Generation and Measurement of Frequency Multimode Entangled States of Light

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Scalability is crucial for the practical application of quantum information technologies, including quantum computing, multi-parameter quantum estimation, and quantum networks. In this context, a continuous-variable (CV) quantum optical system is promising since it allows the generation of a large-scale entangled state in a deterministic way. In CV quantum systems, a squeezed vacuum serves as a fundamental resource to generate entangled states. Generating a large-scale entangled state requires squeezed vacua in many different modes.

In this talk, I will present a method for generating and detecting multimode squeezed vacua in the frequency domain [1]. A brief setup is shown in figure 1. Ten pairs of entangled states are generated simultaneously from a single ultrafast pump beam, maintaining a relative phase between each mode. Because it enables access to arbitrary superposed frequency modes, more complex entangled states, such as cluster states, can be constructed. We verify the generation of 1D, 2D, and 3D cluster states by addressing complexly superposed frequency-mode bases. Finally, I will discuss our recent experiment on simultaneous detection of multiple frequency modes to measure multimode entangled states.

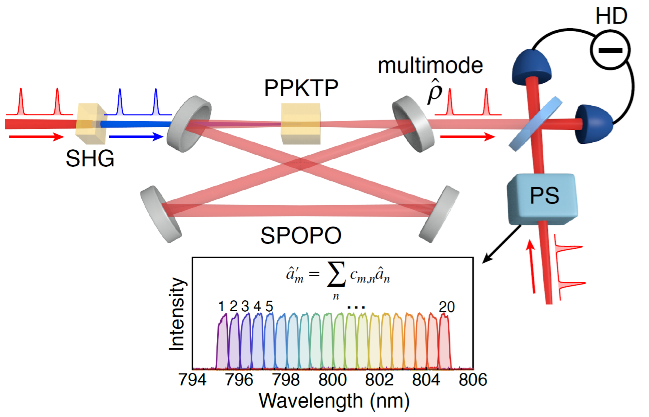

Figure 1: Experimental setup. A multimode squeezed vacuum is generated by a synchronously pumped optical parametric oscillator (SPOPO), in which a PPKTP crystal induces nonlinear interaction. The quadrature outcomes are obtained by a homodyne detector (HD) on the specfic mode determined using a pulse shaper (PS) – 20 frequency modes or an arbitrary superposed mode from frequency modes

References

[1] C Roh, G Gwak, Y-D Yoon and Y-S Ra, arXiv:2309.05437 (2023)