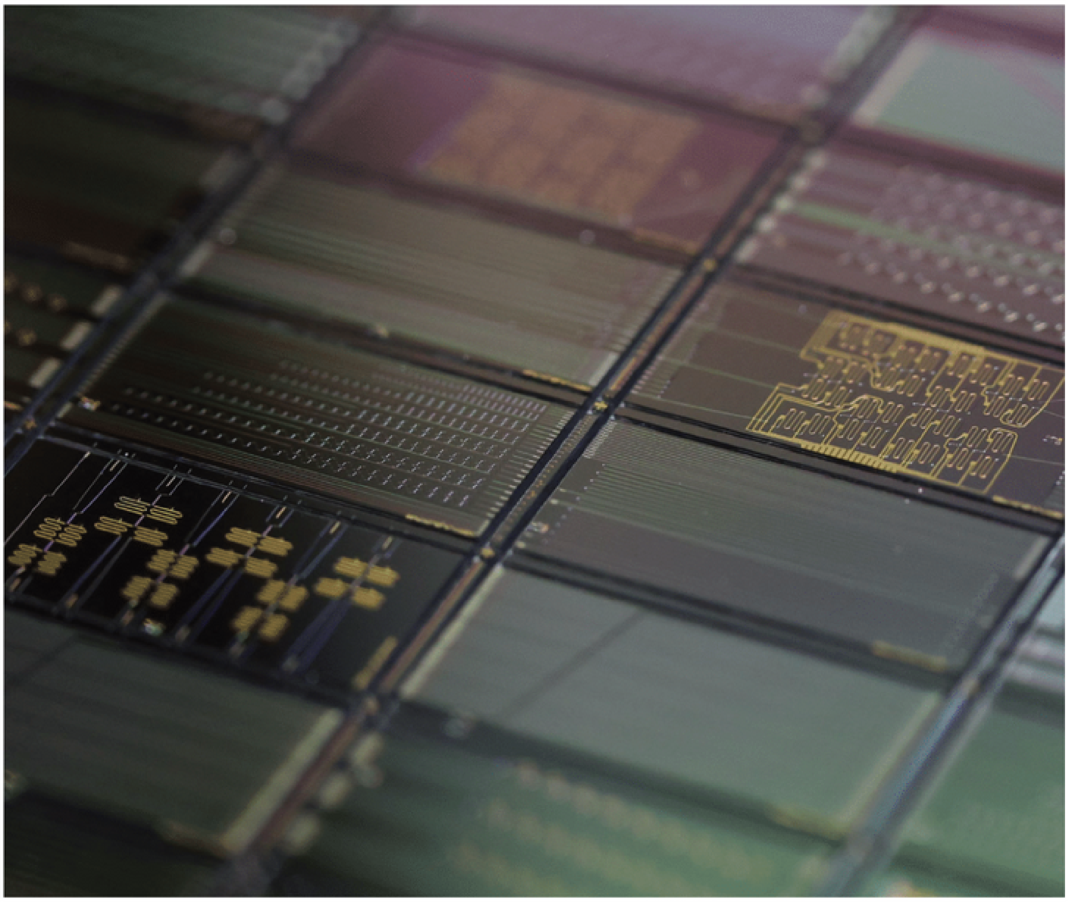
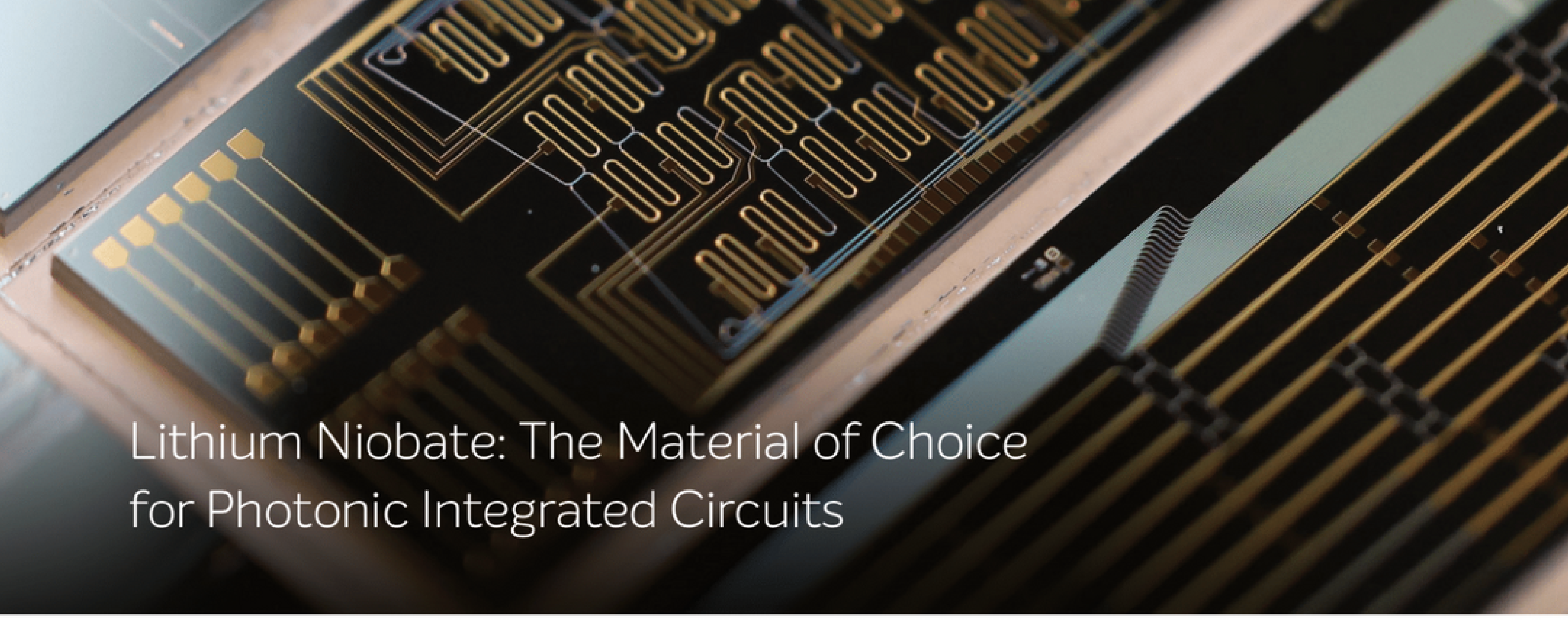
Q.ANT



The Power of Lithium Niobate Photonic Integrated Circuits

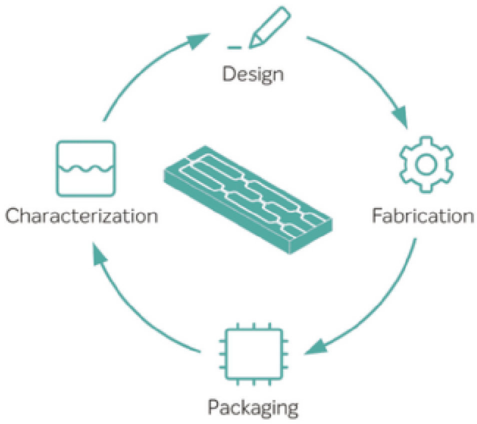
www.qant.com/quantum-computing



Lithium Niobate: The Material of Choice for Photonic Integrated Circuits

Q.ANT relies on its own integrated waveguide technology platform for quantum chips and photonic integrated circuits, based on the material lithium niobate.

The Q.ANT PICs enable the control of light and quantum effects in a highly integrated form. Q.ANT's offering includes the whole value chain, covering design, fabrication, packaging and characterization. The PICs are at the heart of Q.ANT's Photonic Processor.



Performance Matrix

Proven by more than 50 processed wafers

Figure of merit	Today	End of 2024	End of 2025	End of 2026
Waveguide loss (cutback)	1 dB/cm	0.5 dB/cm	0.2 dB/cm	0.05 dB/cm
Qs of resonators	3 Million	5 Million	10 Million	10 Million
Insertion loss per facet	0.8 dB	0.2 dB	<0.2 dB	<0.2 dB
Overlap efficiency per fiber-to-waveguide interface	86%	95%	> 95%	> 95%
Modulation voltage-length product Vπ·L (push-pull)	6 V cm	< 5 V cm	< 5 V cm	< 3 V cm
Beam splitter excess loss	0.1 dB	0.01 dB	0.01 dB	0.01 dB
Bending loss (dB / 90° bend)	0.03 dB	0.01 dB	0.01 dB	0.01 dB
Poled waveguides for nonlinear effects	Available	Available	Available	Available

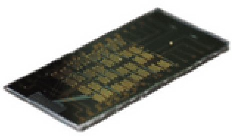
Striking Advantages of Lithium Niobate

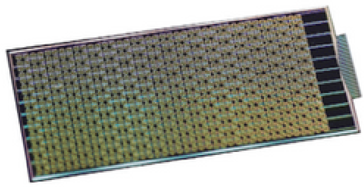
PICs based on LNOI for the Q.ANT photonic processors offer several advantages in the field of photonic and quantum computing and information processing:

- Low losses with a transparency window from 405 nm to 2350 nm, operation in both visible and mid-infrared regions.
- Large electro-optic effect, enabling high-speed modulation and switching of light signals, reaching MHz to GHz ranges, and surpassing platforms like silicon nitride and III-V semiconductors.
- Absence of thermal crosstalk between phase-shifters allows for operations of large interferometer-networks.
- High contrast index enables high-density component integration, leading to smaller processors.
- LNOI's capability for periodic poling and natural phase-matching supports second-order nonlinear effects, making it ideal for efficient quantum sources and integrated quantum applications.
- The z-cut orientation of LNOI PICs allows for spirals and modulators in any direction, providing more design freedom compared to x-cut oriented foundries.

Interferometer Specifications

for 4 mode and 20 mode PICs

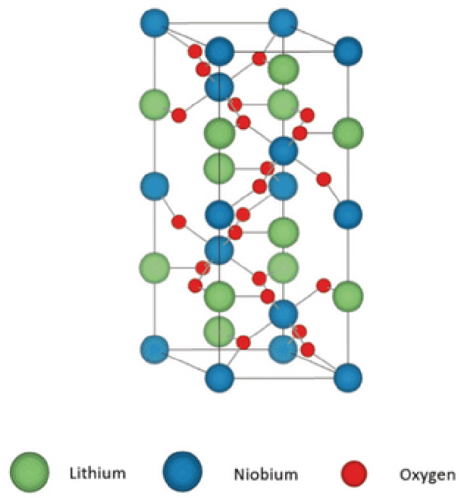




Chip specifications	4 independent optical modes	20 independent optical modes
Platform	Lithium niobate on insulator	Lithium niobate on insulator
Die size	15 x 7 mm^2	15 x 30 mm^2
Operating wavelength	1550 nm	1550 nm
Number of tunable elements	24	800
Number of integrated optical components	> 50	> 1000
Electrical actuation	Pockels electro-optic effect	Pockels electro-optic effect
Electro-optic modulator power consumption	< 5mW@1MHz	< 5mW@1MHz
Electrical on-chip connectivity	planar, single-layer	multi-layer

The Building Blocks of the Q.ANT LNOI Technology

Lithium niobate ($LiNbO_3$) is a crystalline material with a trigonal crystal system exhibiting ferroelectricity and birefringence.
It is characterized by exceptional electro-optic and nonlinear optical properties and a wide transparency range from the visible to the mid-infrared spectrum.
For these reasons, Q.ANT selected lithium niobate on insulator (LNOI), which consists of a thin layer of $LiNbO_3$ bonded to a low refractive index substrate, such as silicon dioxide, as the platform of choice for the development of its core technology.

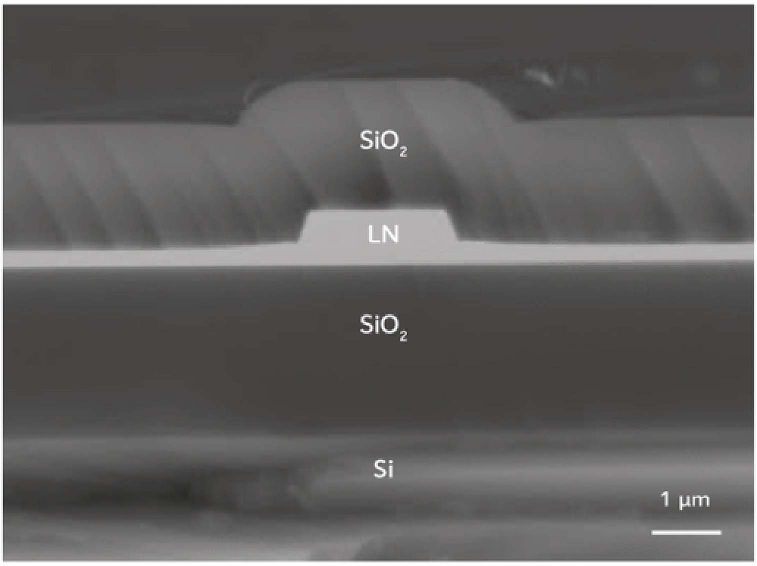


Q.ANT relies on more than 3 years of advancements in processing wafers and characterizing chips, with over 50 wafers processed. With our robust supply chain and in-house capabilities, we can offer the whole value chain.

One of the key advantages of LNOI PICs is its high index contrast. This allows QANT's platform to have waveguide widths starting at 400 nm and bending radii to be as low as 50 µm which significantly boosts the density of integration.

Waveguides

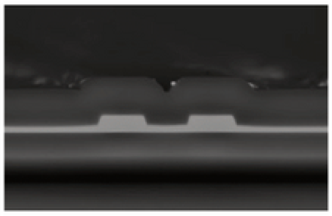
Our waveguides form the backbone of our PIC technology. They are based on a LNOI technology featuring a thin lithium niobate layers with a LN etch process. This ensures low propagation loss, and the platform's high refractive index contrast allows for compact PICs.



Cross section of a LNOI waveguide

Beamsplitters

The beamsplitters are engineered to ensure minimal insertion losses and robustness to fabrication tolerances. Additionally, our state-of-the-art design flow allows for the custom design of arbitrary power-splitting ratios, allowing their use in many applications.



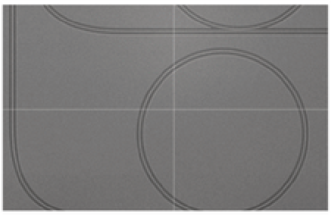
Cross section of an evanescent beamsplitter

Poled waveguides

Q.ANT's z-cut LNOI platform allows for wafer-level creation of arbitrary poled waveguides (PPLN). This enables second-order nonlinear effects and functionalities such as frequency conversion and efficient quantum light generation.

Ring resonators

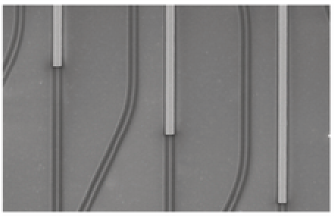
Q.ANT technology allows for the design and fabrication of devices with Q-factors larger than 3 million and high tolerance to fabrication. These resonant structures provide enhanced wavelength selectivity, which is crucial for linear and non-linear applications.



Ring resonator

Electro-optic phase shifters

These devices make use of lithium niobate's strong electro-optic properties to provide efficient and compact phase modulation. They are characterized by low driving voltage, high modulation bandwidth, and reduced footprint thanks to z-cut lithium niobate.



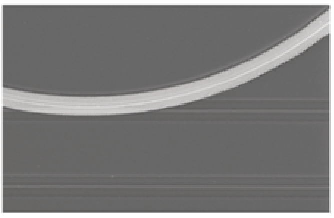
Electro-optical phase shifter

Fiber-to-chip coupling

Efficient fiber-to-chip coupling is achieved through meticulously designed coupling interfaces. Optimized for high coupling efficiencies and alignment tolerance, these interfaces ensure robust connections between optical fibers and photonic integrated circuits, simplifying integration into complex optical systems.

Mach-Zehnder modulators and tunable filters

Featuring integrated electro-optic phase shifters for precise wavelength tuning,these Mach-Zehnder modulators (MZM) and tunable filters leverage the unique properties of Q.ANT's lithium niobate platform. These components enable efficient higher-level functionalities by offering a wide range of operating wavelengths, low insertion losses, high extinction ratios, and low crosstalk.



Tunable ring resonator

Comparison of foundry available materials

Material	Electro-Optic Coefficient (pm/V)	Refractive Index
Lithium Niobate ($LiNbO_3$)	31 (r33)	~2.2
Indium Phosphide (InP)	1.45	~3.17
Gallium Arsenide (GaAs)	1.6 (r41)	~3.3
Cadmium Telluride (CdTe)	6.8 (r41)	~2.7
Silicon (Si)	Negligible	~3.5
Silicon Nitride (Si_3N_4)	Negligible	~2.0

The Q.ANT Photonic Processor

Q.ANT GmbH | Handwerkstraße 29 | 70565 Stuttgart, Germany
+49 711 45969613 | info@qant.de | www.qant.com