Noise mitigation via a quantum autoencoder

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Noise present in experimental preparations of quantum states has a significant impact on their ability to be used as a quantum information resource for many applications. A quantum autoencoder (QAE) is a neural network with inner bottleneck layers, which uses machine learning to compress quantum data [1]. It is established that classical autoencoders can denoise classical data and theoretical work predicts the same is true for quantum data with QAEs [2].

In our work, we are in the process of demonstrating a quantum autoencoder (see Figure 1) that denoises four-dimensional quantum states (ququarts), by compressing them into a two-dimensional representation (in the so-called latent space) and decoding them back to the original space [3]. Our ququarts are implemented by encoding quantum information in the polarization and path degrees of freedom of single photons produced by spontaneous parametric downconversion. We choose the input states such that in the absence of noise, the QAE can be trained to implement lossless compression and decompression where the original states are recovered, similarly to the first optical QAE. The parametrized encoding unitary is trained via an Adam gradient descent algorithm to maximize the probability of the photon occupying the optical modes corresponding to the latent space.

If the input states are corrupted with noise, the encoding-decoding process removes the component of the noise orthogonal to the latent space, thus the returned state is denoised and is closer to the noiseless state. For validation purposes and to test the noise mitigation properties in this ongoing experiment, the trained QAE will be applied to a set of noisy test states where a significant fidelity improvement can be achieved. Our work represents the first effort at demonstrating this novel way of quantum noise mitigation. The QAE approach is also more generally applicable to input qudits and latent spaces with other dimensionalities and can be extended to other physical platforms.

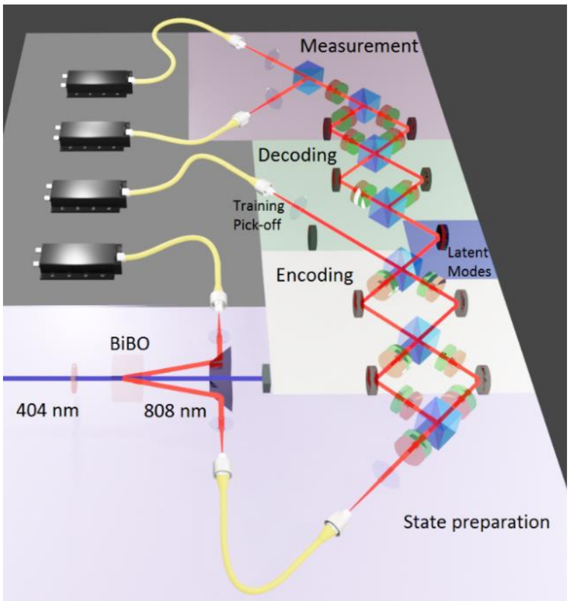

Figure 1: Experimental setup of the optical quantum autoencoder

[1] J. Romero et. al. Quantum Sci. Technol. 2, 045001 (2017)

[2] D. Bondarenko and P. Feldmann Phys. Rev. Lett. 124, 130502 (2020)

[3] A. Pepper, N. Tischler, and G. J. Pryde Phys. Rev. Lett. 122, 060501 (2019)