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Frequency-bin based photonic quantum information processing

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Quantum technologies play a crucial role in both scientific and technological advancement, leveraging the unique properties of quantum mechanics - such as superposition and entanglement - to enhance the performance of classical systems and enable new device functionalities. Light-based quantum technologies utilize photons as fundamental carriers of information, taking advantage of their long coherence times, fast propagation speeds and ease of manipulation. Well-explored degrees of freedom for encoding quantum information include polarization, orbital angular momentum, path, and time of arrival. Less investigated is frequency-bin encoding, in which quantum information is encoded in discrete frequency (energy) bands. This approach has great potential because it inherently supports high-dimensional encoding, is compatible with existing fiber-optic infrastructure, and allows for easy manipulation of the quantum states using standard telecommunication fiber components. Frequency-bin entangled states can be efficiently generated in integrated photonics by exploiting spontaneous parametric processes in microring resonators. On-chip integration enables both the engineering of the generated quantum states and the scalability of the frequency-bin approach. In this talk, we will explore the potential of frequency-bin encoding in quantum information processing, from the generation of non-classical states of light to their applications in quantum communication and computation.

Presenter: TAGLIAVACCHE, Noemi (Università di Pavia)