In quantum state tomography N identically prepared copies of a quantum state are measured to reconstruct a density matrix describing the single particle state [1]. One purpose of reconstructing a density matrix is to allow the prediction of measurements that could have been made on the initial state. On the other hand, if only one measurement is of interest then performing that measurement on the each of the N copies of the state will yield the most accurate estimate. However, if the measurement choice is unknown the quantum states must be stored in a quantum memory until some later time. The question then becomes: how much memory is required?

It is well known that Hilbert space grows exponentially in the number of qubits. For example, the dimensionality of an arbitrary N qubit system is $2^N$. But if all N of the qubits are identical all of the information in the initial N qubit state can be mapped into the symmetric subspace, which has dimension $N+1$. This mapping, known as the Quantum Schur-Weyl transform (QSWT) [2], yields a compression of N identical qubits into $\log_2(N+1)$ qubits – an exponential savings in space.

Here, we present experimental results implementing the QSWT for three qubits, allowing us to compress three quantum bits into two. In our implementation the three qubits are encoded in two photons. The first photon encodes a path and a polarization qubit, while the second photon encodes a single polarization qubit. We use the QSWT to map all of the information from the 3 qubits onto the path and polarization qubits encoded in the first photon, allowing us to discard the second photon. We characterize our compression by performing measurements on the remaining two qubits and show that they obey the statistics of a three qubit system.