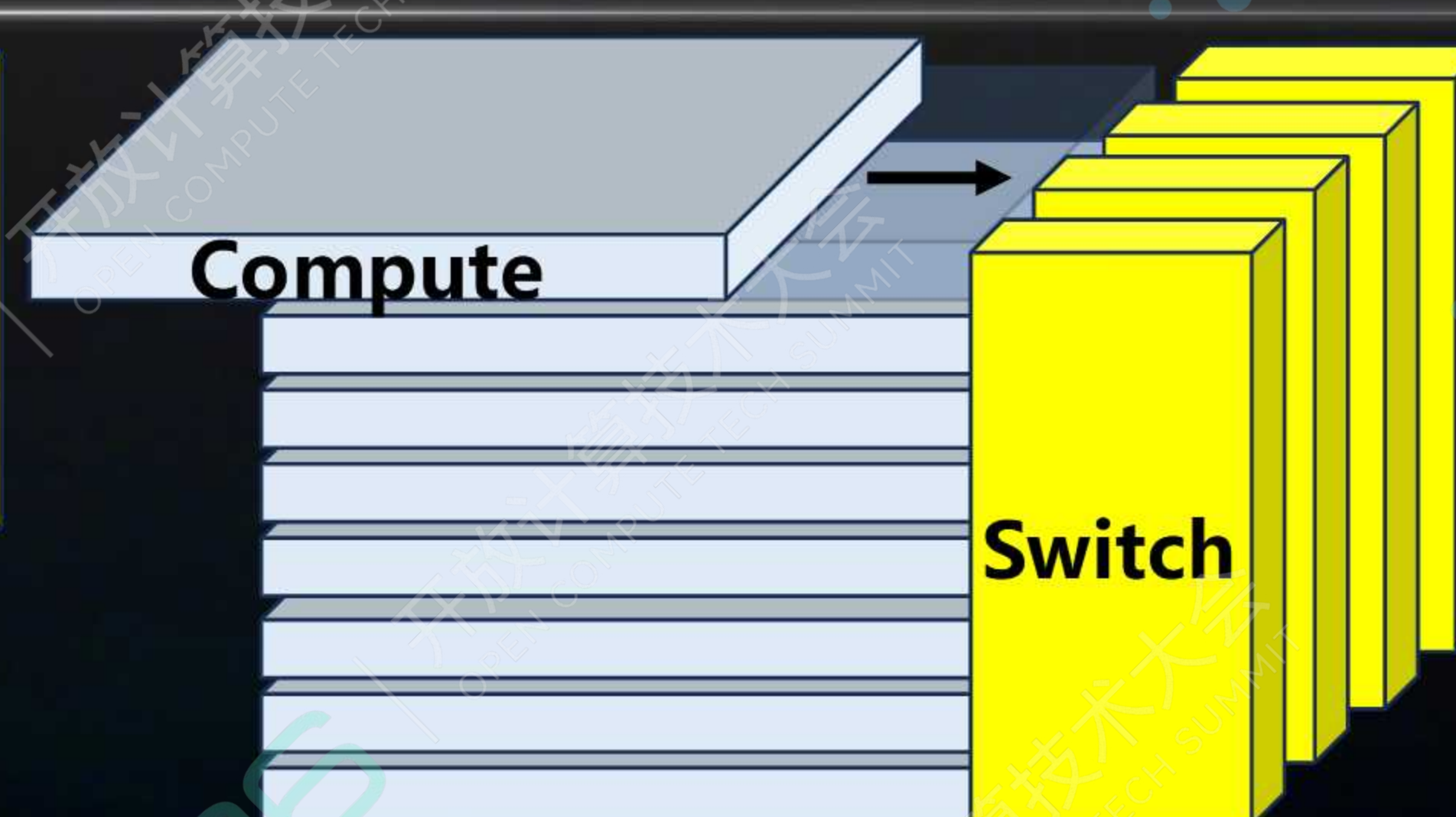
线缆背板互连 (单面横插)



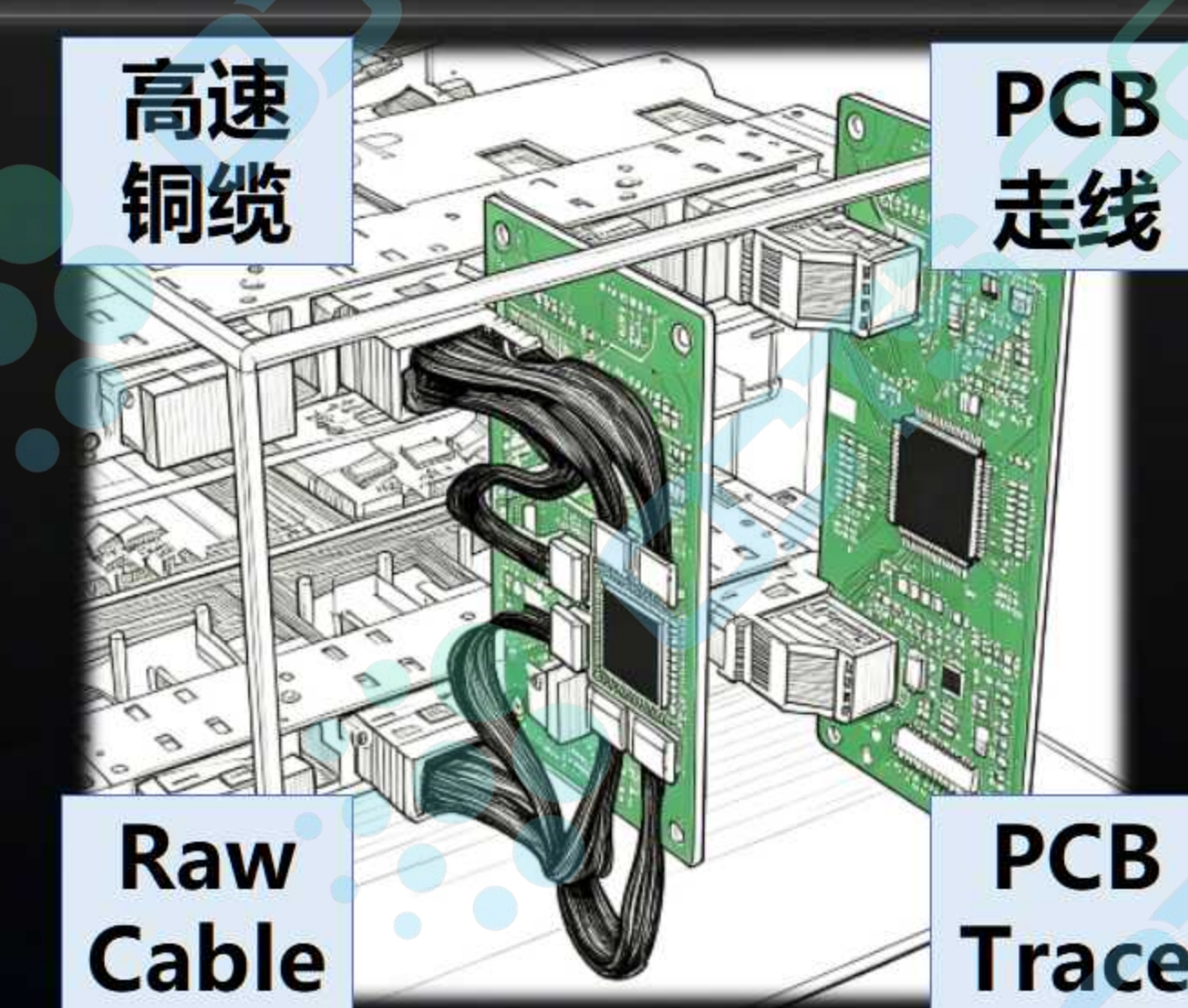
有中板正交互连



无中板正交互连

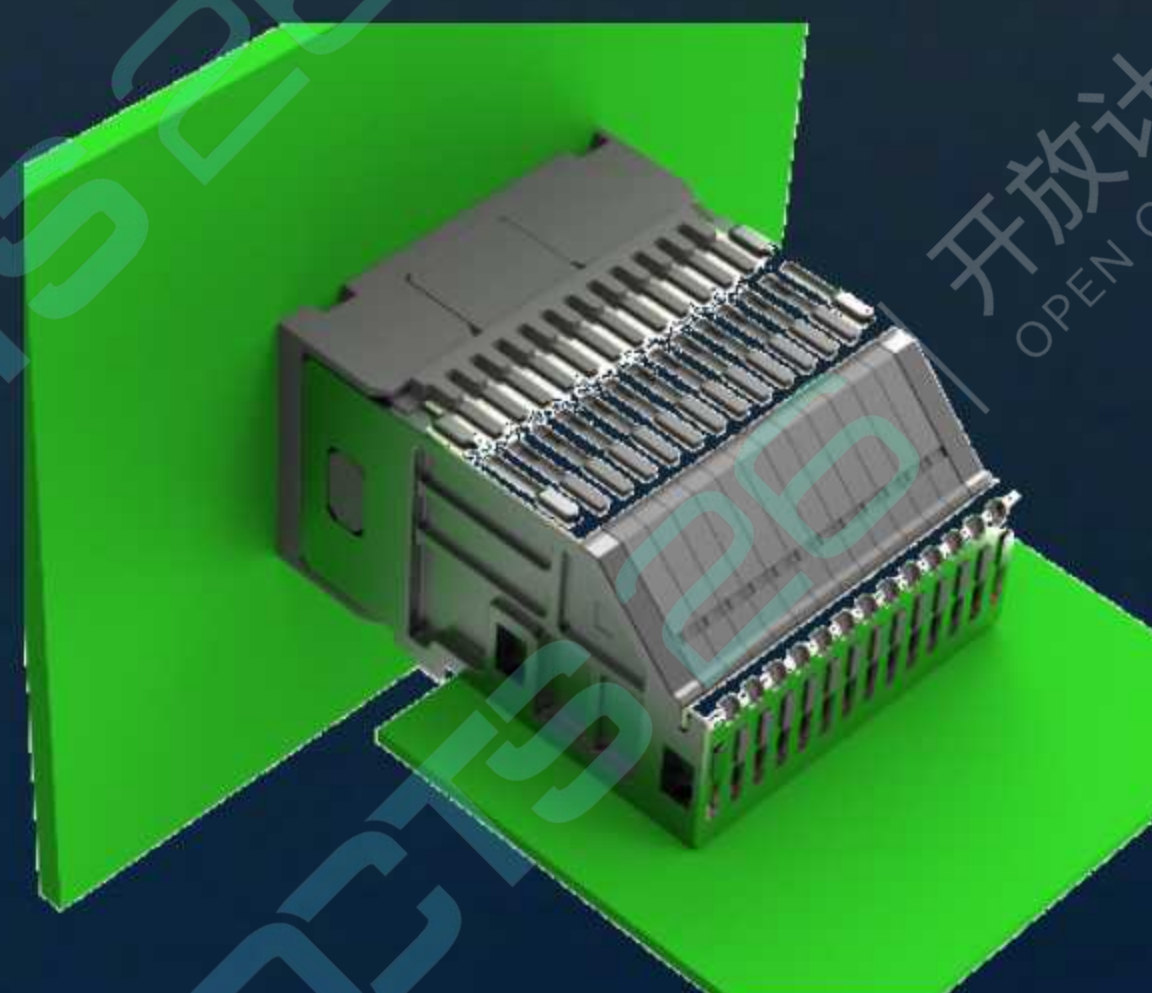


不同高速通道主体

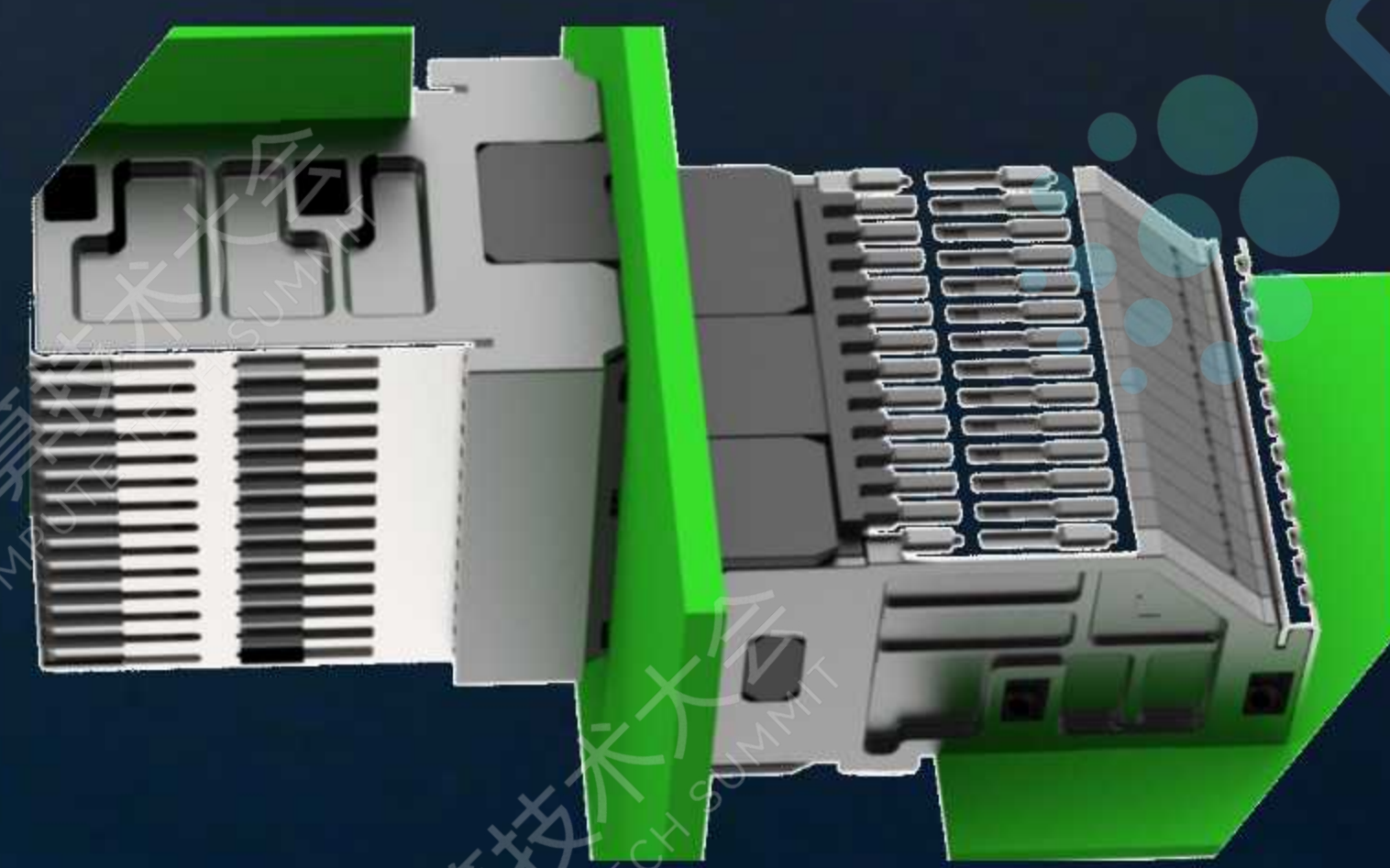


互联协议

NV-Link



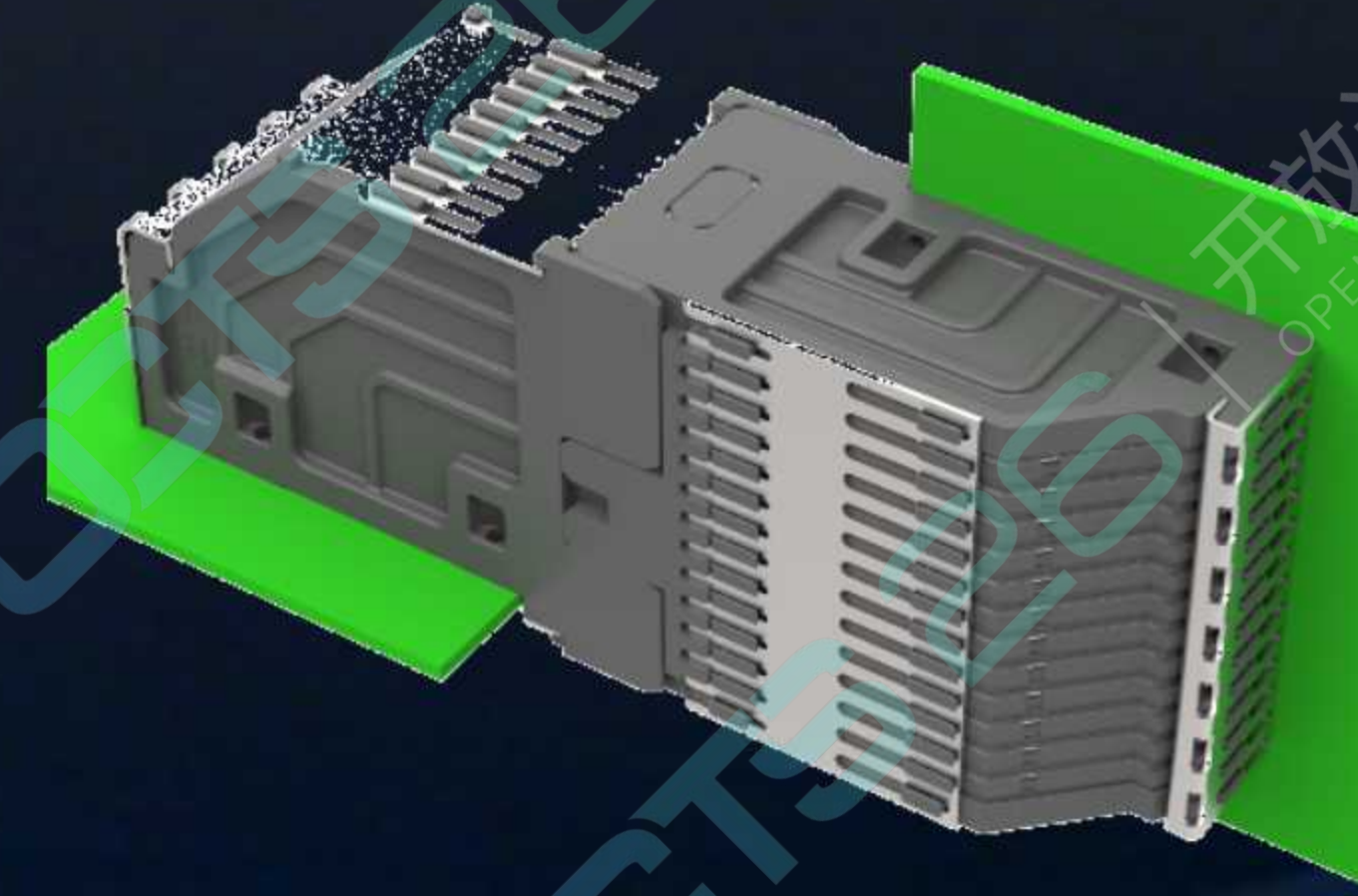
C-Link



UB-Link

OISA

UA-Link



UEC



XPU-Link



高速互连硬件形态

线缆背板

BP Cable Tray

近芯片线缆-NPC

Near Package Copper

板外线缆-OTB

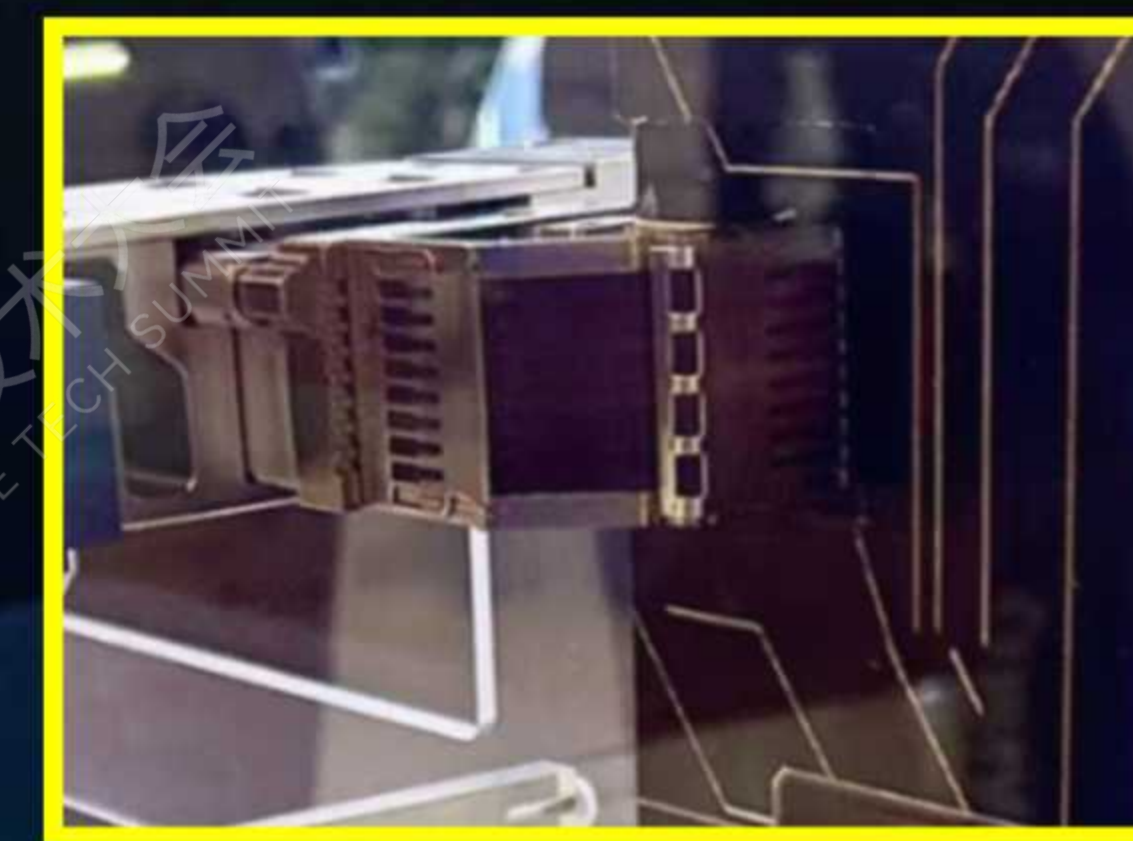
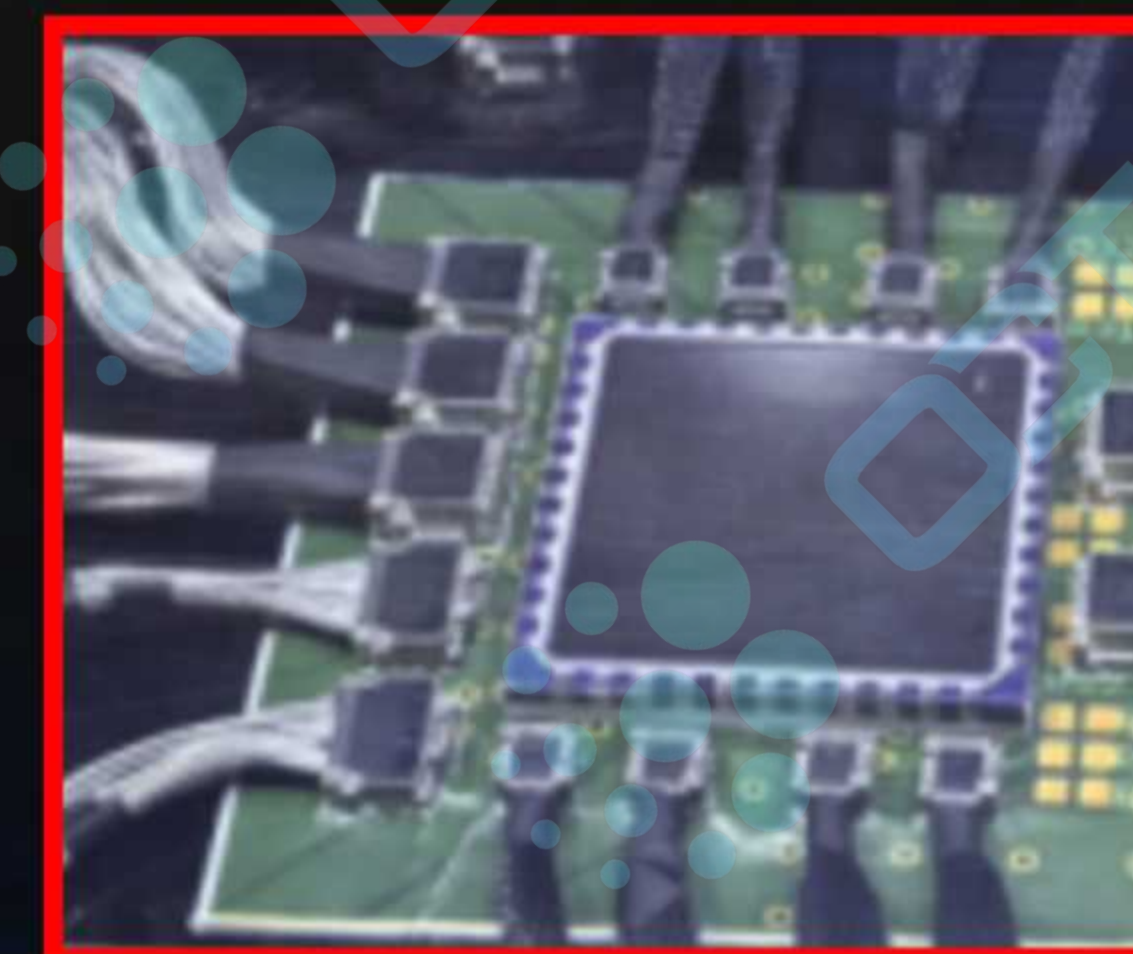
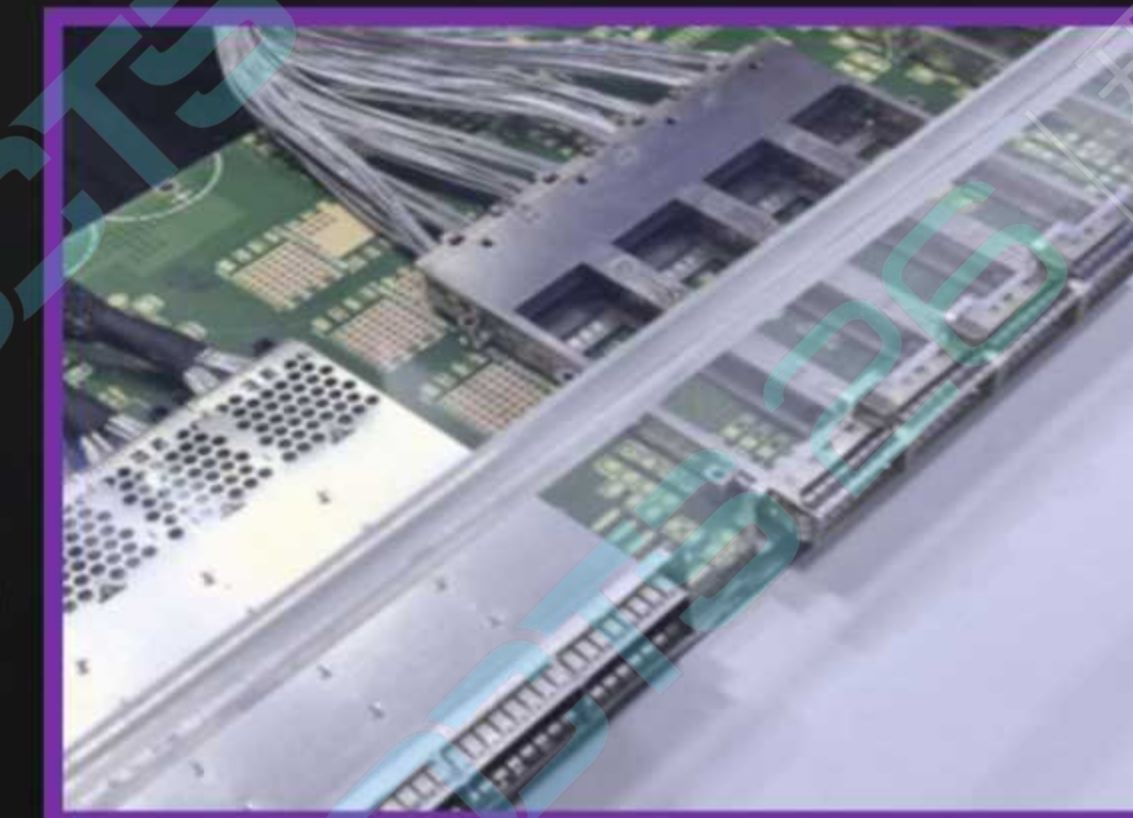
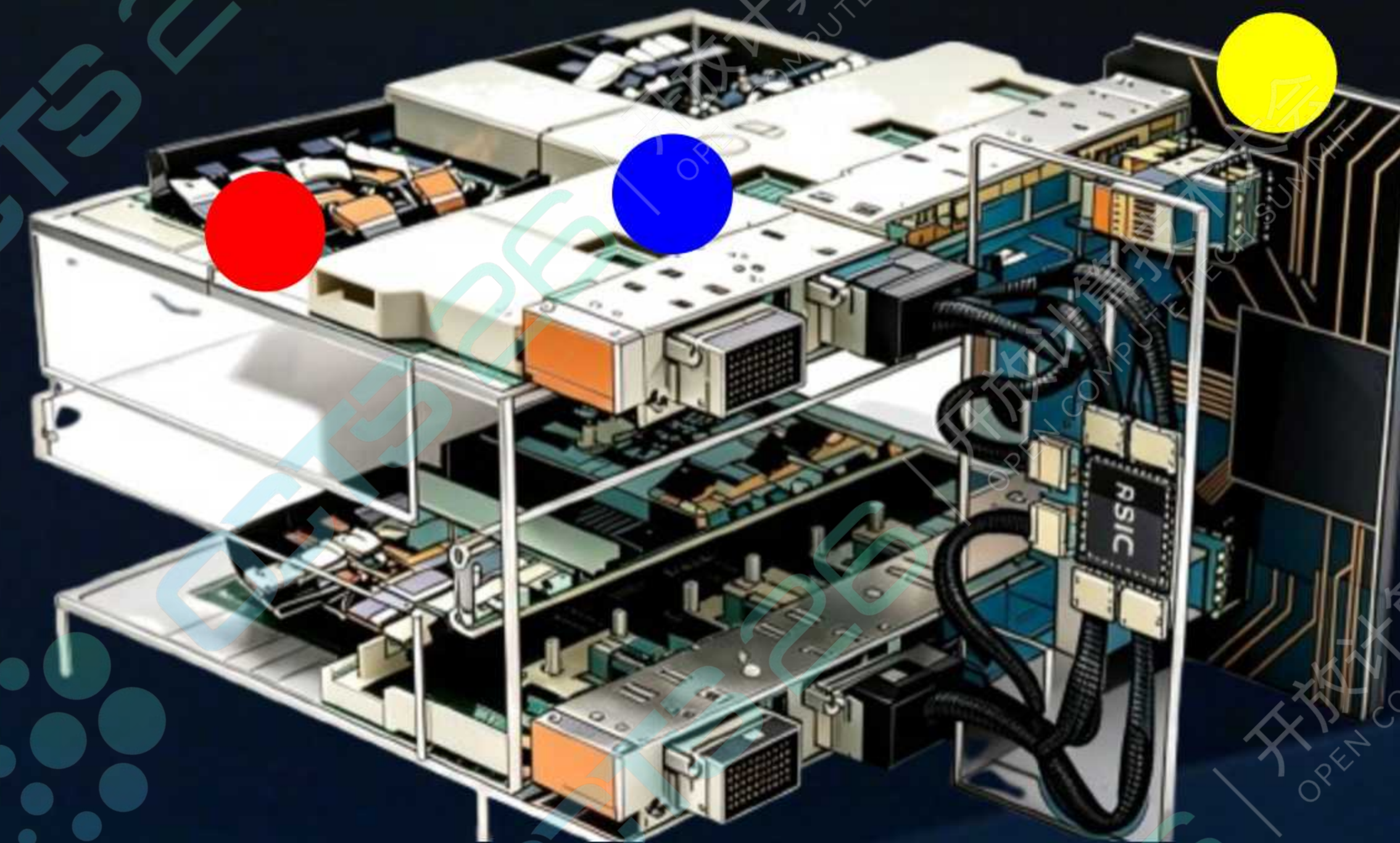
Over Board Cable

板外线缆-CPC

Co-Packaged Copper

板级连接器-BP/IO

Board-Level Connectors



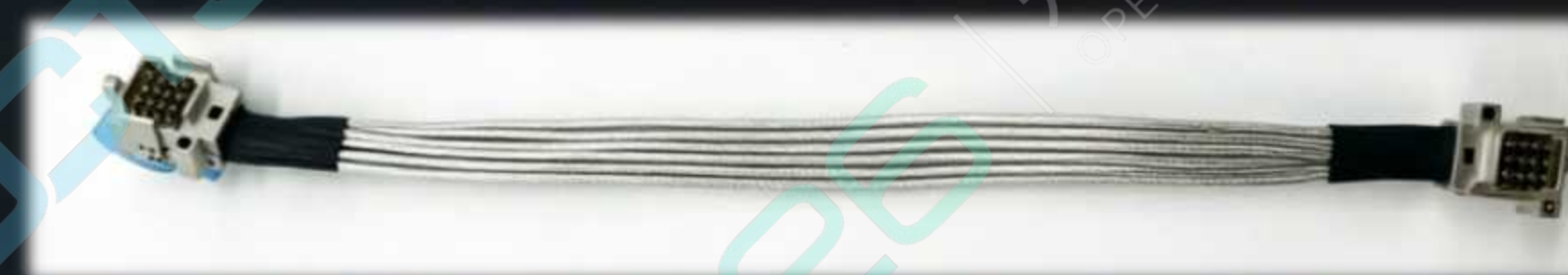
高速互连硬件形态-NPC扩展应用

基础
4x4

Base Unit



节点内互连应用
(NPC-NPC)



核心优势

Core Advantages

兼容 ST 950芯片

16~64 Dp 切换

灵活拓扑规划

(大通道 集中/分散)

深度拓展
4x8x2

Depth
Expansion



后窗互连应用
(BP-NPC)



宽度拓展
12x4

Width
Expansion



前窗互连应用
(IO-NPC)



QSFP-DD

OSFP

覆盖行业主流

800G~1.6T

多种IO模块

224G-自研界面-方舟 (ARK)

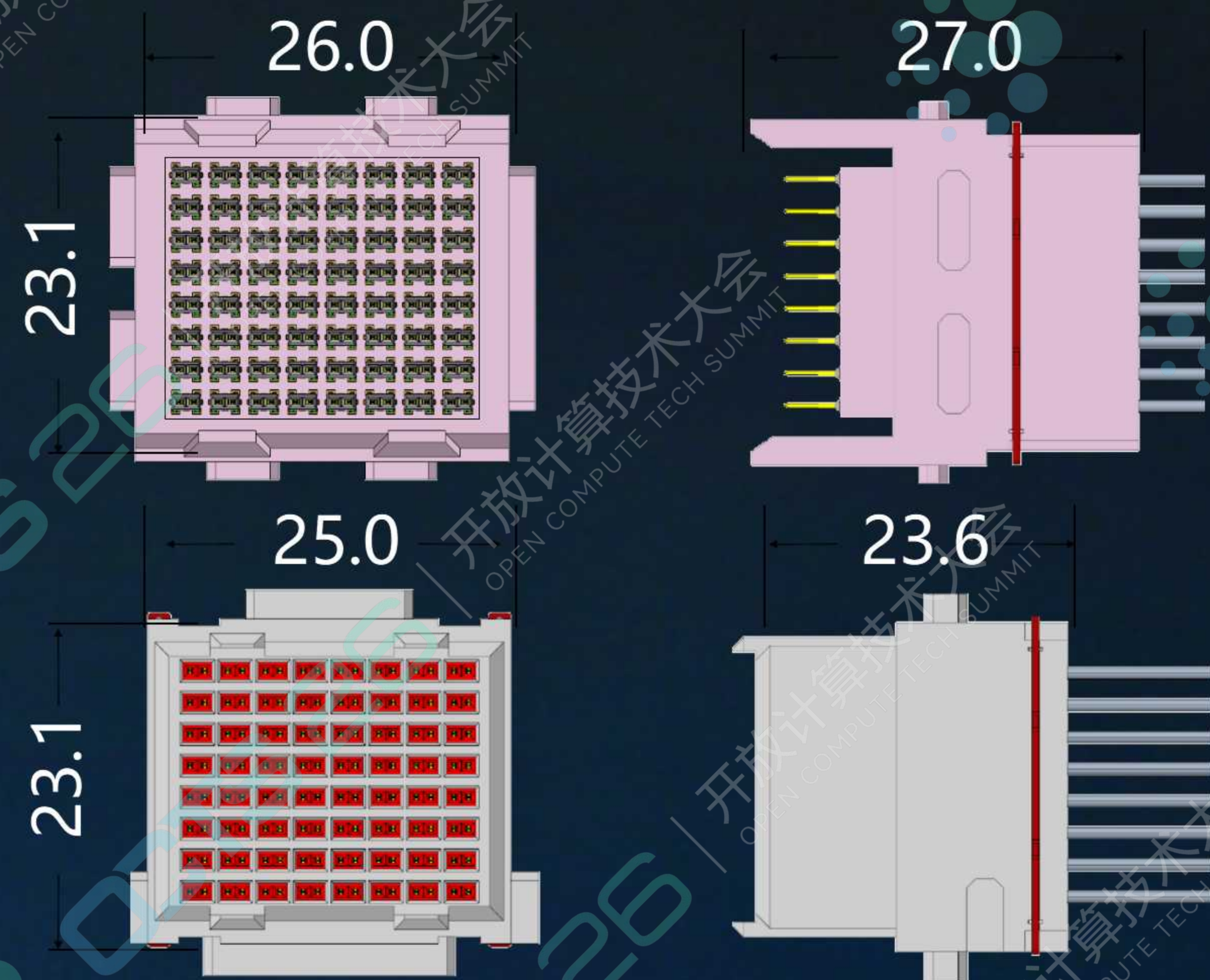
Hyper Ark产品信息

形态: RAR / VH / Cable

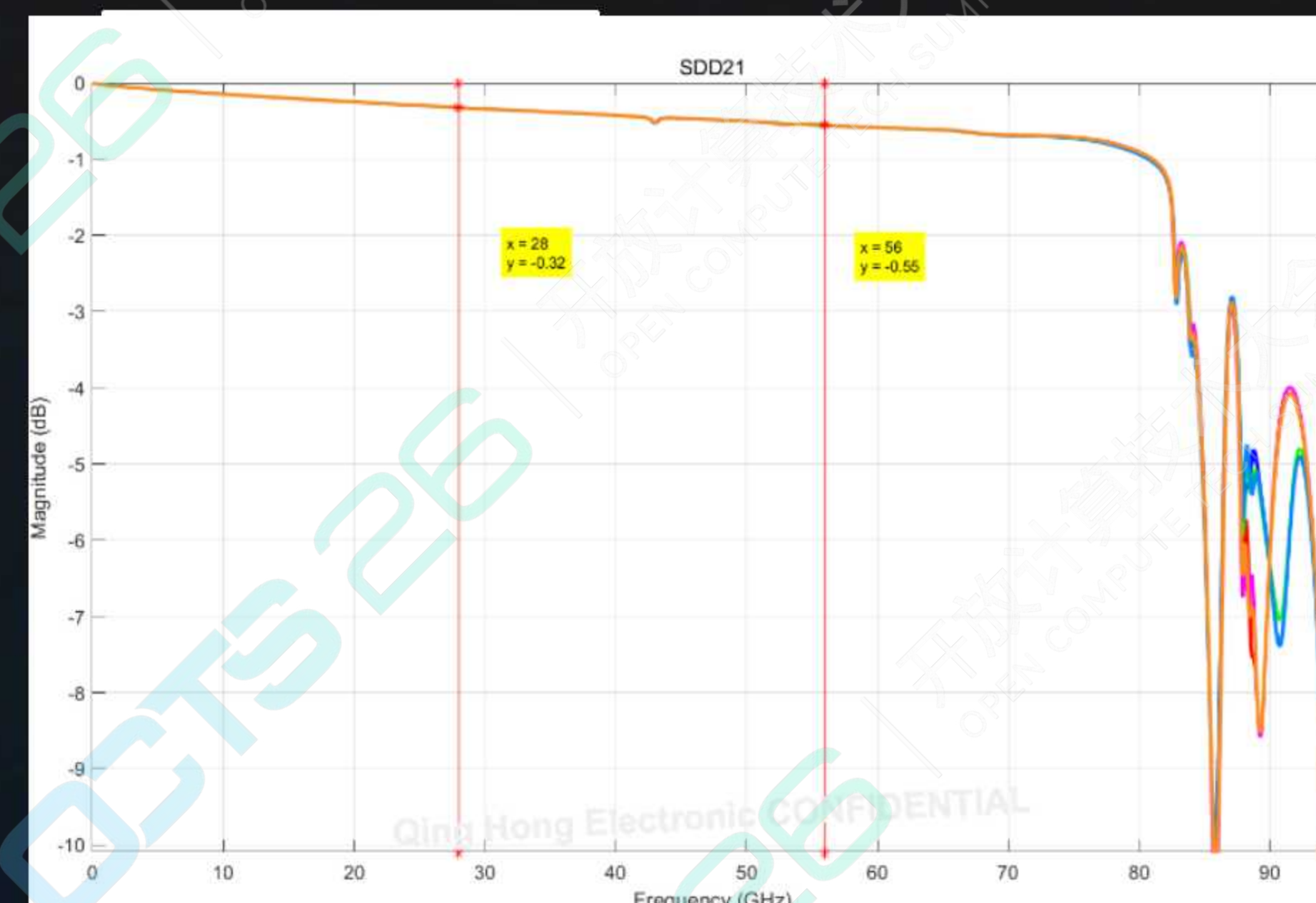
速率: 224G (演进 448G)

线径: 28 ~ 32 AWG

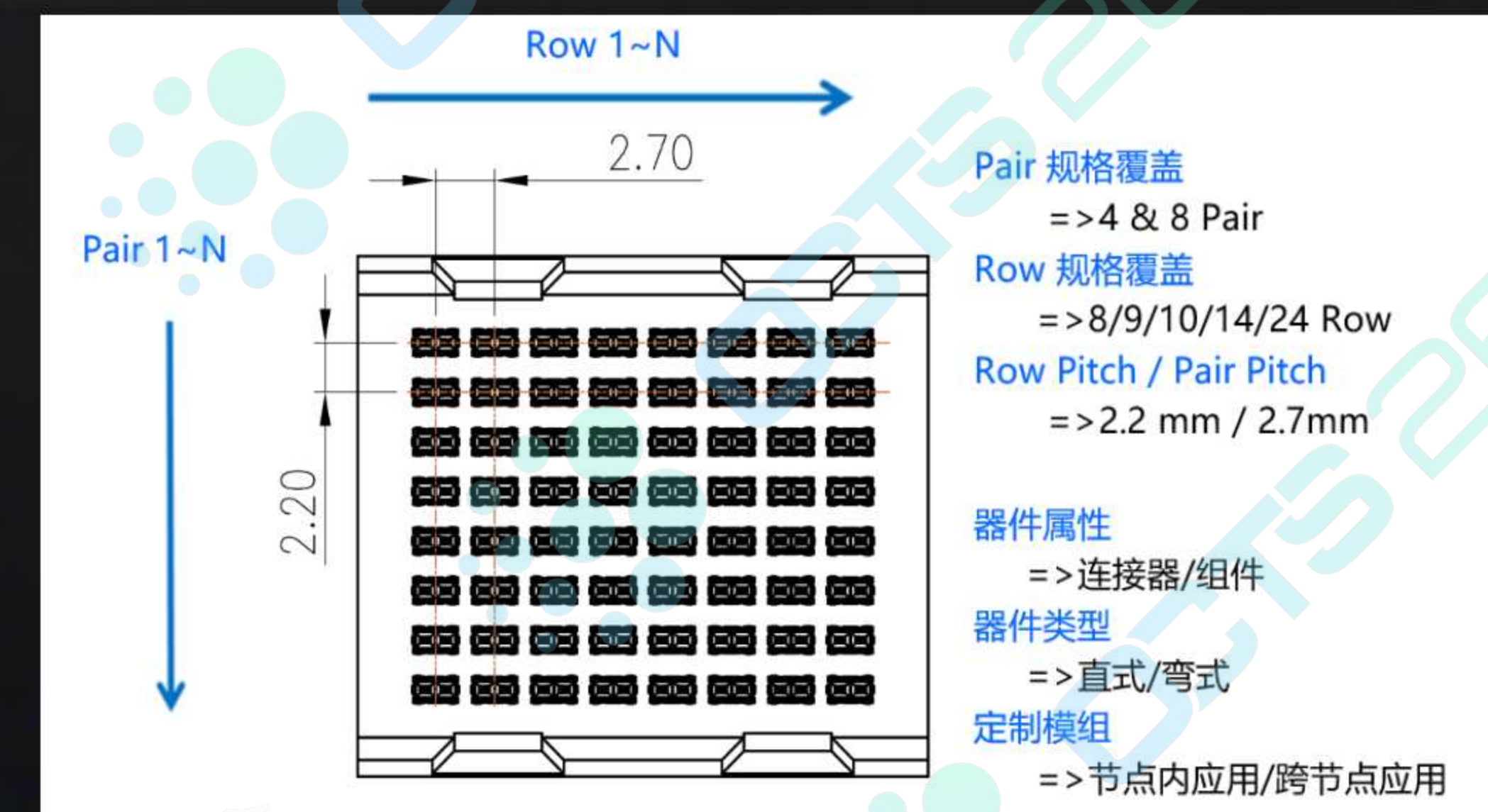
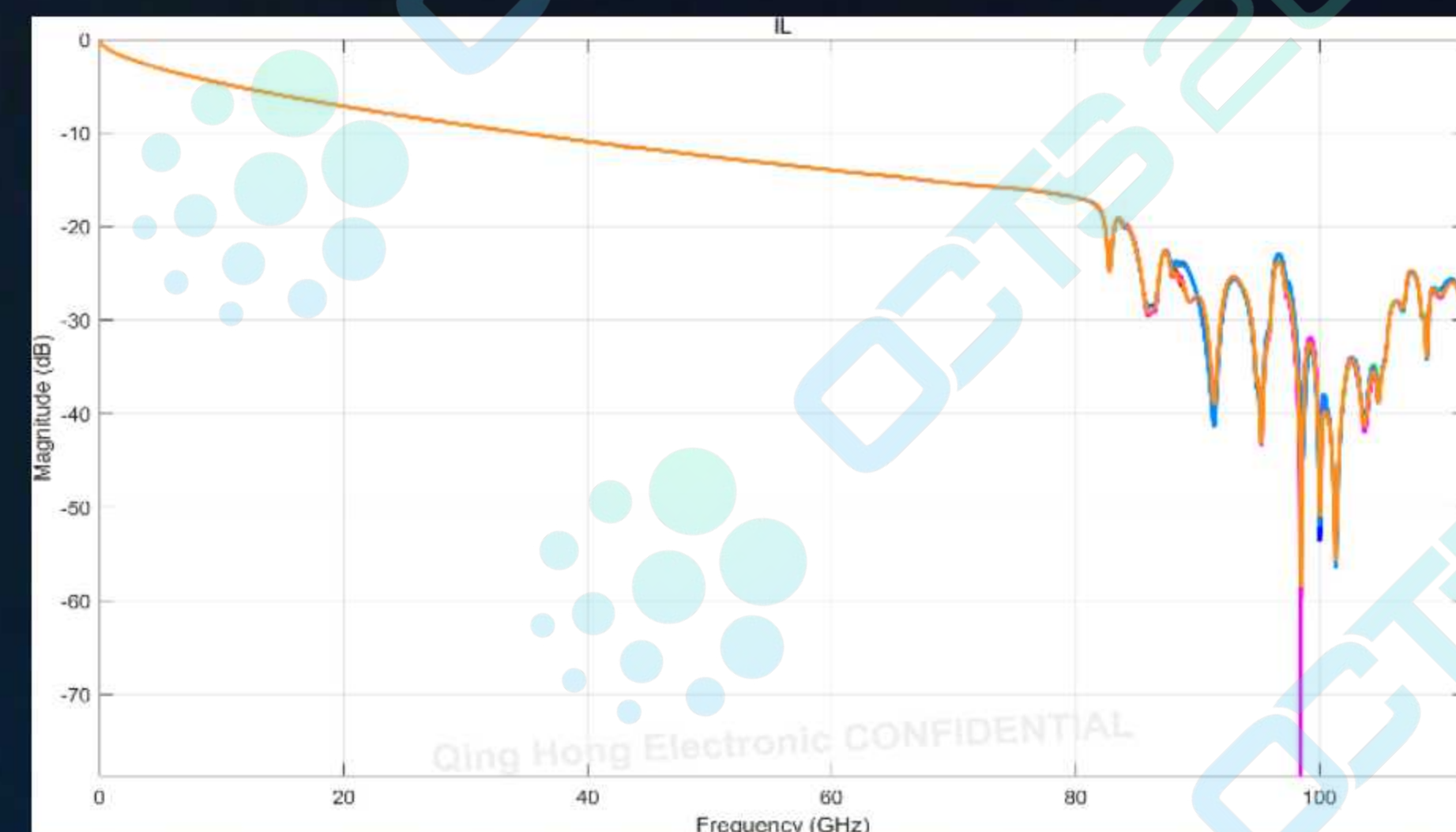
拓展: Cable Tray / NPC / CPC / IO



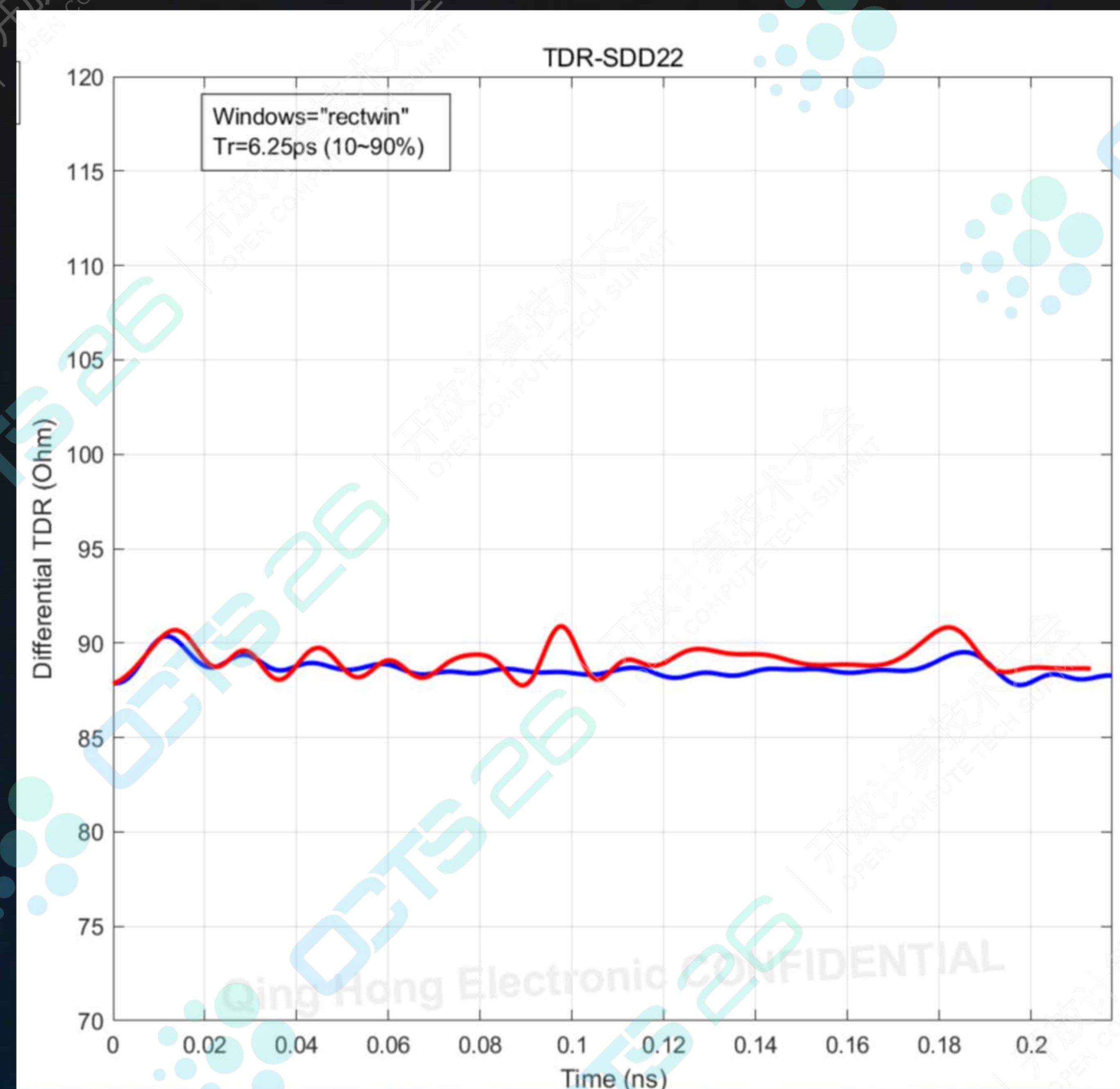
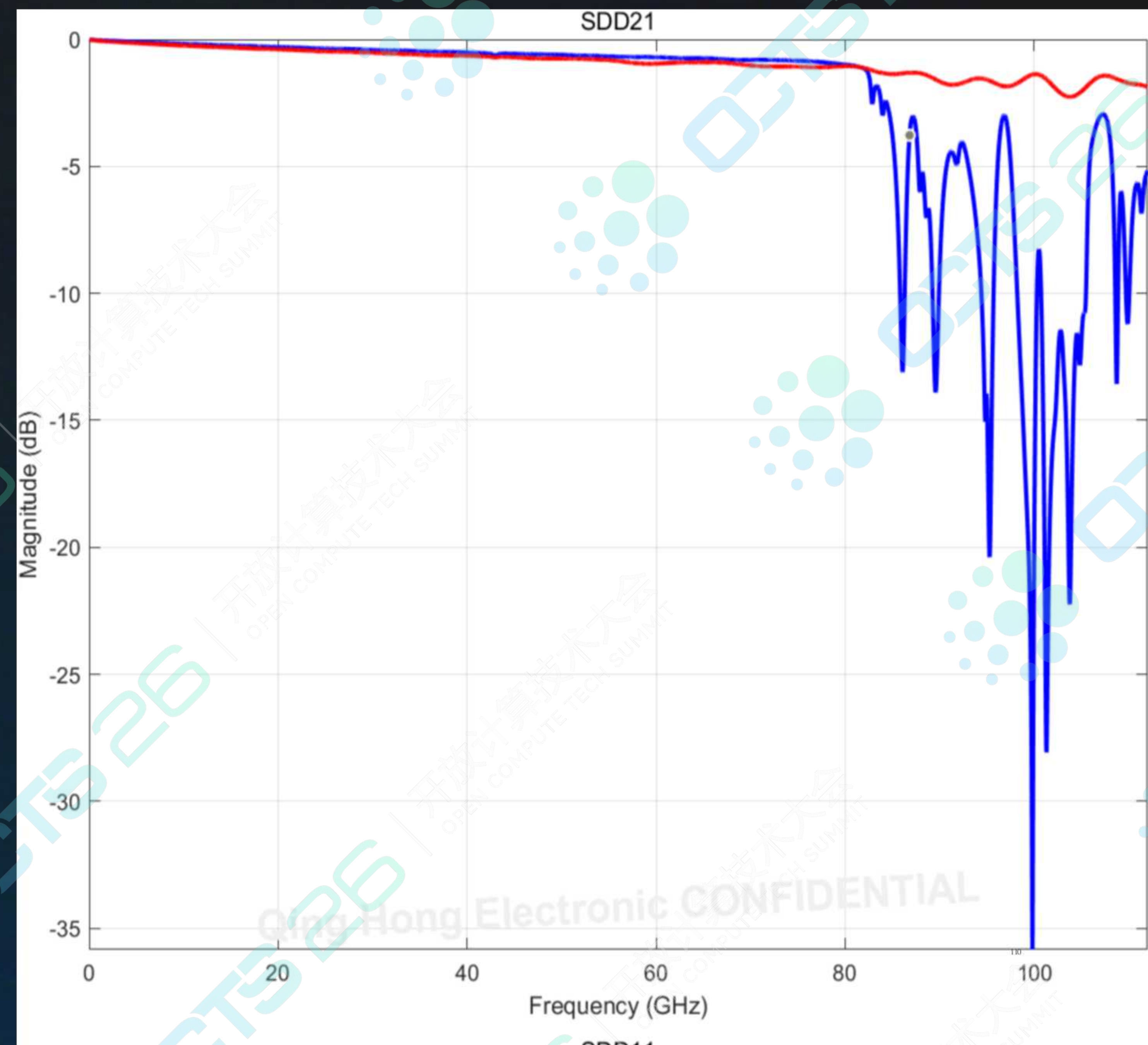
连接器



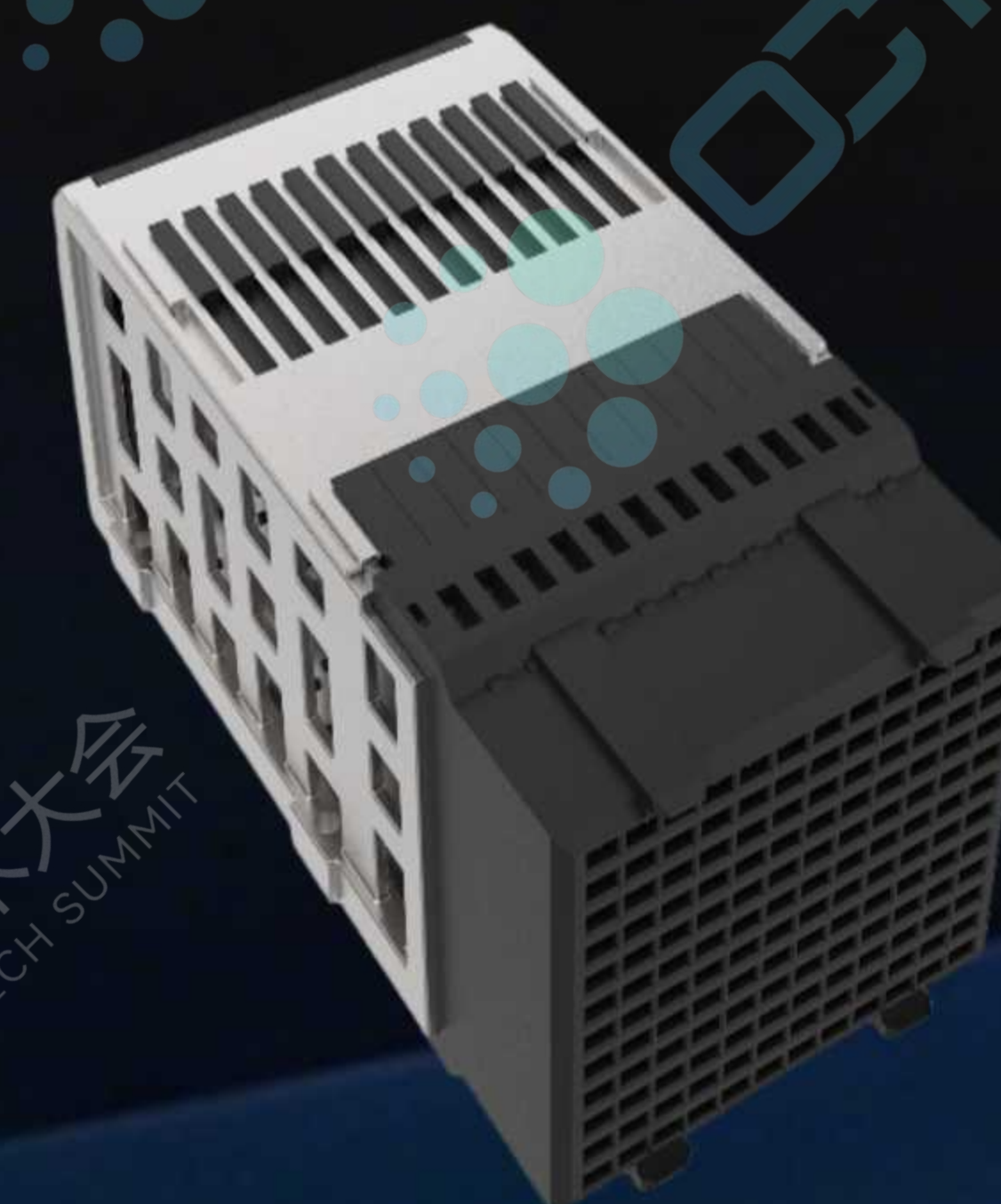
连接器&Cable (800mm-32 AWG)



224G-自研界面-方舟 (ARK+ Pro)

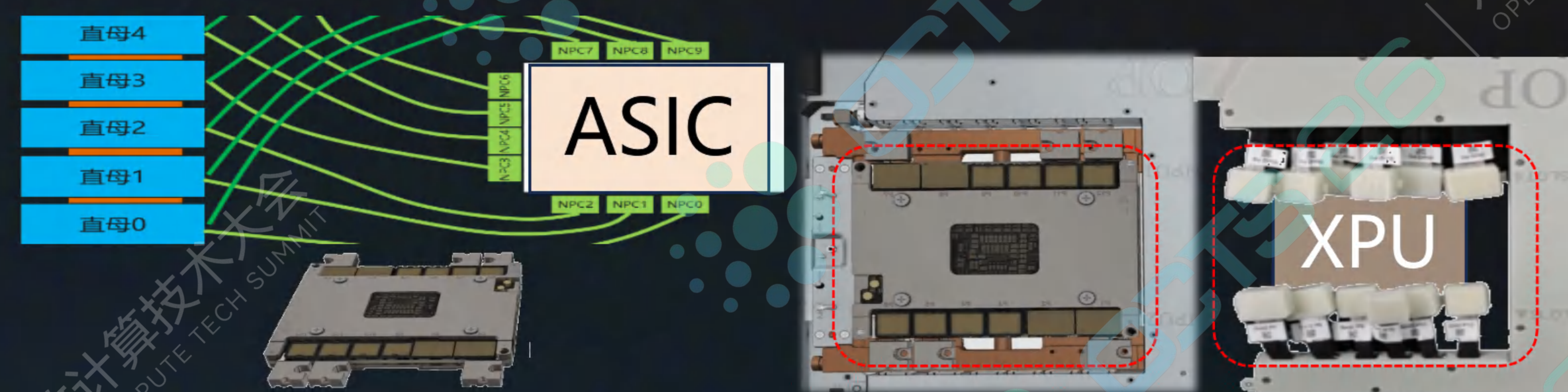


224G+ Ark+
224G Ark

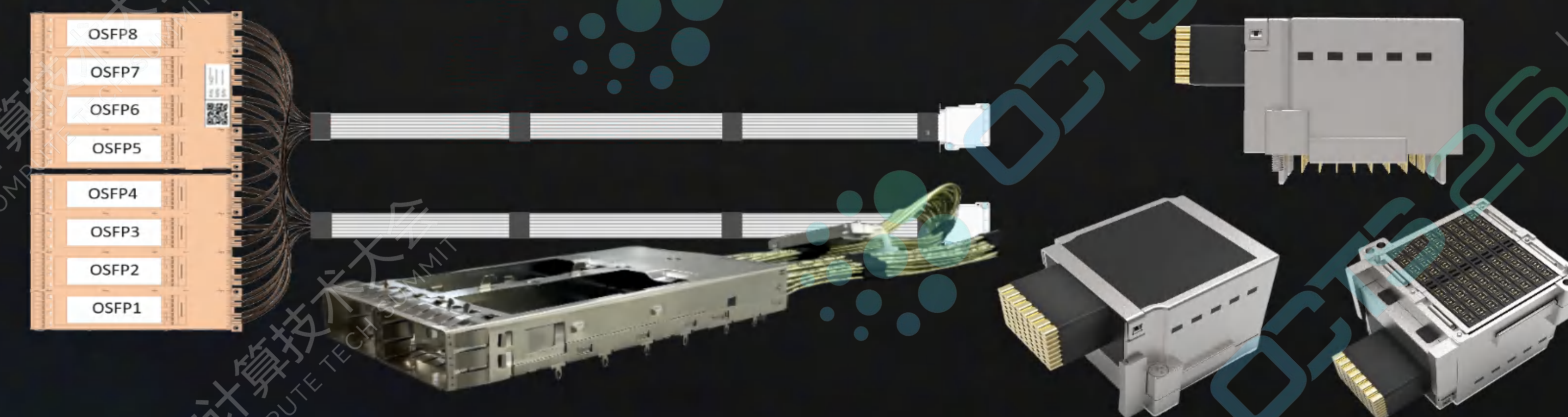


224G-自研界面-方舟 (ARK)

NPC - Cable Tray 模组 (BP)

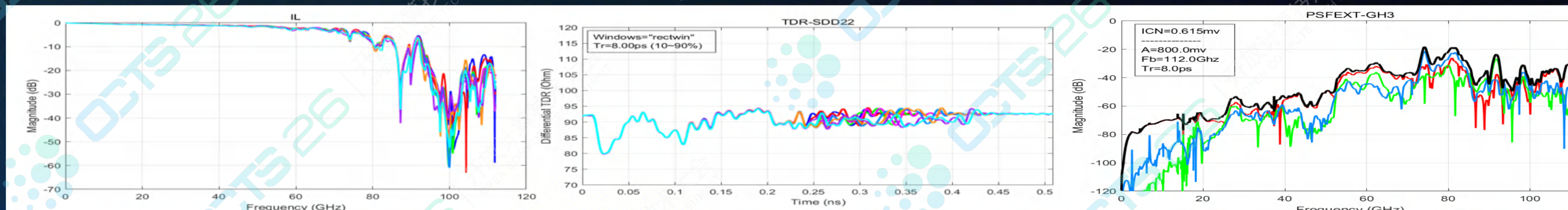


IO模组 (@OSFP&QSFP-DD)



产品应用类型	连接形态	左侧-产品类型	右侧-产品类型	产品速率	规格	密度
高速背板连接器	压接 @PCB	弯公 (正交)	NA	112~224G	12*12	2.7*2.2
高速背板连接器	压接 @PCB	弯母 (正交)	NA	112~224G	12*12	2.2*2.7
高速背板连接器	压接 @PCB	弯公 (标准)*	NA	112~224G	8*9	2.7*2.2
Cable Tray 模组 (BP)	BP to BP @Cable	BP@直公 (标准)	BP@直公 (标准)	112~224G	8*9	2.7*2.2
NPC - Cable Tray 模组 (BP)	BP to Chip @Cable	BP@直母 (标准)	CHIP @ 弯式	112~224G	8*9	2.7*2.2
NPC 模组	Chip to Chip @Cable	CHIP @ 弯式	CHIP @ 弯式	112~224G	8*8	2.3*2.3
CPC 模组 / IO 模组	Chip to IO @Cable	CHIP @ 弯式	(QDD & OSFP) @ 直母 + Cage	112~224G	8*12	2.3*2.3

高速连接器(BP & IO)



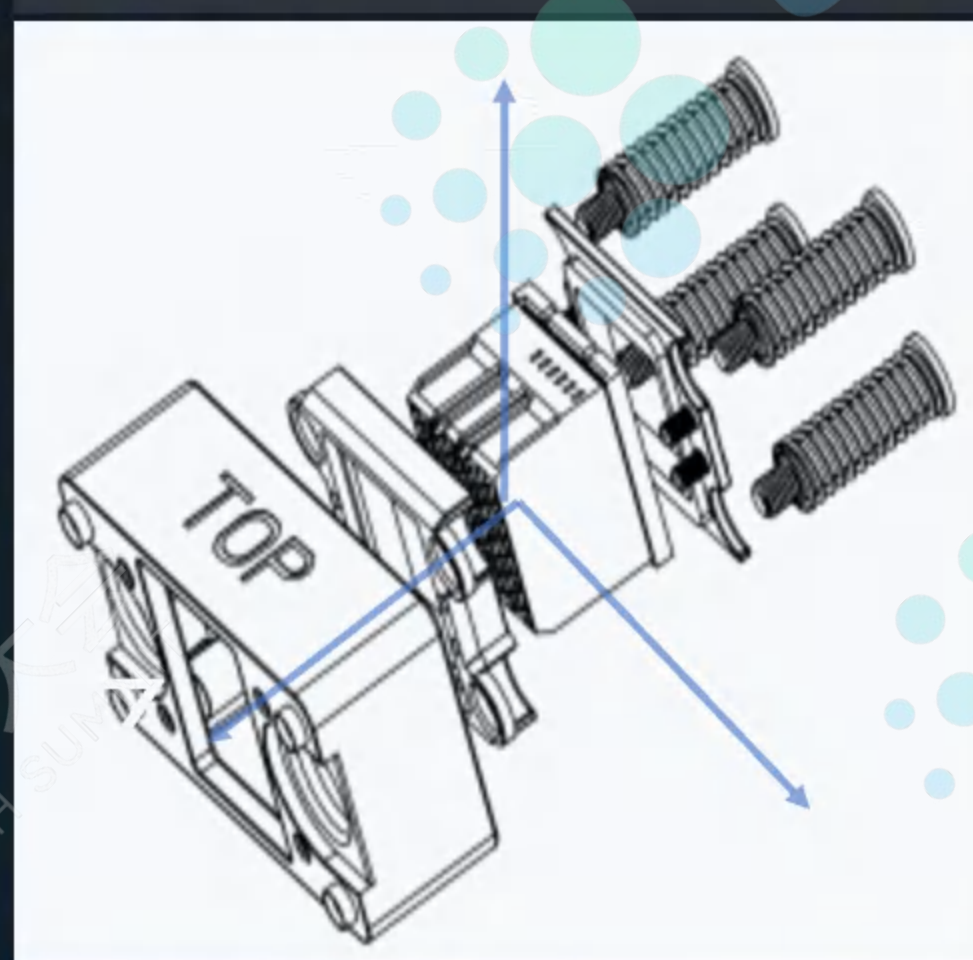
超节点高速互连的实践-可靠性

浮动设计 - 使用自主浮动设计，实现XYZ 三轴向浮动，XYZ 方向实现 $\pm 1.5 - 4.0 \text{ mm}$ 的互配浮动量

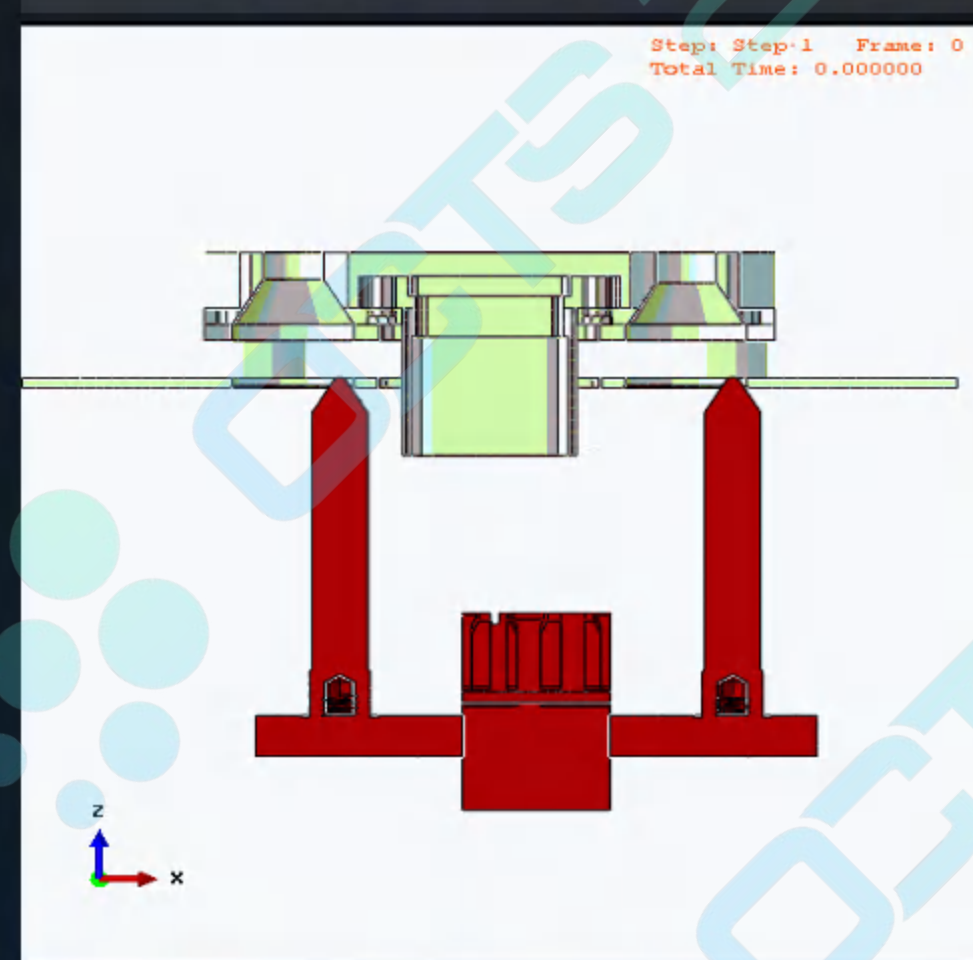
BP出线设计



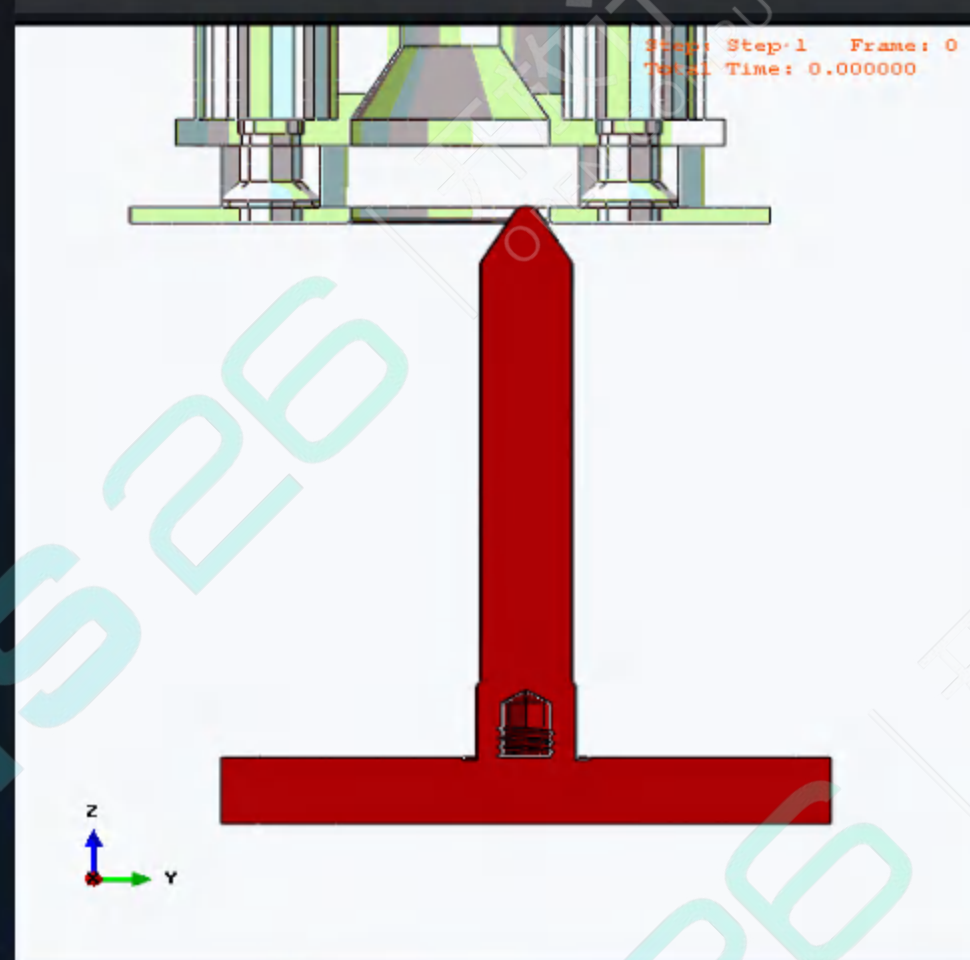
浮动设计



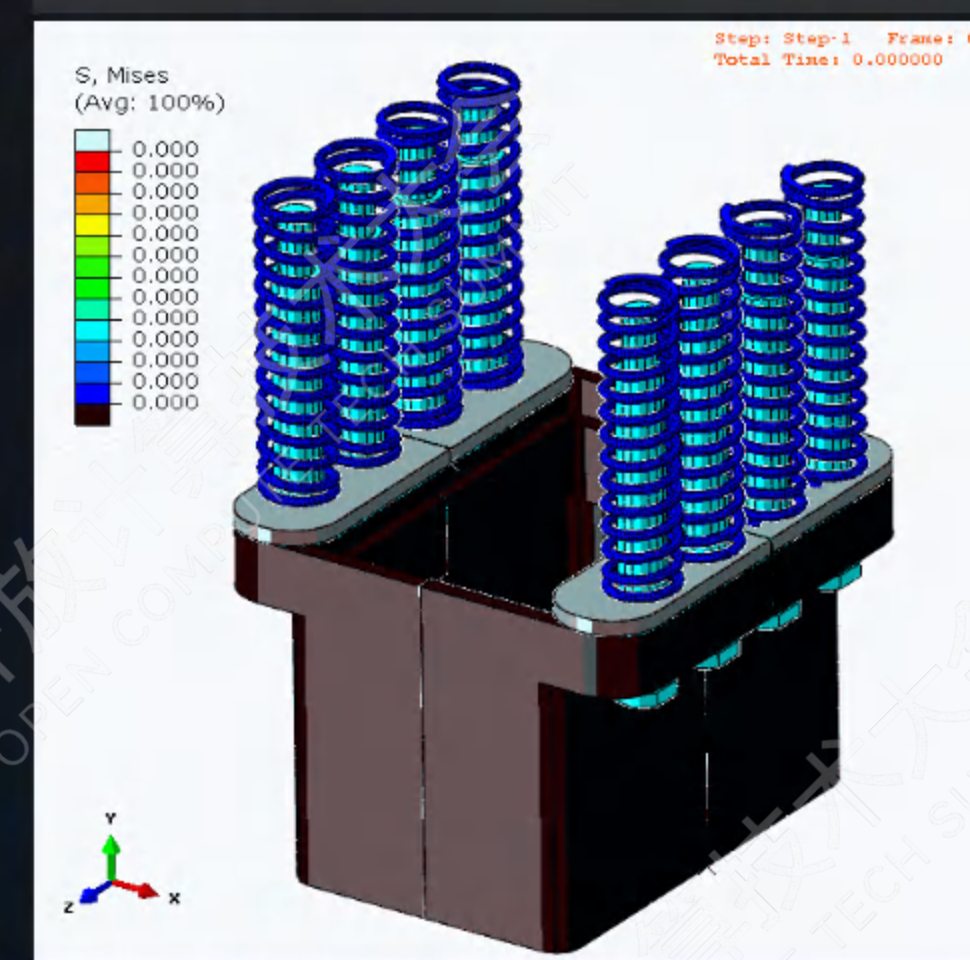
X方向浮动



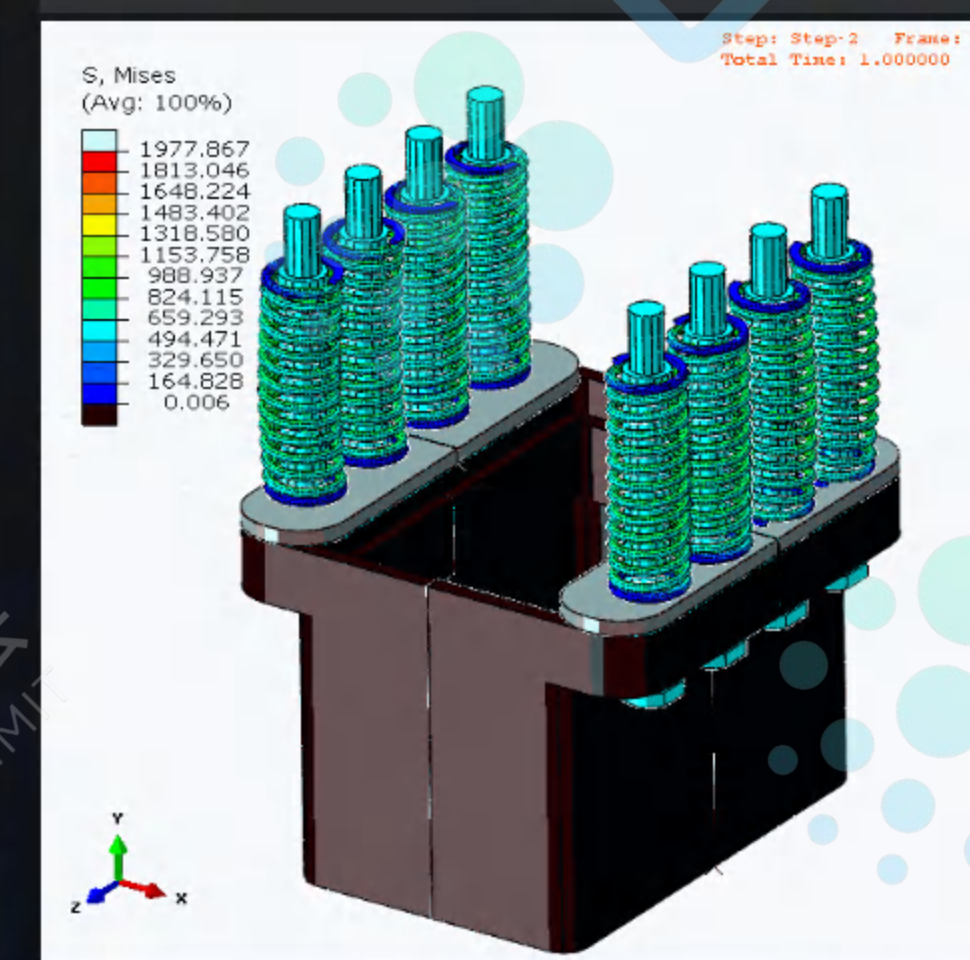
Y方向浮动



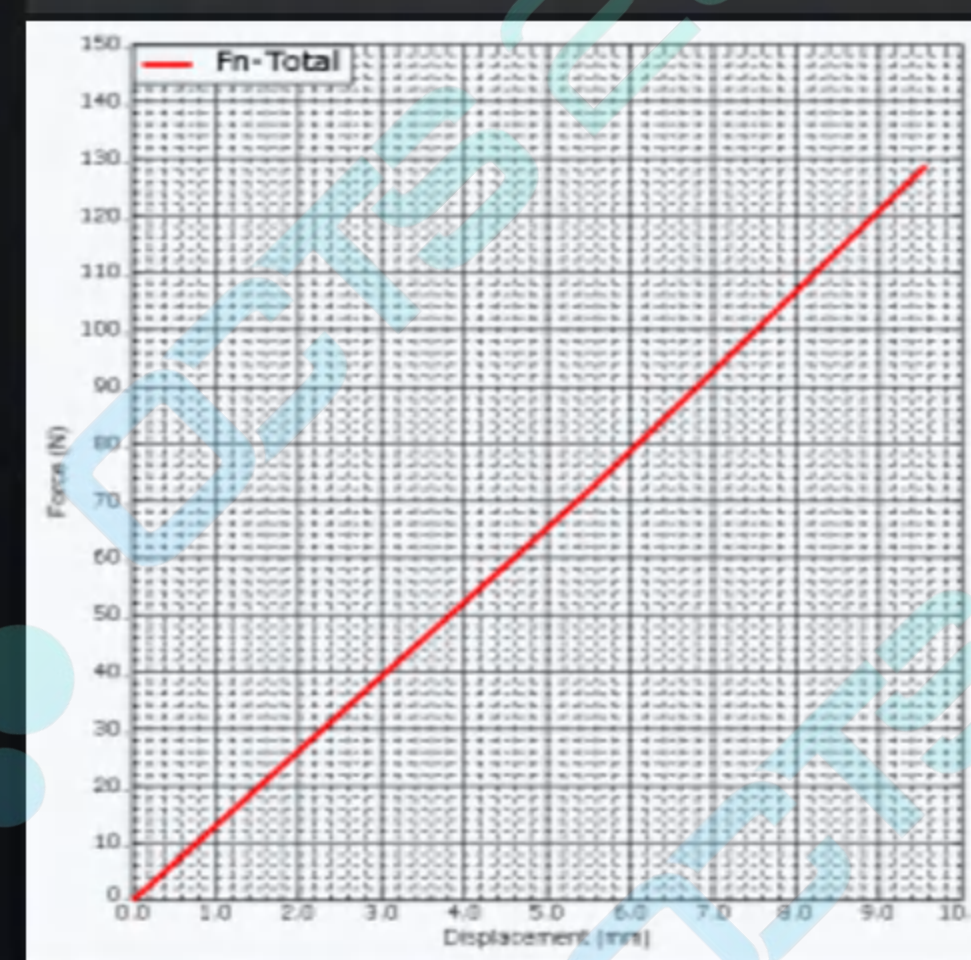
Z方向压缩



Z浮动压缩



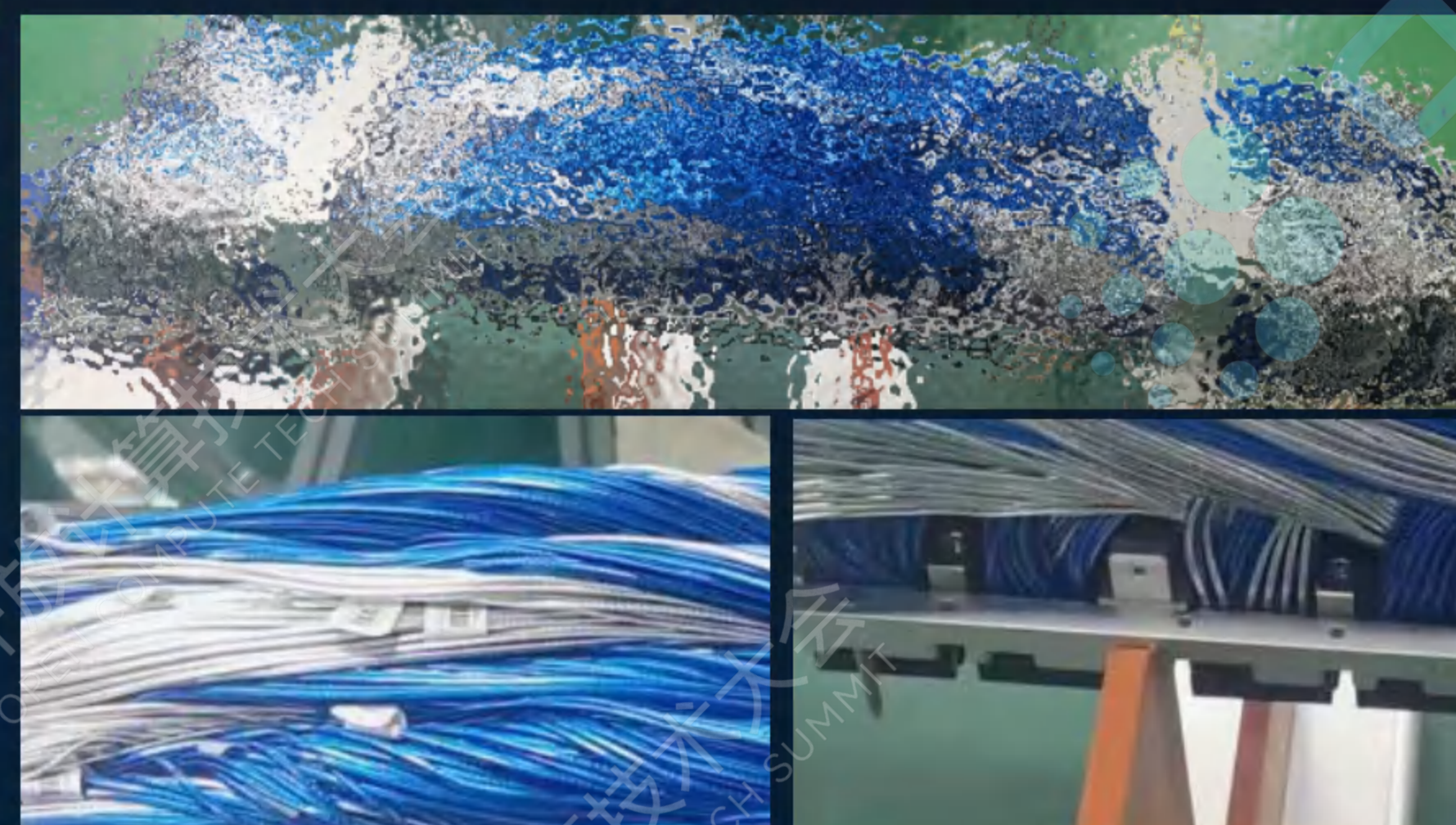
彈簧皆無降伏



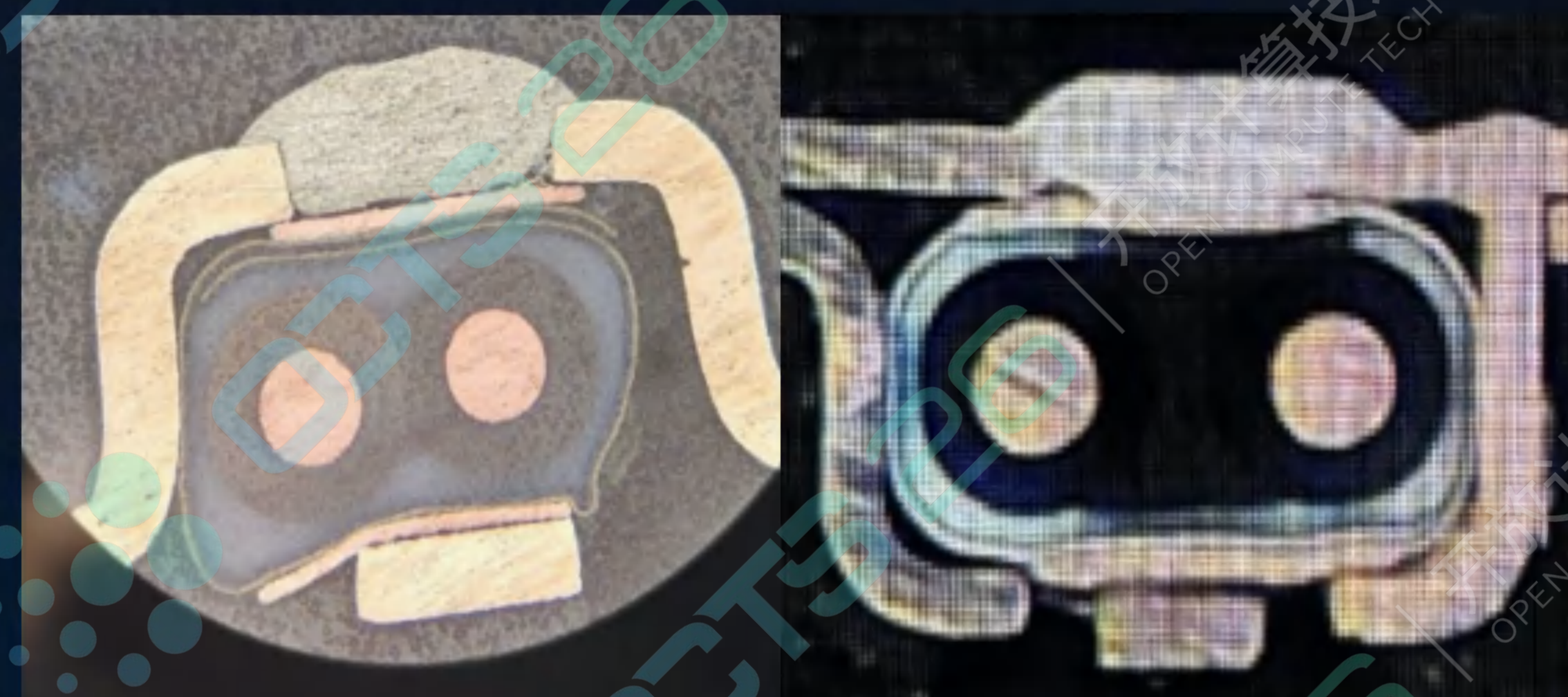
面板极限偏角插拔/强度

Group B (Step 1) : Change Panel Strength					Unit: N		
测试项目 (Test Item)	F1	F2	F3	F4	测试项目 (Test Item)	C1	C2
样品编号 (Sample No.)					样品编号 (Sample No.)		
					PIN 1	181.5	157.8
					PIN 2	199.9	218.5
					PIN 3	181.5	226.6
					PIN 4	234.6	238.1
测试照片 (Test Photo)					测试照片 (Photo)		

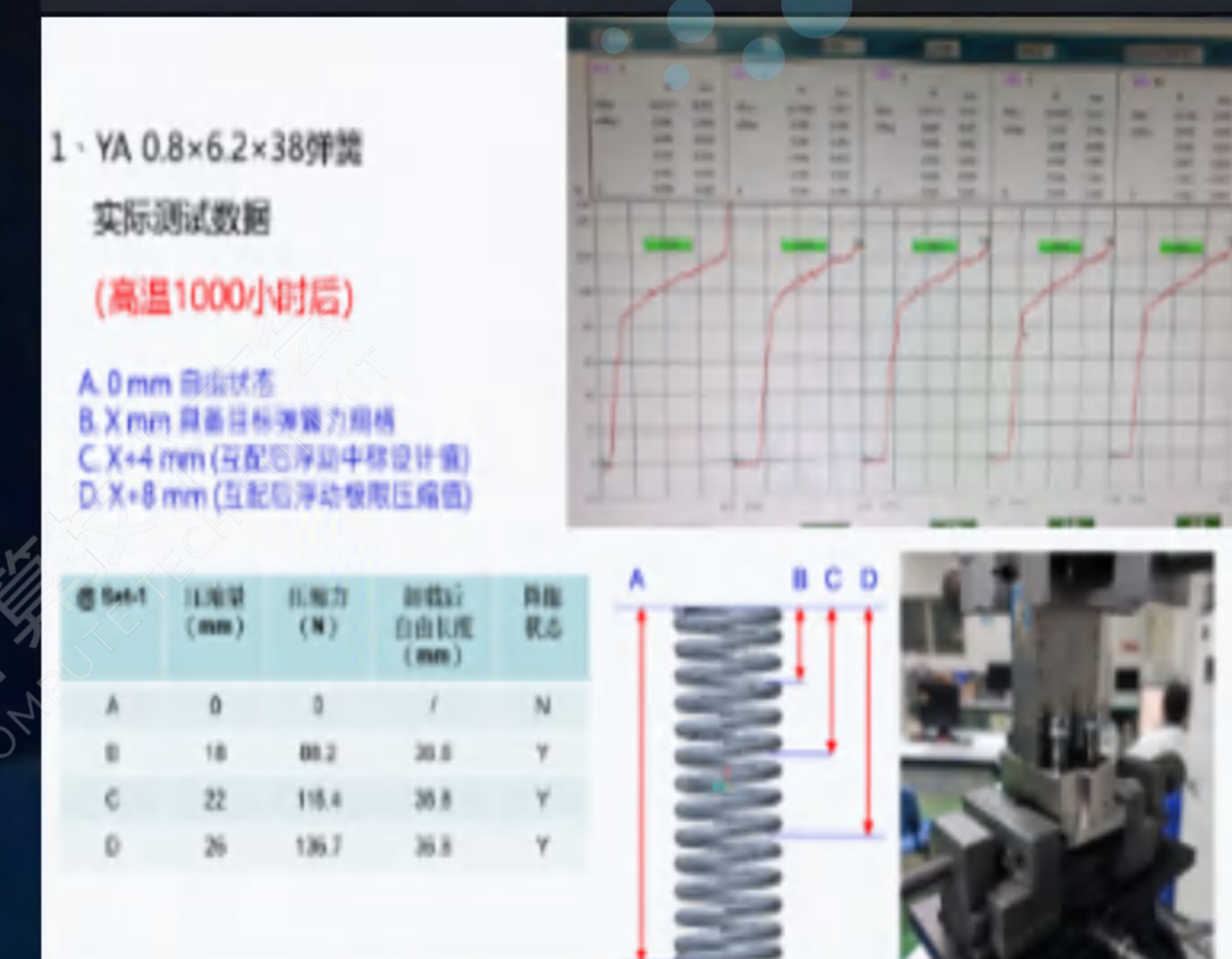
混合线材应用与梳理



复合焊接有效性

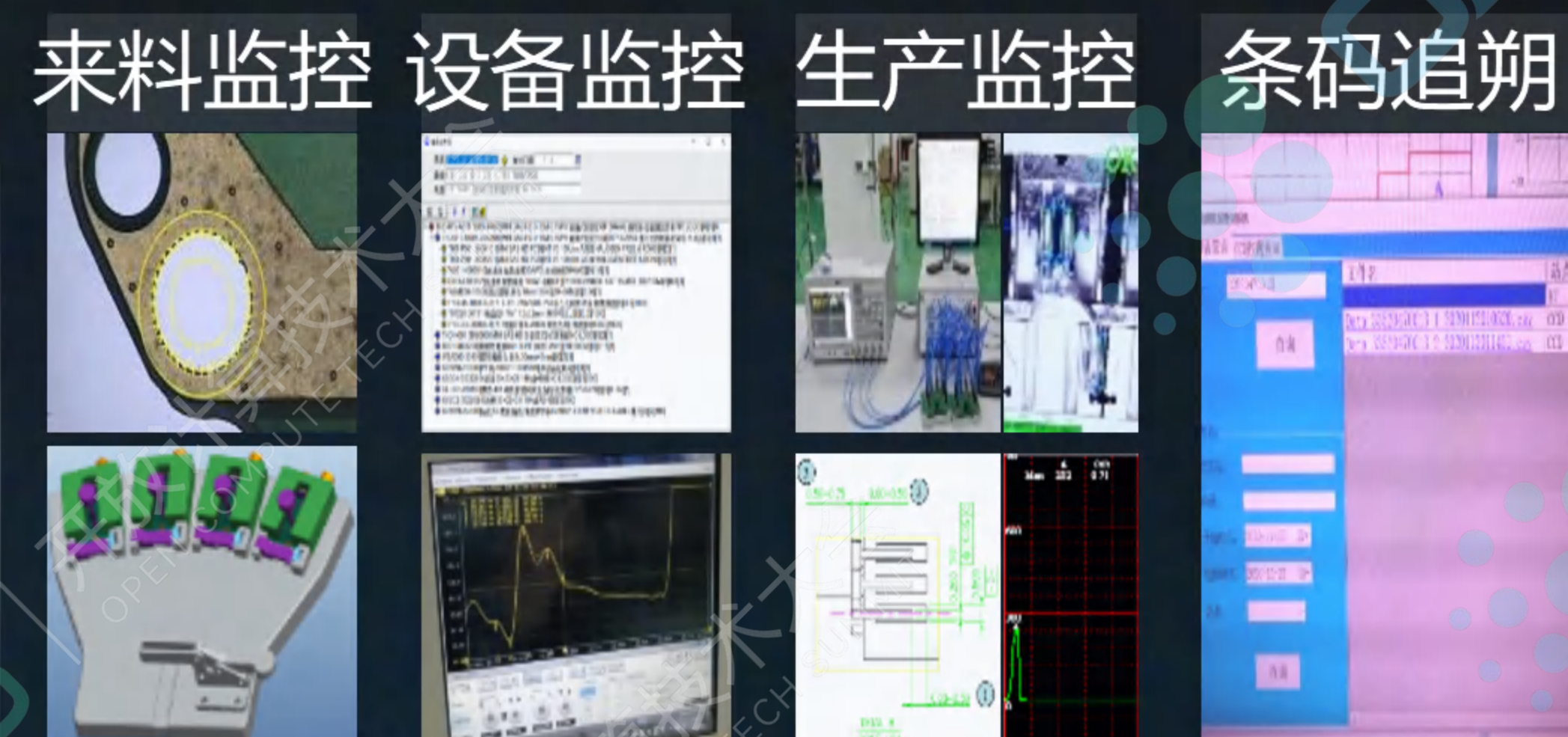


高温老化-1K小时

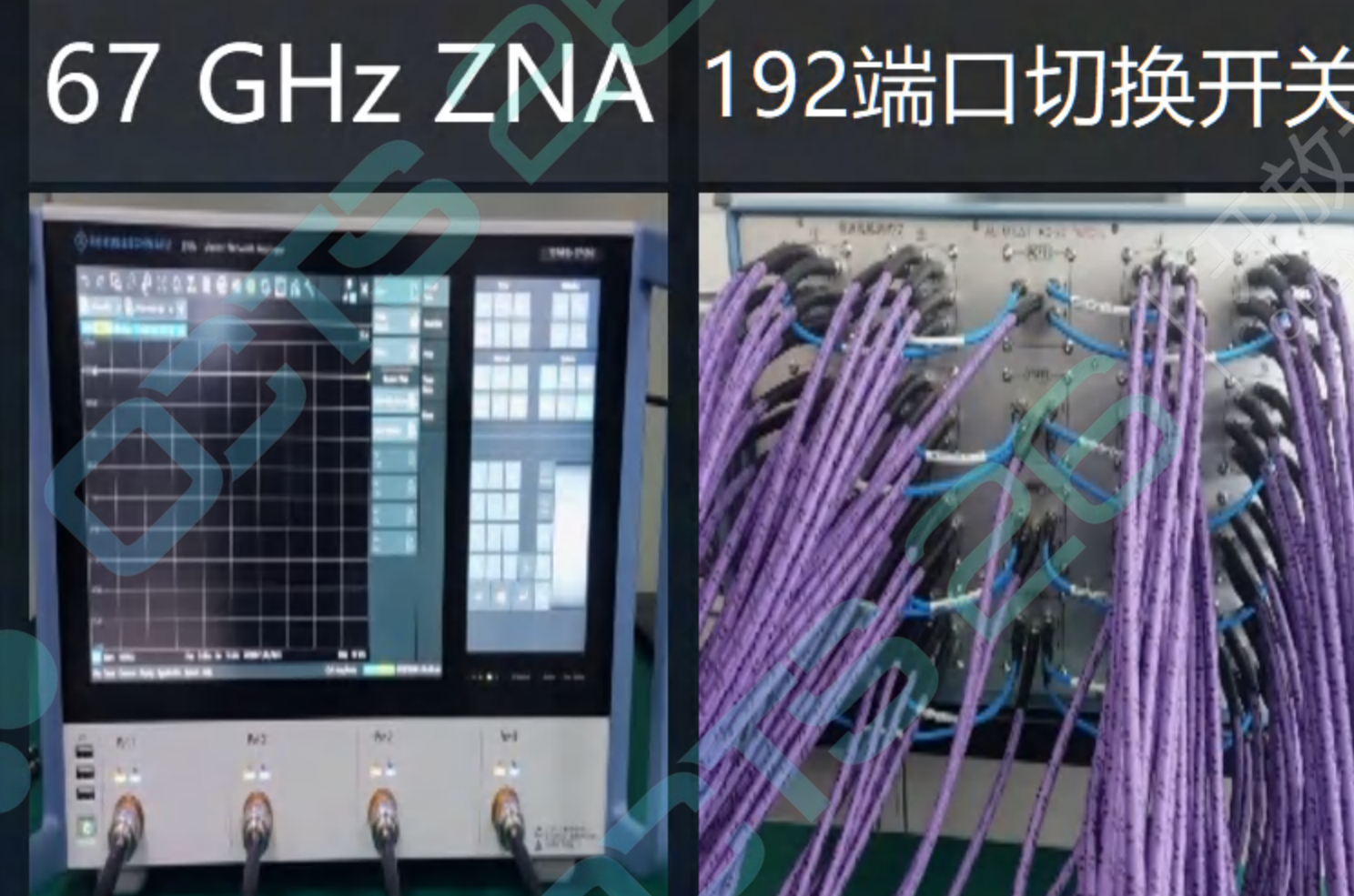


超节点高速互连的实践-品质保障

常规测试



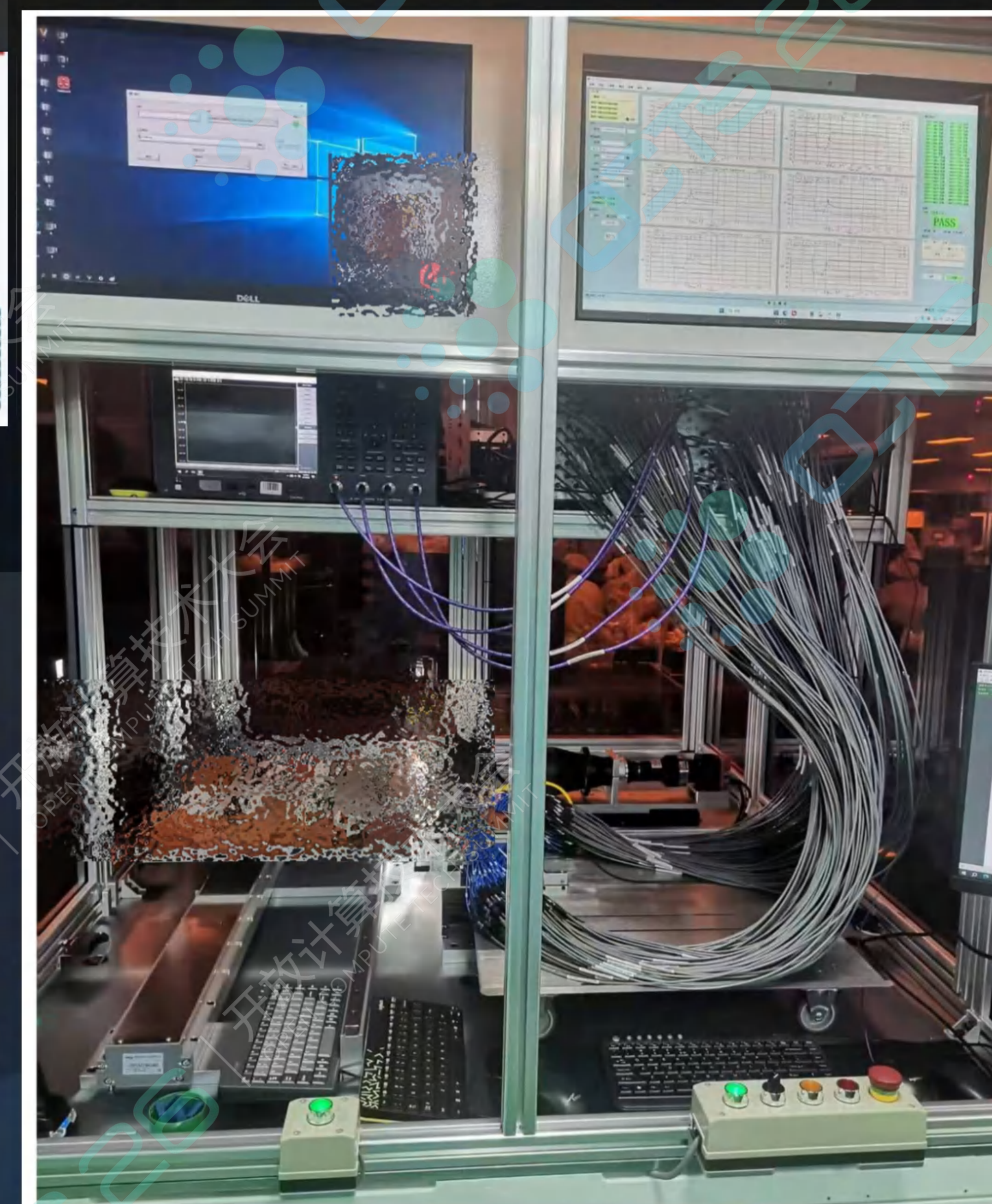
网分换矩阵开关



SI 100%检测



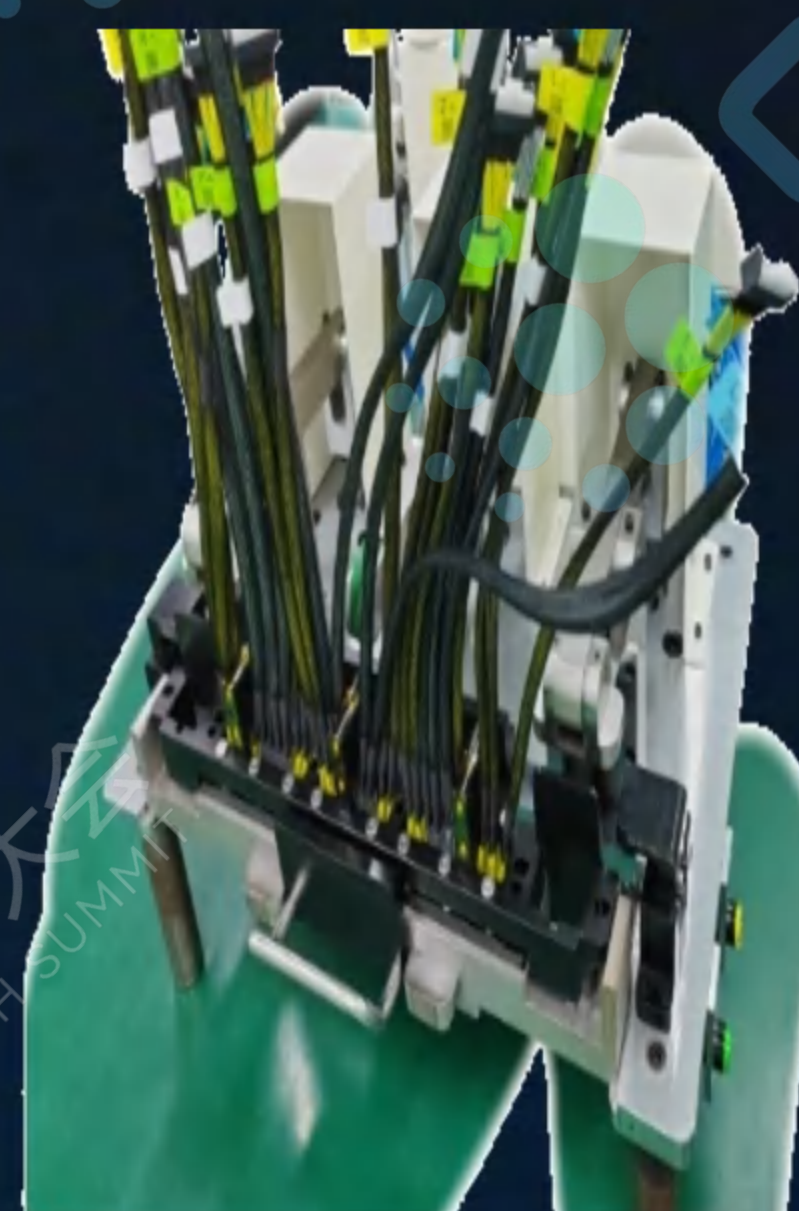
整Tray级-全通道检测 (SI-TDR & AOI)



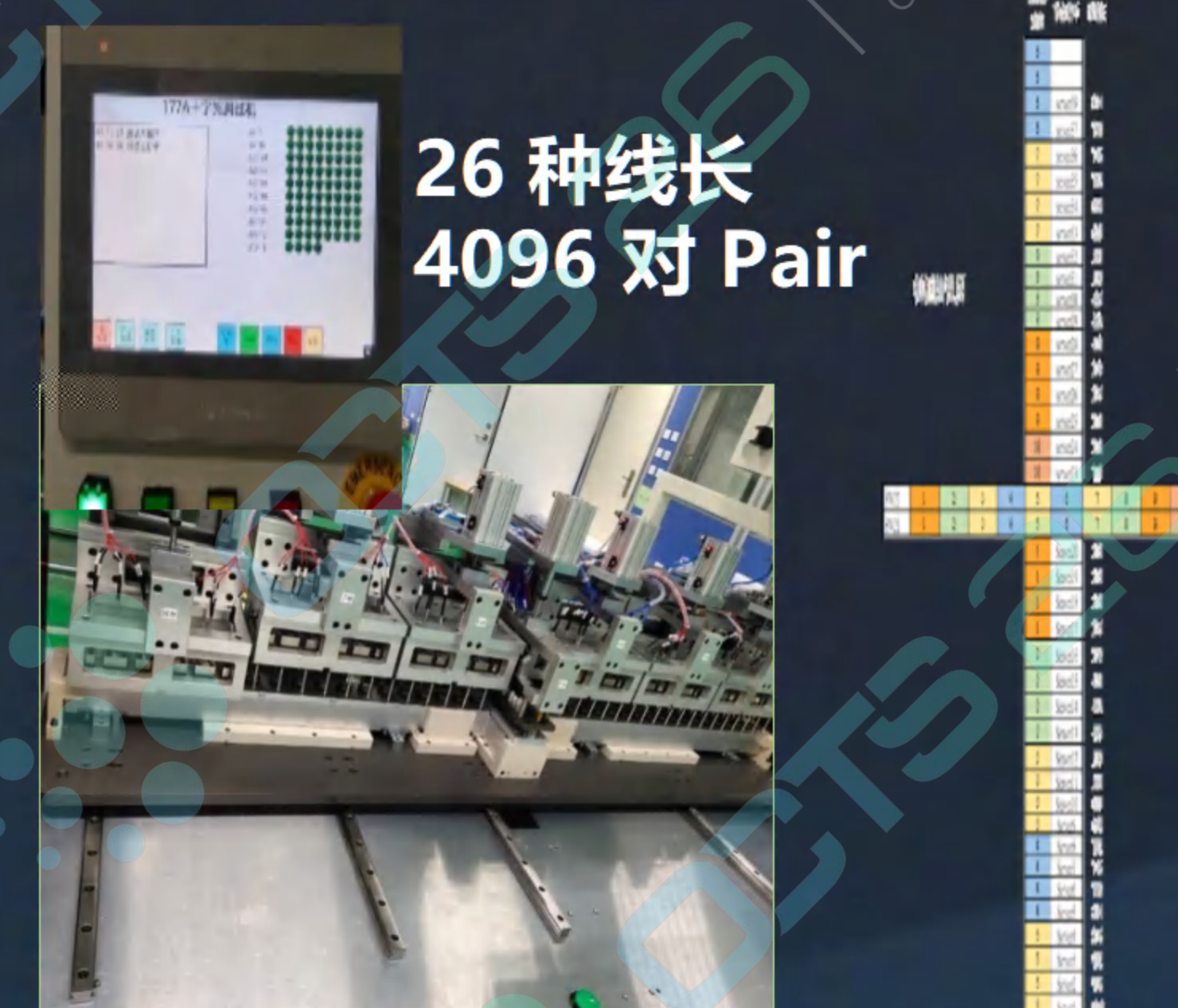
关键尺寸AOI检验



浮动力测试

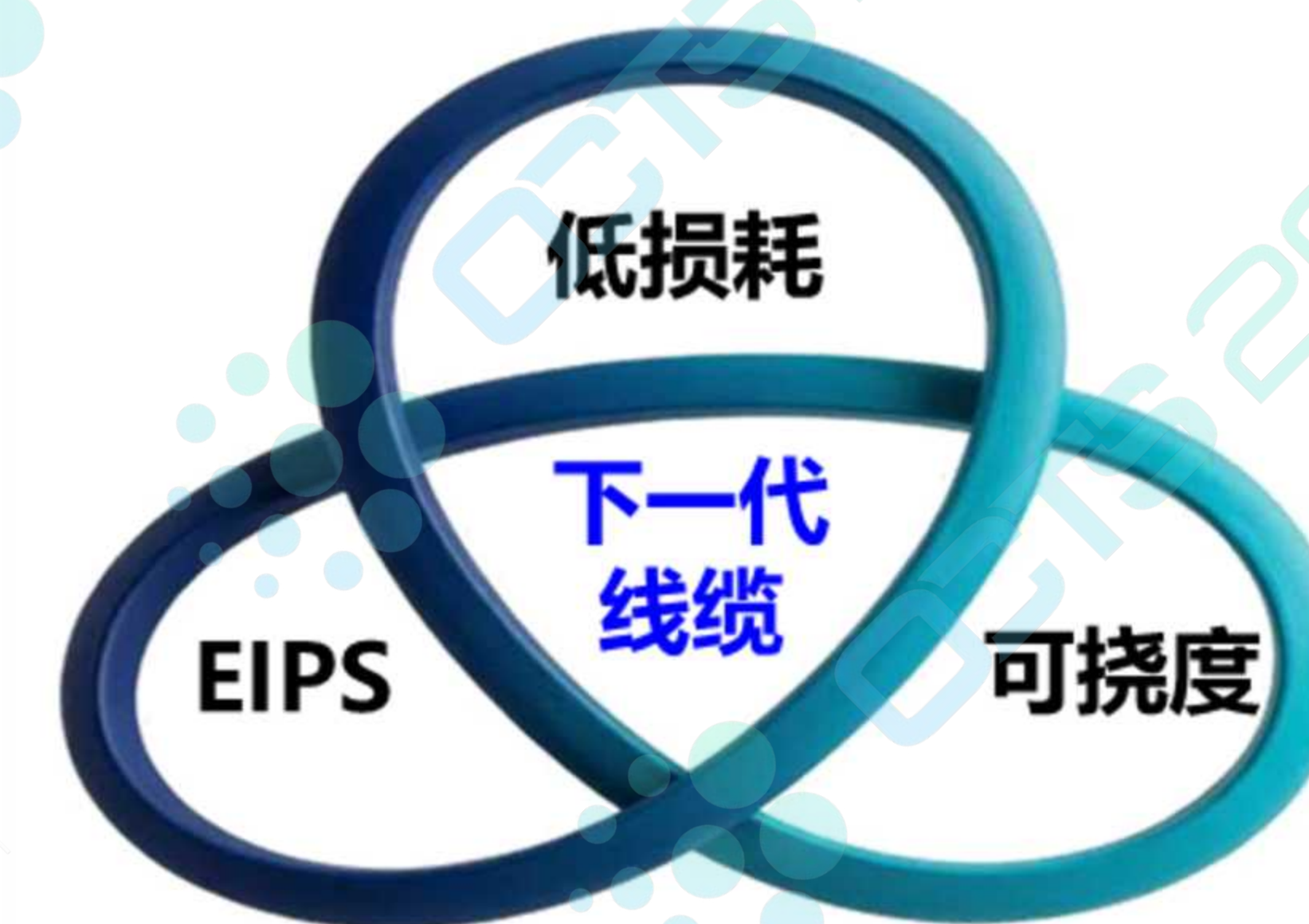


12-40U-Tray级 全线序检验 (*TDR*)

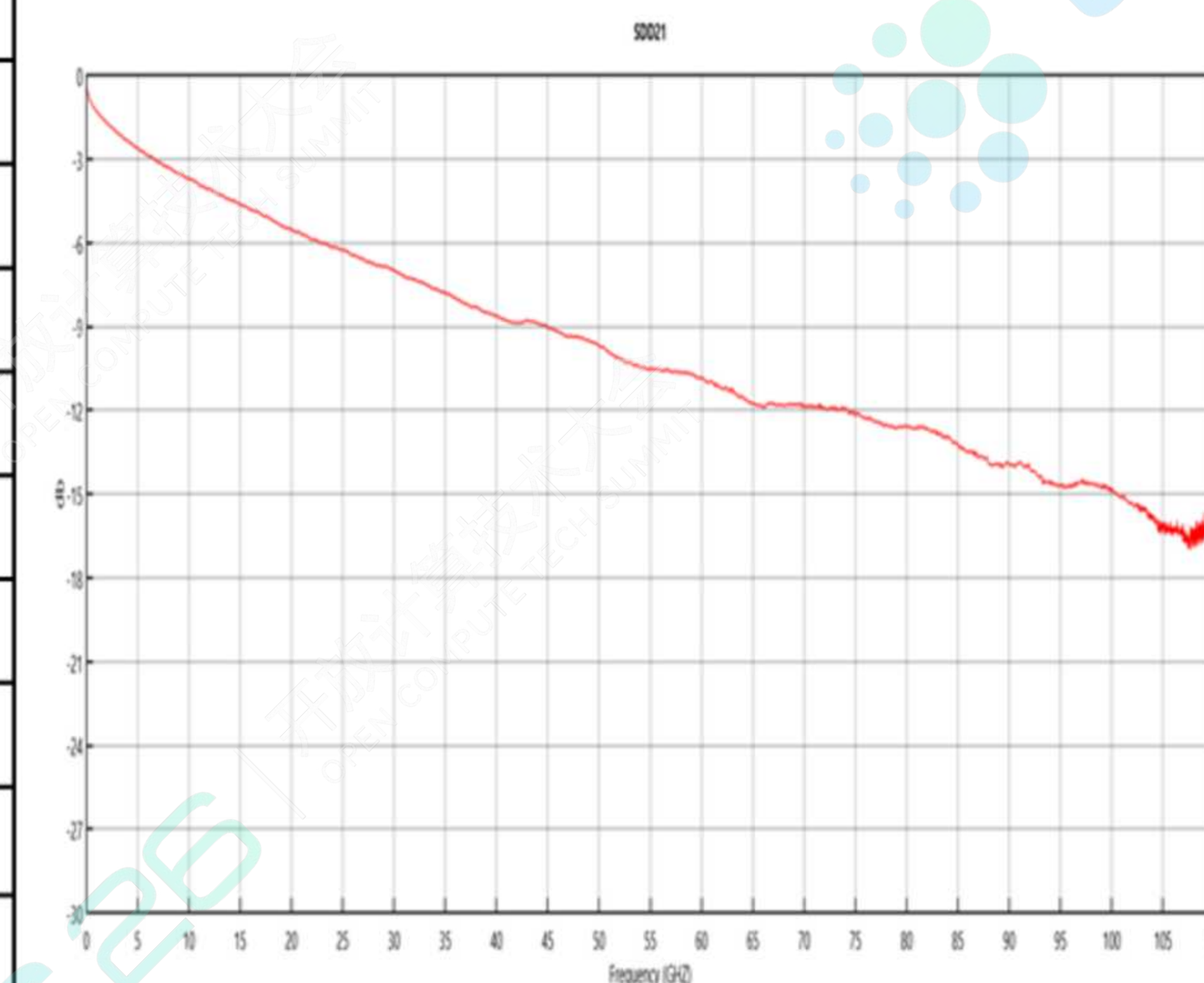


224&224+ Raw Cable 生态伙伴推动

合作伙伴	线规 (AWG)	阻抗	导体	结构	IL dB@1M		
					112Gbps (26.65GHz)	224 Gbps (53.13GHz)	224+ Gbps (89.6 GHz)
厂家-A	25	92	0.455	Foam-FEP+铜箔	4.56	7.29	-
厂家-A	26	101.5	0.405	FEP+EPTFE	4.31	6.98	-
厂家-A	26	94	0.425	FEP+EPTFE	4.39	7.25	-
厂家-A	26	92	0.405	Foam-FEP+铜箔	5.25	8.10	-
厂家-C	28	93.5	0.32	FEP+FEP	5.94	10.03	-
厂家-A	28	90	0.35	FEP+EPTFE	5.44	8.67	-
厂家-B	30	91.5	0.254	FEP双抽共挤	7.13	11.93	-
厂家-D	30	88.5	0.275	FEP+PE铜箔	7.07	10.79	-
厂家-A	30	92	0.285	FEP+EPTFE	6.58	10.20	-
厂家-A	30	94.5	0.283	FEP+FEP	7.14	10.98	-
厂家-B	32	95.5	0.2	FEP双抽共挤	9.44	16.86	-
厂家-C	32	95	0.22	FEP+FEP	9.06	15.25	-
厂家-A	32	92	0.225	FEP+EPTFE	9.04	14.46	-
厂家-D	32	92	0.22	FEP双抽共挤	-9.11*	15.16	-
厂家-B	32	92	0.20	FEP双抽共挤	7.91	11.5	16.1
厂家-A	34	92	0.18	FEP+FEP	-9.35*	16.67	-



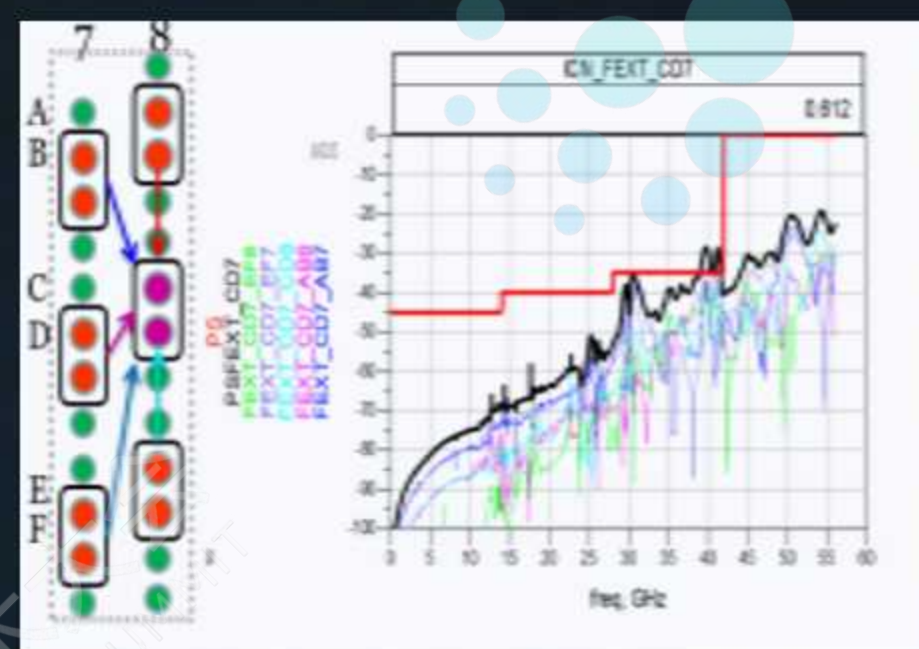
2.3 Attenuation (SDD21)



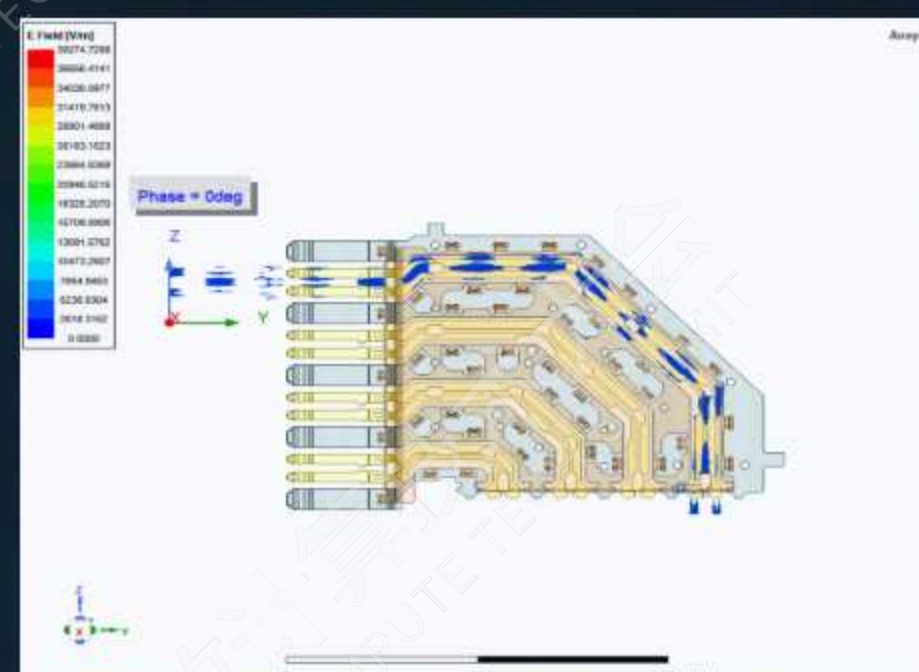
技术发展-下一代速率224 & 448G 思考点

性能指标

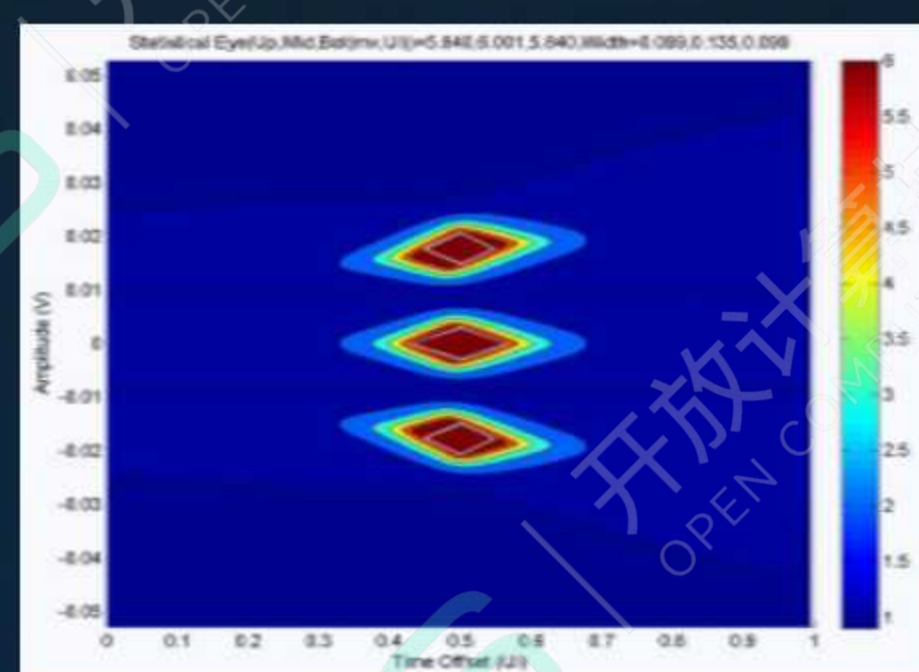
无源模拟



动态场分析



眼图分析

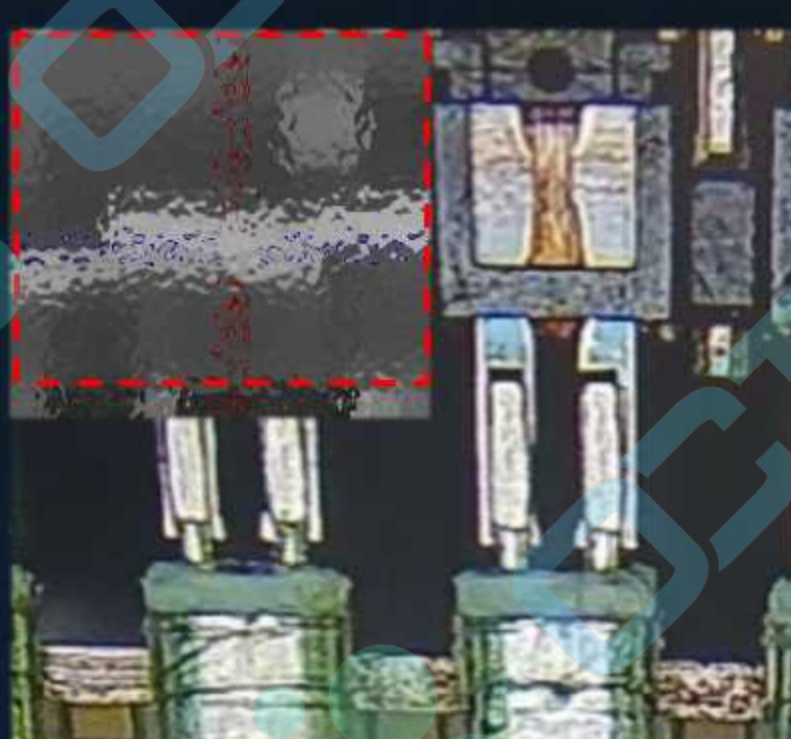


新结构

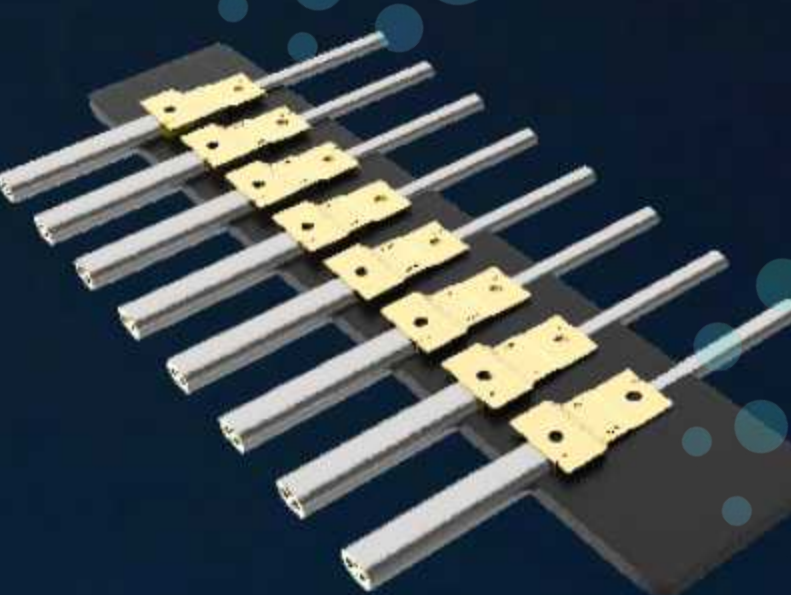
超微型鱼眼



弹性导电材



多合金焊接



变线径连接

加工根技术

双面异型材



镦圆技术



包圆工艺技术



扭转工艺技术

新材料线缆

56G



112G



224G
(448G)



THANKS

THANKS

THANKS