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Bosonic network architectures for quantum simulation and thermodynamics

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Friday, 30 January 2026 @ 15h00-16h00 SAST

Venues: Online and NITheCS Seminar Room, Stellenbosch University

ABSTRACT

We study quantum-optical complex networks of multimode bosonic (continuous-variable) systems as a unified platform for information and energy processing. Building on a photonic variational simulation framework, our approach targets infinite-dimensional bosonic models without Hilbert-space truncation, enabling scalable simulation of ground-state and dynamical properties. The numerical/analytical strategy combines generalized Wick-contraction techniques for efficient evaluation of high-order correlators with a symplectic-geometry description of the Gaussian manifold and its tangent space, which together drastically reduce the cost of simulating non-Gaussian operations and structured entanglement. In thermodynamics, we derive signal-to-noise and fluctuation bounds that serve as operational witnesses of nonclassicality and non-Gaussianity in the input states, and directly quantify how these quantum resources enhance precision and work extraction. Our results connect variational bosonic simulation primitives to concrete thermodynamic advantages and are compatible with current photonic technology.

BIOGRAPHY

Dr Federico Centrone is a theoretical physicist working at the intersection of continuous-variable quantum information, non-equilibrium quantum thermodynamics, and quantum optical networks. His research focuses on understanding how correlations, energy, and information flow in realistic quantum systems, with contributions ranging from quantum advantage in photonic networks to energetic constraints in open quantum dynamics. He is currently a Marie Skłodowska-Curie Global Fellow at the Institute of Photonic Sciences (ICFO) in Spain, collaborating widely with experimental and theoretical groups.

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