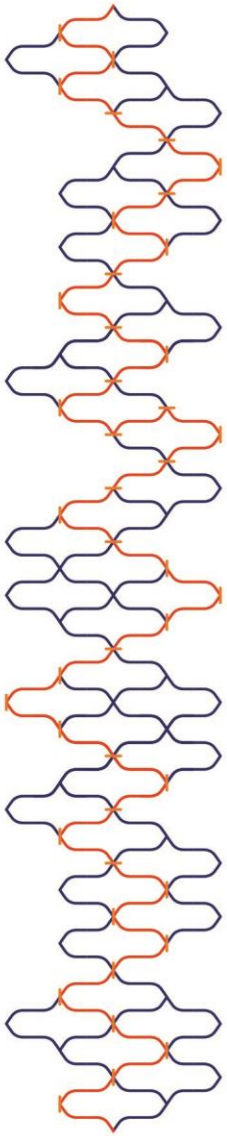
Integrated Photonic Processors for Quantum Computing

J J Renema

j.j.renema@{quix utwente}.nl



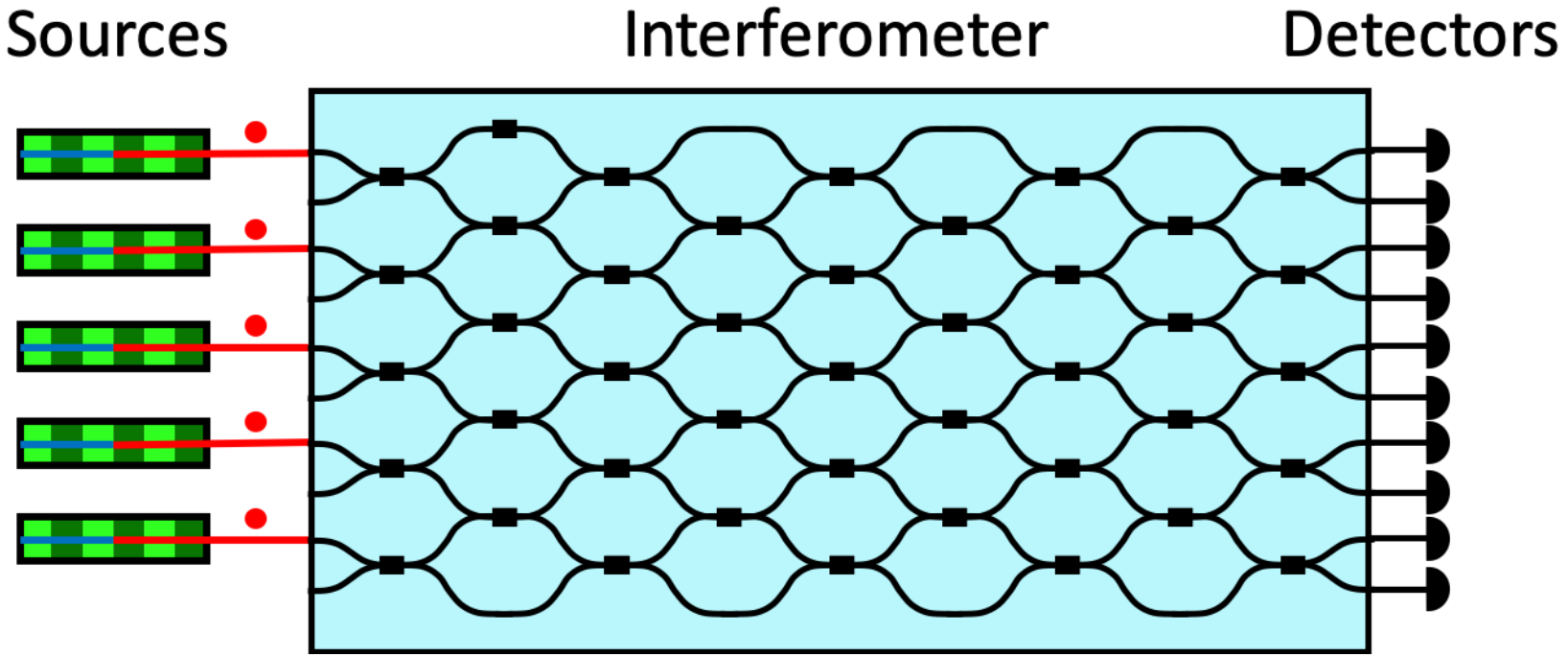
ADAPTIVE QUANTUM OPTICS

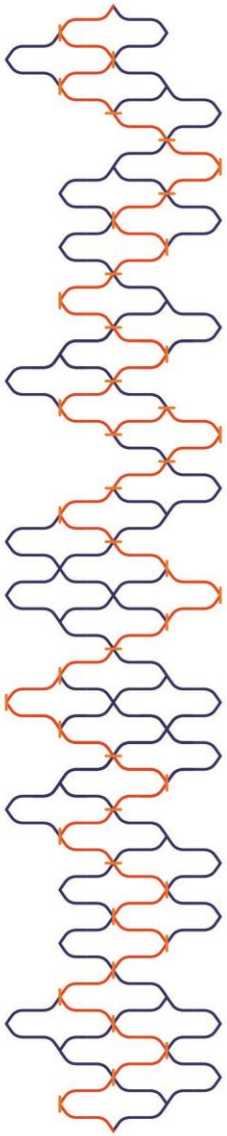
The vision

- Near-term quantum computing with photons

The device

- We want to do near-term quantum computing with photons





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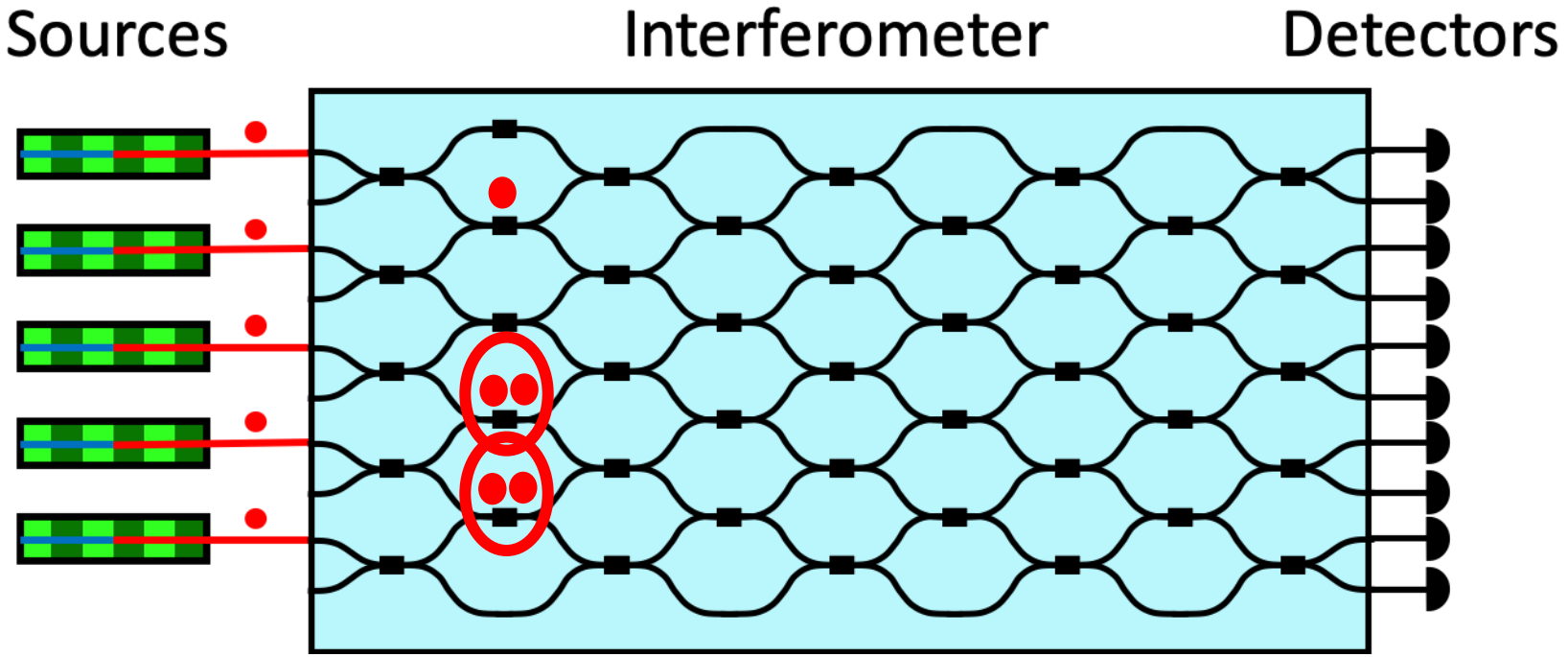

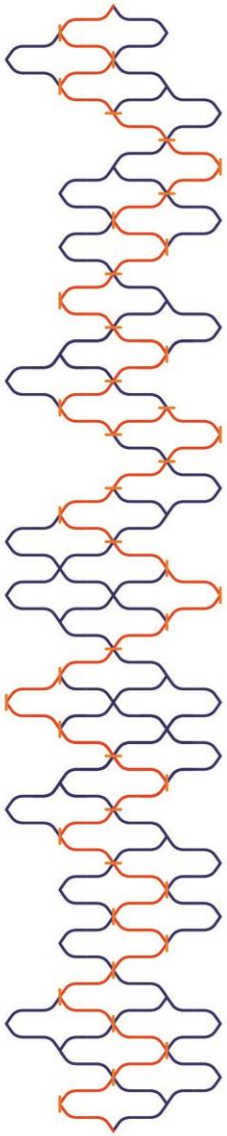

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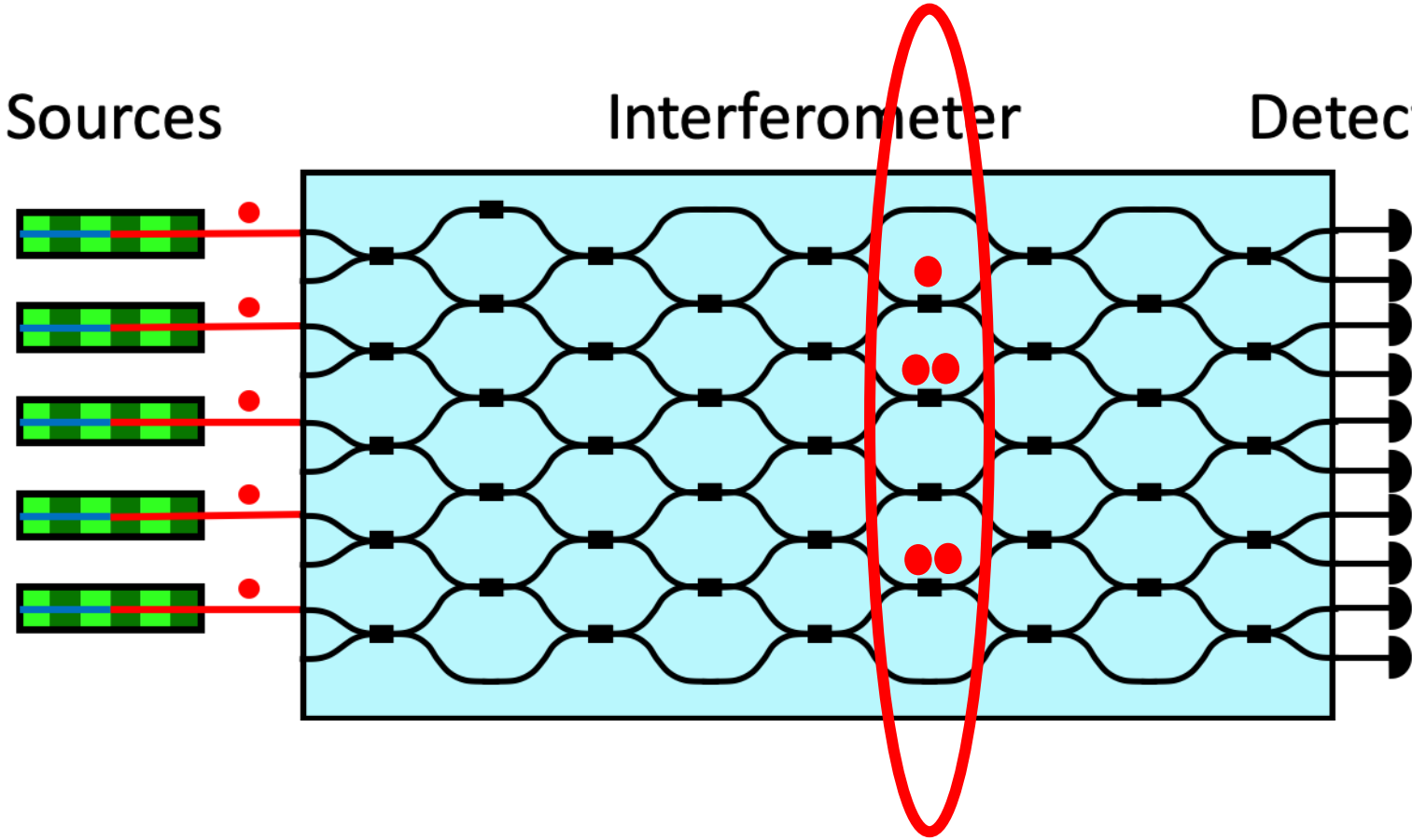

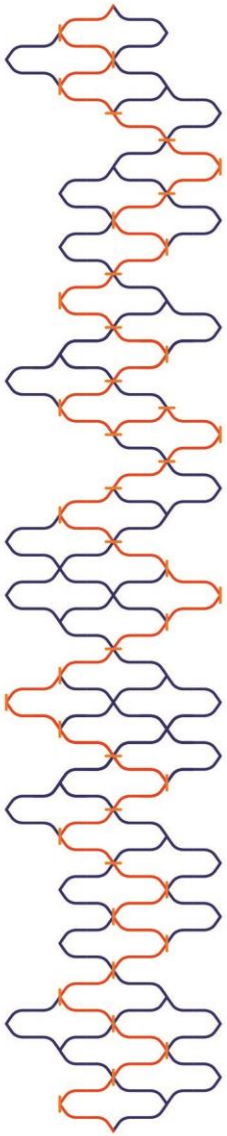

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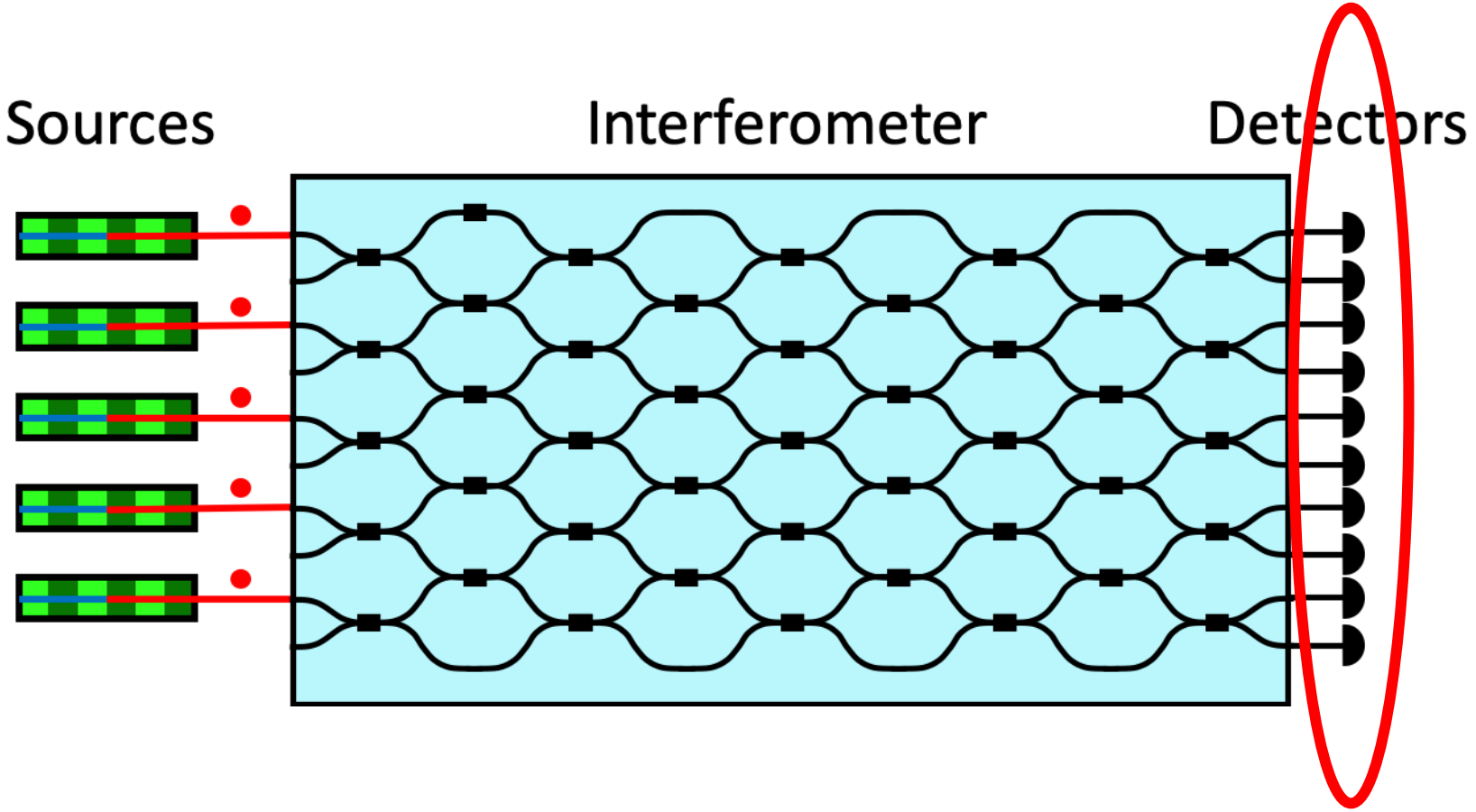

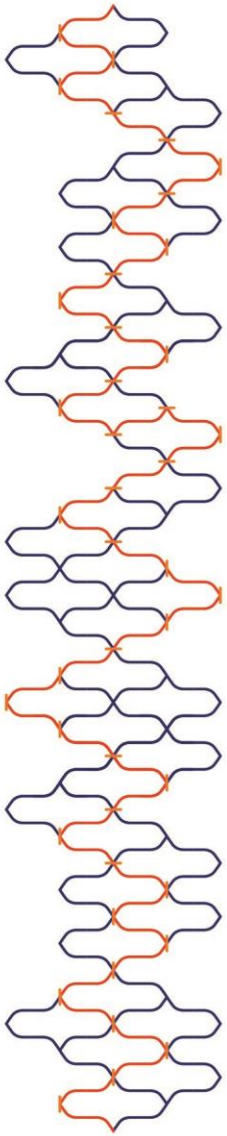

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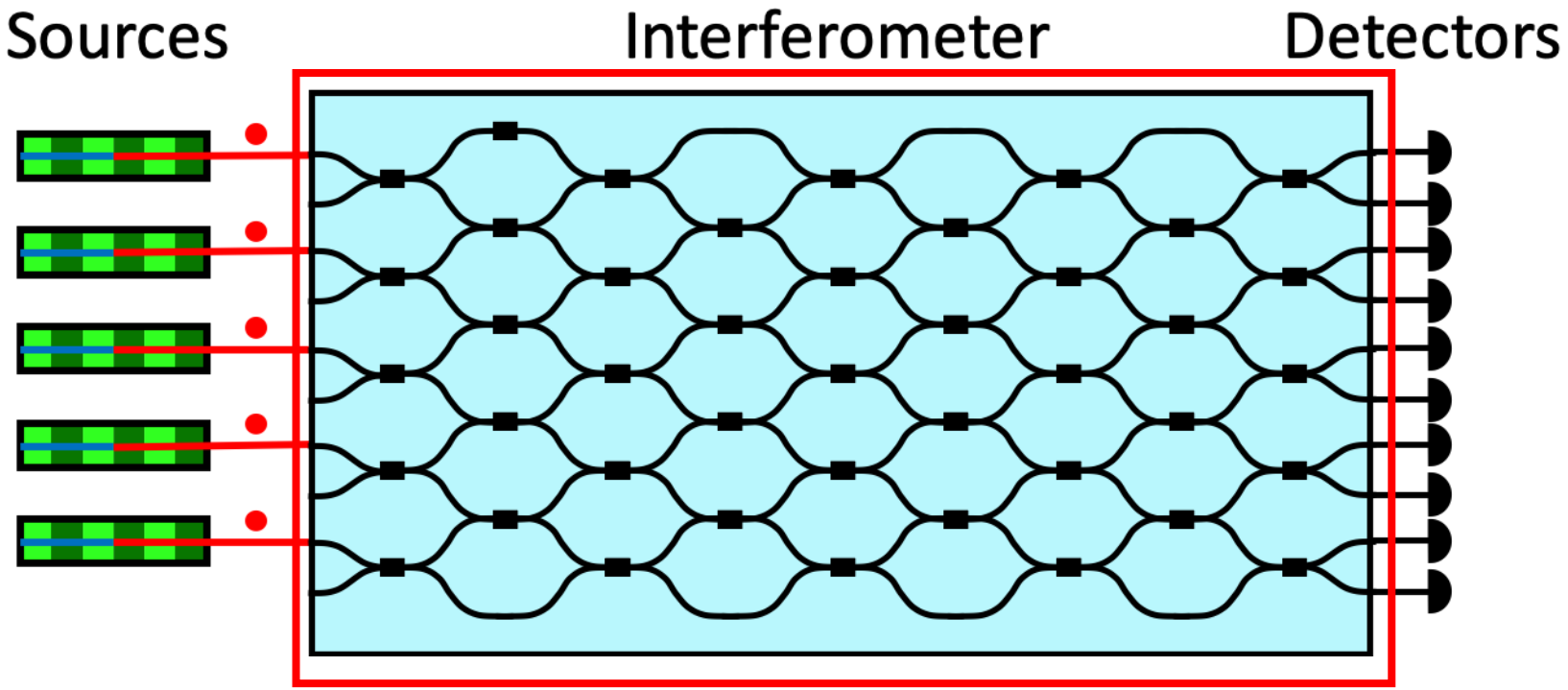

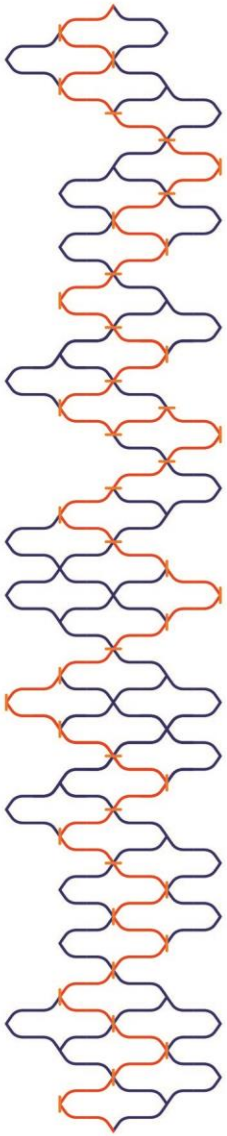

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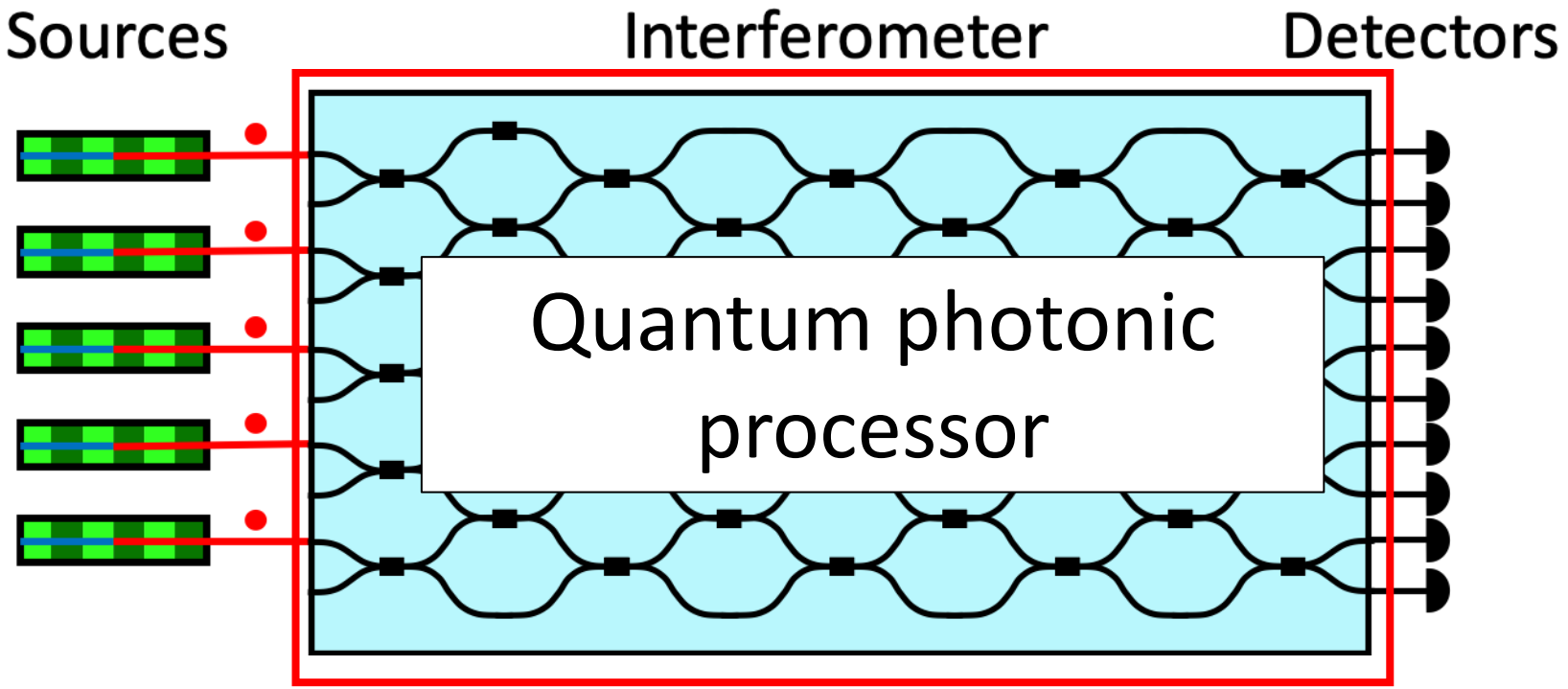

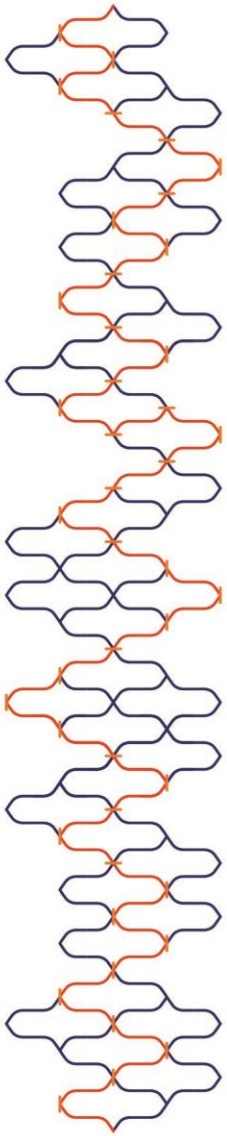

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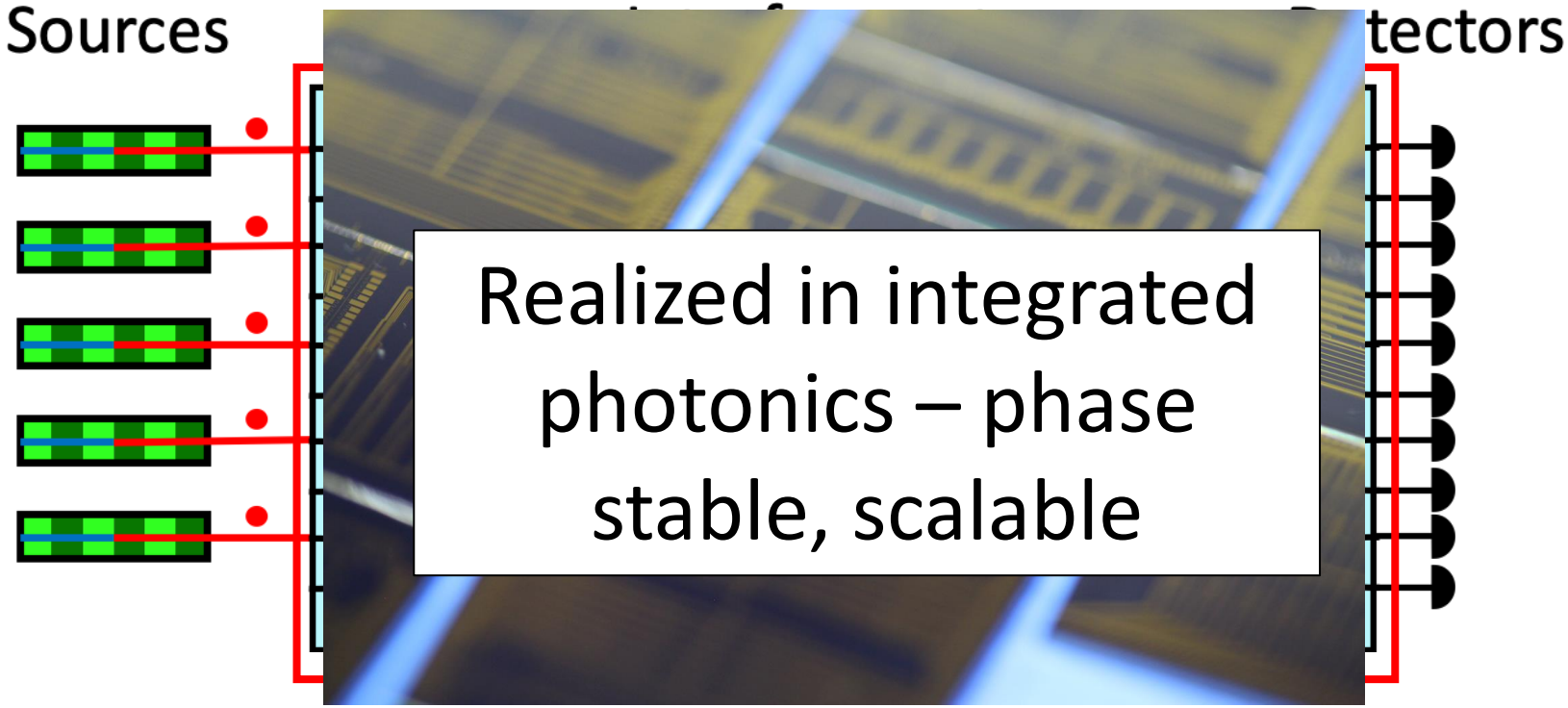
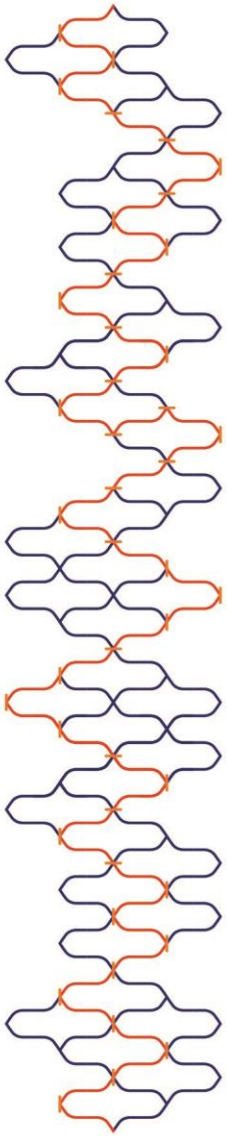
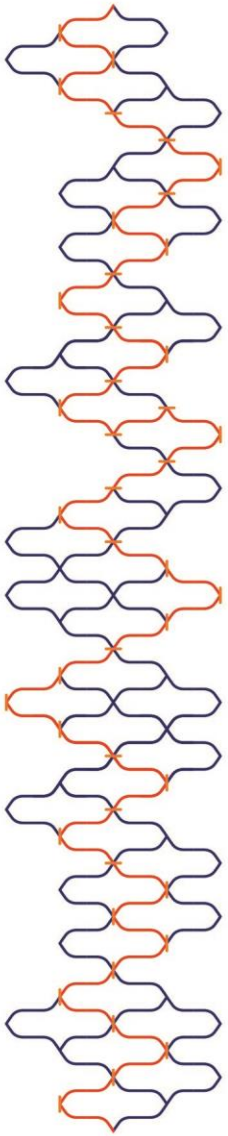




Requirements on the processor

- Computing power set by number of optical modes
- Engineering requirements:
  - Fully programmable (i.e. arbitrary all-to-all coupling)
  - Low optical loss (equivalent to decoherence)
  - Interference-preserving



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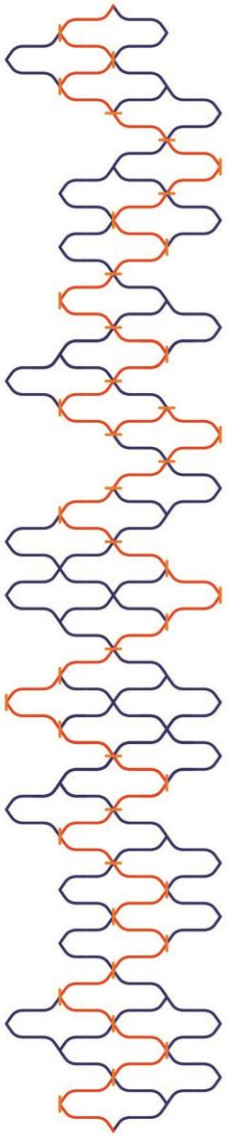
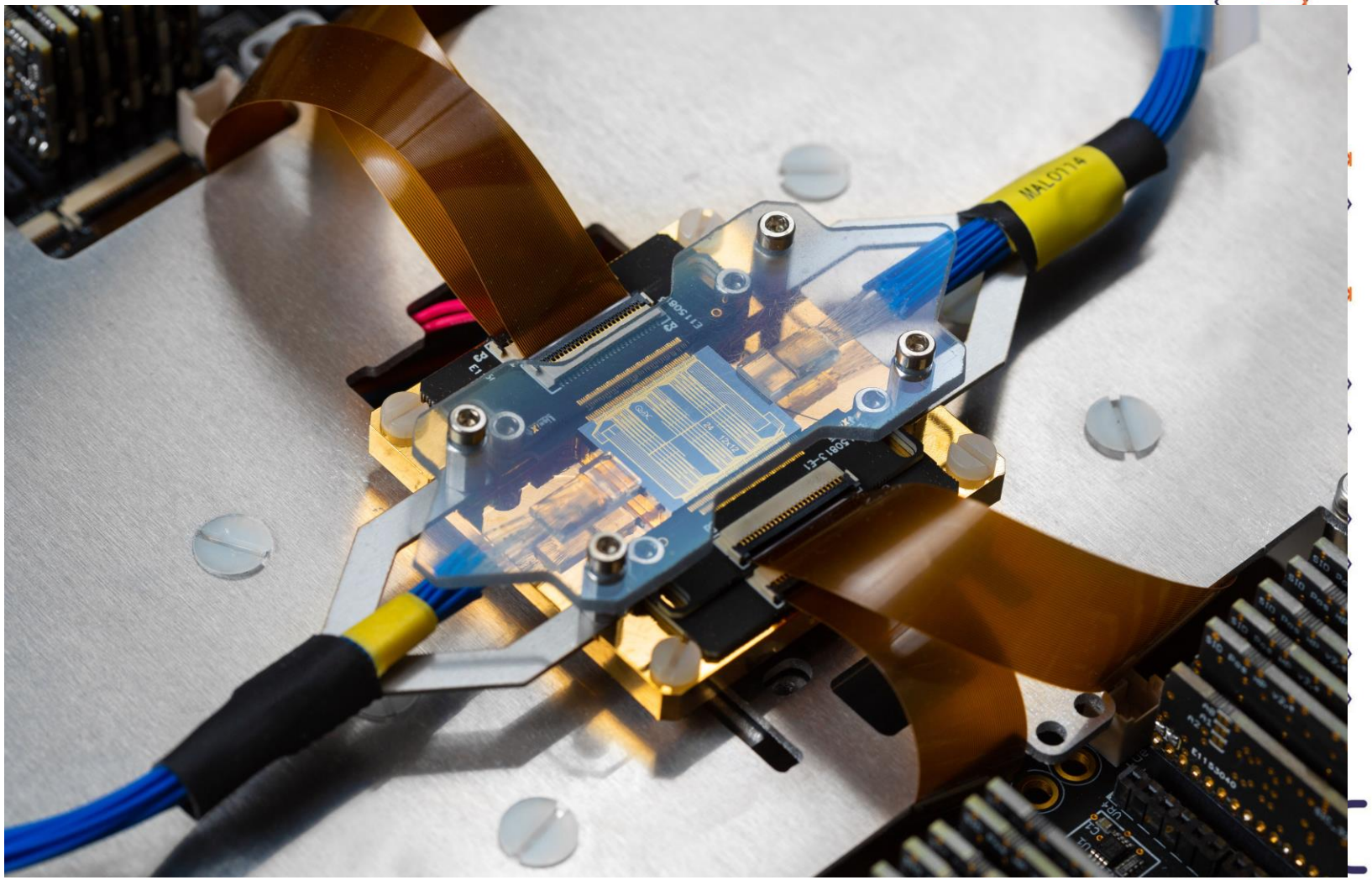


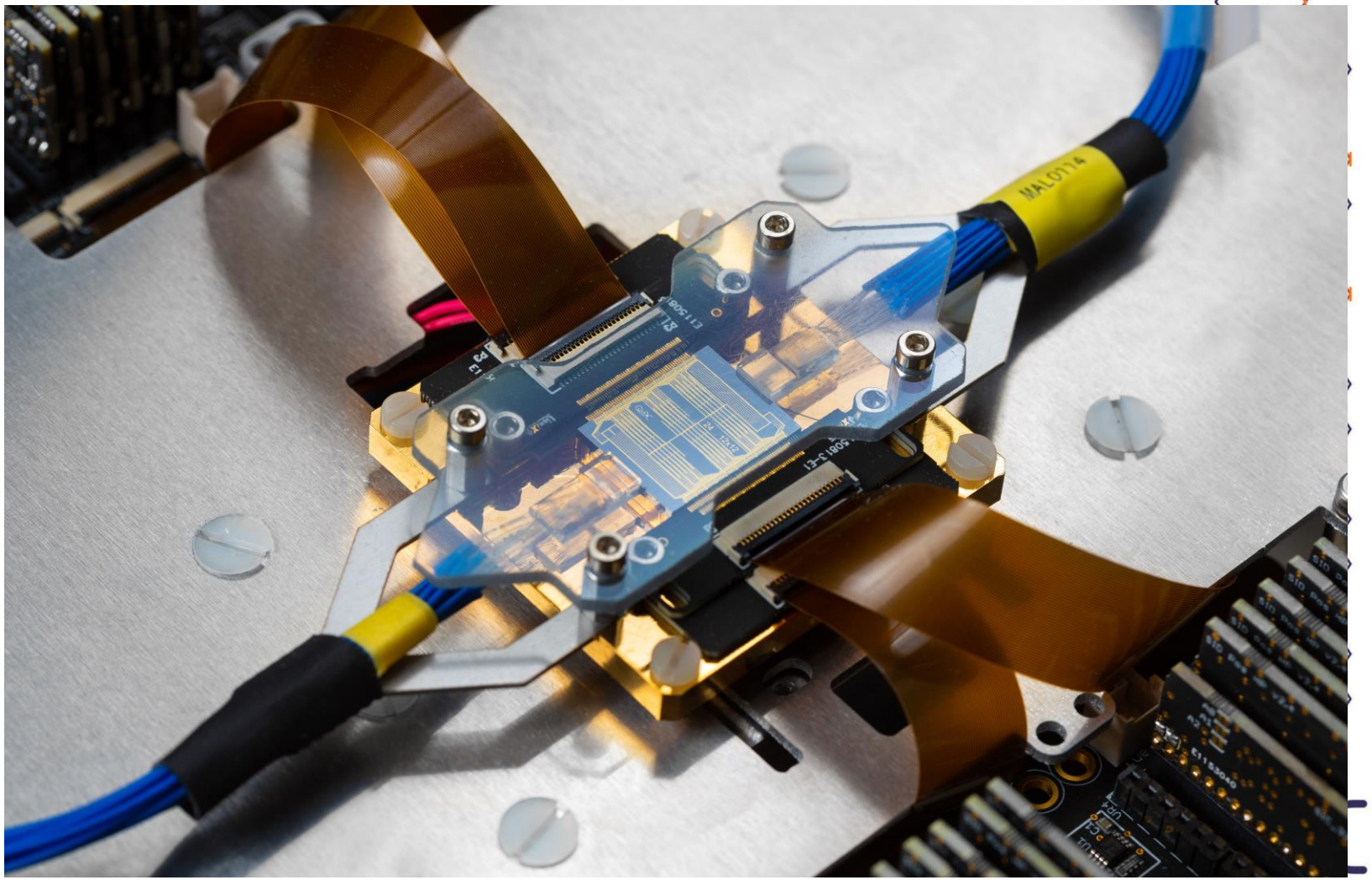
12 mode photonic processor



Taballione et al, Materials for Quantum Technology 1 (3), 035002 (2021)

12 mode photonic processor

- Largest low loss photonic interferometer in the world
- Not a hero device!



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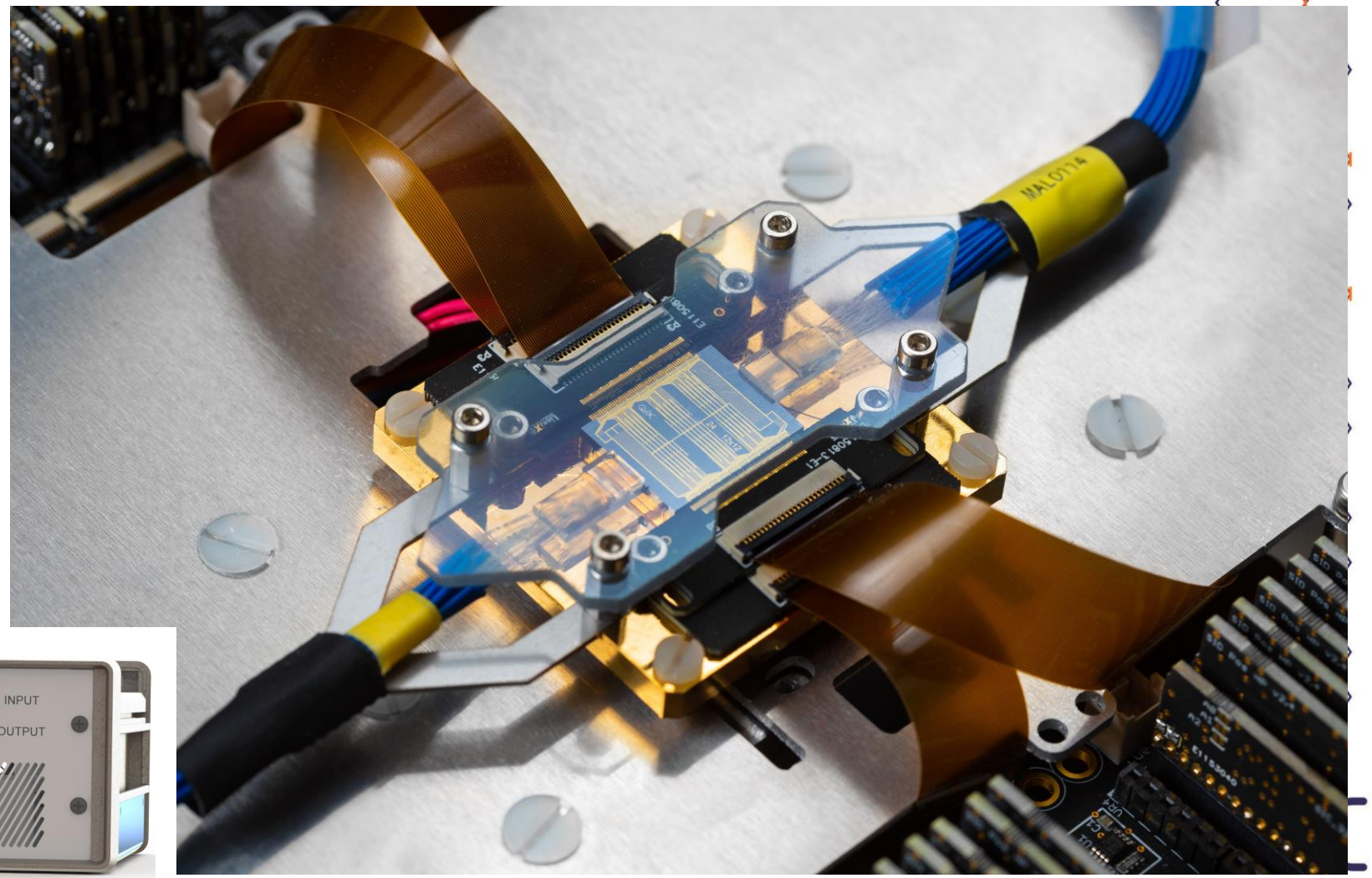
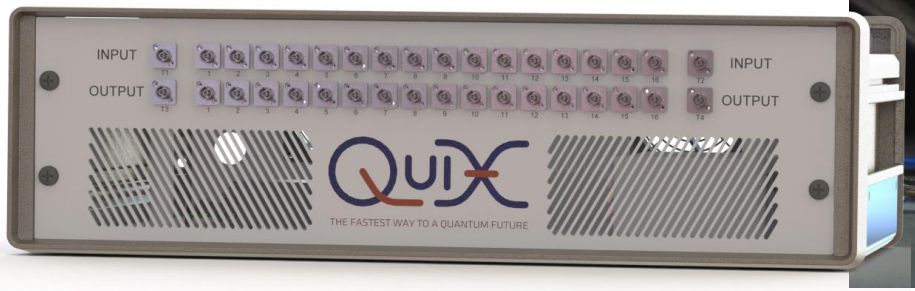
12 mode photonic processor

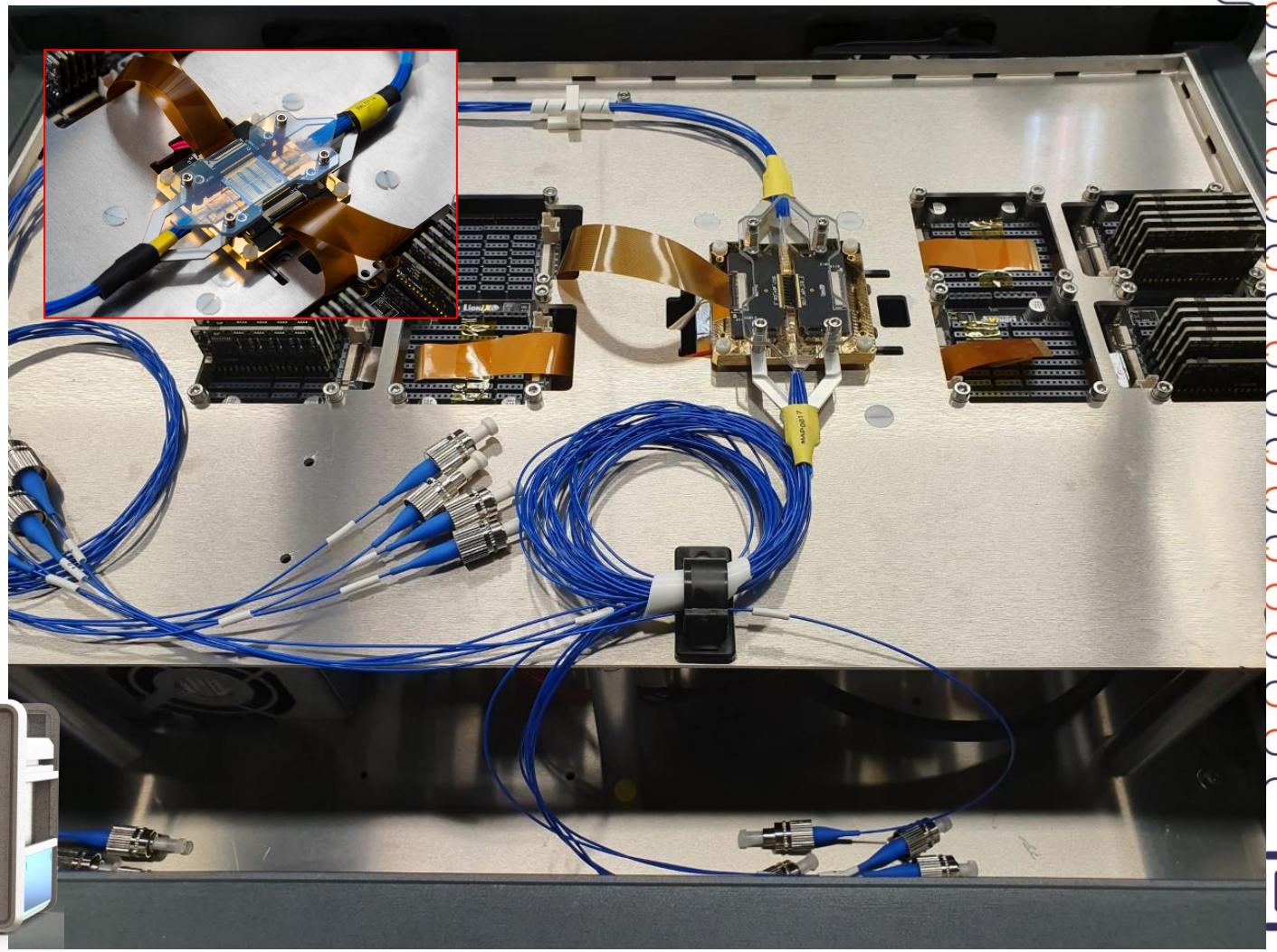
- 12-mode, low-loss photonic universal processor
- With all peripheral electronics



12 mode photonic processor

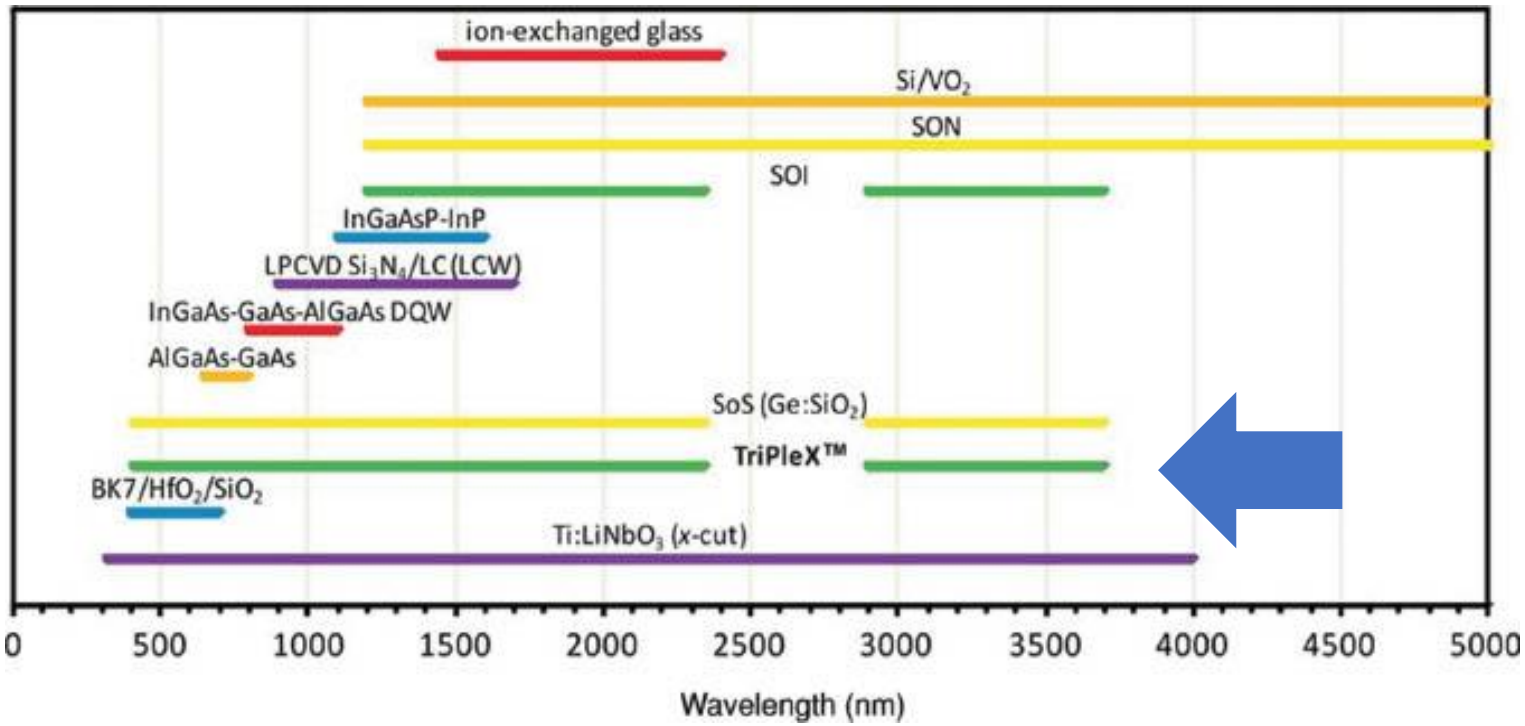
- 12-mode, low-loss photonic universal processor
- With all peripheral electronics
- Turnkey, swappable between electronics modules

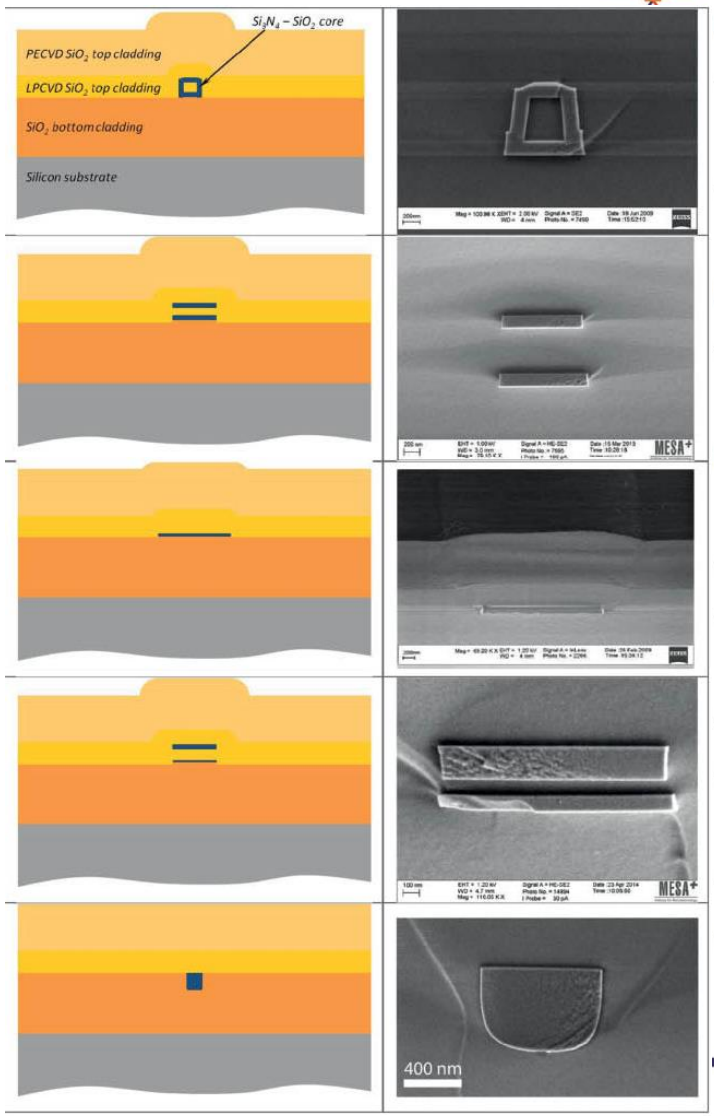




The platform: SiN

- Wide transparency window (425-3700 nm) – compatible with all sources
- Versatile, mature technology





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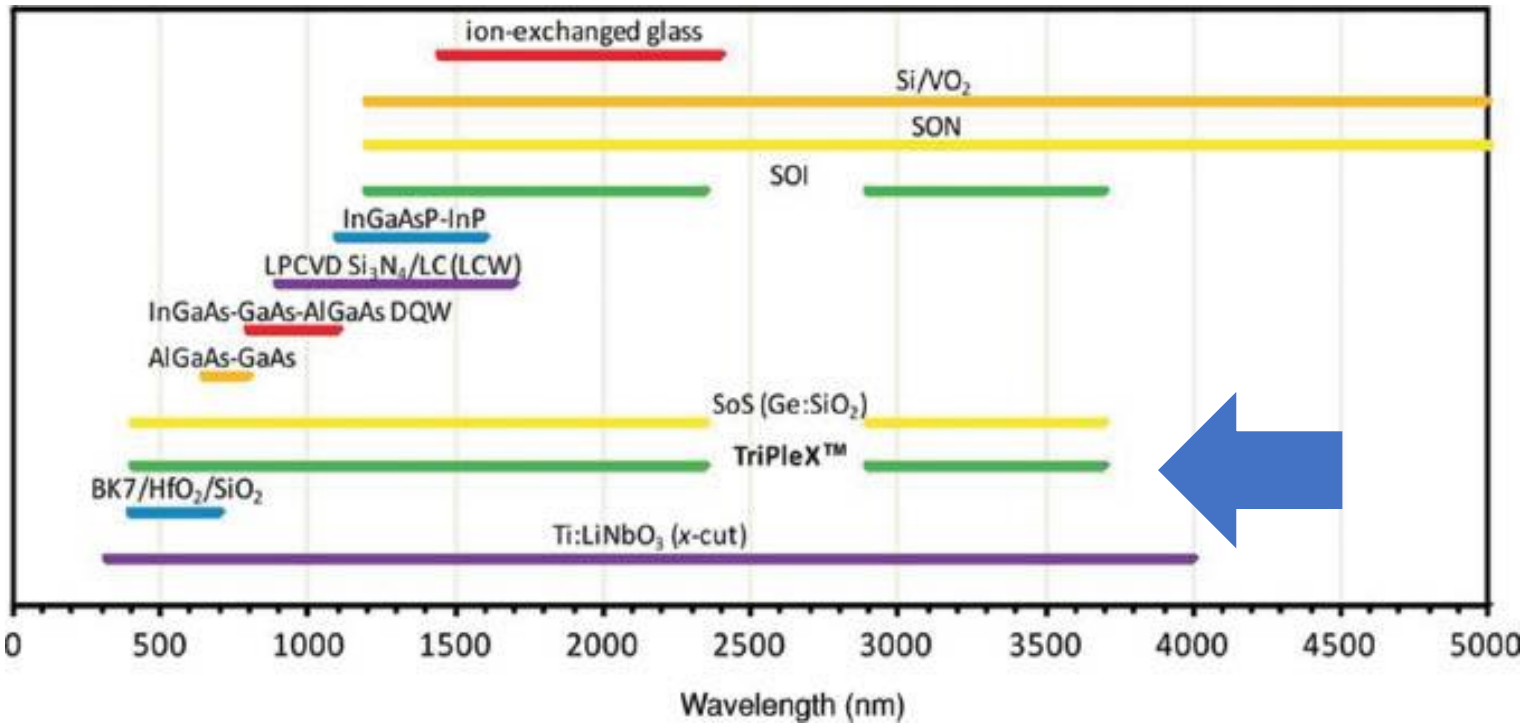

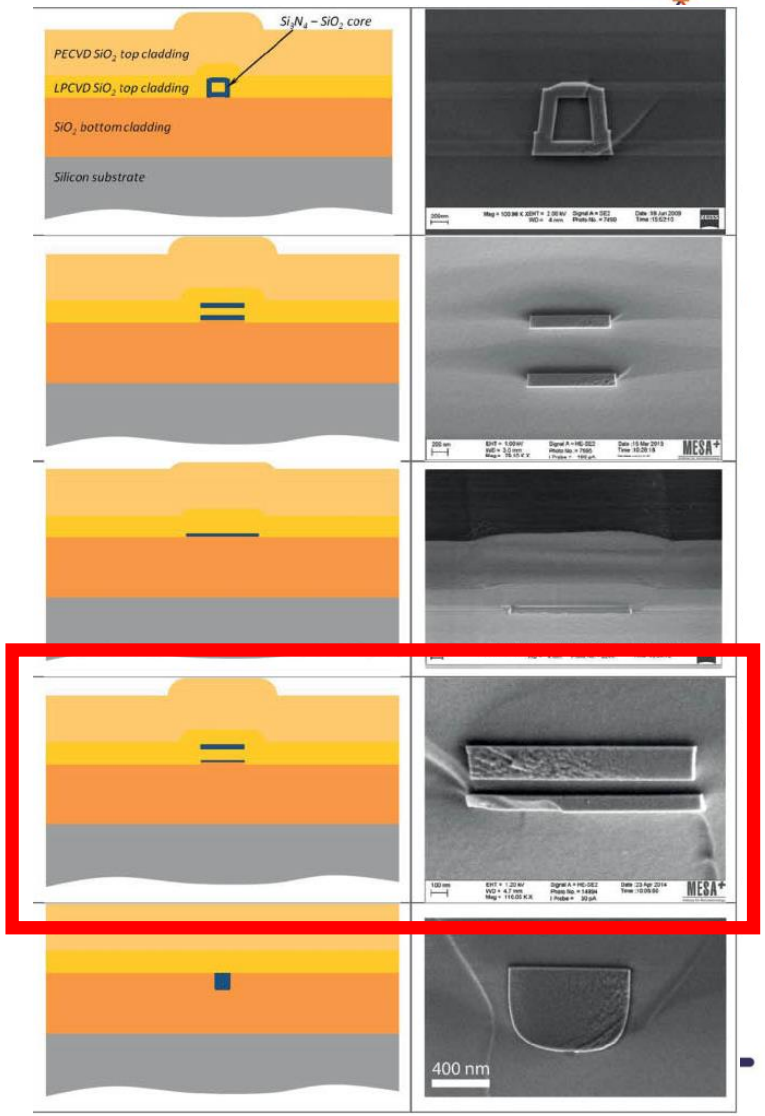

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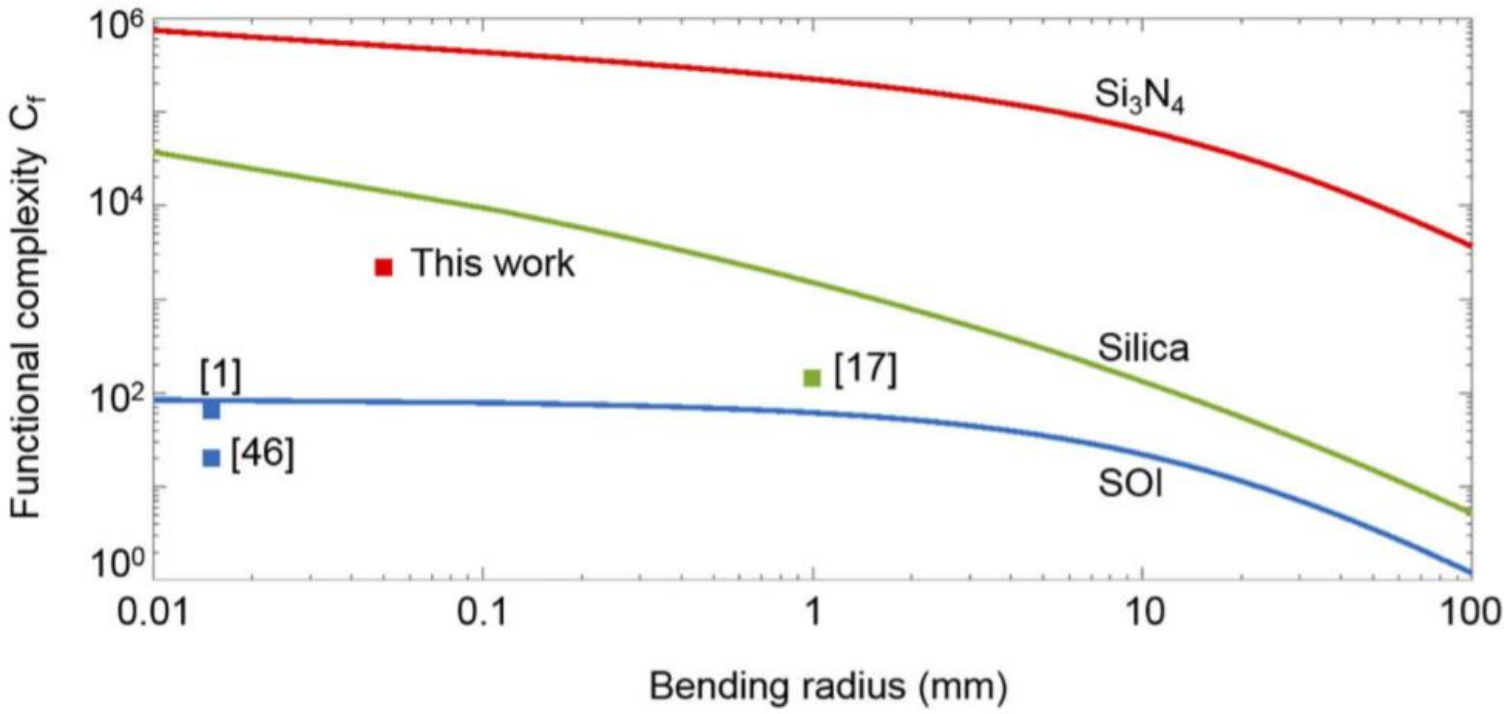
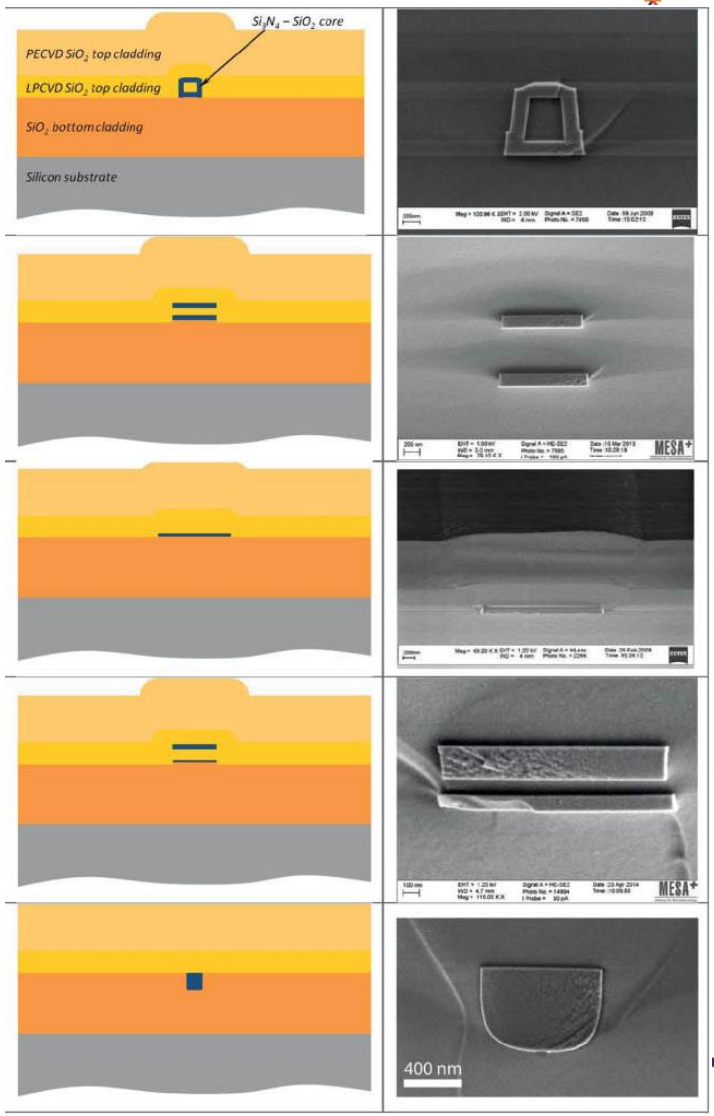
- Very low optical loss (< 0.1 dB / cm)
- Relatively short bend radius (BS ~ few 100 um)
- Low coupling loss (0.5 dB / w tapers)





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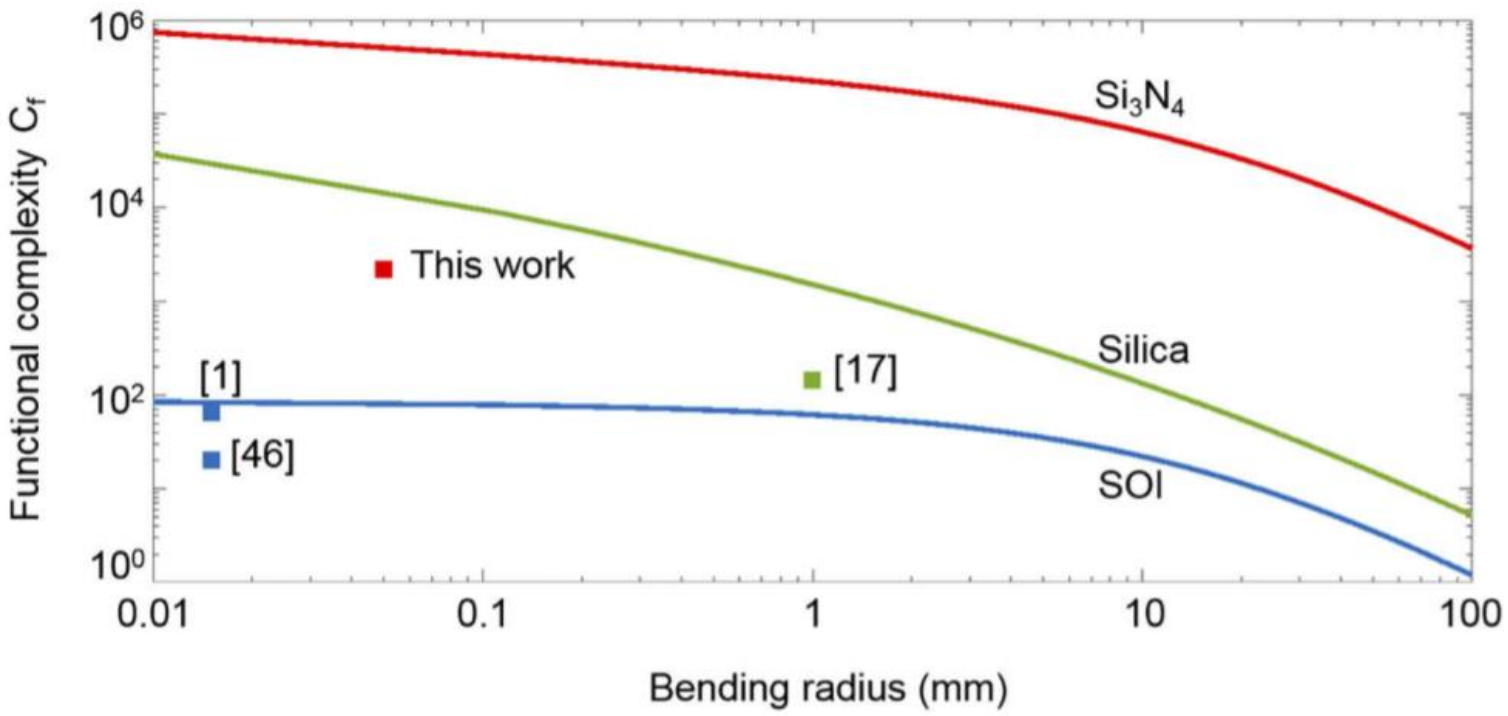
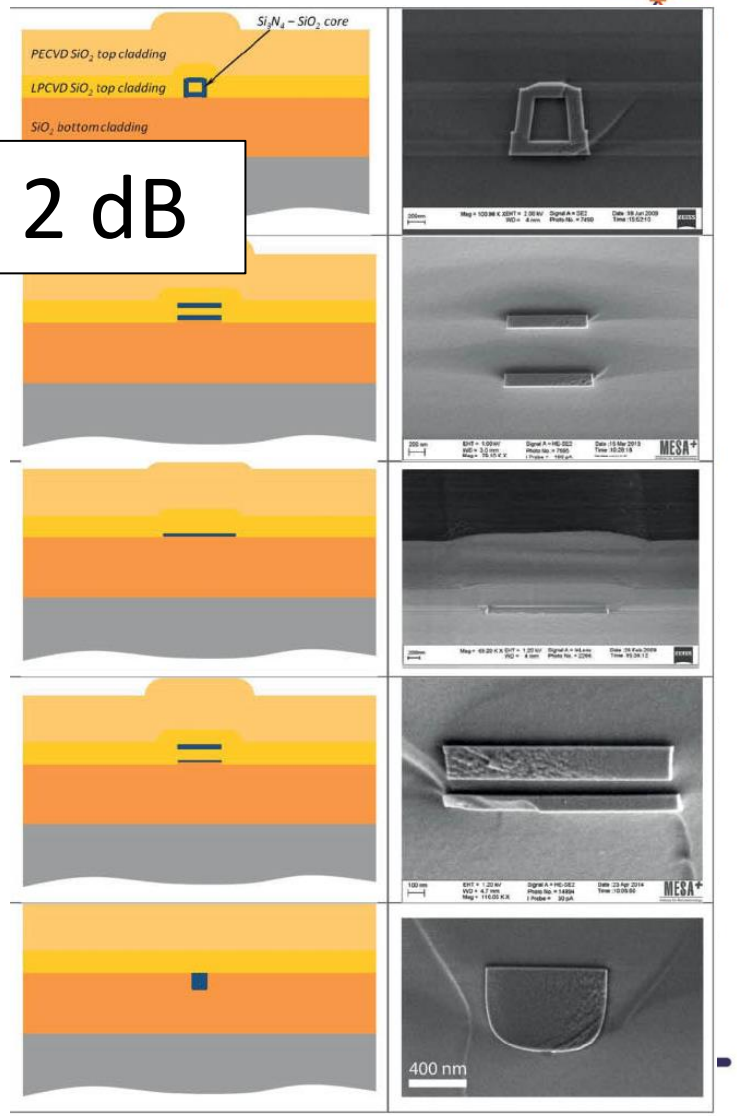


2 dB



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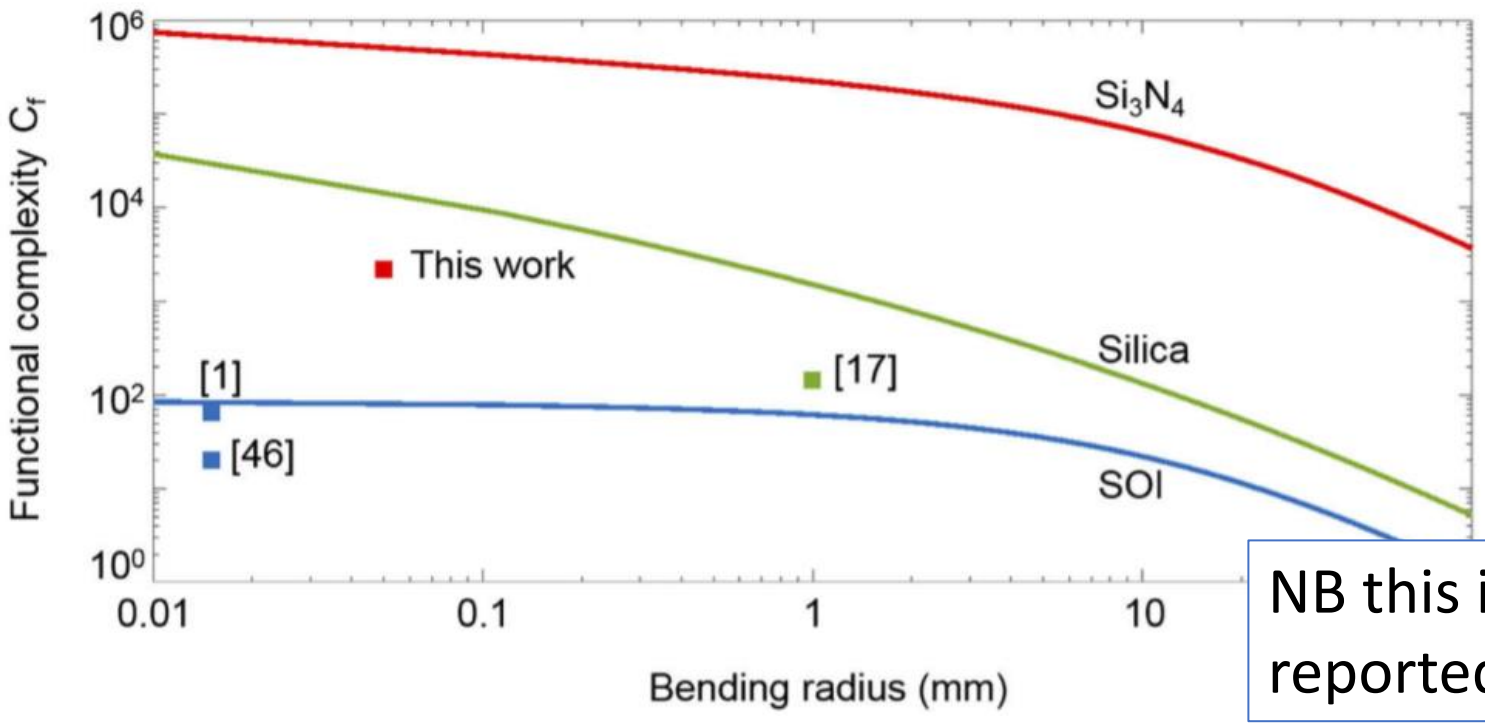
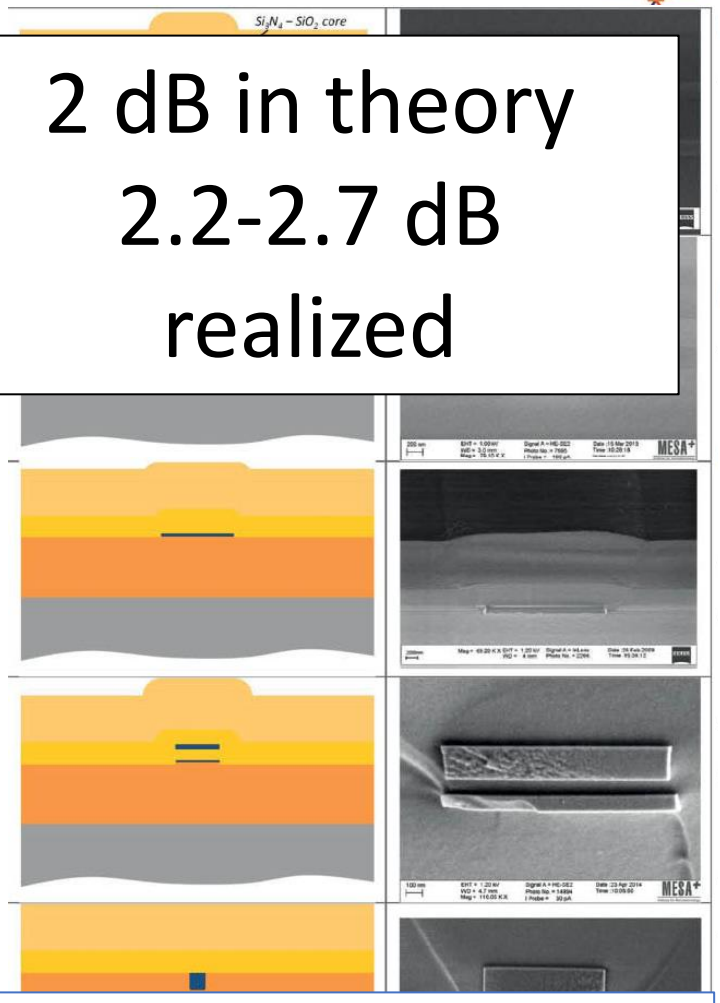
2 dB in theory
2.2-2.7 dB
realized

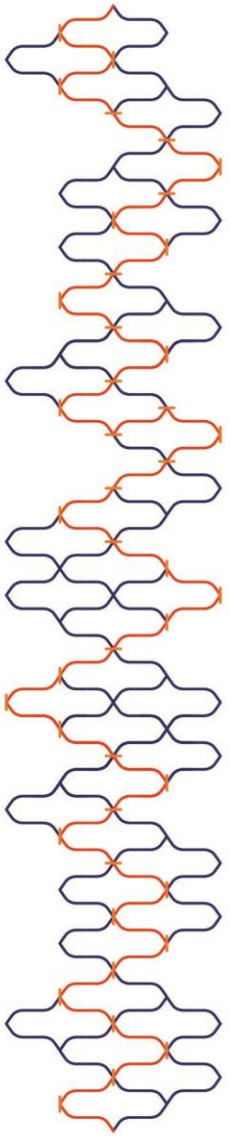




NB this is 2-3 dB better than what we reported in December 2020

Processor loss budget

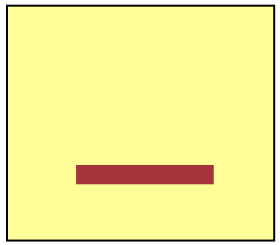
- 0.5 dB / facet x 2
- 0.1-0.2 dB fiber-fiber coupling into box
- 12 cm propagation @ < 0.1 dB / cm

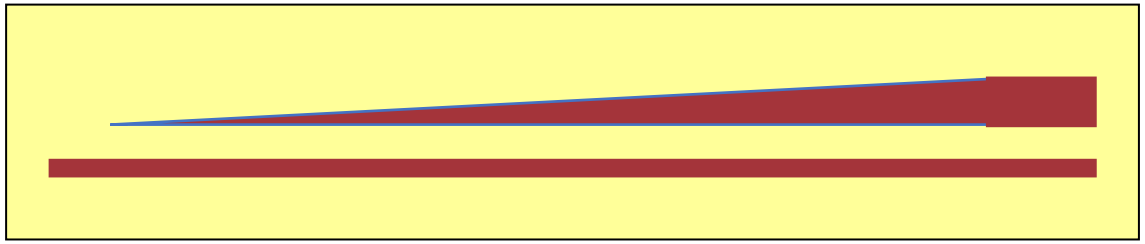


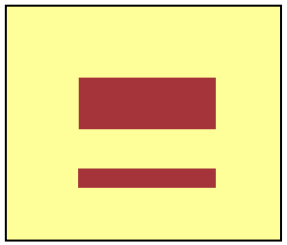
Processor loss budget

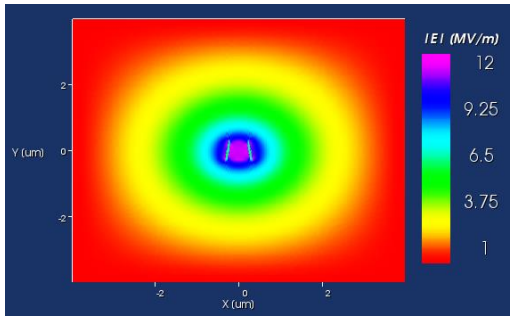
Low index contrast

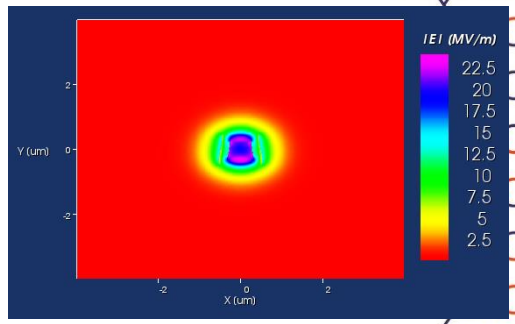
High index contrast

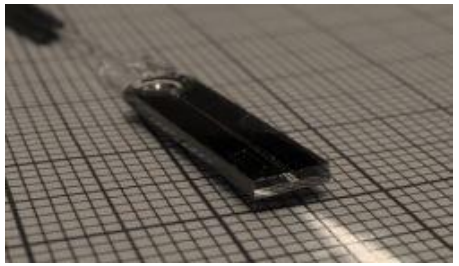






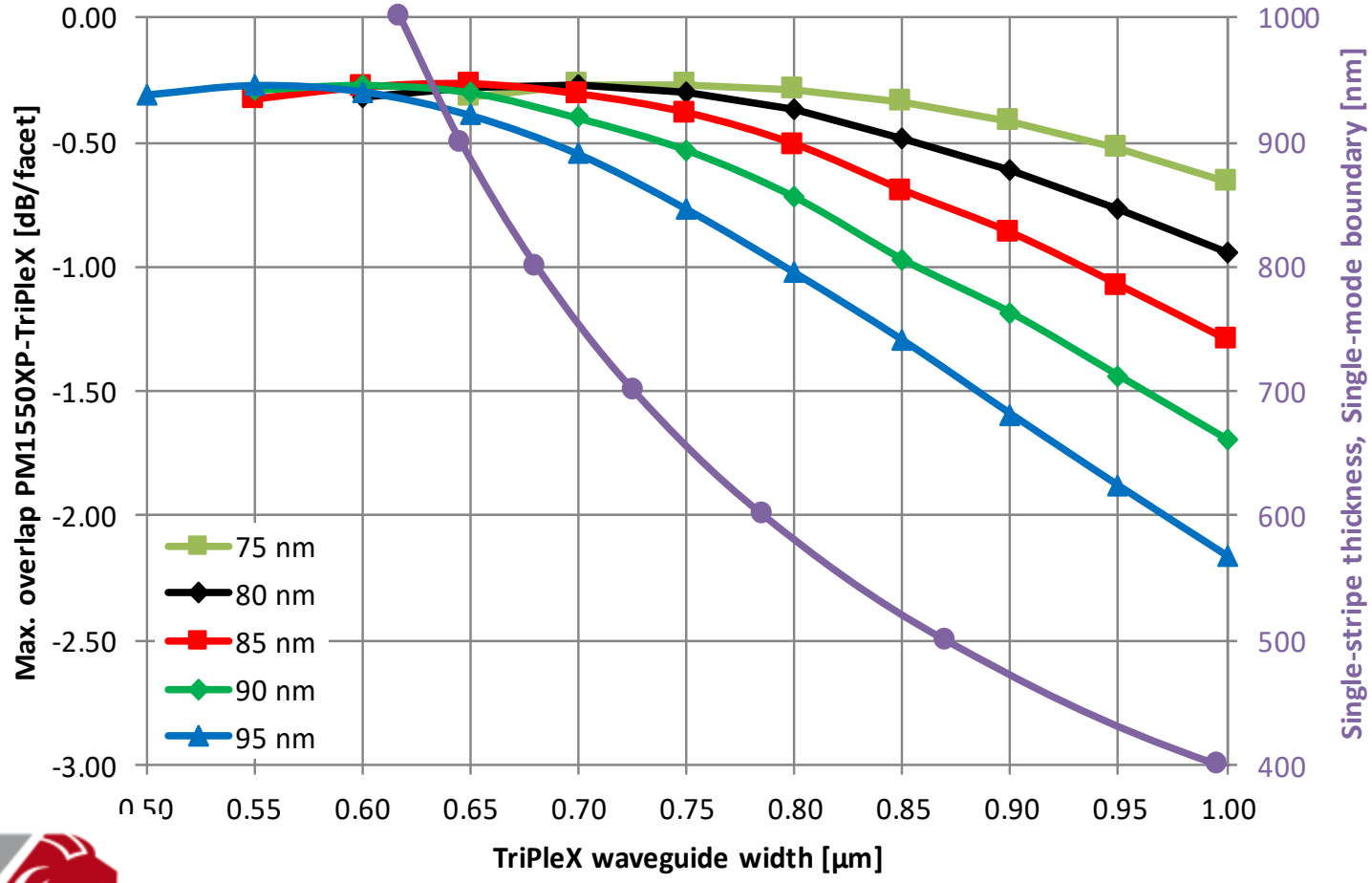


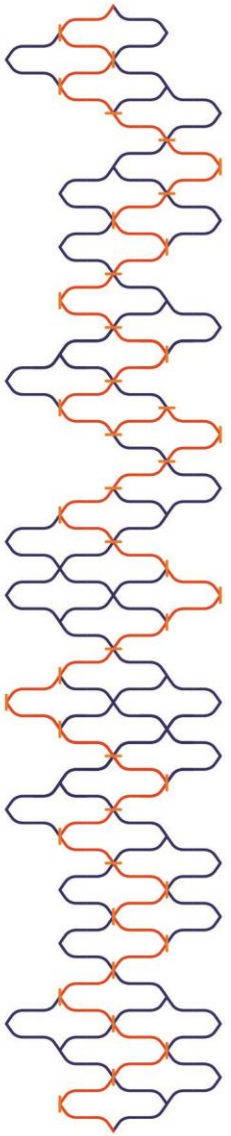




- Mode profiles from 1 µm to > 10 µm
- Modefield conversion
- Pitch conversion
- Low loss coupling to almost any external component, including SM fiber, InP and Si (SOI)
- Typical <1 dB coupling in assembly to SMF-PM fiber

Processor loss budget

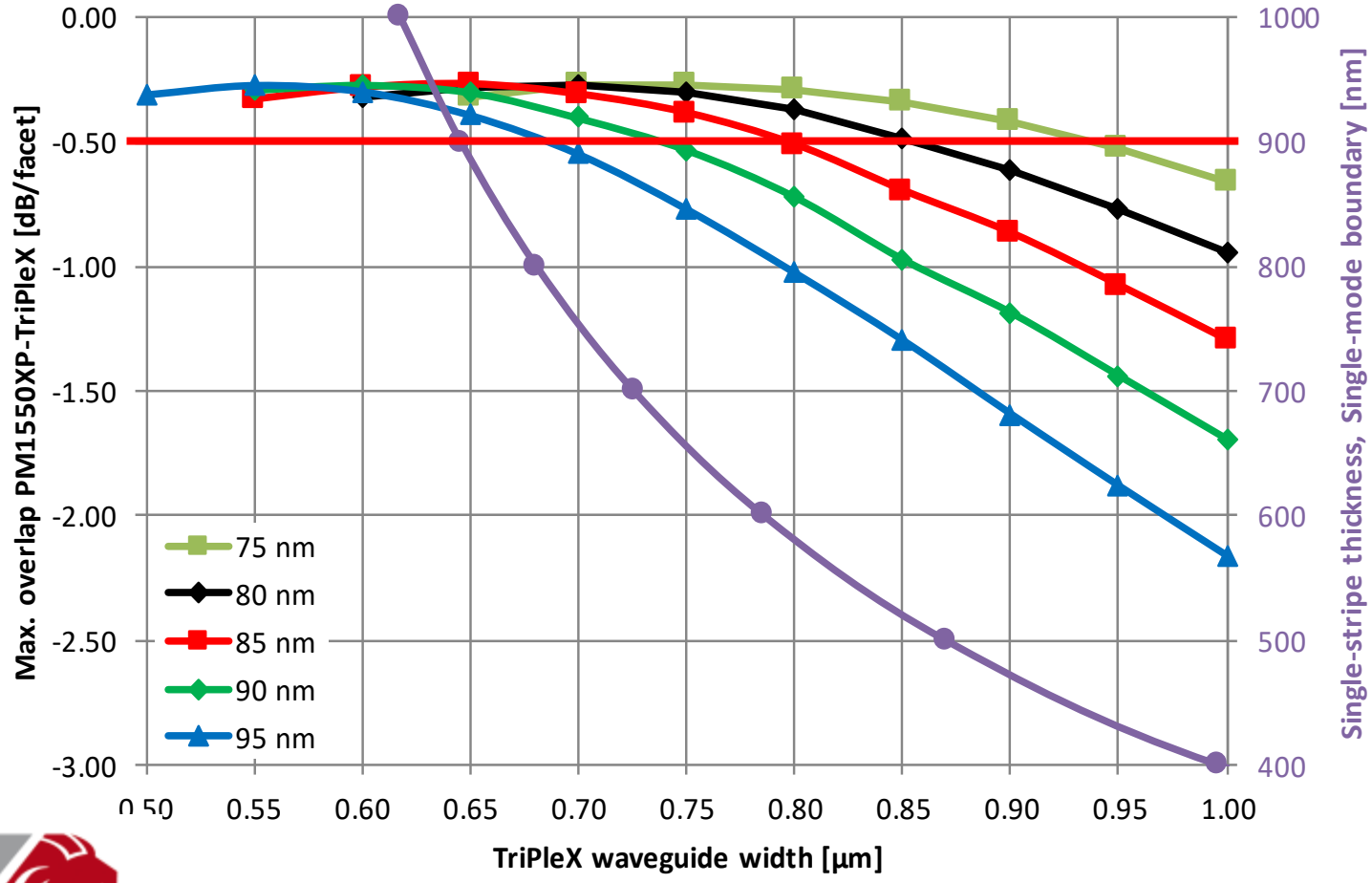


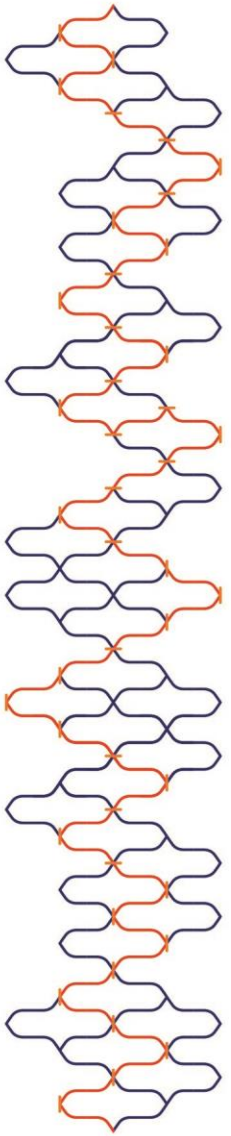


LioniX INTERNATIONAL

QuiX

Processor loss budget

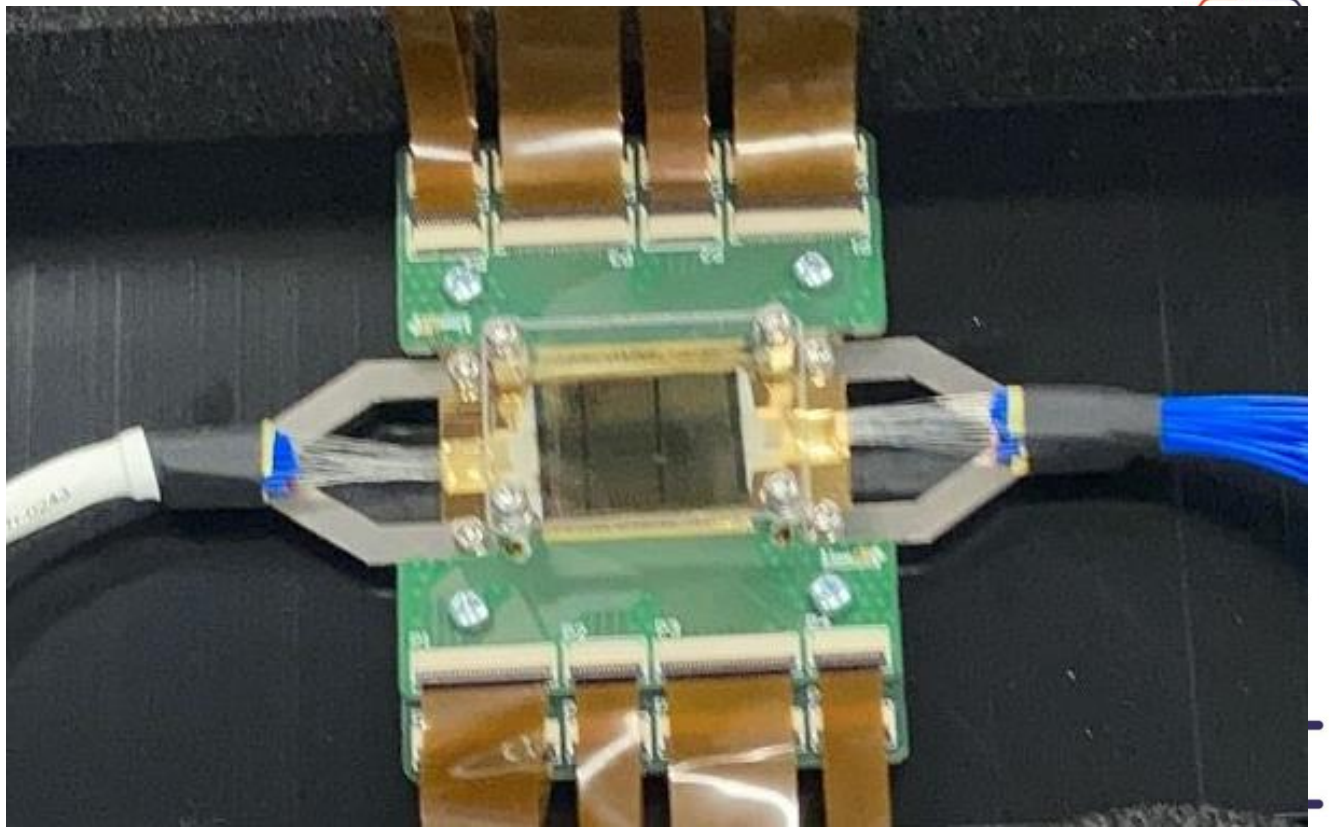




LioniX INTERNATIONAL

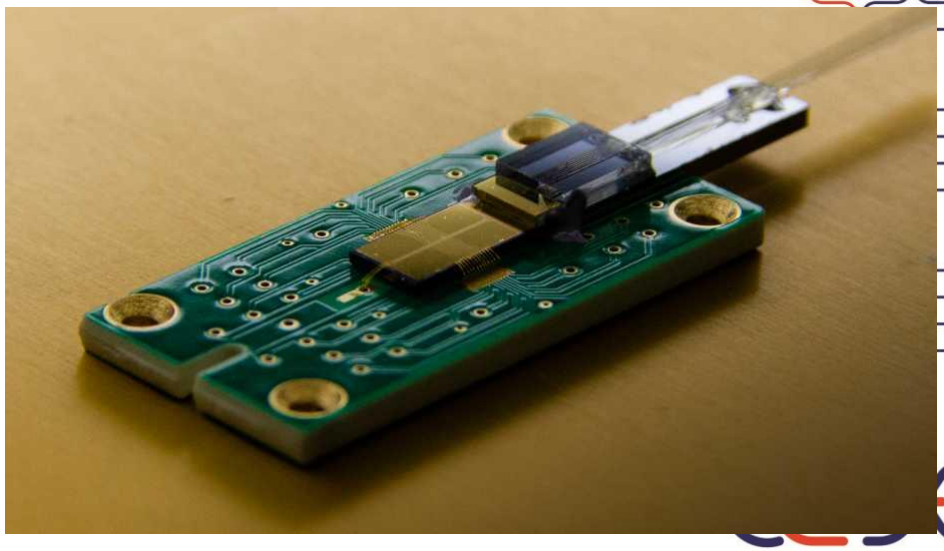
Teaser for the future: 20 x 20

- This is being measured right now



Engaging with QuiX

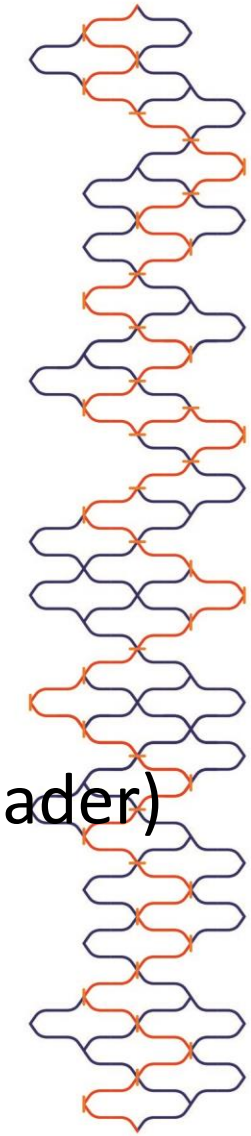
- Not just processors!
- Also sell complete photonic QC
- Provide custom circuits for quantum applications (QKD, ion traps, photon sources)



Advertisement: open positions

- PhD students (Photonic QIP, Q Auth, Ising)
- Postdoc QRNG

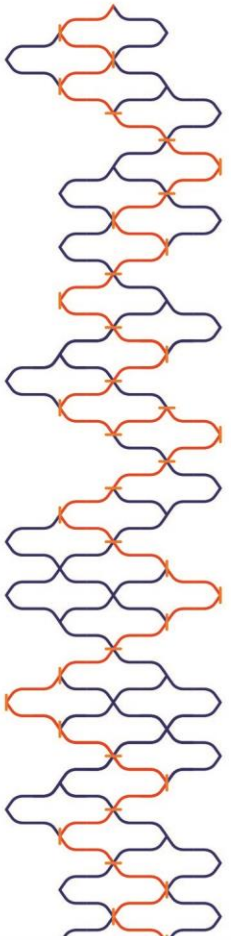
- Photonics engineers (Senior / Junior / Team Leader)
- Electrical engineers (s / j / tl)
- Quantum optics experts (s / j / tl)

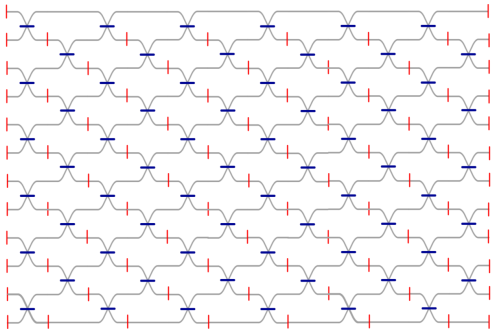


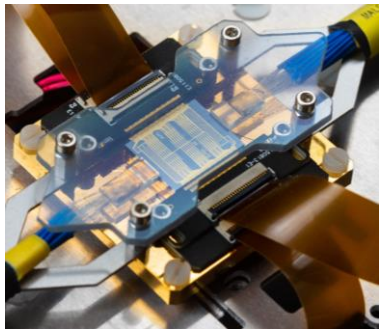
j.j.renema@utwente.nl / j.j.renema@quix.nl

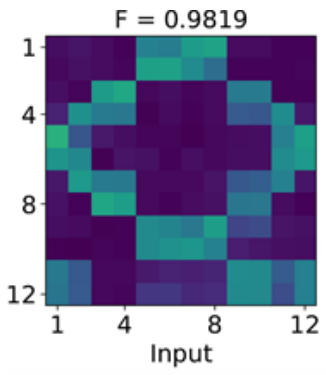
Conclusion

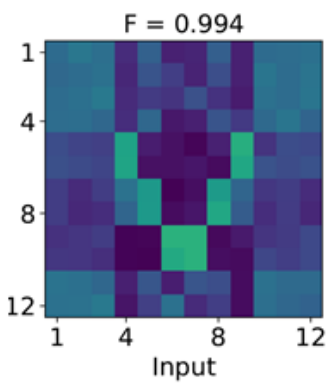
- Largest photonic quantum processor
  - Low loss
  - High fidelity
  - Coherence-preserving
- Taballione et al, Materials for Quantum Technology 1 (3), 035002 (2021)

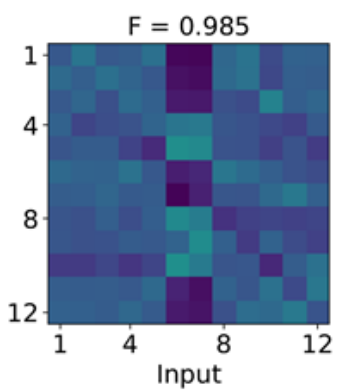


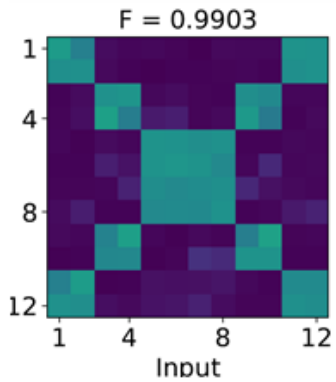


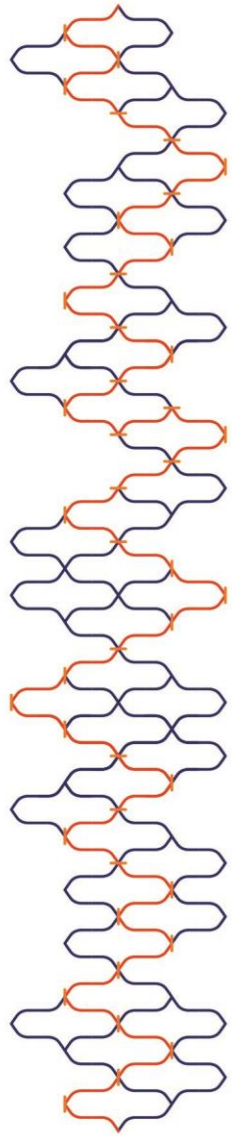












CONFIDENTIAL