Programmable integrated photonics using liquid crystal

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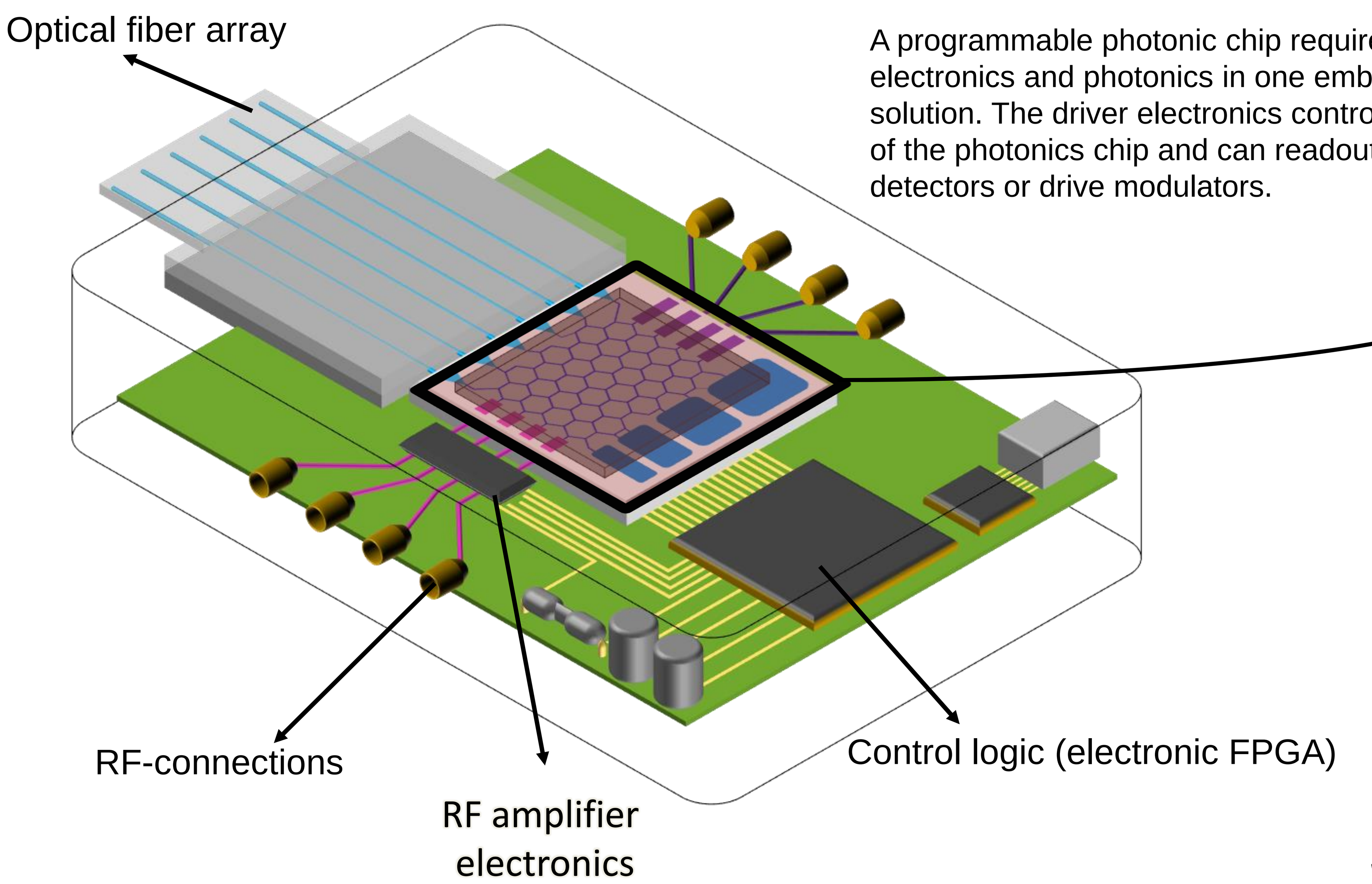
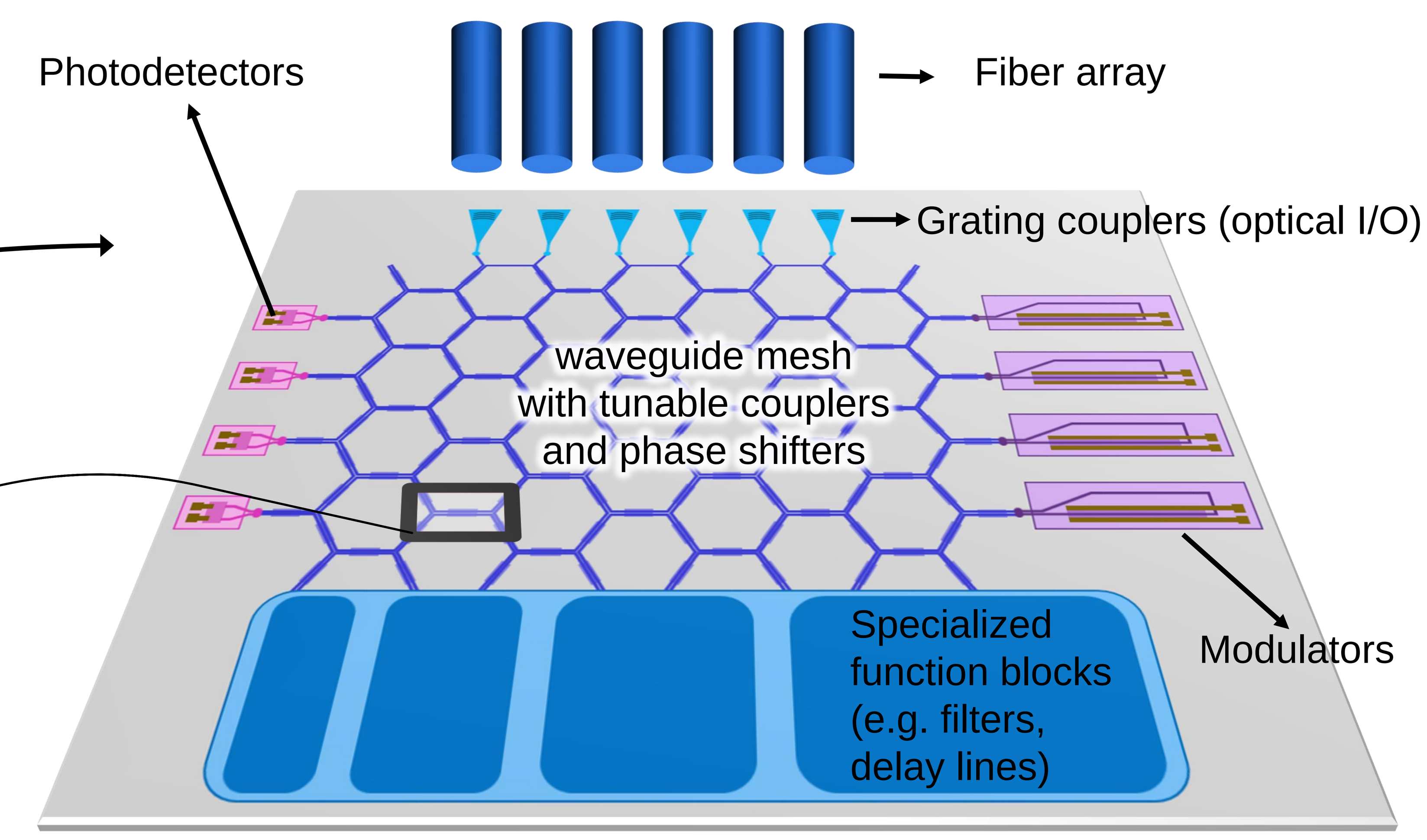
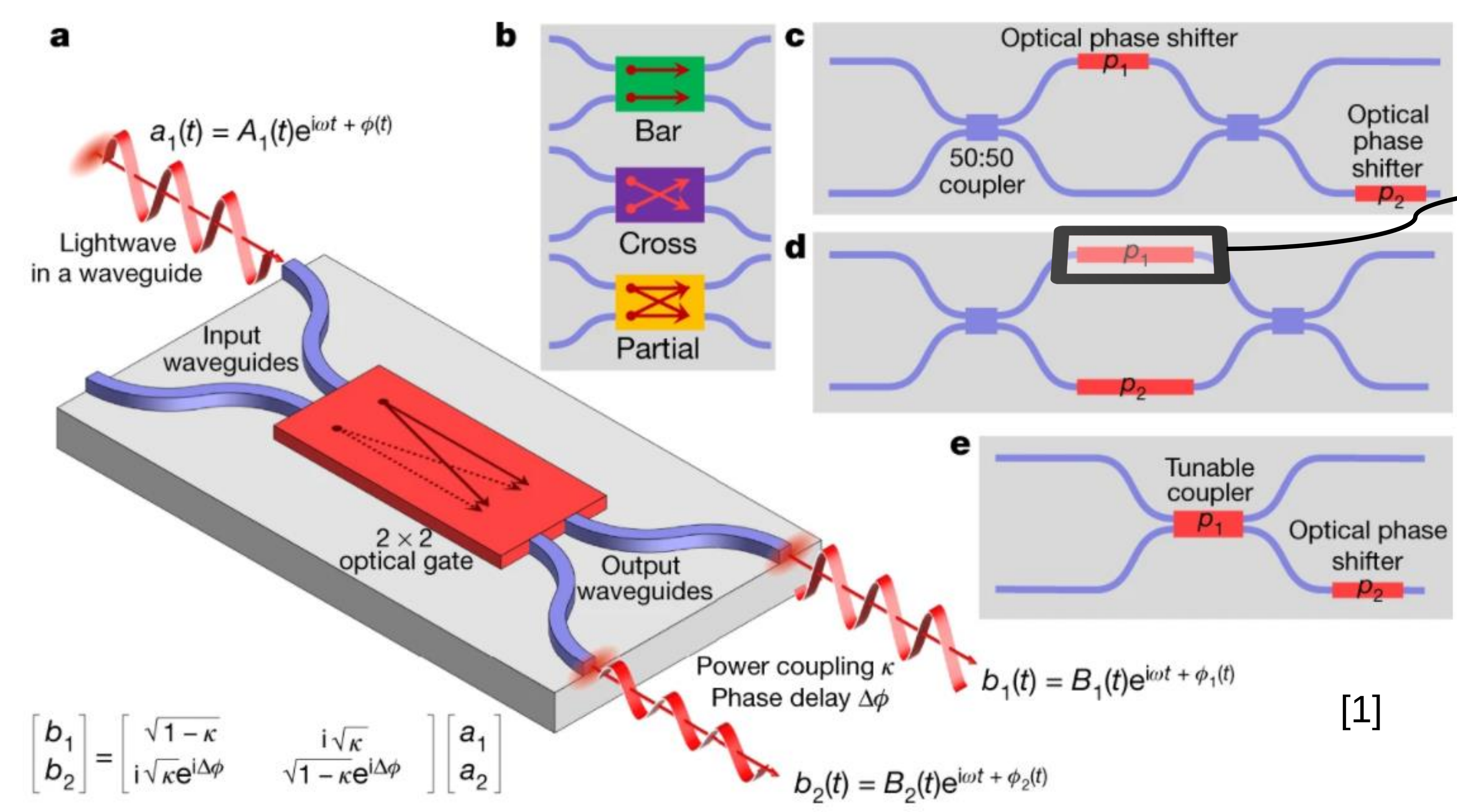
PhotonICSWARM



A programmable photonic chip requires electronics and photonics in one embedded solution. The driver electronics control actuation of the photonics chip and can readout photo-detectors or drive modulators.



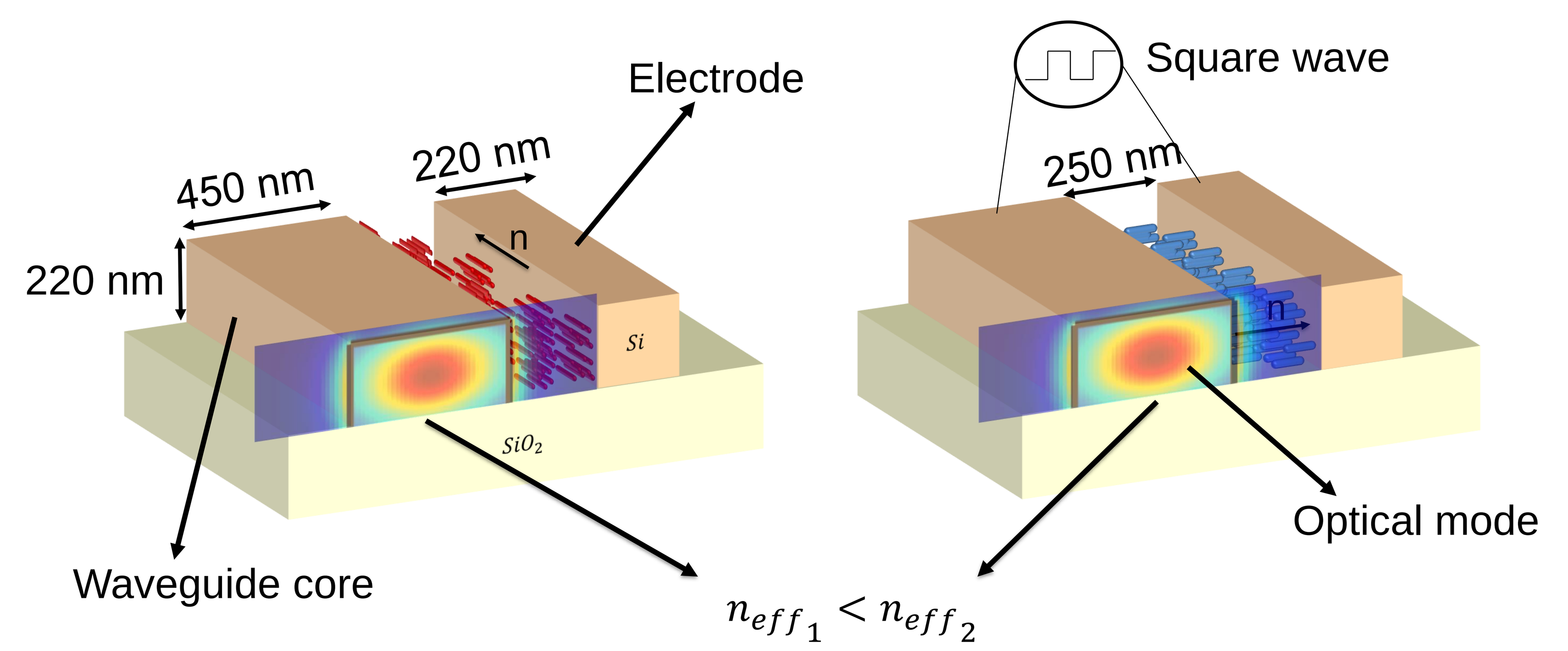
The actual photonics chip without peripheral electronics and drivers consists of a waveguide mesh with tunable couplers and phase shifters. This mesh can route signals, split the light in parallel paths and perform interferometric operations. Optical signals can be modulated with incoming microwave signals, and photodetectors can convert optical signals to the microwave domain.



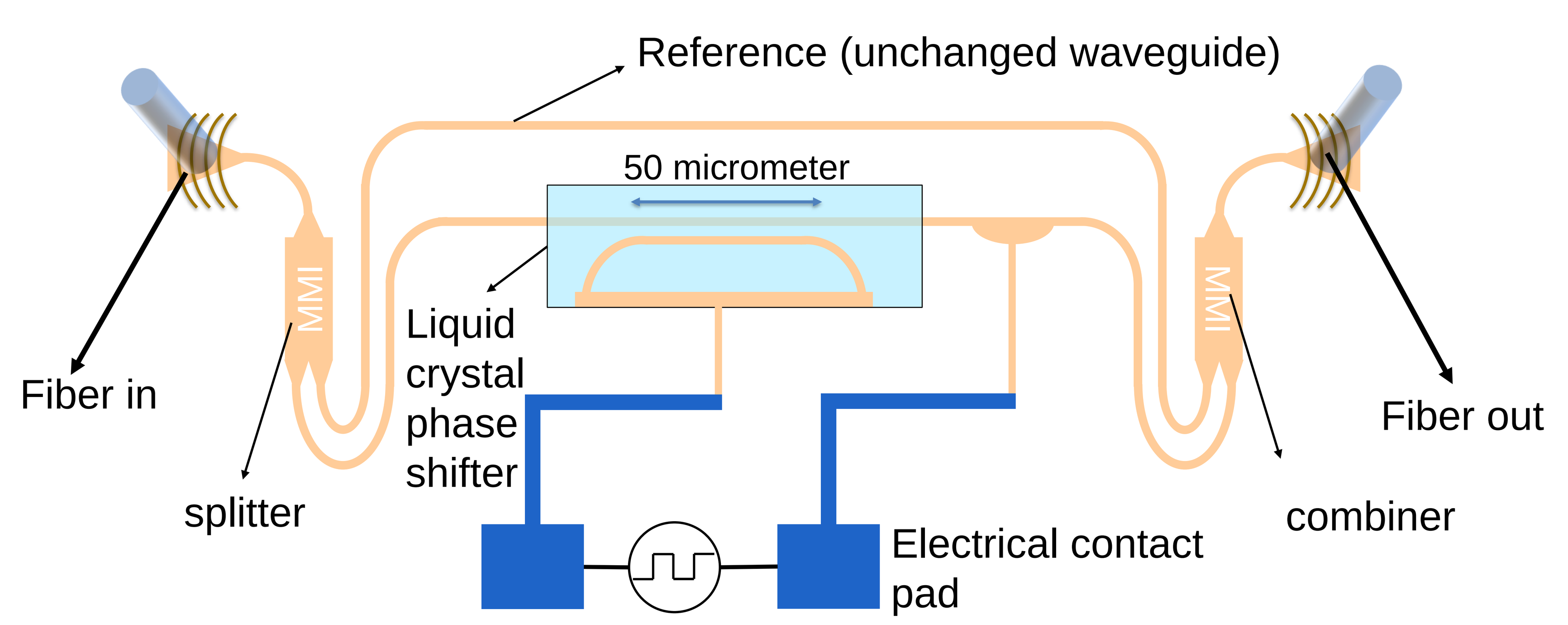
The waveguide mesh connects 2x2 optical (analog) gates together in hexagons. a) These 2x2 gates can take light from any input waveguide and couple it to any of the two output waveguides b) There are 3 states possible in one of these gates. In c), d) and e) different possible implementations of such gate are shown.

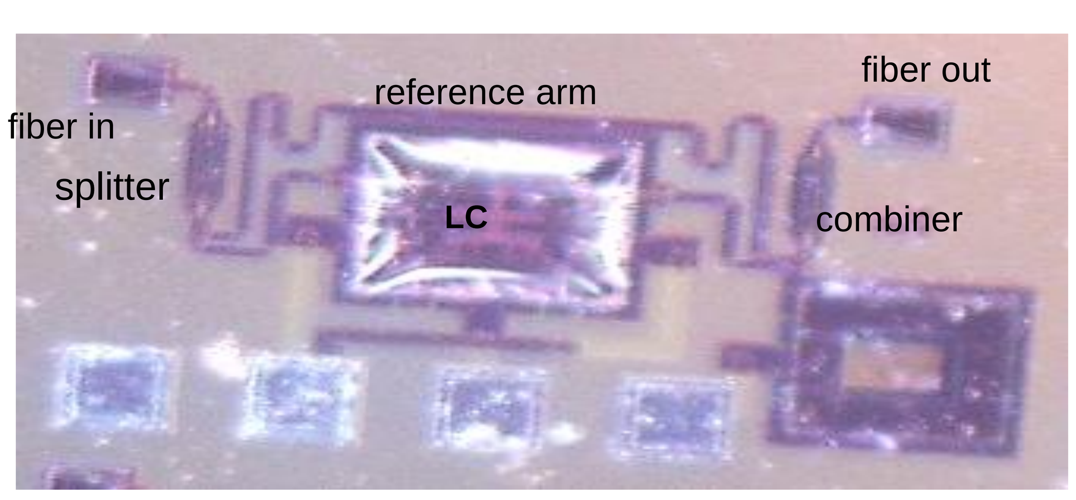
Optical phase shifters with a short optical length are at the heart of the programmable mesh. They can be realized with heaters, micro-electromechanical systems (MEMS) or liquid crystals (LC), each changing the properties of an optical waveguide locally. Heaters consume too much power for scalability and MEMS have the risk of collapse. Liquid crystal can achieve short optical length phase shifts with low power consumption.

A phase shifter is a silicon photonics waveguide with locally changed material properties. The change in the waveguide cladding has an effect on the phase velocity of the propagating optical mode, referred to as the effective refractive index. This is possible because light in a waveguide core is not fully confined and has a fraction that propagates in the cladding material. Applying a voltage over the gap creates an electrical field that rotates the LC molecules (change in director n) next to a waveguide, inducing a phase shift because of the birefringence (anisotropy) of the LC.

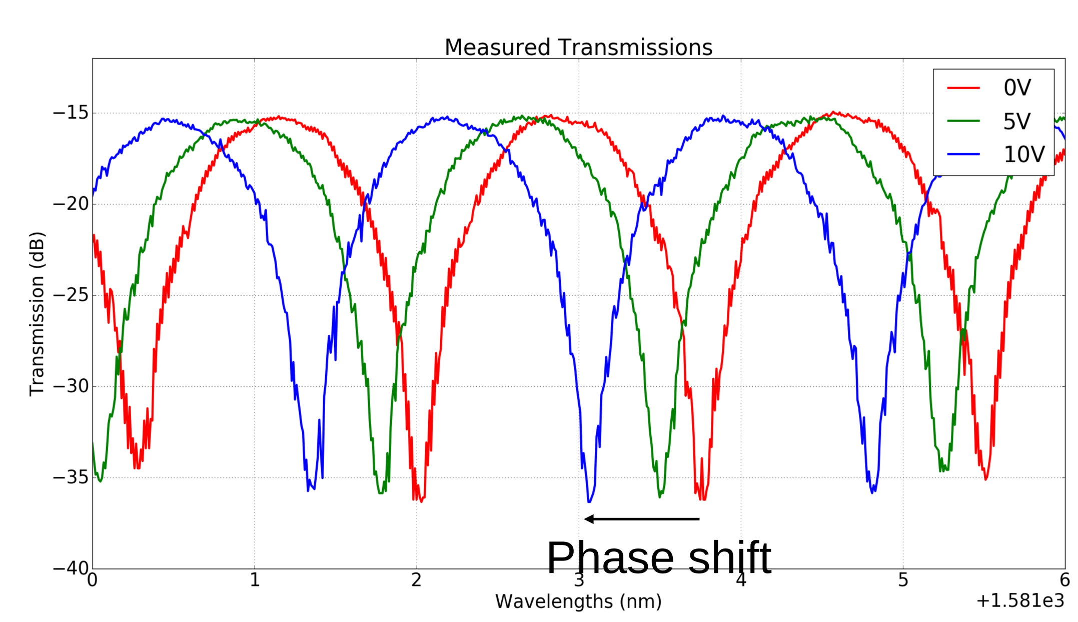


To measure the performance of a phase shifter, the component is embedded in a Mach-Zehnder interferometric circuit on chip.

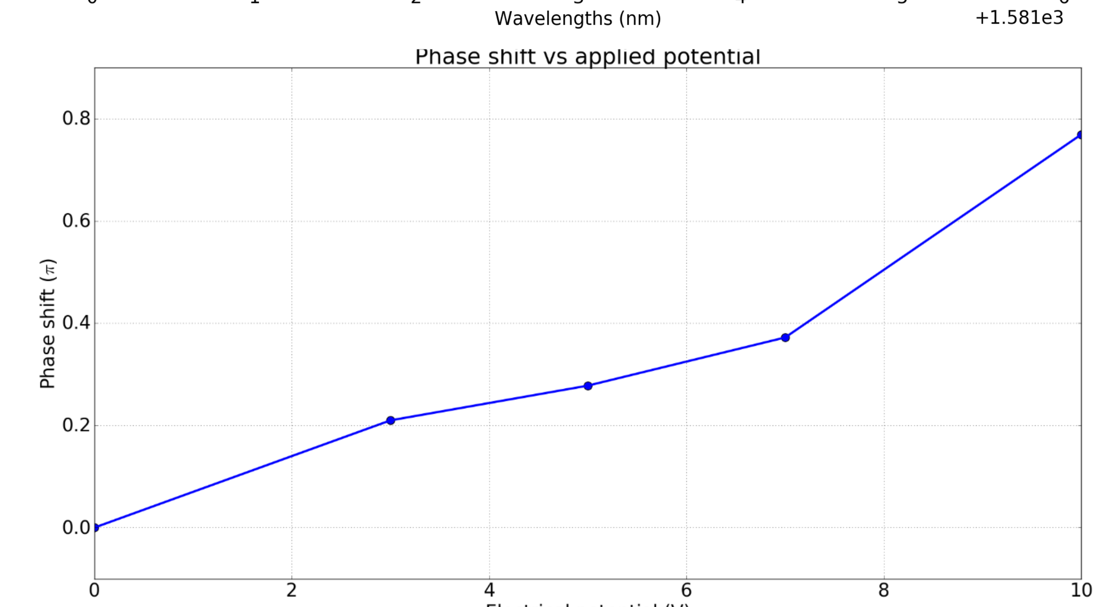




As can be seen in the picture on the left, liquid crystal is applied locally to the chip. This is possible because of an etched cavity (hole) in the chip surface.



The spectrum of the interferometric circuit is measured for each voltage. The phase shift can be found in the shift of the spectrum of this measurement.



This experiment obtained a phase shift of 0.8π at $10V$. This is promising, but to cover full tuning range 2π should be obtained. Future experiments with double sided tuning are being prepared, and better performance is expected.

[1] Bogaerts, W., Pérez, D., Capmany, J. *et al.* Programmable photonic circuits. *Nature* **586,** 207–216 (2020)

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