High-Dimensional Frequency Bin Entanglement

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Entanglement and encoding in discrete frequency bins – essentially a quantum analogue of wavelength-division multiplexing – represents a relatively new degree of freedom for quantum information with photons. Potential advantages include generation of high dimensional units of quantum information (qudits), which can carry multiple qubits per photon, robust transmission over fiber, frequency parallelism and routing, and compatibility with on-chip implementations, as well as hyperentanglement with other photonic degrees, *e.g.*, time-frequency hyperentanglement. In this talk, I first give an overview of the manipulation and measurement of quantum states encoded and entangled in the photonic frequency degree of freedom. I will then discuss selected recent experiments, including those that focus on high dimensional entanglement and mixing of multiple frequency bins in a single operation, going well beyond nearest-neighbour "interactions". As one example, we exploit high-dimensional frequency bin entanglement to measure photon pair delays at the few picosecond levels, $\sim 30\times$ faster than the single-photon detectors employed.