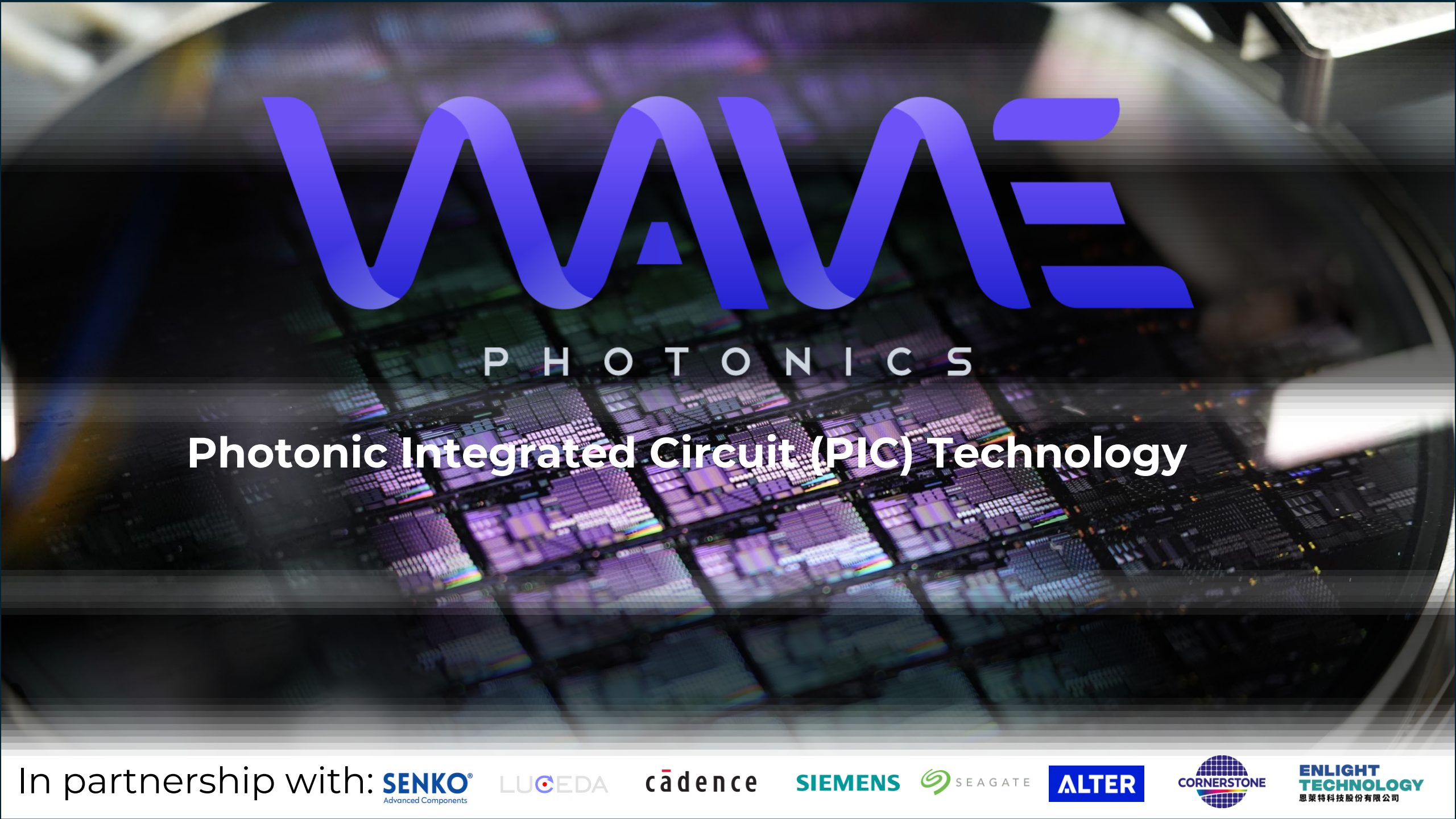
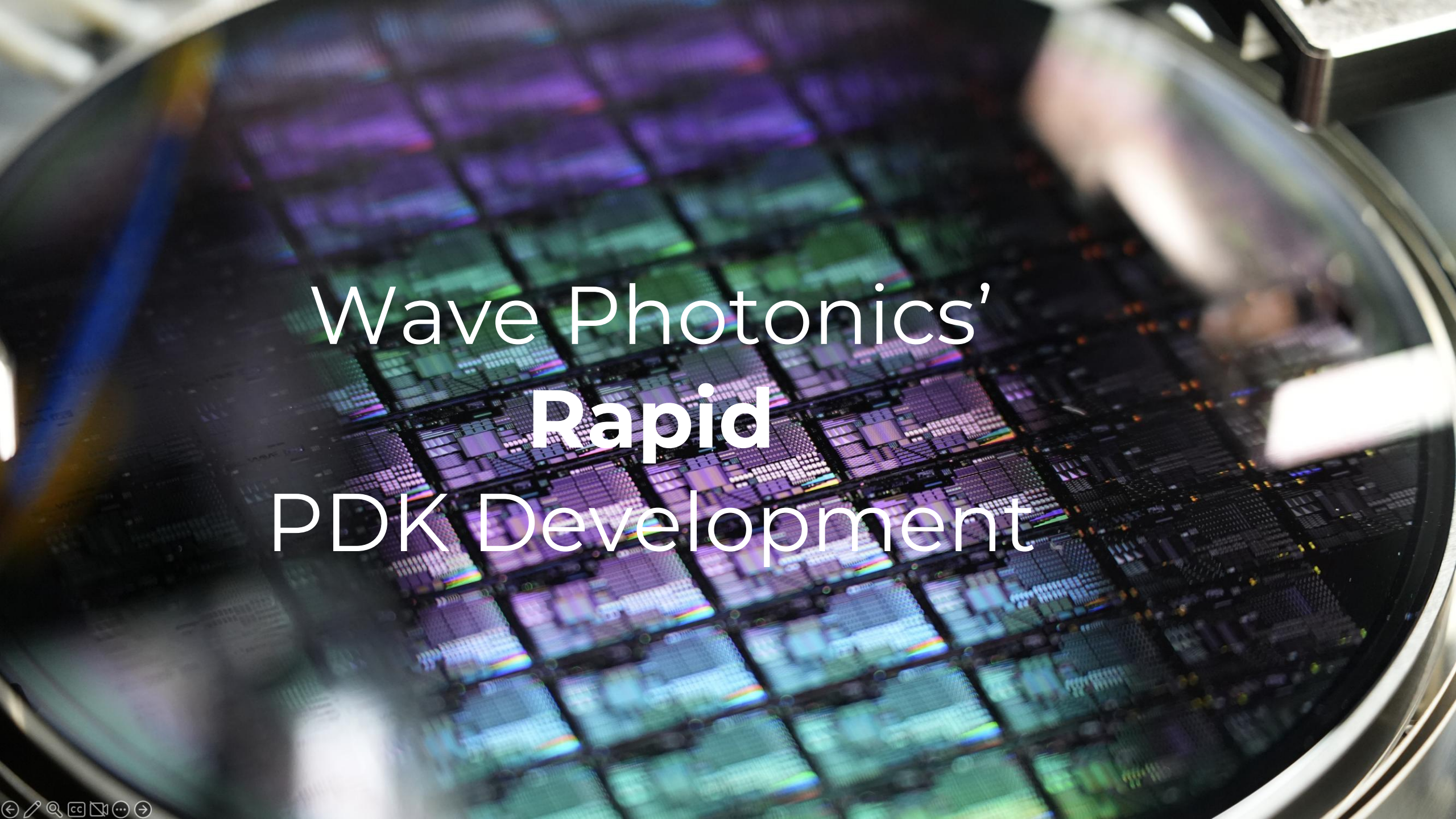

PHOTONICS
Photonic Integrated Circuit (PIC) Technology
In partnership with:
SENKO
Advanced Components
LUCEDA
cadence
SIEMENS
SEAGATE
ALTER
CORNERSTONE
ENLIGHT TECHNOLOGY
恩萊特科技股份有限公司

Wave Photonics is a Cambridge-based photonics company offering photonics IP and design services

- Three founders (quantum photonics, stats, quant finance) thought that stats/optimisation could be used to improve integrated photonics

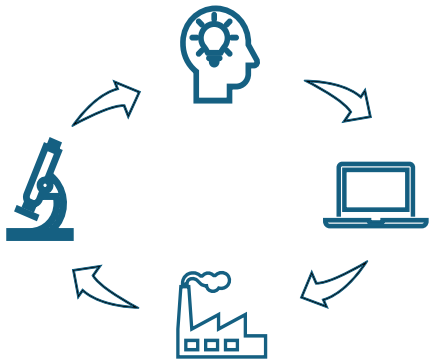
- A talented team:
  - Backgrounds spanning integrated photonics, high-performance computing, quantum photonics, statistics, optimisation and semiconductors
  - Prior experience from Toshiba, Microsoft, Cambridge Consultants, NPL and academic research


Wave Photonics'
Rapid
PDK Development

PDKs are required for PIC uptake, **but**

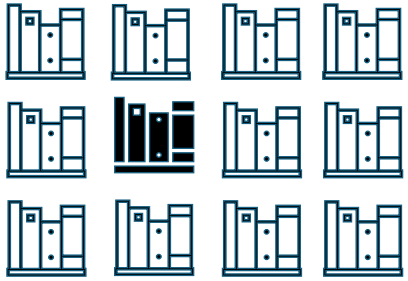
resource-intensive workflows, limited libraries, and poor tolerance to variation make customer uptake hard

Development is Labour-Intensive



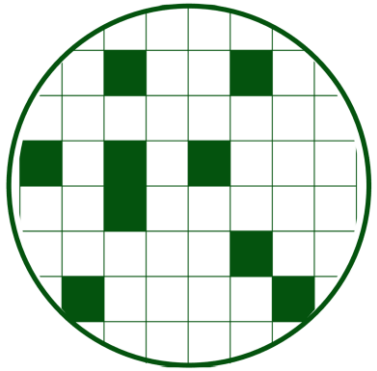
- Parameter sweeps or optimisation for each component
- Slow and expensive fabrication
- Requires optical testing for validation
- Multiple design iterations and continuous updates are needed

Narrow PDKs = Higher Costs for Customers



- PDK performance is a key differentiator for customers
- Dedicated runs require huge design efforts
- Quantum, bio and sensing customers are neglected
- Limited ADKs as standard

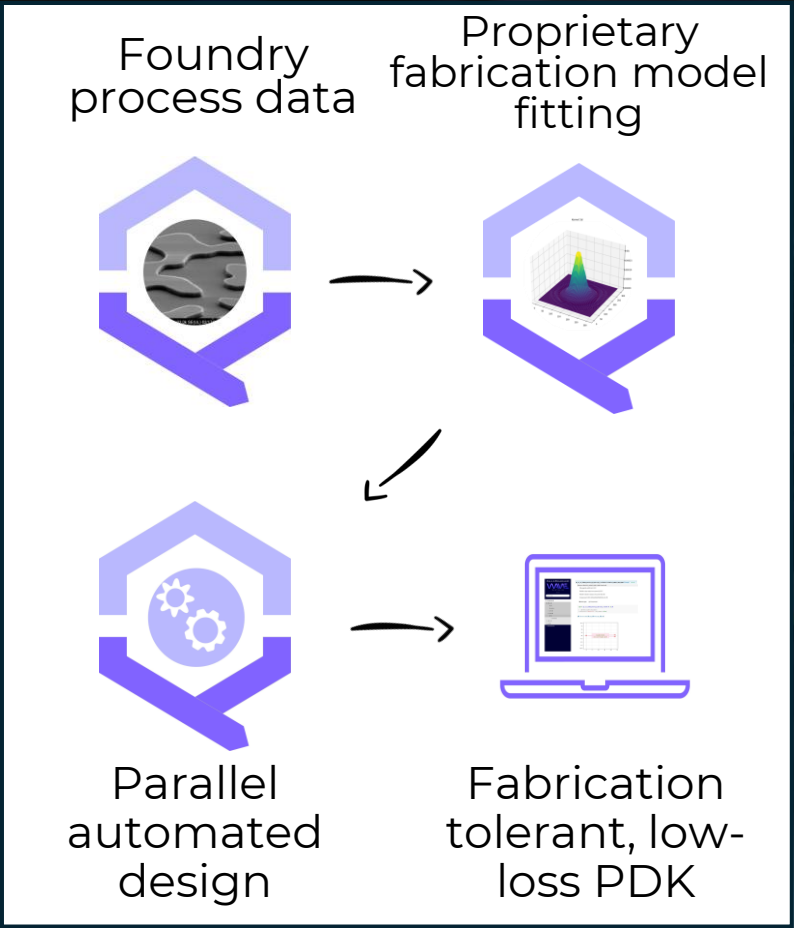
Fabrication-Intolerant Designs Reduce Yield/KGDs



- Designs based on parameter sweeps and basic variation models are highly sensitive to process changes
- Conventional designs leave performance on the table

Wave Photonics Mission: bring the barriers down for PIC development

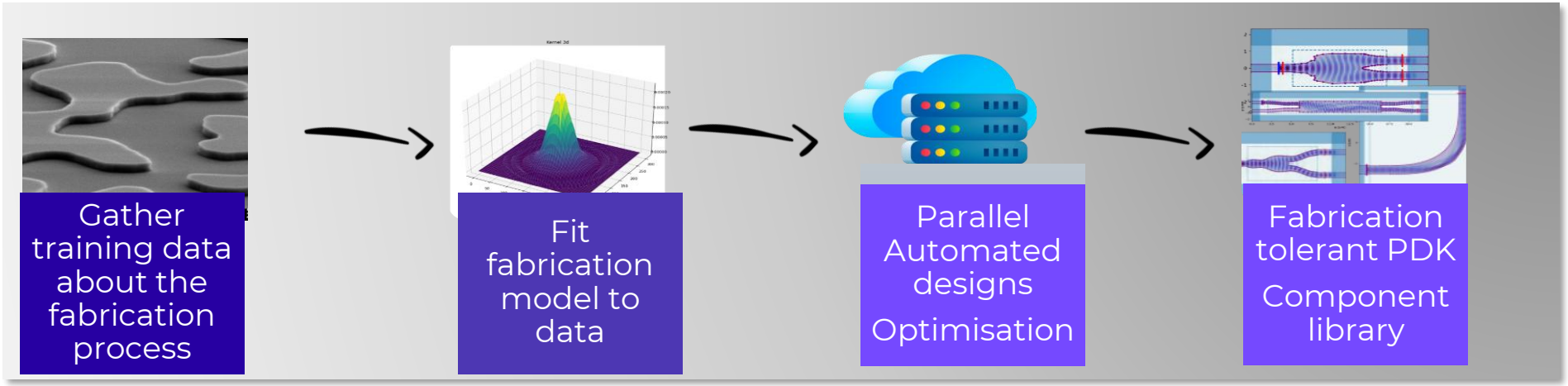
From process data to PDK in 3 weeks



- Proprietary process characterisation and variation modelling
- Built-in integrations with GDSFactory, Siemens, Cadence, Luceda, LDS, and (coming soon) Synopsys
- Validate with wafer-scale characterisation
- Rapid transition to new processes - re-optimisation of PDK streamlines the transfer from R&D to a volume process

Core technology

Designing and adapting components for new **wavelengths** and **processes** without manual and iterative design.



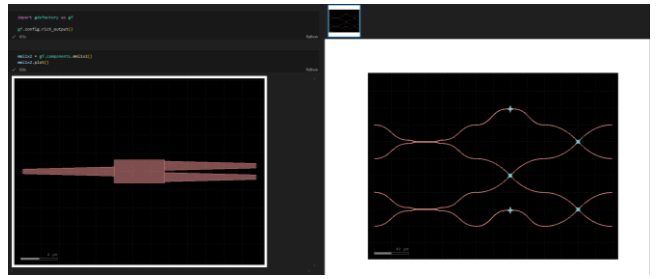
- Proprietary fabrication-aware “Inverse Design” technology
- Combines process characterisation, process modelling, FDTD simulation and optimisation for automated component design
- Can adapt a whole PDK for a new process or wavelengths within weeks
- Components offer improved performance and tighter tolerances

PDK Integrates with EDA tools

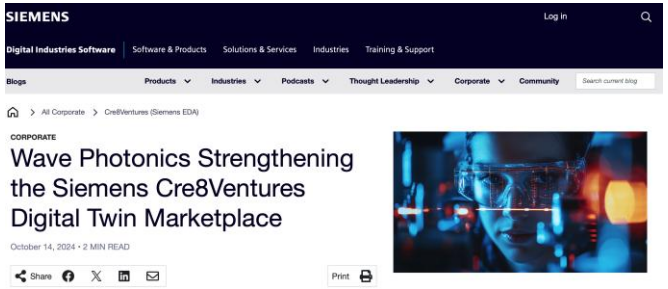
- Support multiple EDA tools (Siemens L-Edit, GDSFactory, K-Layout, Cadence, LUCEDA IPKISS – more to come) - Users do not need to change their workflow
- Every component is generated with an associated compact model for circuit simulation

SIEMENS LUCEDA PHOTONICS

GDS FACTORY cadence



PDK being used for circuit layout in GDSFactory

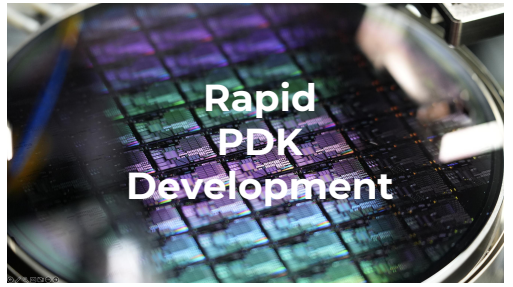


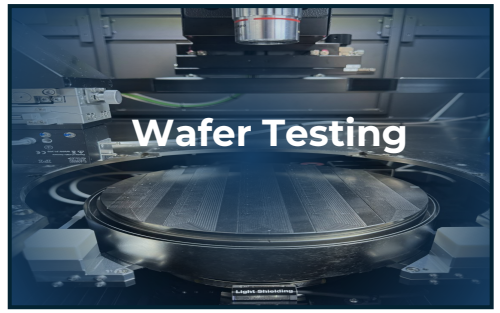
Siemens partnership for seamless L-Edit integration

WAVE PHOTONICS

Products and Services

- **Highly optimised and process variation-tolerant PDK IPs**
  - Most expansive wavelengths from visible to telecom bands
  - Significant reduction of design iterations
  - seamless move from R&D fab to volume fab without major re-design
- **Custom PDKs Design for target applications**
  - Choose a target wavelength and material platform and have a PDK in weeks rather than months
- **Pre-designed PIC packaging / fibre Interconnect templates**
  - Significantly reduce NRE cost and design time
- **Testing**
  - In-house 8-inch wafer scale characterisation capability
- **Wave PDK Management Platform**
  - All foundries' and Wave Photonics' PDKs are hosted under one platform
- **Full design service**
  - From device / system concept, architecture, component design, packaging, testing to foundry tape-out support





Packaging Design / Template

QPICPAC - PIC packaging is normally bespoke (expensive) and the final performance is not known. QPICPAC offers a turnkey solution which provides:

- Multiple optical, electronic and RF connections
- Performance and cost known in advance
- No NRE and short lead times

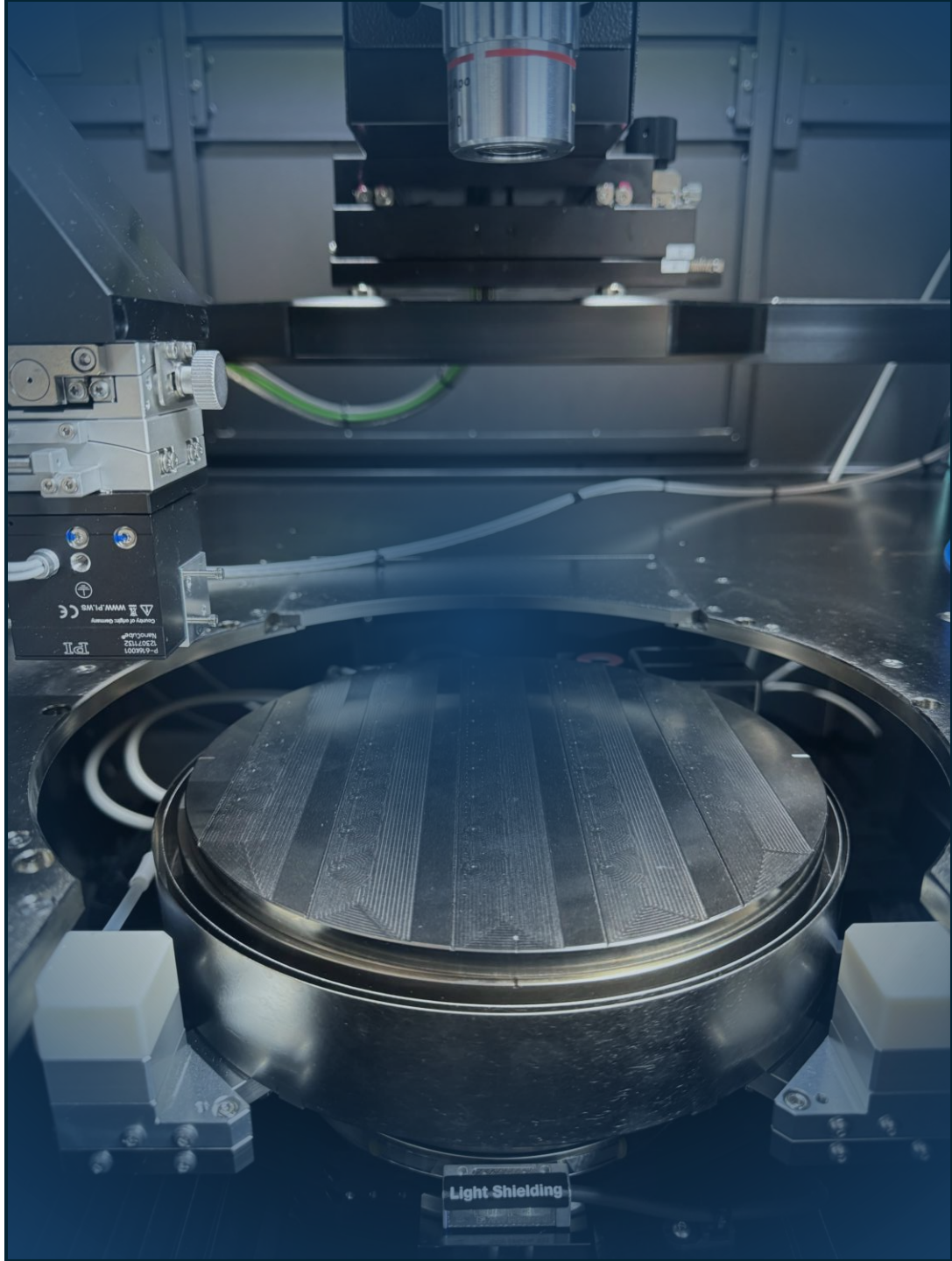
This offering is being improved to facilitate low-loss edge and polarisation coupling via the £1M PAQNet project and the £2M EQUINOX Project

- Additional compatibility with PhiX packaging

WAVE PHOTONICS

In-house wafer-scale characterisation

- Automated characterisation capability for both individual PICs and full wafers.
- Highly parallelised to capture statistical data on component or circuit performance.



Product Development Service

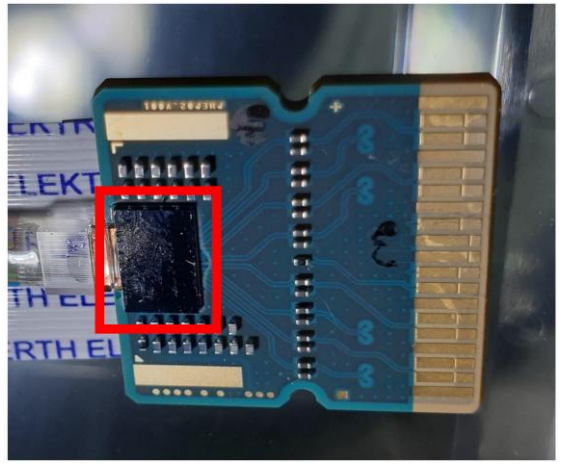
Discovery	Conceive	Design/ Develop/ Implement	Realise	Support
• Innovation Strategy /PIC Biz Case • Requirement • Costing /Economic model • Supply Chain Appraisal and Management • Partner Selection	• Architecture • Specification • Prototyping • Technology / IP Selection	• PIC Architecture and Specification • System design including possible electronics, software algorithm • Concurrent circuit design, system modelling / simulation, optimisation – shorten time-to-market significantly.	• Chip tape-out • Validation, characterisation, qualification • Fab & OSAT selection & support	• Co-ordinate activities from design, manufacturing and foundry partners. • Act as “gate keeper” to manage the design verification, optimisation, certification, upgrade, etc.

5-Phase Product Development

WAVE PHOTONICS

New capability - CPO and Transceiver IP Acquisition

- Phoelex (optical transceiver company) spent $20M on developing high-performance transceivers – Wave Photonics acquired all of the company's IP
- Key IP in low energy modulation driven from a CMOS chip and the driving/processing electronics
- Wave is seeking partners high-speed electronics expertise for collaboration on CPO development



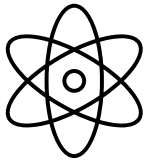
Example Phoelex transceiver

Case Studies

Example use cases

Wave Photonics' design capability for any platform or wavelength enables:

Atoms and ions



Cold atom systems
- Rb and other elements for atomic clocks and magnetic field/inertial sensing
- Quantum computing

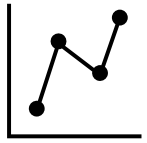
Tapped ion systems
- Address multiple transitions with a single chip

Environmental sensing

Water quality sensing
- Refractive index sensing for label-free detection of contaminants and biomarkers

Gas sensing
- SiN and Ge-on Si design for long wavelength sensing

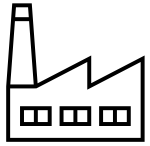
Datacoms



Fibre
- Acquired IP in transceiver and CPO design

Free space
- Phased arrays for custom wavelengths (850nm, 940nm, 1064nm etc.)

Novel materials



Rapid photonics design for novel material platforms
- GaAs, GaN, TFLN, AlN, SiN, SOI, SiC

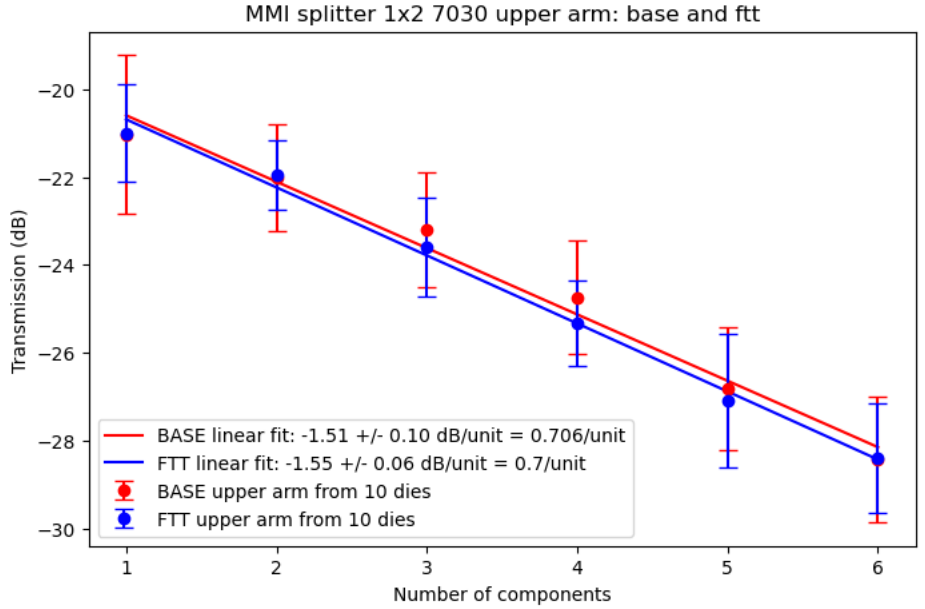
PDKs with increased fabrication tolerance

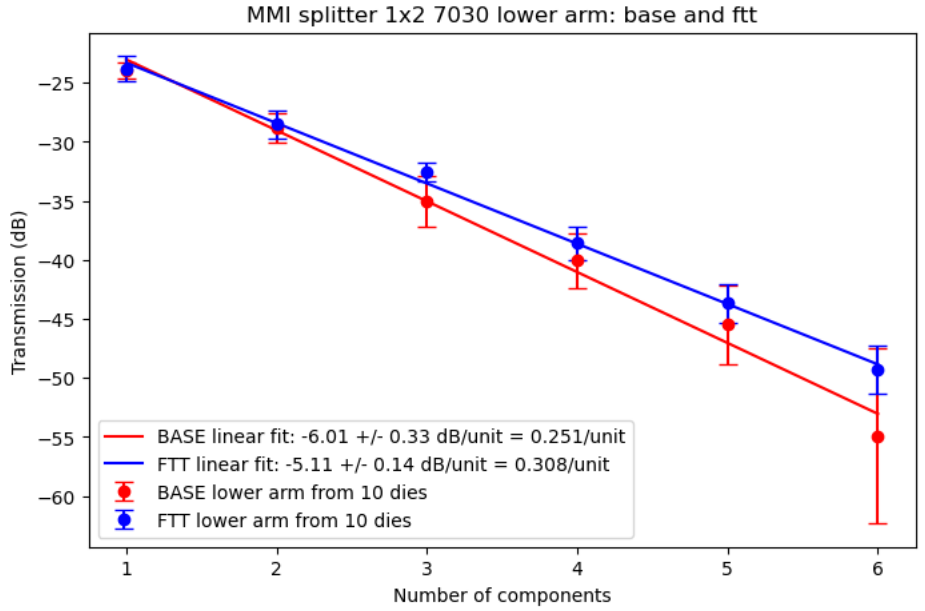
Comparison to conventional inverse design:

MMI splitter 70:30 at a visible wavelength

- Measured data from 10 dies in a wafer
- Relative to conventional inverse design, we see:
  - **2x lower loss**
  - **2x lower performance variation**
  - **Achieved target ratio on first fabrication run**

	Loss	Split ratio	Variability (upper arm)	Variability (lower arm)
Without our fabrication model	0.19 dB 4.3%	74:26	2.4%	7.6%
With our fabrication model	< 0.1dB < 2.3%	69.5:30.5	1.3%	3.2%





Silicon Nitride for Quantum (SiNQ) PDK – 493-1550nm

- **The world's most expansive PDK -** PDK for 33 wavelengths containing 1,056 elements
- Building upon work with Oxford Ionics – trapped ion quantum computing company. Developed PDK on new SiN process.
- Wave's optimisation pipeline was used to accelerate process development
- CORNERSTONE MPW runs on 200nm SiN starting this year

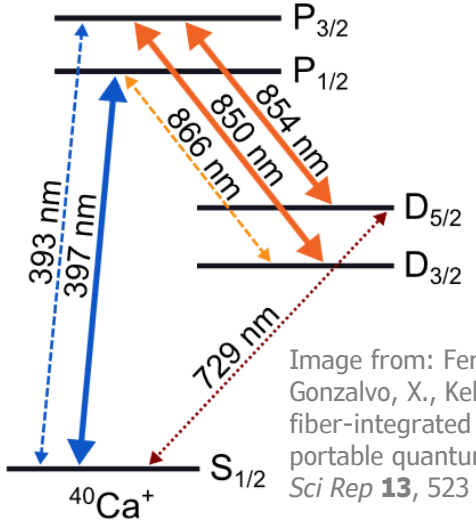


Image from: Fernandez-Gonzalvo, X., Keller, M. A fully fiber-integrated ion trap for portable quantum technologies. *Sci Rep* **13**, 523 (2023)

Wavelengths and Systems Supported by the SiNQ PDK

Covers 33 wavelengths from 493nm – 1550nm

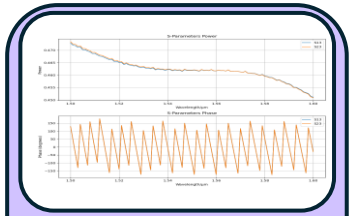
Wavelengths and systems supported

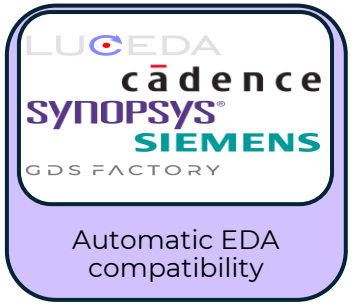
λ(nm)	Fibre	Emitter(s)/System	λ(nm)	Fibre	Emitter(s)/System
493	SM450	Ba+ cooling	807	780HP	WSe2
532	SM450	NV spin, CsPbBr3 nanocrystal	850	780HP	Comms, Free space comms
552	SM450	PbV – Lead vacancy	852	780HP	Cs cooling
589	SM450	Na+ cooling	854	780HP	Ca+ repump
602	SM450	GeV – Germanium vacancy	866	780HP	Ca+ repump
614	SM450	Ba+ qubit transition	880	780HP	Nd3+ rare earth
619	SM450	SnV – Tin vacancy	895	780HP	Cs cooling
637	630HP	NV centre ZPL peak	920	780HP	InAs/GaAs QDs
645	630HP	hBN colour centre	980	1060XP	Yb3+ rare earth
650	630HP	Ba+ repump, NV centres	1033	1060XP	Sr+ repump
674	630HP	Sr+ qubit manipulation	1064	1060XP	SPDC pump
700	630HP	NV centre phonon sideband	1092	1060XP	Sr+ repump
729	630HP	Ca+ qubit	1127	1060XP	3C-SiC DV colour centre
738	630HP	SiV – Silicon vacancy	1310	SMF28	InAs/GaAs QDs, datacoms
780	780HP	GaS/AlGaAs QDs, Rb cooling	1468	SMF28	3C-SiC NV colour centre
785	780HP	DBT anthracene	1550	SMF28	InAs/InP QDs, Er3+, datacoms
795	780HP	Rb cooling	Your	System	Here: info@wavephotonics.com

WAVE PHOTONICS

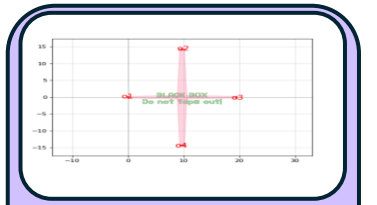
Wave PDK Management Platform
– Key Features

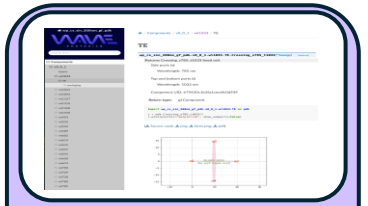
- All foundries' and Wave Photonics' PDKs are hosted under one platform and are easily accessible with built-in tiered access right control.
- Automated process with very little or none human intervention.
- S-Params generated for every PDKs – enable circuit simulation.
- EDA Tools compatibility – support major EDA tools such as Cadence, Simens L-edit, Luceda IPKISS and open-source GDS Factory, etc.
- Built-in IP management tools to effectively protect, assign / share or license IPs.
- Provide complete design solution with packaging and testing services (from multiple partners).
- Automated up-to-date documentation generation.


S-Parameter generation



Automatic EDA compatibility


Black-boxing for IP protection


Automatic documentation