Spatial mode detection by means of a nonlinear parametric upconversion process

Adam Vallés[1], Bereneice Sephton[2], and Andrew Forbes[2]

[1]Chiba Univ., Japan, [2]Wits Univ., South Africa

E-mail: adam.valles@chiba-u.jp

The efficient creation and detection of spatial modes of light has become topical of late, driven by the need to increase photon bit-rates in classical and quantum communications. Here we put forward a new spatial mode detection technique based on the nonlinear optical process of SFG.

There has been a great development in methods to create and detect optical spatial modes, in particular complex structured light fields [1], fuelled for example by the desire for higher bit-rates in classical and quantum communication. Such mode creation and detection processes are traditionally achieved with tools based on linear optics, i.e., refractive or diffractive field mapping by allowing lossless phase and amplitude modulation of an input beam. However, mode creation has also been demonstrated with nonlinear optics. It is instructive to outline how spontaneous parametric down-conversion (SPDC) generates anticorrelated modes, as schematically depicted in Fig. 1(a) for a Gaussian pump and orbital angular momentum (OAM) modes as an example. When a Gaussian beam pumps the SPDC process, it mediates the generation of paired entangled down-converted photons, as shown in the simulated spiral bandwidth of Fig. 1(b).

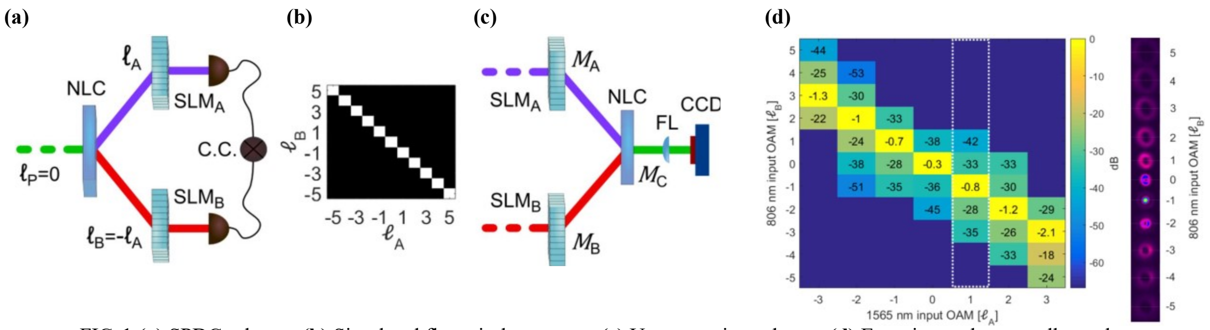

FIG. 1 **(a)** SPDC scheme. **(b)** Simulated flat spiral spectrum. **(c)** Upconversion scheme. **(d)** Experimental cross-talk results.

In this work we make use of the dual process sum-frequency generation (SFG) for the detection of spatial modes, contrasting the similarity with the anti-correlated relation from the SPDC. In the SFG process, schematically depicted in Fig. 1(c), two incoming signals (M_A and M_B) are engineered to be in specific states. The upconverted signal is detected in the far field, so that there is a nonzero signal only when the phases are conjugate. In this scheme the nonlinear crystal (NLC) is the detector rather than the generator. Our results shown in Fig. 1(d) confirm the concept of spatial mode detection by upconversion using intense beams carrying orbital angular momentum (ℓ_A and ℓ_B) as example [2].

[1] H. Rubinsztein-Dunlop, et al., "Roadmap on structured light," J. Opt. **19**, 013001 (2017).

[2] B. Sephton, A. Vallés, F. Steinlechner, T. Konrad, J. P. Torres, F. S. Roux, A. Forbes "Spatial mode detection by frequency upconversion," Opt. Lett. **44**, 586 (2019).