Hardware-inspired Continuous Variables Quantum Optical Neural Networks

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Abstract
We present a physically-implementable architecture for quantum optical neural networks (QONN) in continuous variables (CV) that combines natural and efficient photonic components for input encoding, trainable data processing and output readout.
Analytic expressions derived for the proposed design reveal:

- A family of adaptive non-polynomial activation functions
- Emergent highly-expressive quantum-optical neurons
- Universal approximation within a single layer

To support scalable optimization of the model, we introduce an exact high-performance classical simulator (*QuaNNTO*) based on such analytic expressions, enabling multi-layer expectation values computation and gradient-based training without any truncation in the infinite-dimensional Hilbert space.
Benchmarks on supervised classical tasks and quantum applications, such as state engineering and gate synthesis, show strong expressivity and generalization capabilities in a state-of-the-art context.
This analytic formalism is extended to any CV platform that admits the same underlying representation: quantum states built by Gaussian and ladder operators.
Together, these results establish the versatility of our hardware-compatible CV-QONN for variational quantum simulation and learning, relevant for near-term quantum technologies, quantum many-body physics and quantum field theory.

References

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Figures

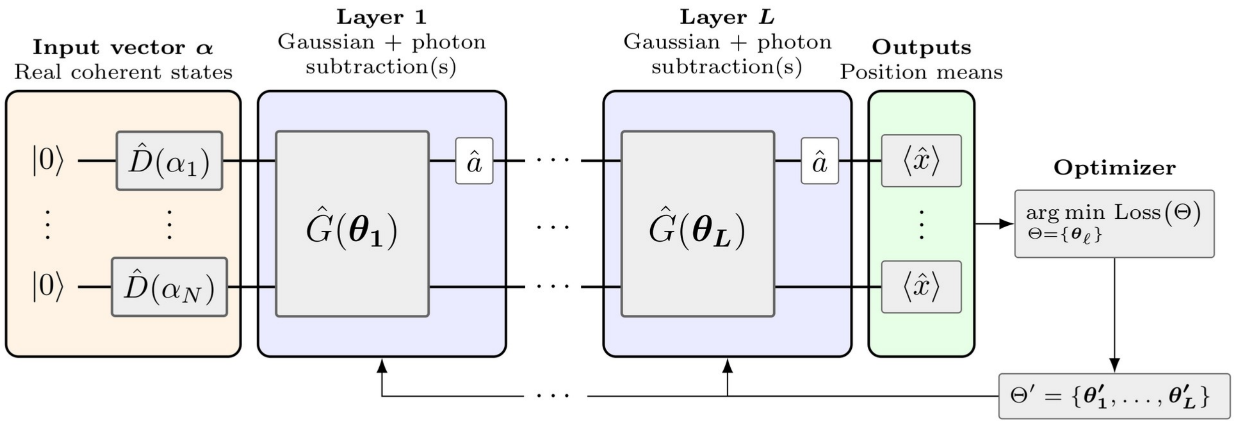

Figure 1: General CV-QONN architecture of *N* optical modes and *L* layers.