Entangled states contain nonlocal correlations that enable technologies in quantum imaging, communication, and computation. For entangled photons, these correlations can be used to nonlocally compensate for dispersion in the evolution of one photon by applying an appropriately tailored dispersion to the second one [1]. This compensation can only be observed in the joint detection results of the two photons, in accordance with causality. Imaging aberration is the spatial analogue of frequency dispersion, and can therefore be similarly canceled [2].

Here, we experimentally investigate the cancellation of both even and odd orders of spatial aberration. We generate pairs of degenerate, near-collinear spatially entangled photons at 810 nm with type-II phase matching in a BBO crystal. The photons are spatially separated, and the aberrations are applied as phase shifts $\phi_s(p_s)$ and $\phi_i(p_i)$ in the Fourier (momentum) plane of the photon states. The photons are re-imaged onto a plane where 100 $\mu$m wide slits are translated across each beam. By measuring the coincidence detection rate, we reconstruct the joint spatial states of the two photons (Figure 1).

Without any aberration, we obtain the joint state shown in Figure 1(a), which is entangled: $\Delta x^2 - \Delta p_x^2 = 0.09 \pm 0.01 \hbar^2 < 0.25 \hbar^2$. Introducing aberration into either photon path causes the coincidence spectra to broaden, hiding the entanglement from being direct observation (Figure 1(b) and (c)). However, introducing matched aberrations $\phi_s(p_s) = -\phi_i(-p_i)$ into both paths allows the recovery of entanglement, with $\Delta x^2 - \Delta p_x^2 = 0.16 \pm 0.02 \hbar^2$ in Figure 1(d). Compensating even-order aberration requires an opposite phase shift for both signal and idler photons, $\phi_s = -\phi_i$, while odd orders require the same sign in both arms, $\phi_s = \phi_i$.

We demonstrate the nonlocal cancellation of both second-order and third-order aberrations with entangled photons. These results can be applied for the nonlocal compensation of aberrations in ghost imaging [3, 4].