CMOS photonic devices characterization and quantum computing architecture design

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MOTIVATION

Quantum computing is a new computational paradigm that will allow to solve problems in quantum simulation and cryptography that are impossible for modern supercomputers.

Since quantum computers only offer speed-up over classical ones in some areas, the idea is to have a classical processor that offloads specific tasks onto a quantum coprocessor. However, current technologies for quantum computing require ultra-low (~20 mK) temperature in order to minimize thermal noise. This requires special refrigerators called dilution refrigerators, which have very little capacity and can only dissipate about 100 µW of power.

Therefore, in order to have practical quantum computers, a distributed architecture, with very low-power intercommunications is needed.

QUANTUM ARCHITECTURE

The top-level view for the quantum computer is the following:

This allows for several nodes to communicate with the classical processor using one single optical fiber, taking advantage of Wavelength-Division Multiplexing.

This is the internal structure of a single node: qubits are connected in a 2-D mesh structure, there are specific qubits for communicating with other nodes, and input and output are carried out with ring modulators.

PV MODULATOR

A PV modulator is a ring modulator that takes advantage of the light it absorbs to generate a voltage.

\[ V_{OC} = \frac{\eta k T}{q} \cdot \ln\left(\frac{I_{ph}}{I_o} + 1\right) \]

Using a MOSFET transistor, we can short-circuit and open-circuit the P-N junction with a small voltage difference.

Experimental setup

A 4.5x reduction in peak-to-peak voltage leads to a 20x reduction in electrical power needed. Further improvements could be achieved with modulators with higher Q factors.