A complete POVM description of multi-channel quantum electro-optic sampling with monochromatic field modes

E. Hubenschmid[1], T. L. M. Guedes[1], and G. Burkard[1]

[1] *Department of Physics, University of Konstanz, D-78457 Konstanz*

We propose a multichannel version of quantum electro-optic sampling involving monochromatic field modes. It allows for multiple simultaneous measurements of arbitrarily many $\hat{X}$ and $\hat{Y}$ field quadratures for a single quantum-state copy, while independently tuning the interaction strengths at each channel. In contrast to standard electro-optic sampling, the sampled midinfrared (MIR) mode undergoes a nonlinear interaction with multiple near-infrared pump beams. We present a complete positive operator-valued measure description for quantum states in the MIR mode. The probability distribution of the electro-optic signal outcomes is shown to be related to an s- parametrized phase-space quasiprobability distribution of the indirectly measured MIR state, with the parameter s depending solely on the quantities characterizing the nonlinear interaction. Furthermore, we show that the quasiprobability distributions for the sampled and postmeasurement states are related to each other through a renormalization and a change in the parametrization. This result is then used to demonstrate that two consecutive measurements of both many $\hat{X}$ and $\hat{Y}$ quadratures can outperform eight-port homodyne detection.

References:

[1] E. Hubenschmid, T. L. M. Guedes, and G. Burkard, *Physical Review A* **106**, 043713 (2022).