vanguard
AUTOMATION

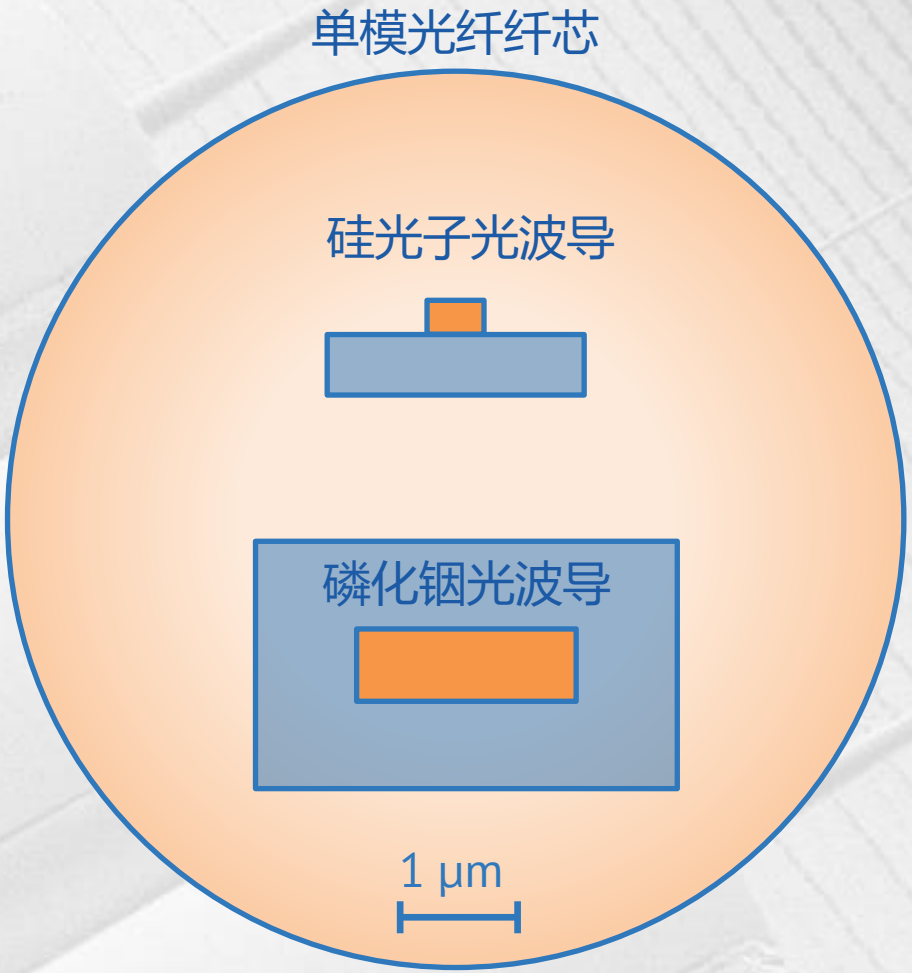
bright connections

下一代光子集成和封装的解决方案

- 光子引线键合（Photonic Wire Bonding）
- 附面微光学元件（Facet-Attached Micro-Lenses）

当今光子集成及封装的挑战

不同的模场尺寸以及异质材料平台



→ 模场匹配

→ 高精度组装对准

→ 快速且可重复的封装

→ 在不同条件下的可靠性

→ 光子集成系统中超过70%的成本来自于封装工艺

迅速增长的光子集成电路行业

25.9% 复合年均增长率 (来源: MarketFutureResearch.com)

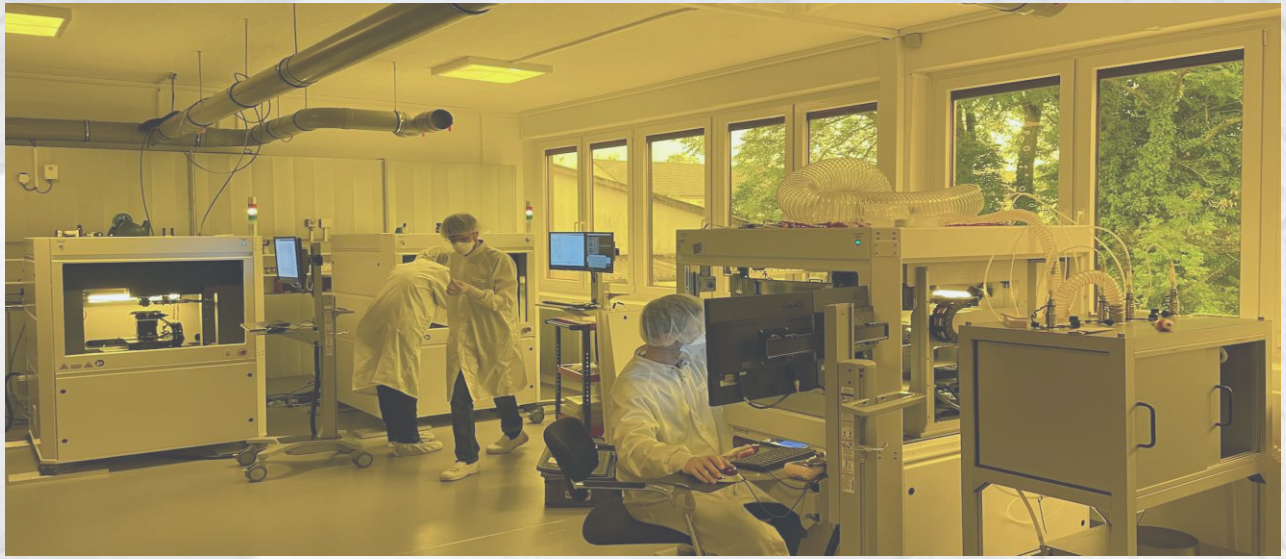
电信通信行业

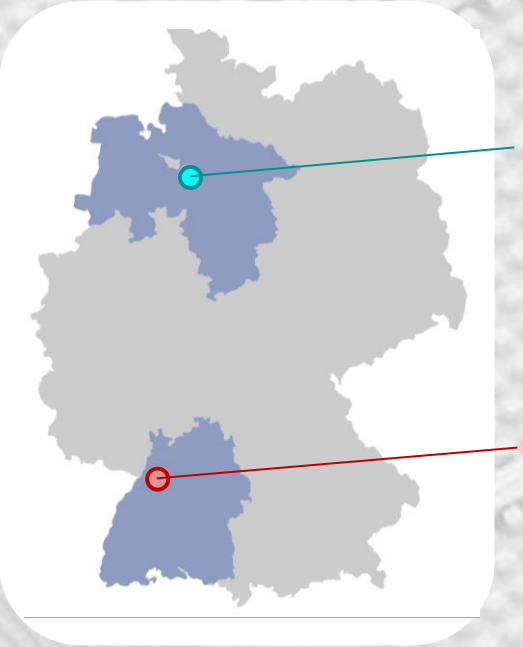
3D 传感

量子应用

然而，封装和组装混合多芯片的光子集成系统仍然是一项重大的技术和商业挑战。

Vanguard Automation





Bremen **Manufacturing**

ficonTEC photonics assembly & testing

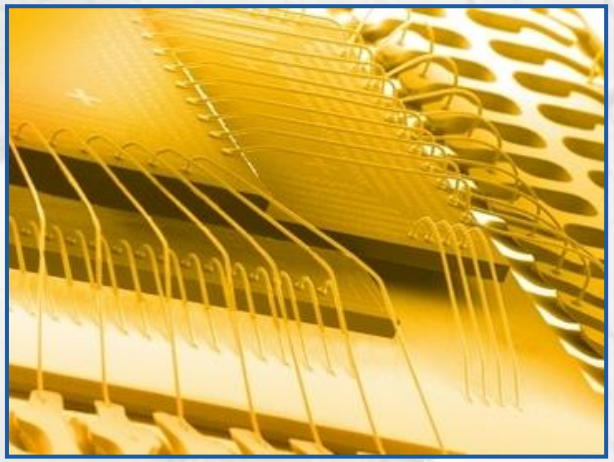
Karlsruhe

vanguard AUTOMATION bright connections

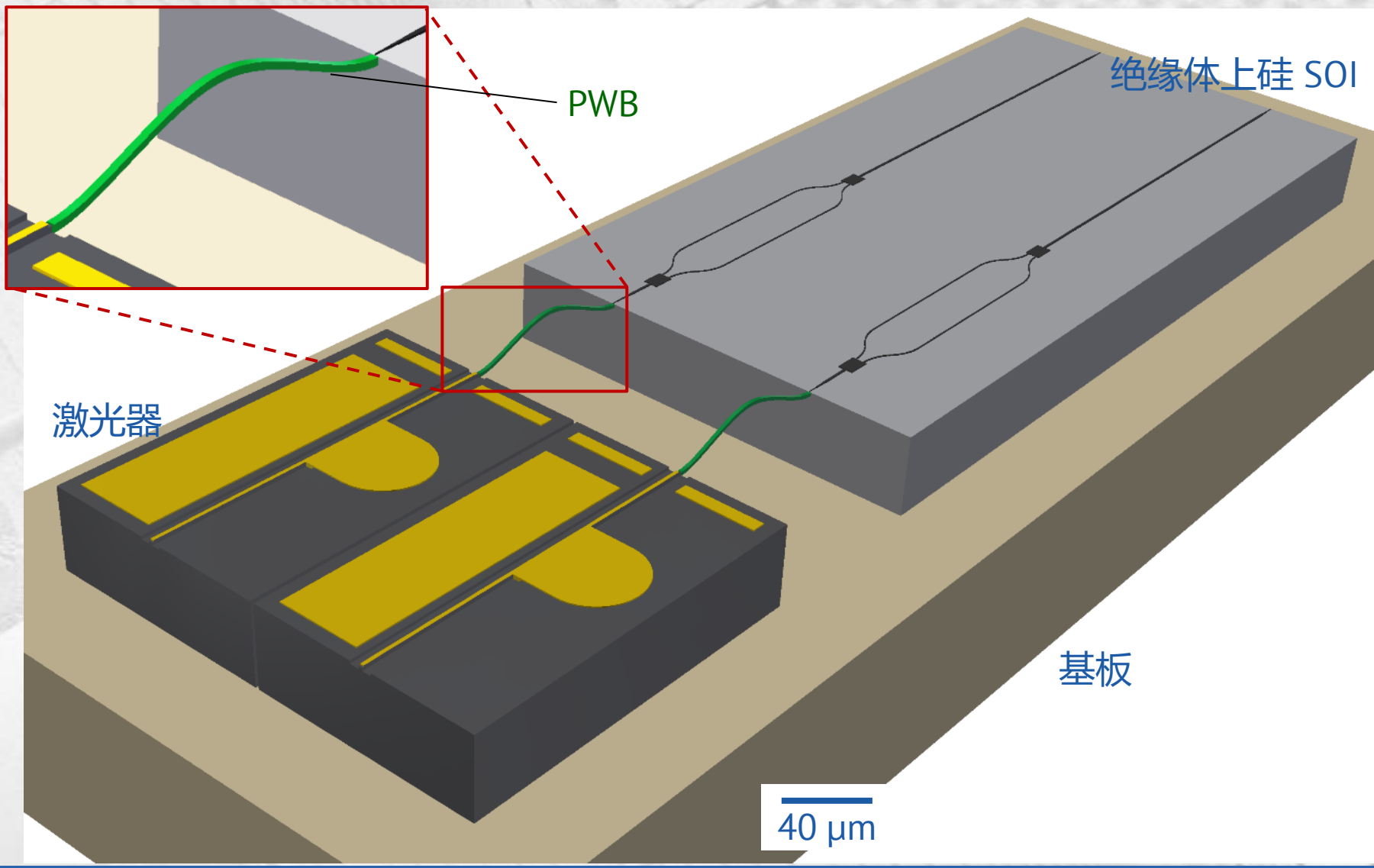
Mission

通过可扩展的3D纳米加工技术，为原型机和**工业生产**提供先进光子封装和组装解决方案

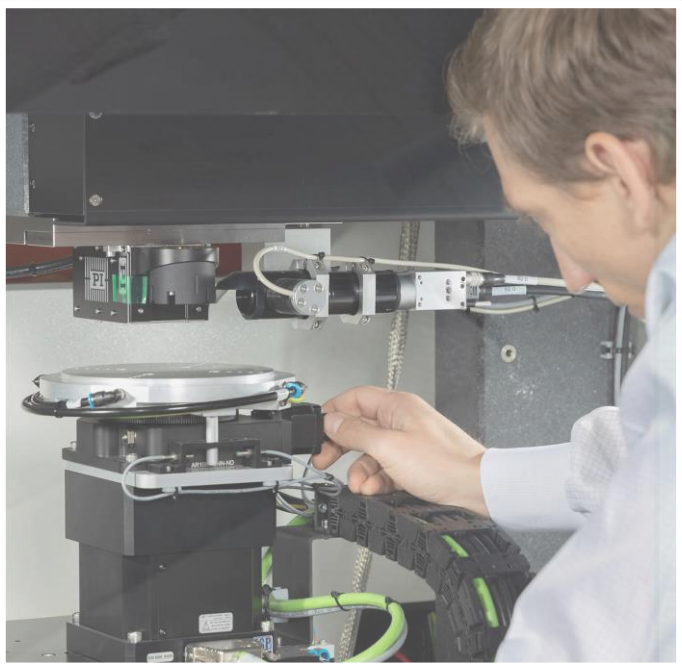
电子引线键合–光子引线键合 Photonic Wire Bonding (PWB)



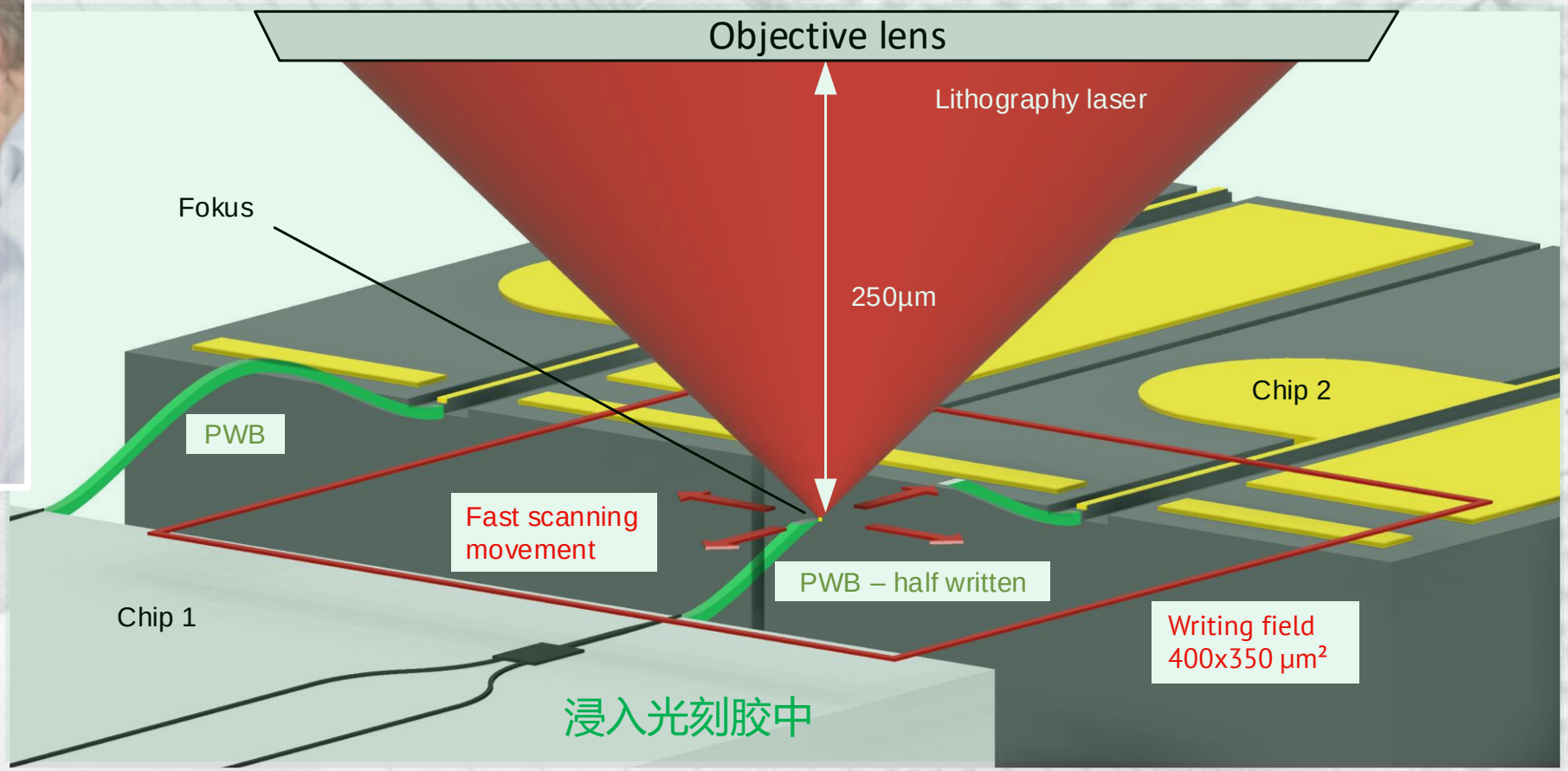
Source: Kulicke & Soffa, http://www.kns.com/



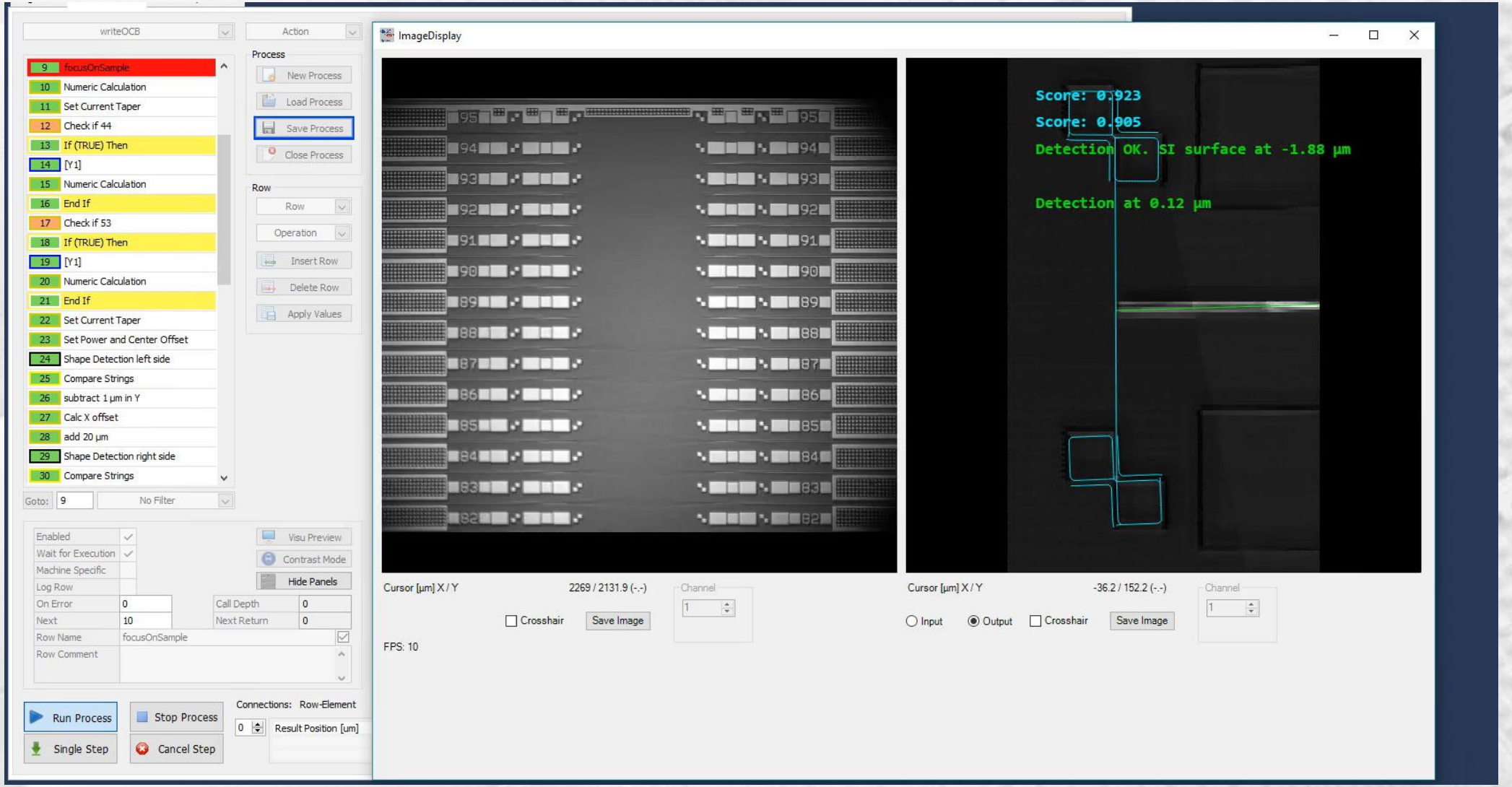
光子引线键合 Photonic Wire Bonding: The Concept



SONATA 1000

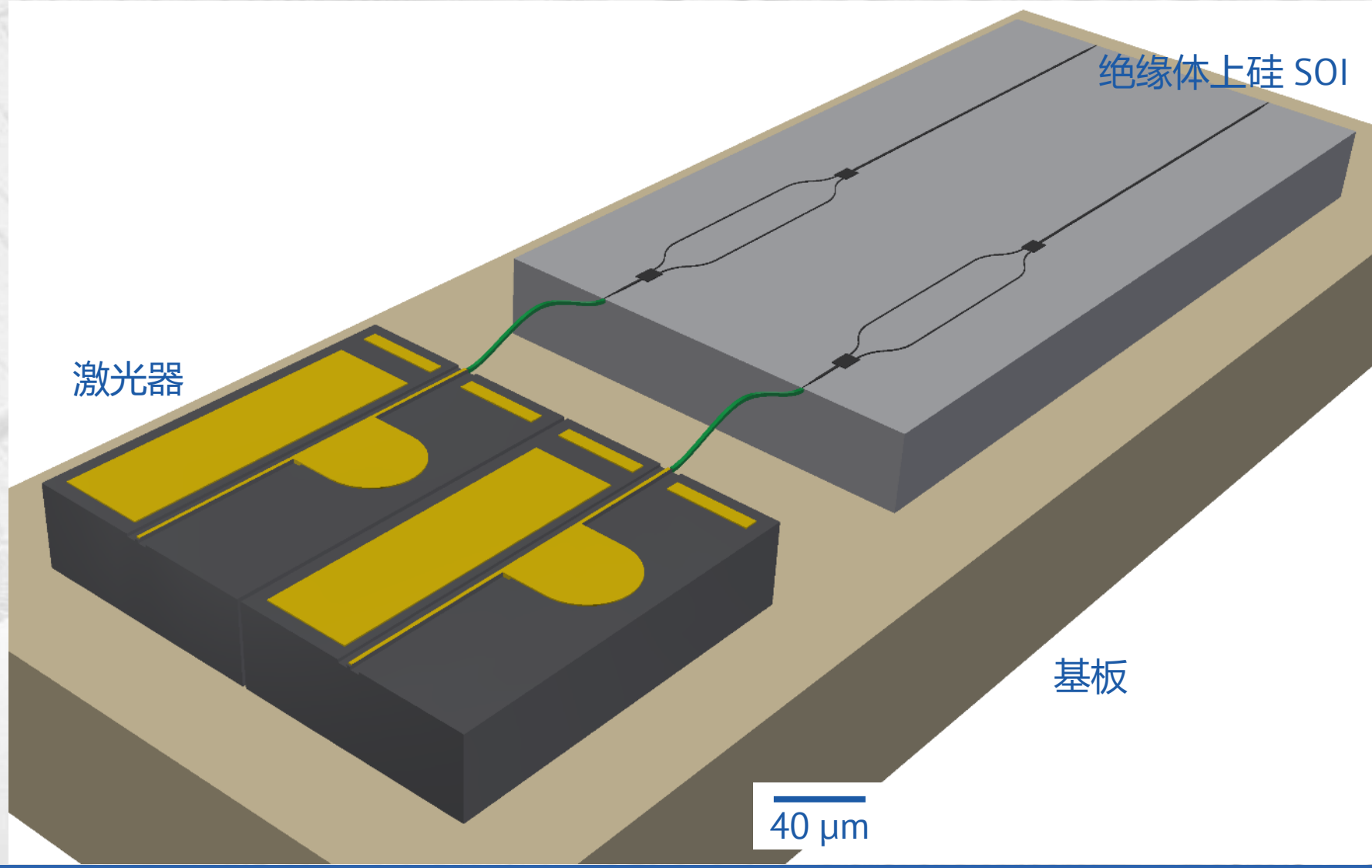


光子引线键合 Photonic Wire Bonding: The Reality



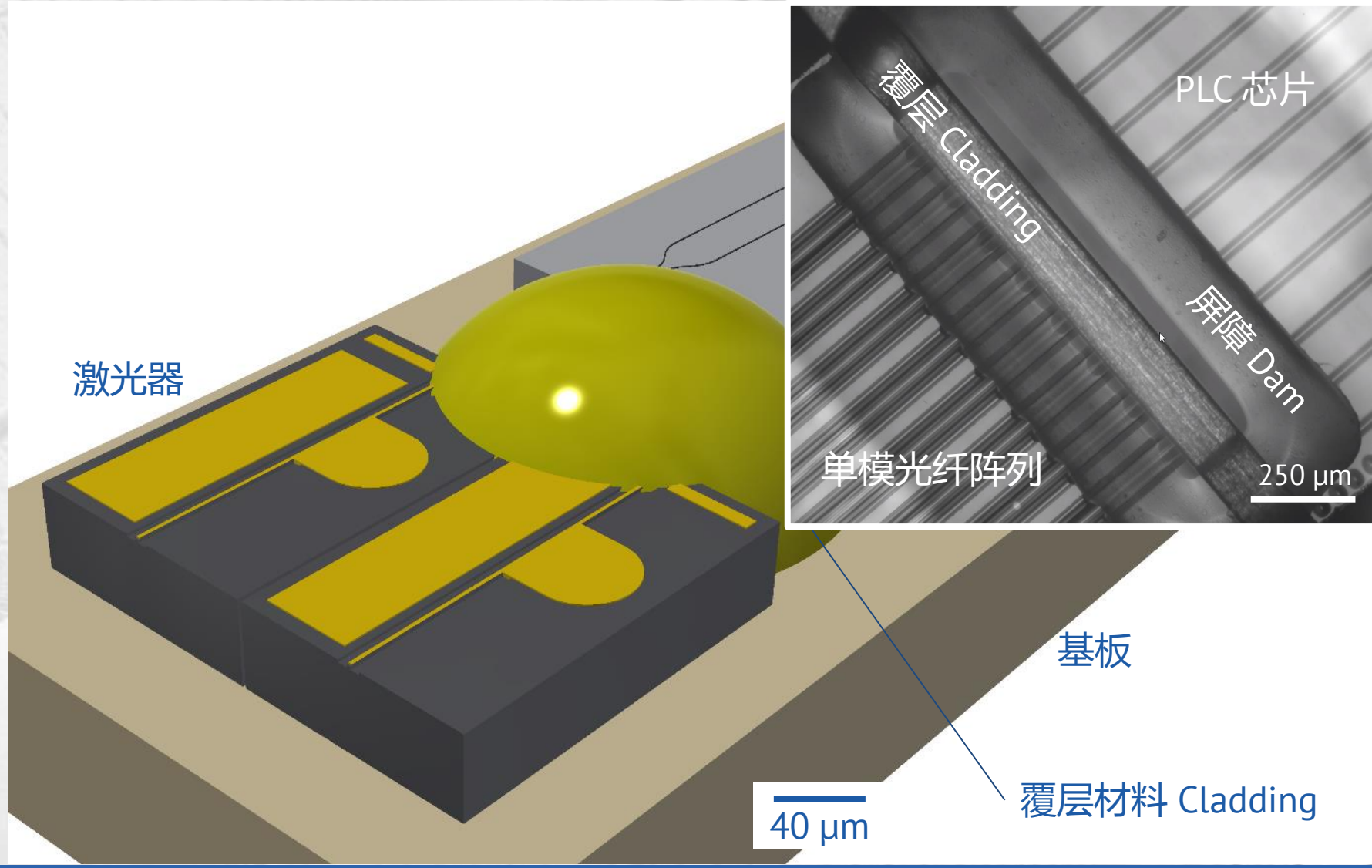
光子引线键合 Photonic Wire Bonding: The Concept

REPRISE 1000

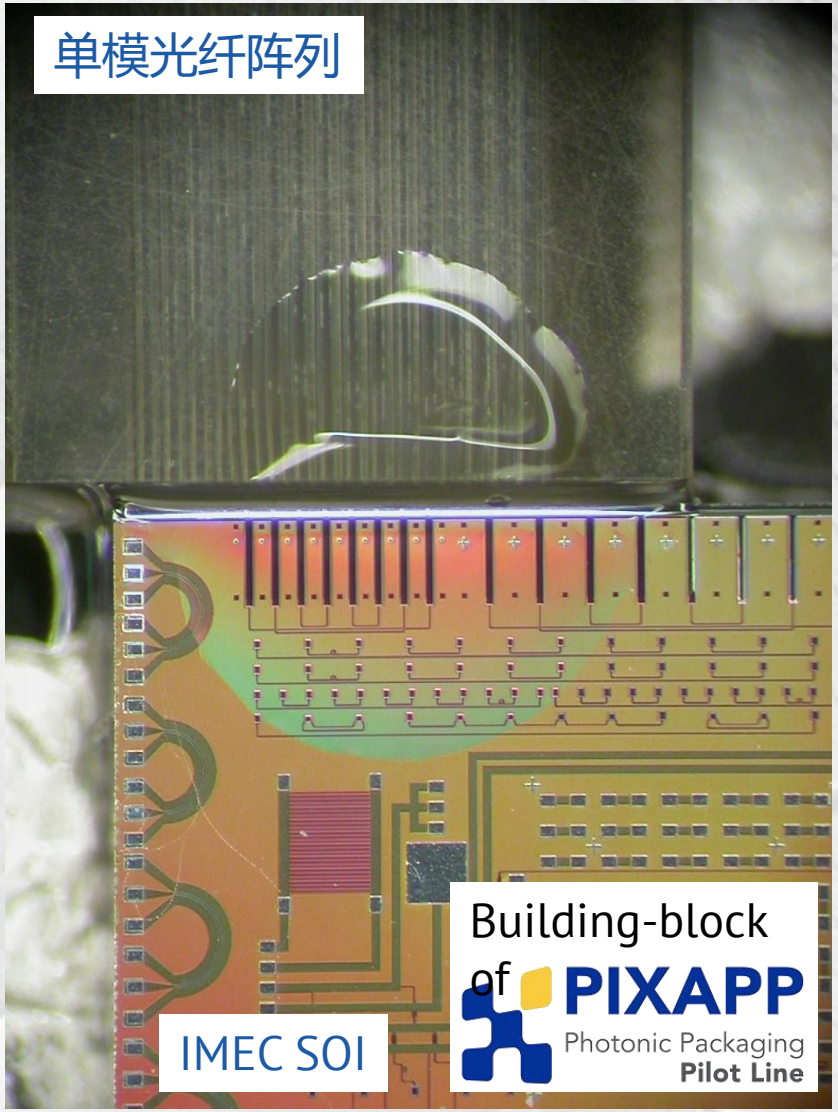


光子引线键合 Photonic Wire Bonding: The Concept

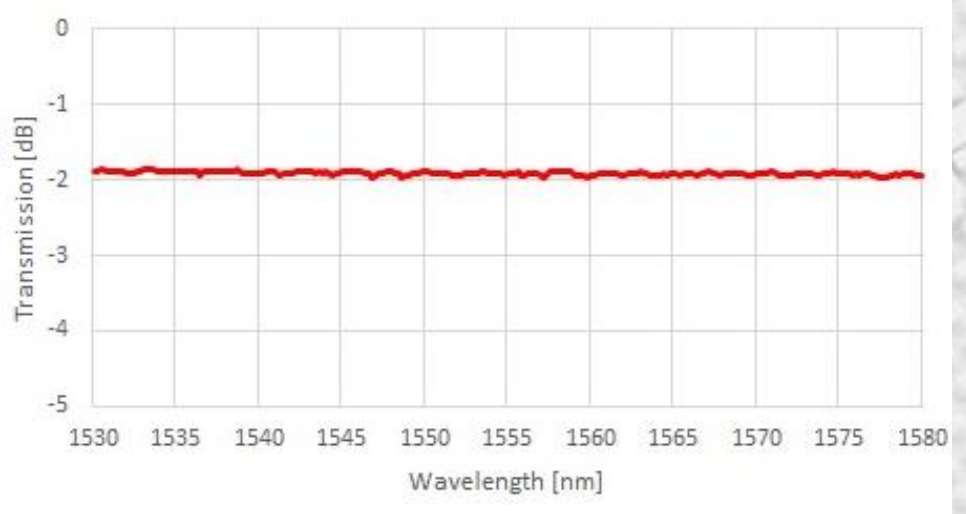
REPRISE 1000

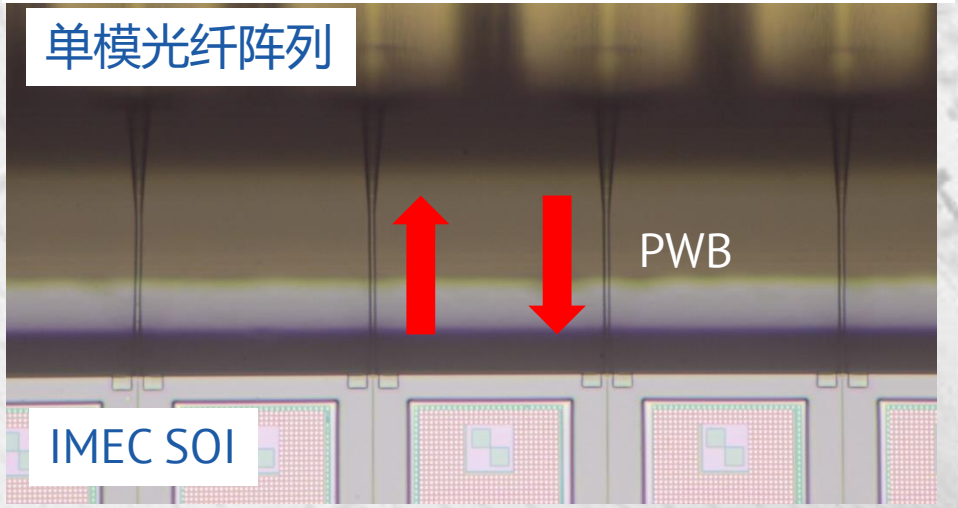


连接单模光纤阵列和绝缘体上硅芯片

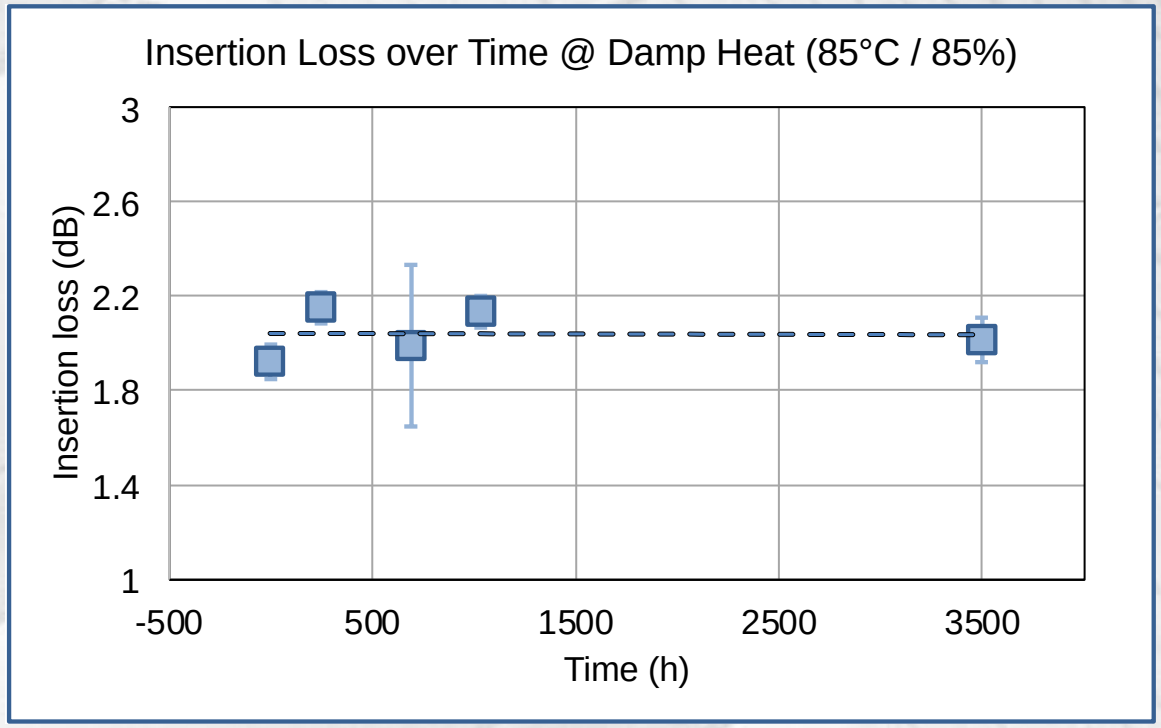


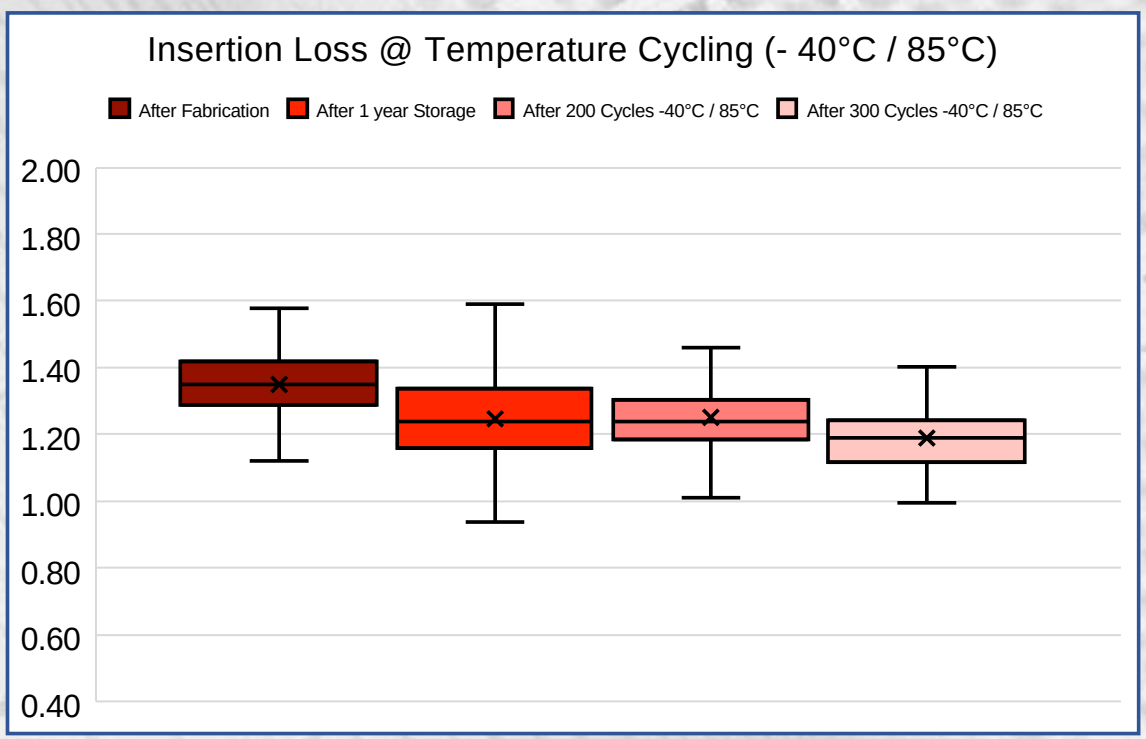
单个连接的插入损耗





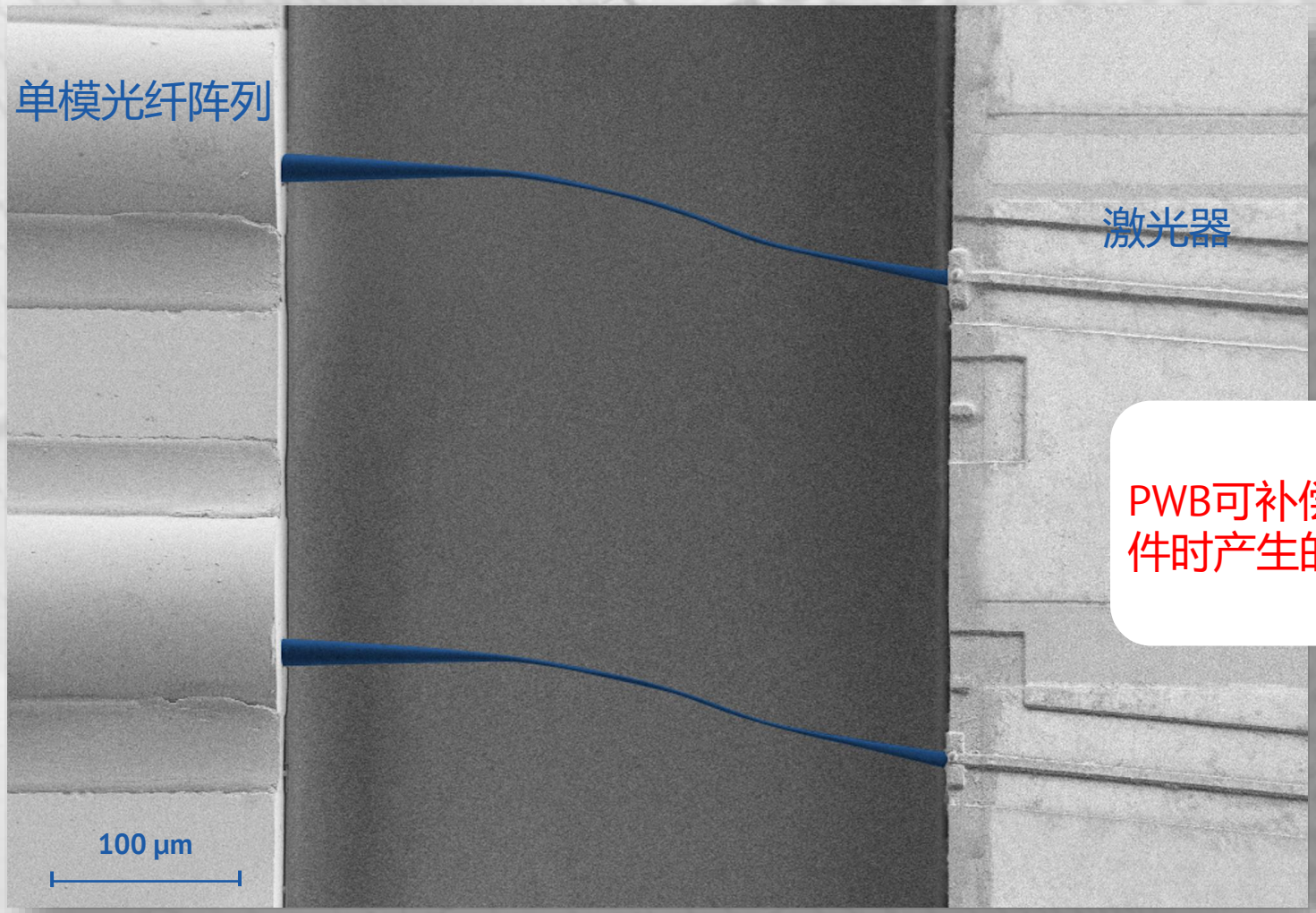
在双85湿热和高低温循环条件下的稳定性测试





光子引线键合 Photonic Wire Bonding: The Benefits

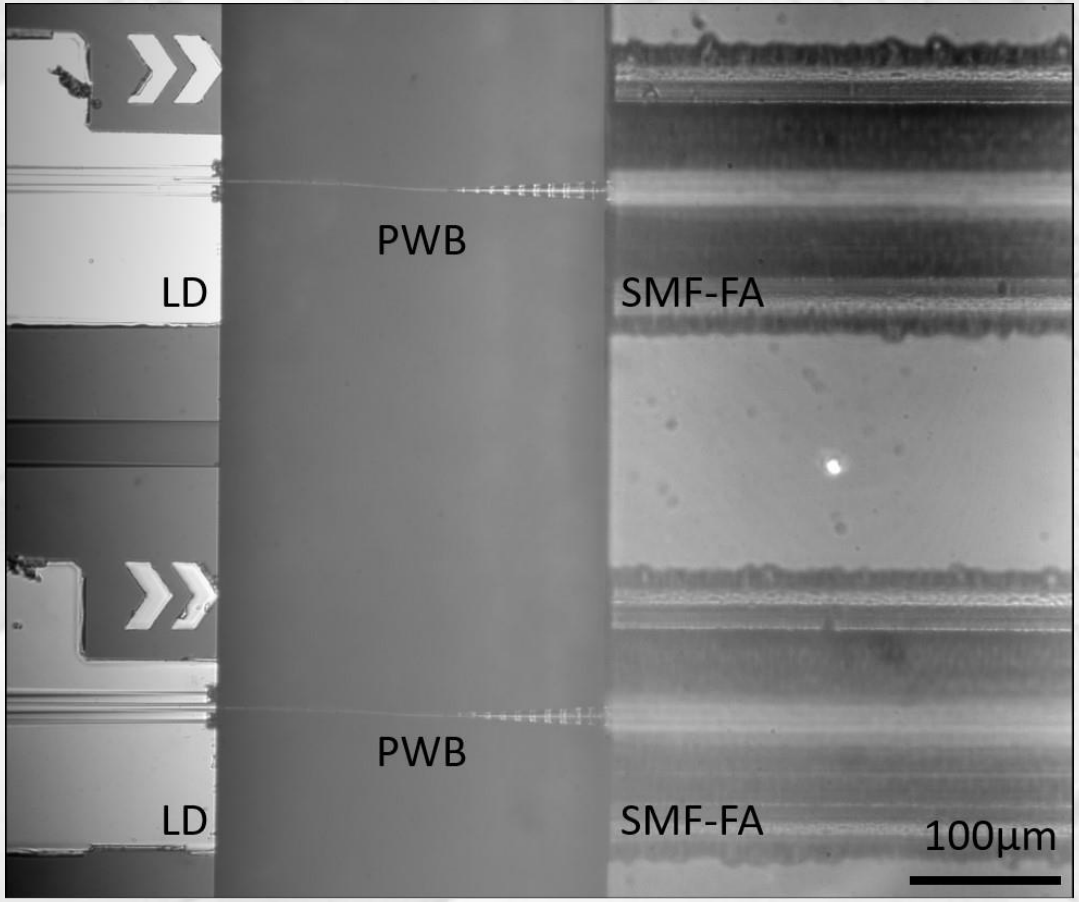
- 实现任意模场之间的低损耗连接
- 自动化，快速可重复的工艺
- 在不同测试条件下的可靠连接
- 实现高密度紧凑连接
- 高设计灵活性的混合多芯片集成



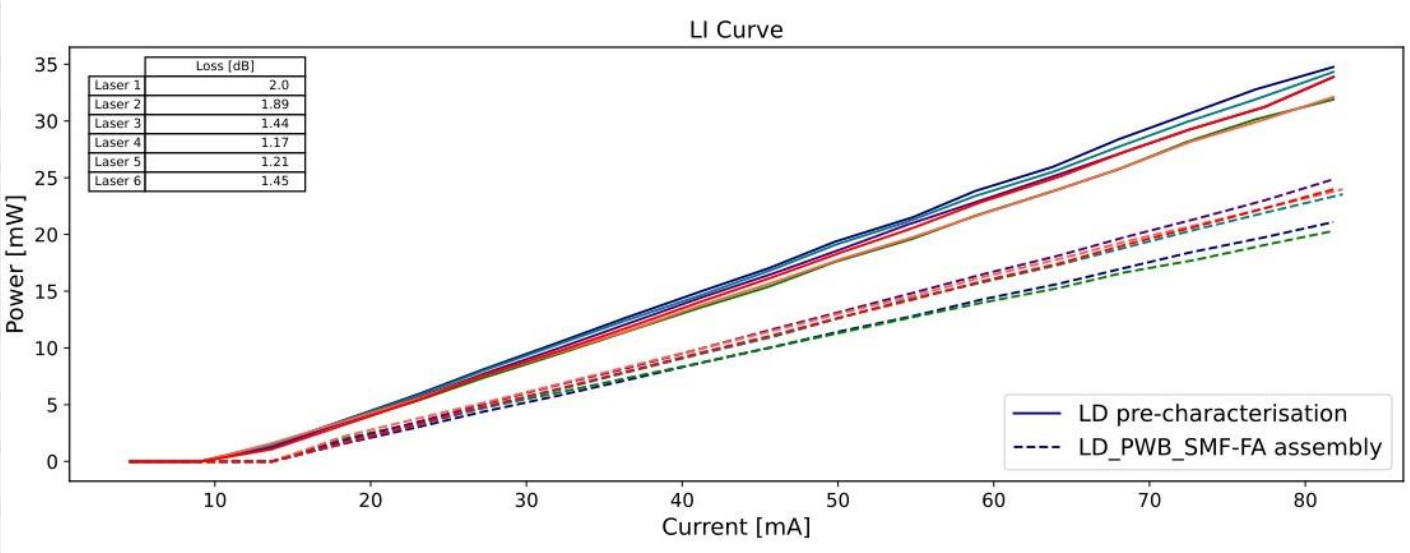
PWB可补偿放置元件时产生的偏移

Laser by Freedom Photonics LLC

光子引线键合（PWB）应用实例 - 铭普



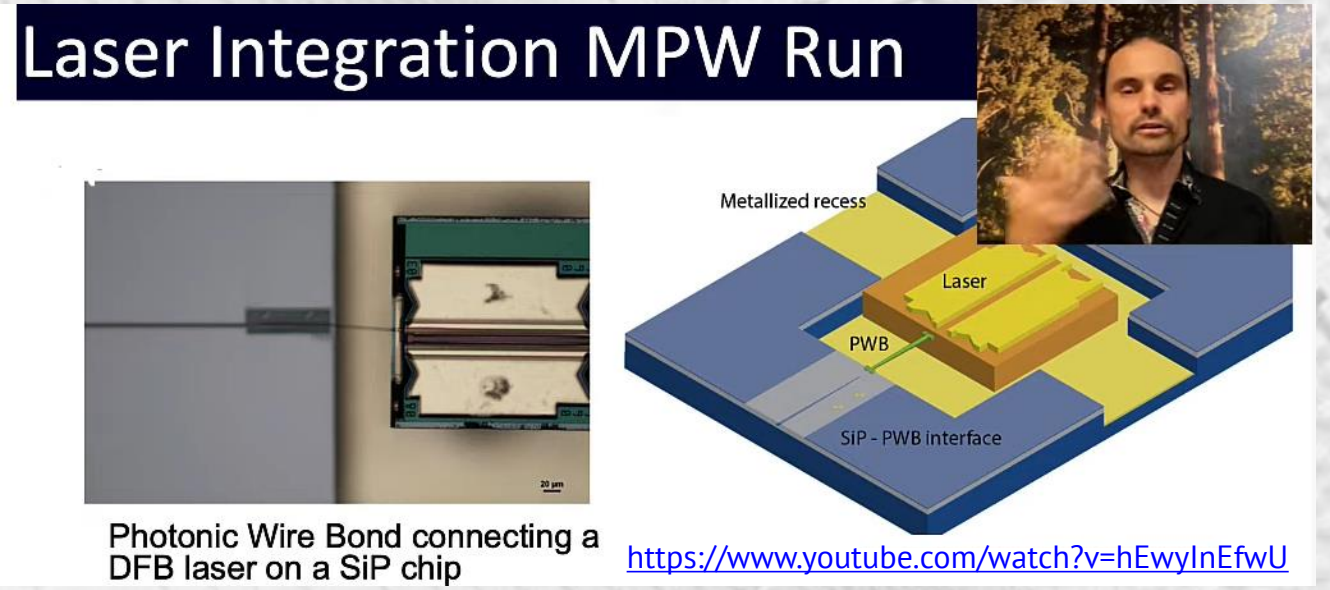
平均损耗 1.53 ± 0.35 dB*



*共同发表在第四届光电子集成芯片立强大会, FPIC 2023, 厦门

生态系统合作伙伴的最新应用实例

晶圆上激光器的集成
Laser-on-wafer integration

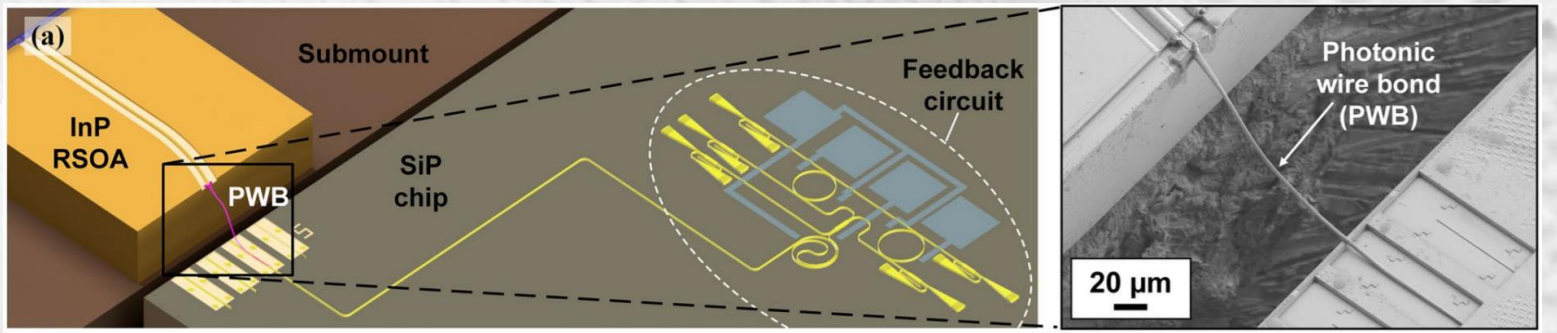


https://www.youtube.com/watch?v=hEwyInEfwU

Darcie et al. "SiEPICfab: the Canadian silicon photonics rapid-prototyping foundry for integrated optics and quantum computing," Proc. SPIE 11691, Silicon Photonics XVI, 116910C (2021)

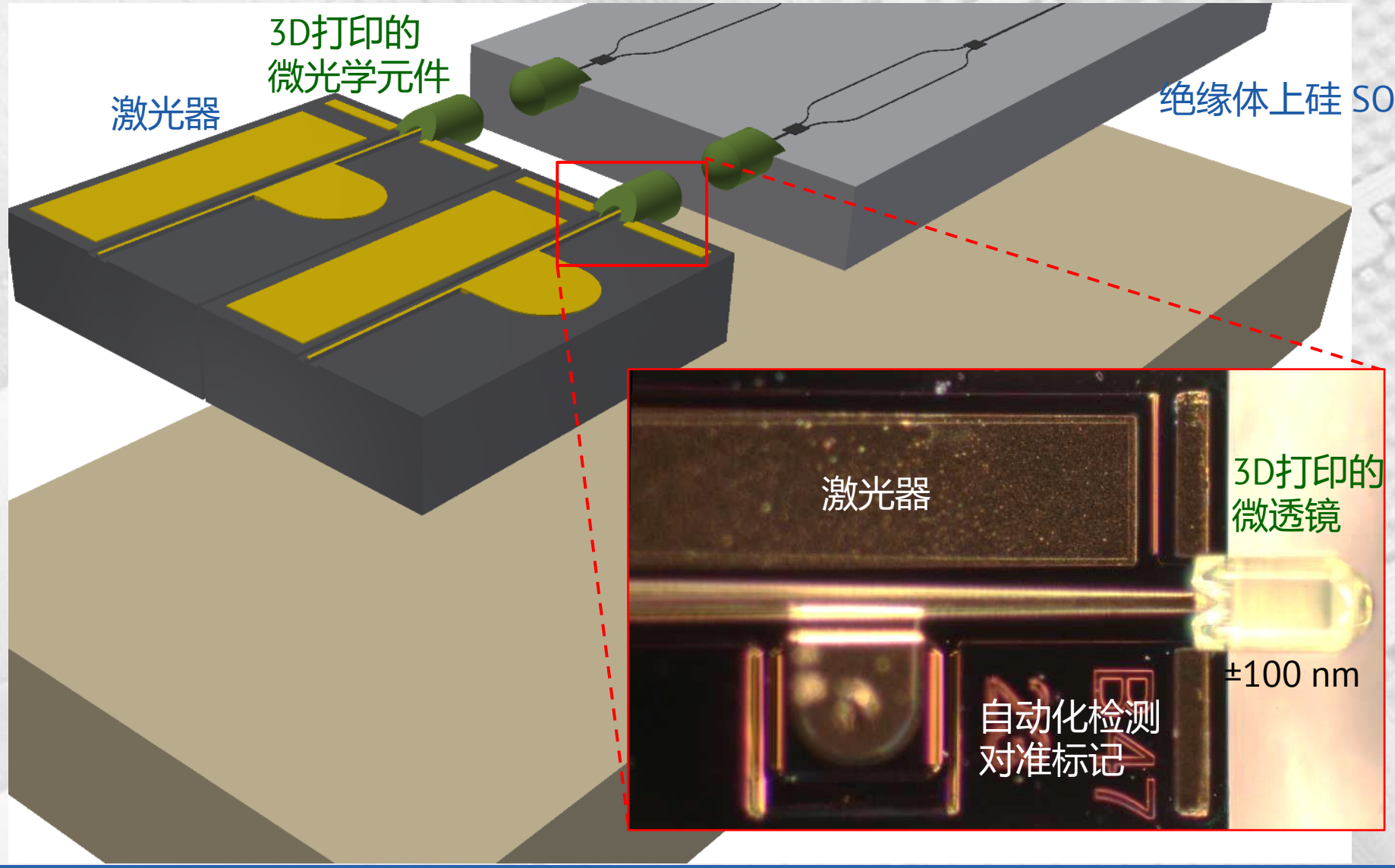
混合外腔激光器
Hybrid external-cavity lasers

Karlsruhe Institute of Technology

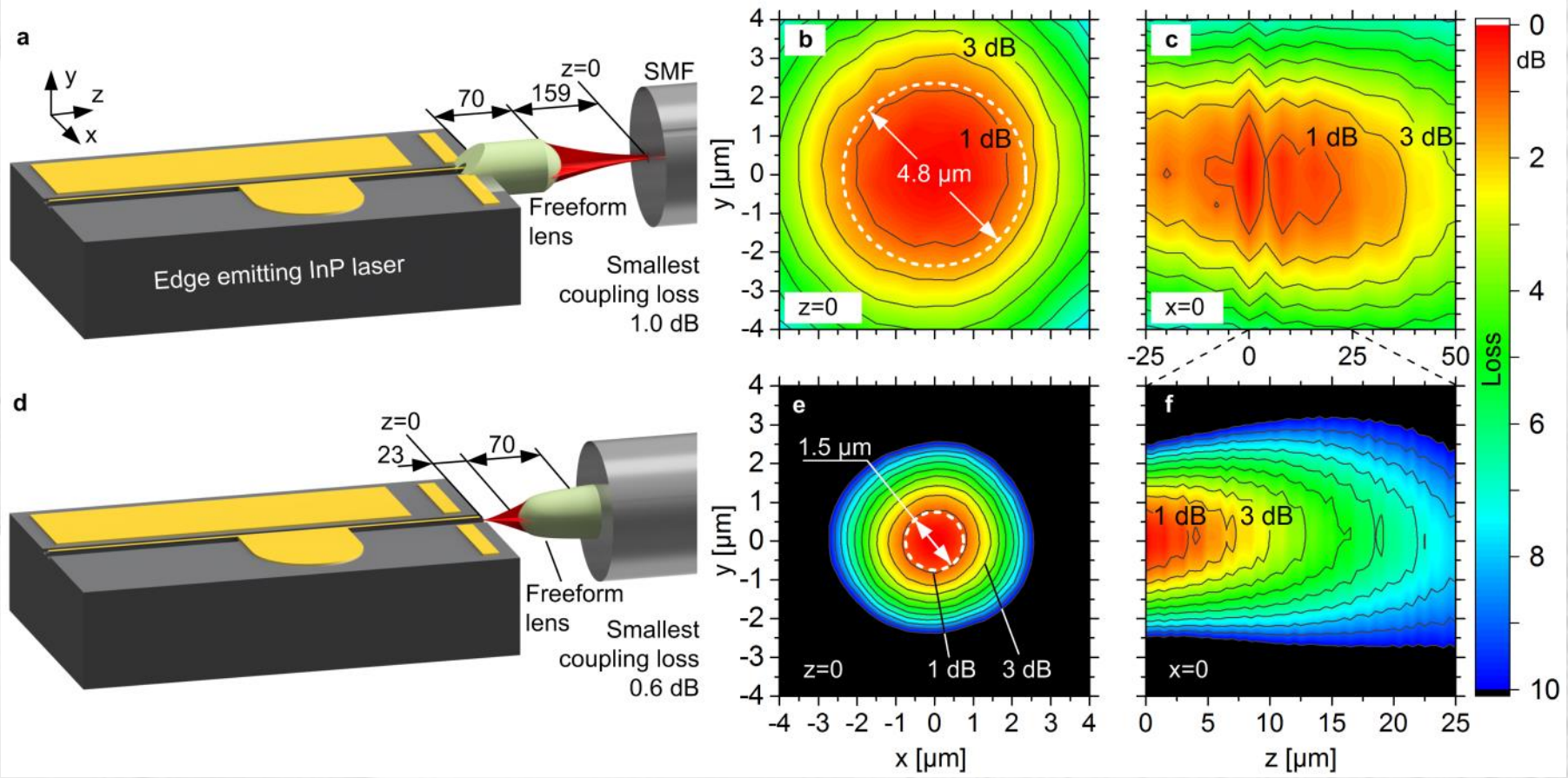


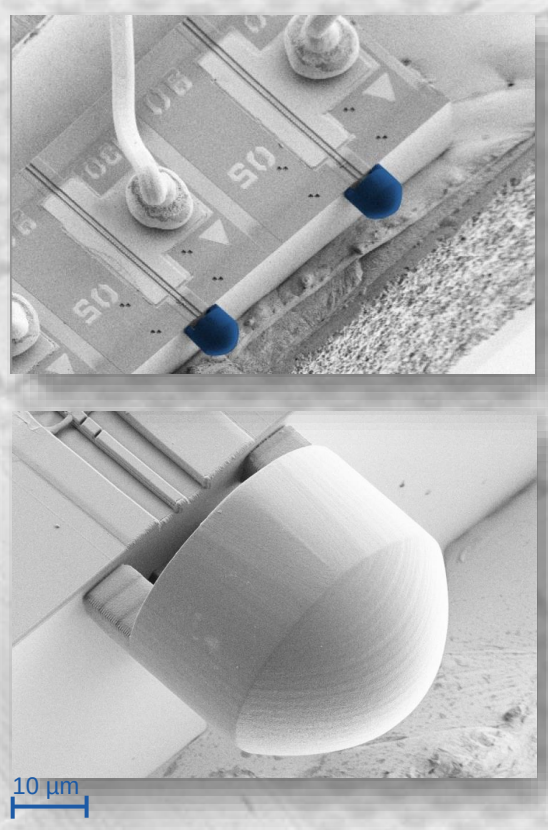
Xu et al., "Hybrid external-cavity lasers (ECL) using photonic wire bonds as coupling elements", Sci Rep 11, Article Number 16426 (2021)

在组装前的原位3D打印



从激光器到单模光纤的耦合

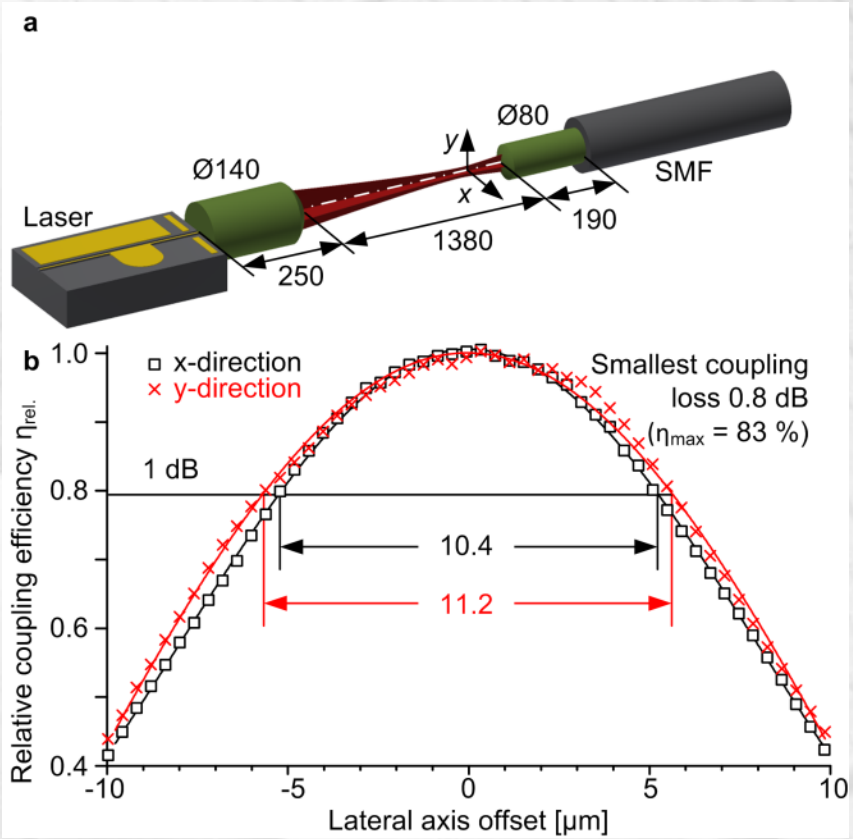




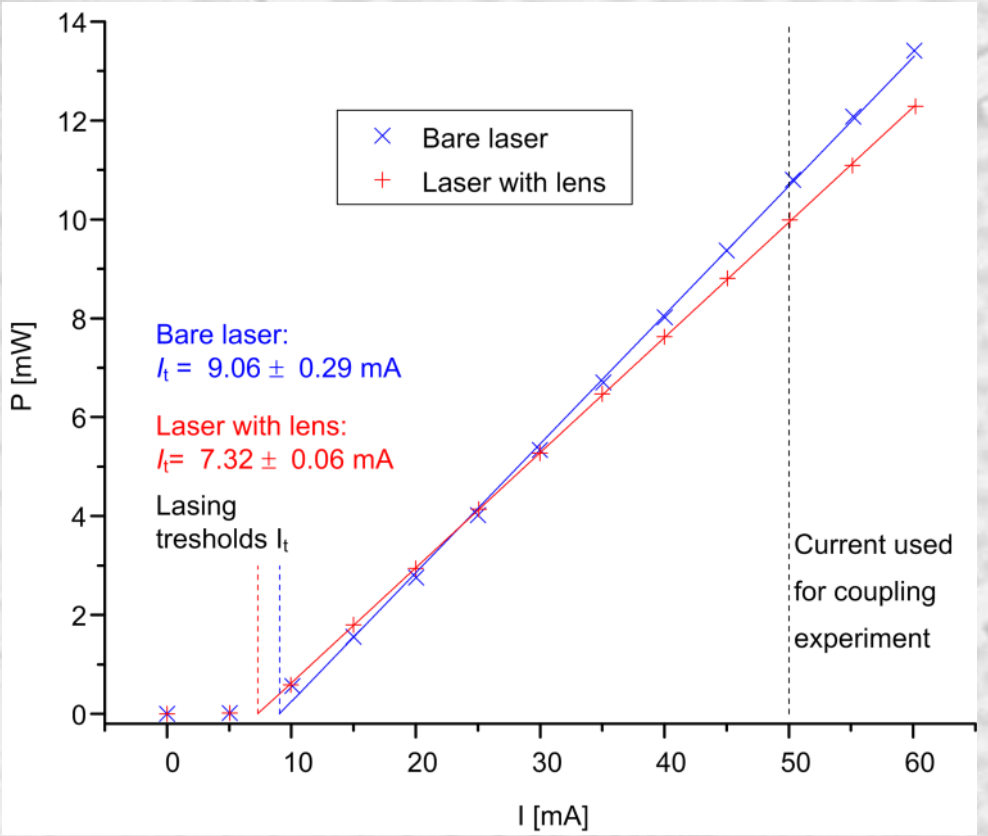
Samples bx PIXAPP
(Photonic Packaging Pilot Line)

将波长为 1590 纳米 的 3 微米模场直径大小的DFB激光器与单模光纤进行模场匹配。

通过扩展光束的耦合



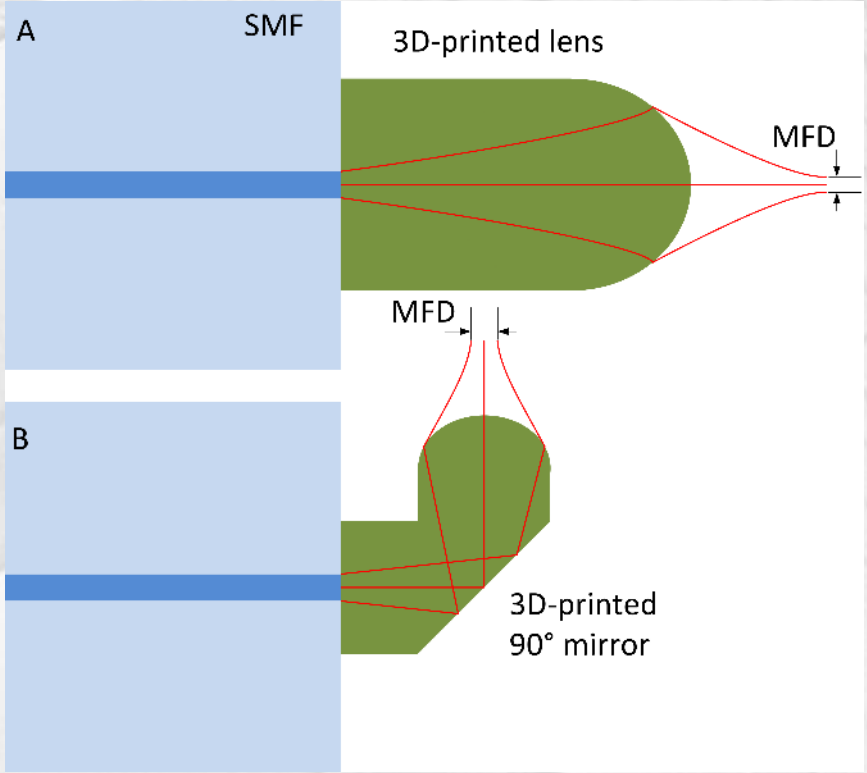
可将 1 dB 耦合容差放宽至 ±5.2 微米



带微透镜和不带微透镜激光器的电流-功率曲线

已在工业应用中的Vanguard微透镜

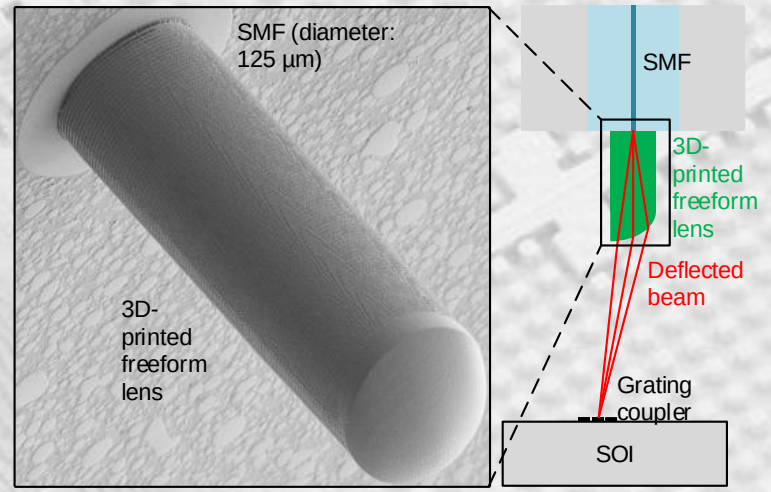
光纤阵列上的标准光学器件



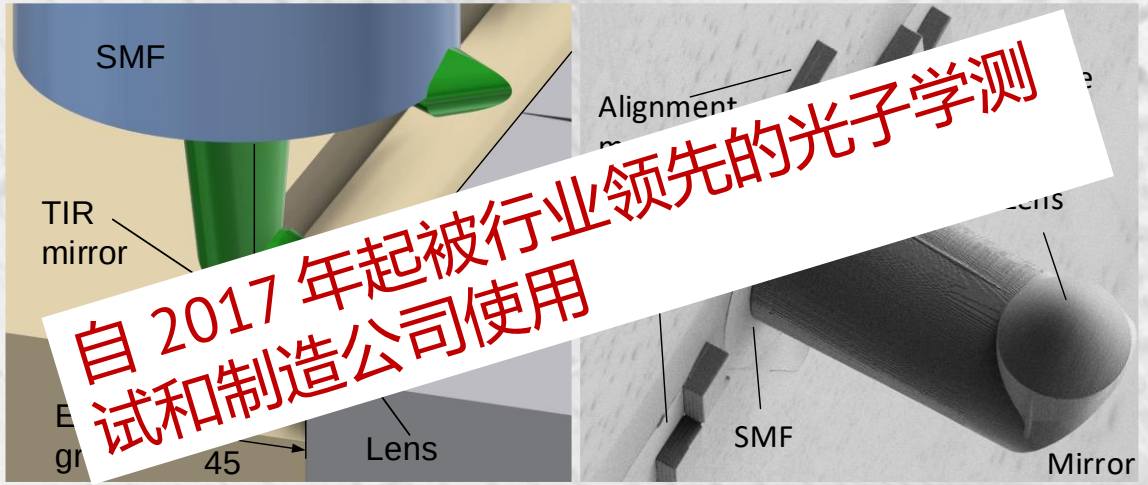
提供各种光纤阵列间距，模场尺寸，波长及微光学元件大小

https://www.vanguard-photonics.com/shop/

开发客户专用微光学元件



针对特定应用，例如用于晶圆级探测



自 2017 年起被行业领先的光子学测试和制造公司使用

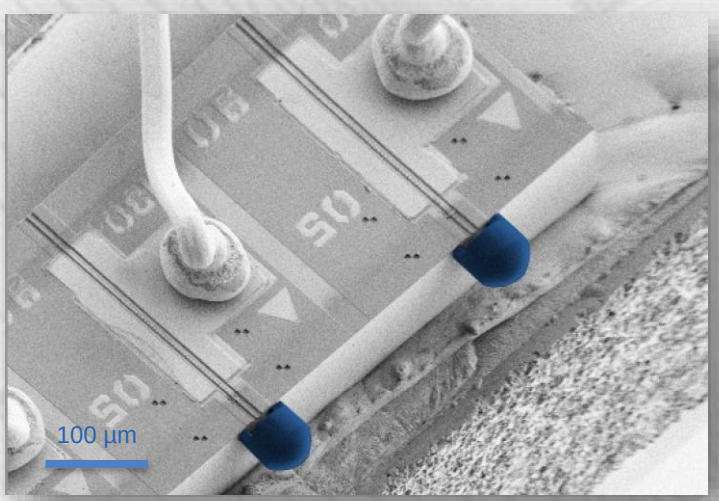
vanguard AUTOMATION

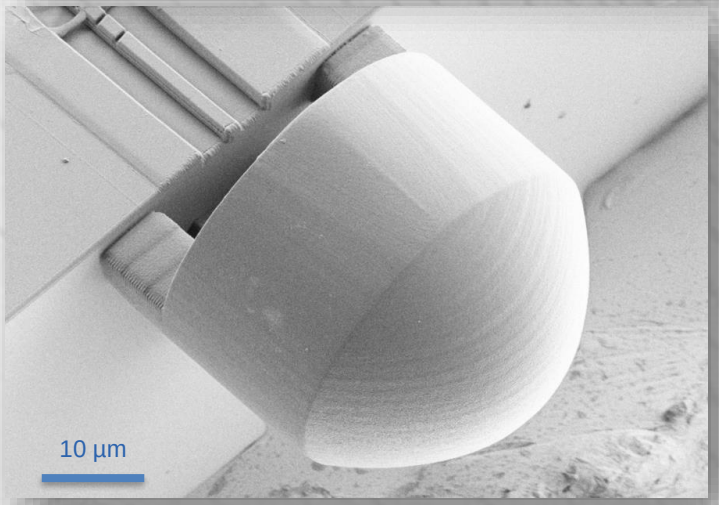
ficonTEC photonics assembly & testing

FormFactor™

3D 打印的自由曲面微光学元件 - 技术数据表

- **可兼容光学元件**
  - 激光器 (分布式反馈激光器及其他类型)
  - PIN型和雪崩光电二极管
  - 单模，保偏，多模光纤阵列
  - 光子集成芯片: 绝缘体上硅, 氮化硅, 磷化铟, 铌酸锂及其他
- **标准模块**
  - 透镜焦距可达厘米级别，其模场直径为 2.0 微米 至 100 微米 (@$1/e^2$ 强度)
  - 全内反射镜
  - 3D 打印模斑转换器
- **耦合** （取决于激光器和芯片）
  - **激光器-芯片:** 0.6 至 2.5 dB
  - **芯片-光纤:** 1.5 至 2.5 dB,
- **1dB内的对准容差**
  - ±1.5 微米 (单个透镜在单个元件上) 到 ±15 微米 (扩束器)
- **可操作波长范围**
  - 530 纳米 到 1650 纳米





- **可重复性**
  - 耦合效率差异小于 0.2 dB
  - 小于10%的模场和焦距偏差
- **准确性**
  - 标准差小于 50 纳米的探测准确性
  - 小于 ±100 纳米的形状准确度
  - 小于 10 纳米的表面粗糙度
- **可靠性测试**
  - > 4000 小时 85°C/85% 湿度
  - > 250 个循环, -40°C 到 85°C
  - 回流焊接，3 个循环，270°C
  - 金锡键合 310°C
- **冲击测试**
  - 加速度至1500 g
  - 全轴振动测试 20 g
- **高功率运行**
  - > 1 瓦 @ 1550 纳米
- **低温运行**
  - > 10 个循环, 4K 到室温

vanguard SYMPHONY 1000

由软件定义功能的高精度纳米加工的光子引线键合（PWB）和附面微光学元件

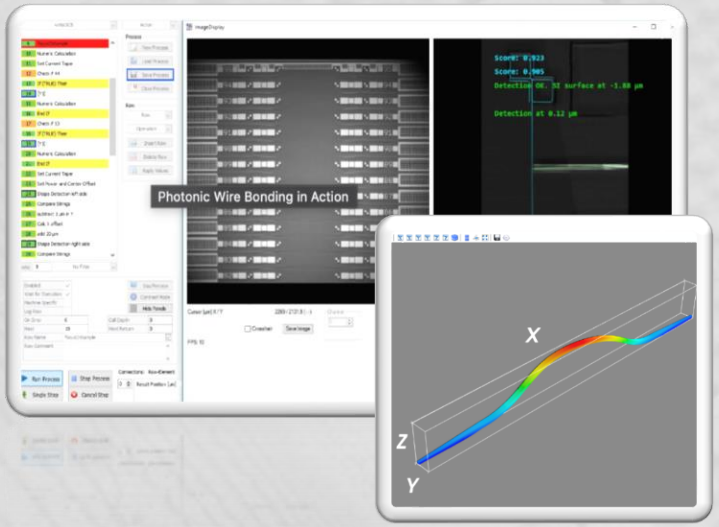
基于纳米加工的自动化
3D 光刻技术

SONATA 1000

全自动化预处理以及
后处理工艺流程

REPRISE 1000

软件定义的机器操作, 工艺开发
以及管理



Composer and BrightWire3D

标准加工制造工艺 | 自主研发材料 | 产品技术支持和服务

"As PIC Production Ramps Up, Fabricator Eye Alignment Options", Photonics Spectra, June 2022

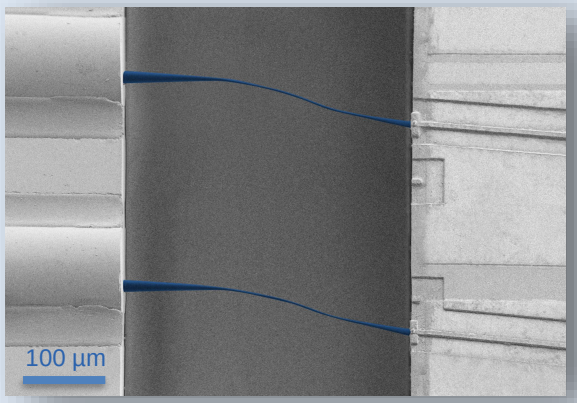
"Photonic Wire Bonding: Using Lasers to Integrate Lasers", Photonics Spectra, August 2022

"Integrated photonics for quantum applications", Laser Focus World, September 2022

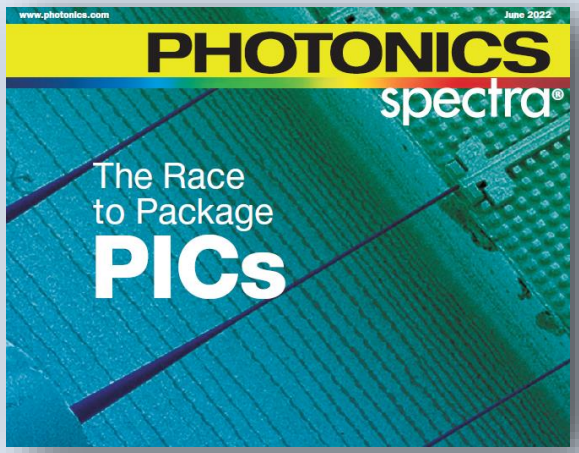
"Enabling next generation photonic integration and packaging solutions", PIC Magazine, November 2022

下一代光子集成和封装解决方案

光子引线键合 PWB

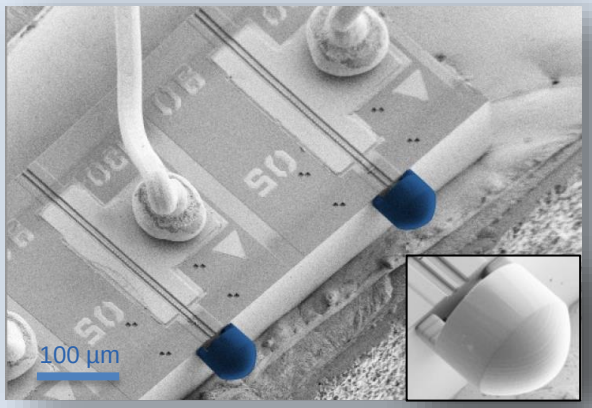


Laser by Freedom Photonics LLC

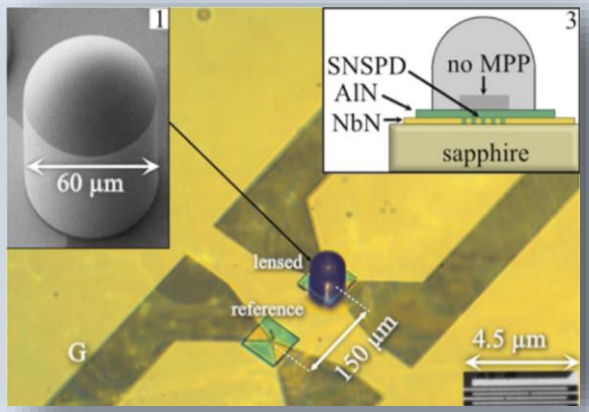


PIC by Institut für Mikroelektronik Stuttgart

微光学元件

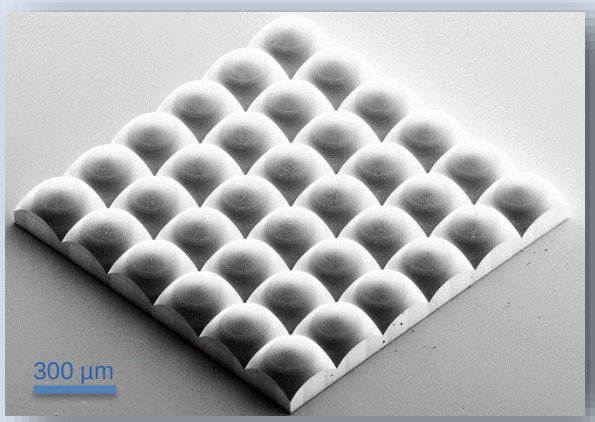


Samples by PIXAPP (Photonic Packaging Pilot Line)



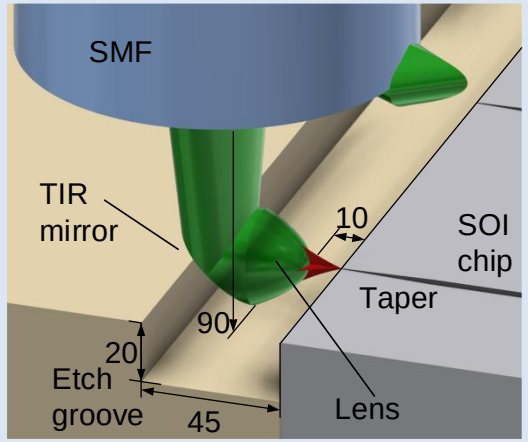
Xu et al., Superconducting nanowire single-photon detector with 3D-printed free-form microlenses, Opt. Expr. 29, 27708-27731 (2021)

写场扩展



Design by Moveon Technologies Pte Ltd.

晶圆级的探测



生态系统合作伙伴和客户

UBC

KIT
Karlsruhe Institute of Technology

RIT
Rochester Institute of Technology

University of Stuttgart

南京大学

中山大學 SUN YAT-SEN UNIVERSITY

POET Technologies

SUMITOMO ELECTRIC
Connect with Innovation

AEPONYX™
PHOTONICS IN MOTION

FORMFACTOR™

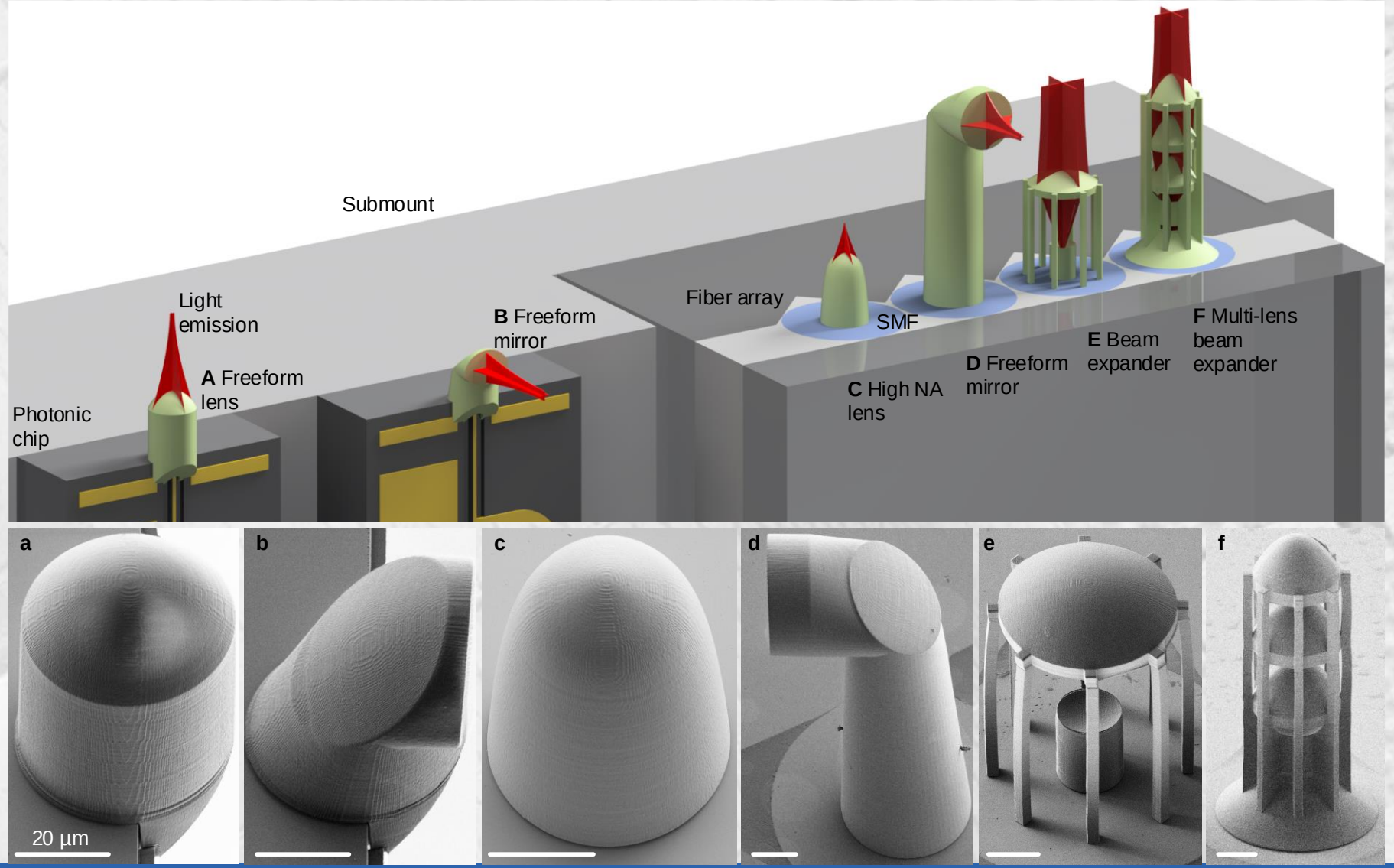
DREAM PHOTONICS

FREEDOM PHOTONICS
a Luminar company

C2MI
Centre de Collaboration MiQro Innovation

ficonTEC
photonics assembly & testing

附面微光学元件

3D打印微光学元件:
模场匹配及扩展

- 晶圆和芯片级自动化加工
- 自由空间距离可达毫米级
- 可连接任意模场
- 适用于高功率 (> 3 瓦) 及宽带光源