

# Polarization entanglement-enabled quantum holography

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- Intensity correlation measurement
- Spatial and polarization entanglement of the source

# Intensity correlation measurement

intensity distribution

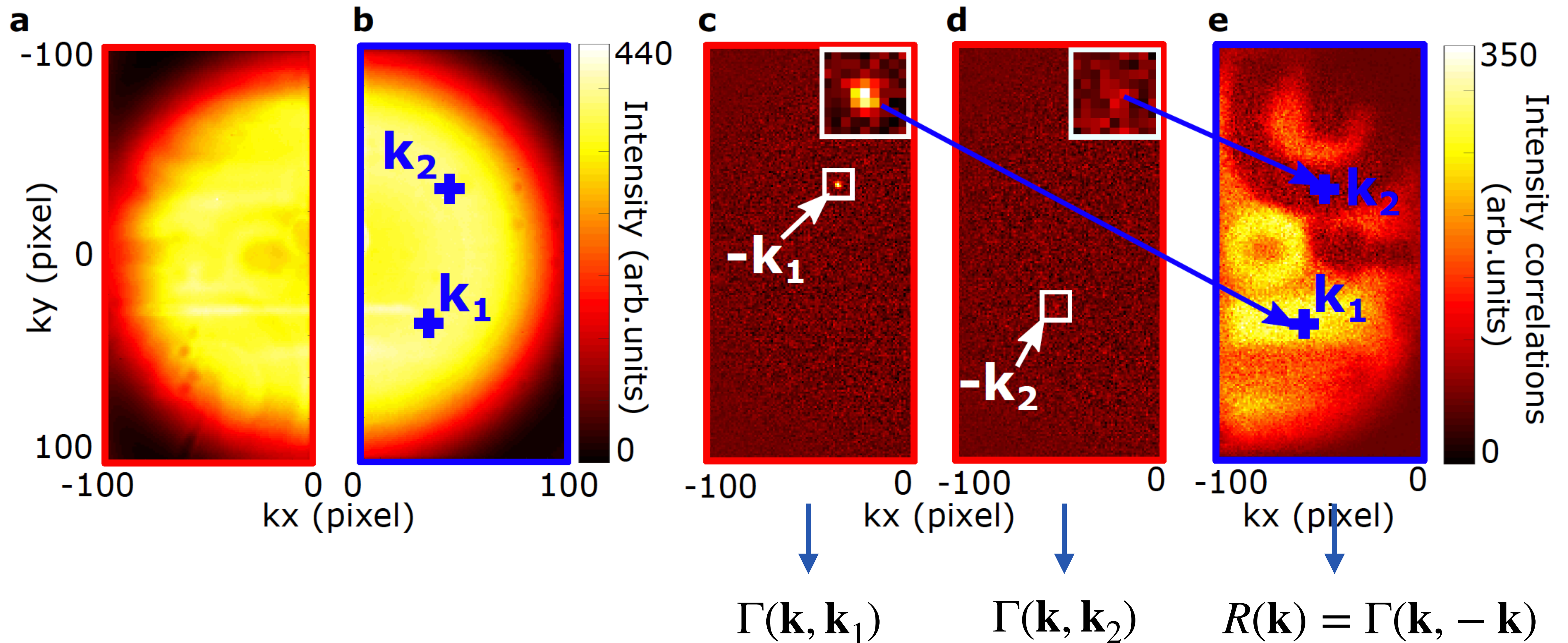
$$I(\mathbf{k}) = \frac{1}{N} \sum_{l=1}^N I_l(\mathbf{k})$$

intensity correlation distribution

$$\Gamma(\mathbf{k}_1, \mathbf{k}_2) = \underbrace{\frac{1}{N} \sum_{l=1}^N I_l(\mathbf{k}_1) I_l(\mathbf{k}_2)}_{\text{Real coincidence}} - \underbrace{\frac{1}{N-1} \sum_{l=1}^{N-1} I_l(\mathbf{k}_1) I_{l+1}(\mathbf{k}_2)}_{\text{Accidental coincidence}}$$

$\mathbf{k}$ ,  $\mathbf{k}_1$  and  $\mathbf{k}_2$  correspond to positions of camera pixels.

# Intensity and intensity correlation measurements between photon pairs with an EMCCD camera

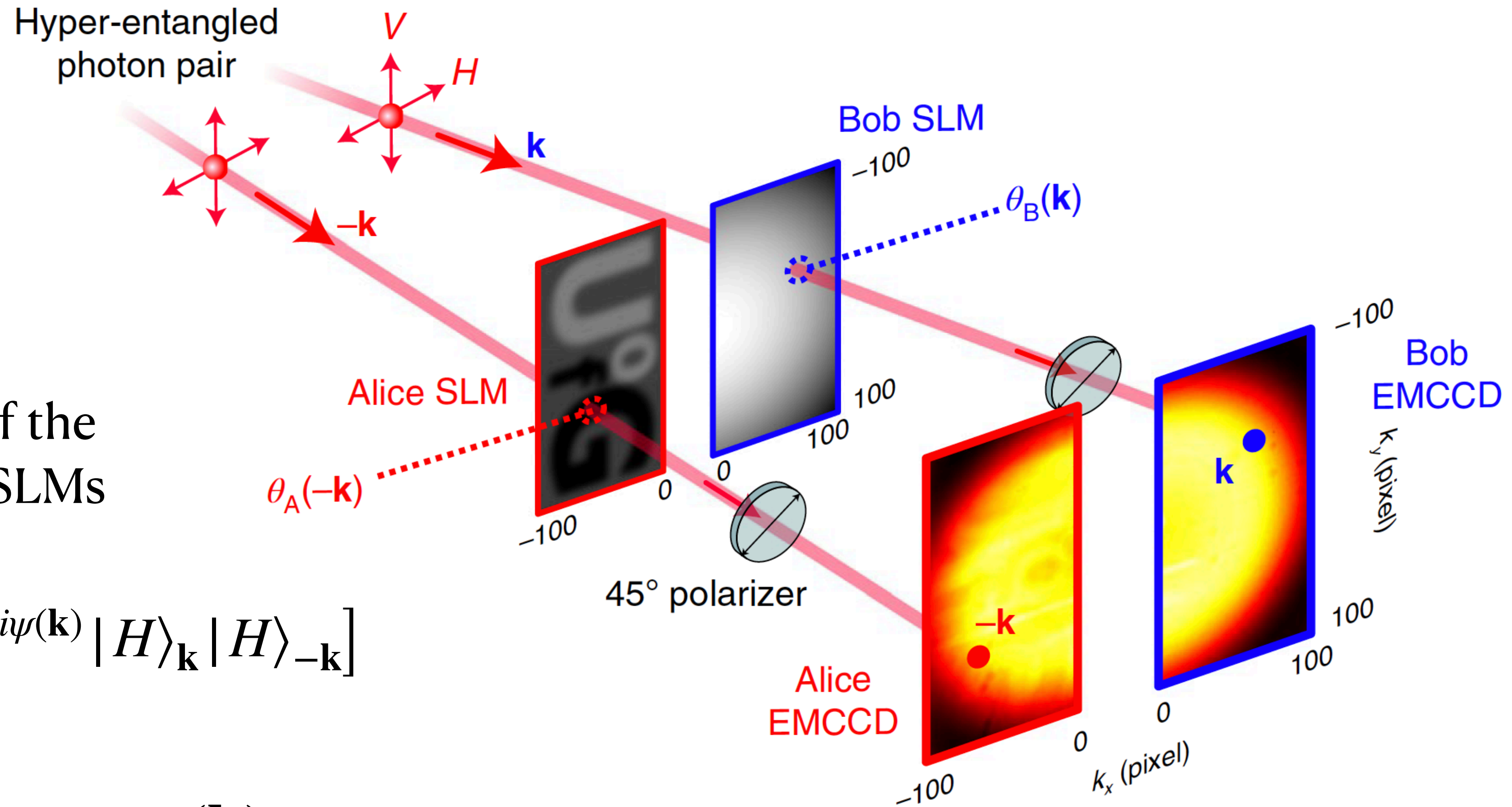




The quantum state of the photo pair after the SLMs

$$\sum_{\mathbf{k}} \left[ |V\rangle_{\mathbf{k}} |V\rangle_{-\mathbf{k}} + e^{i\psi(\mathbf{k})} |H\rangle_{\mathbf{k}} |H\rangle_{-\mathbf{k}} \right]$$

$$\rightarrow R(\mathbf{k}) \propto 1 + \cos \psi(\mathbf{k})$$

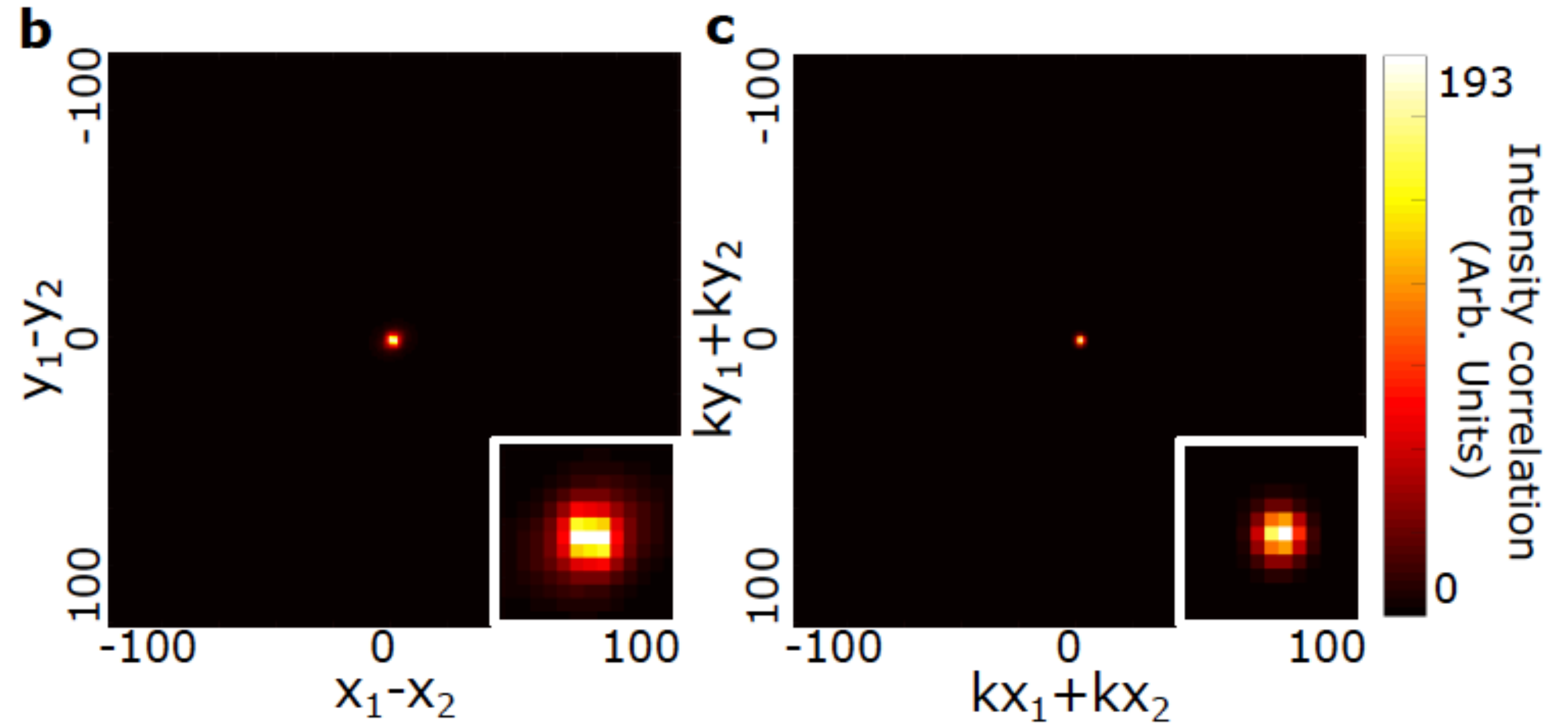
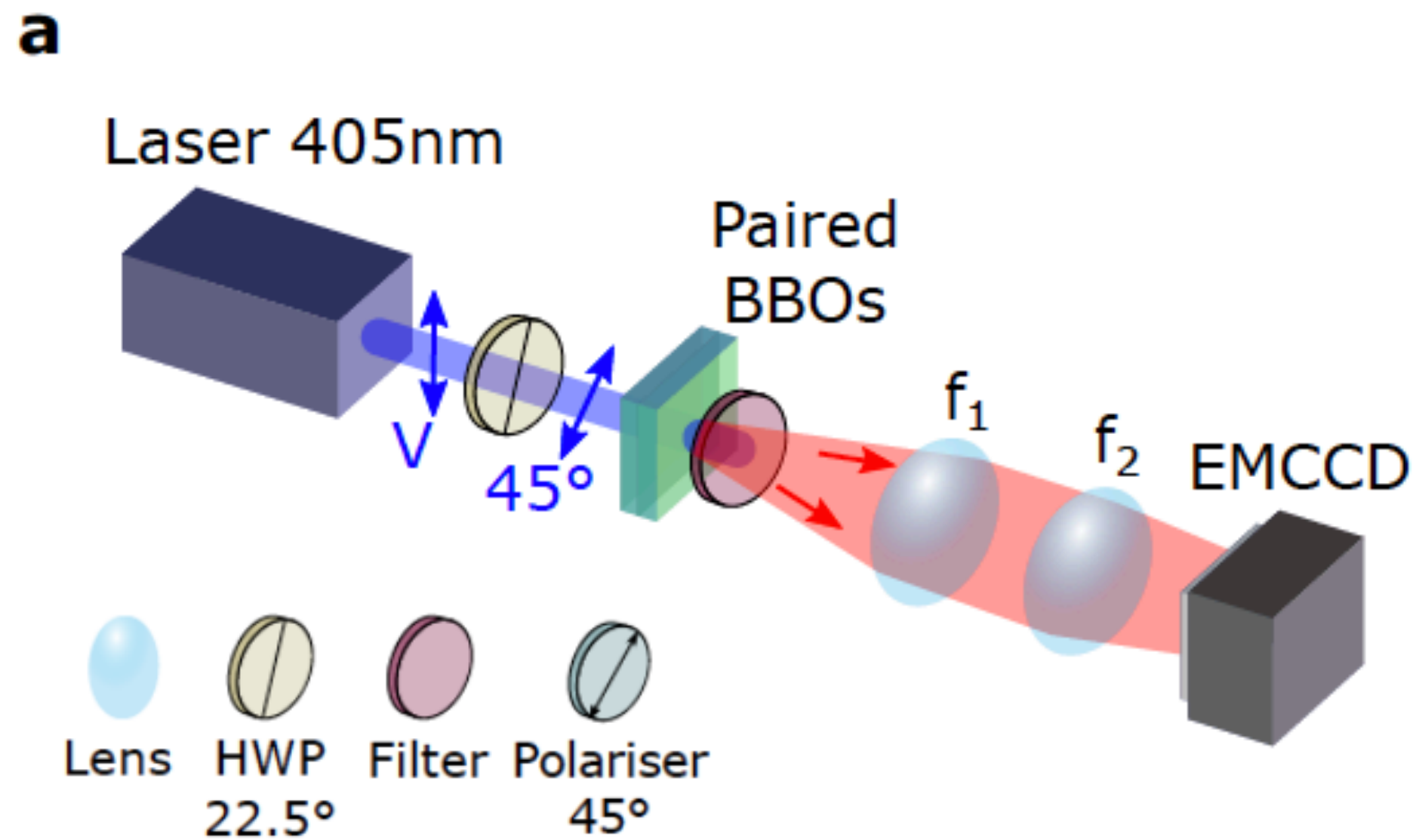


# Spatial and polarization entanglement of the source

## (a) Spatial entanglement

$$a \exp \left( -\frac{|\mathbf{x}_1 - \mathbf{x}_2|}{2\sigma_r^{(c)2}} \right)$$

$$a \exp \left( -\frac{|\mathbf{k}_1 + \mathbf{k}_2|}{2\sigma_k^{(c)2}} \right)$$

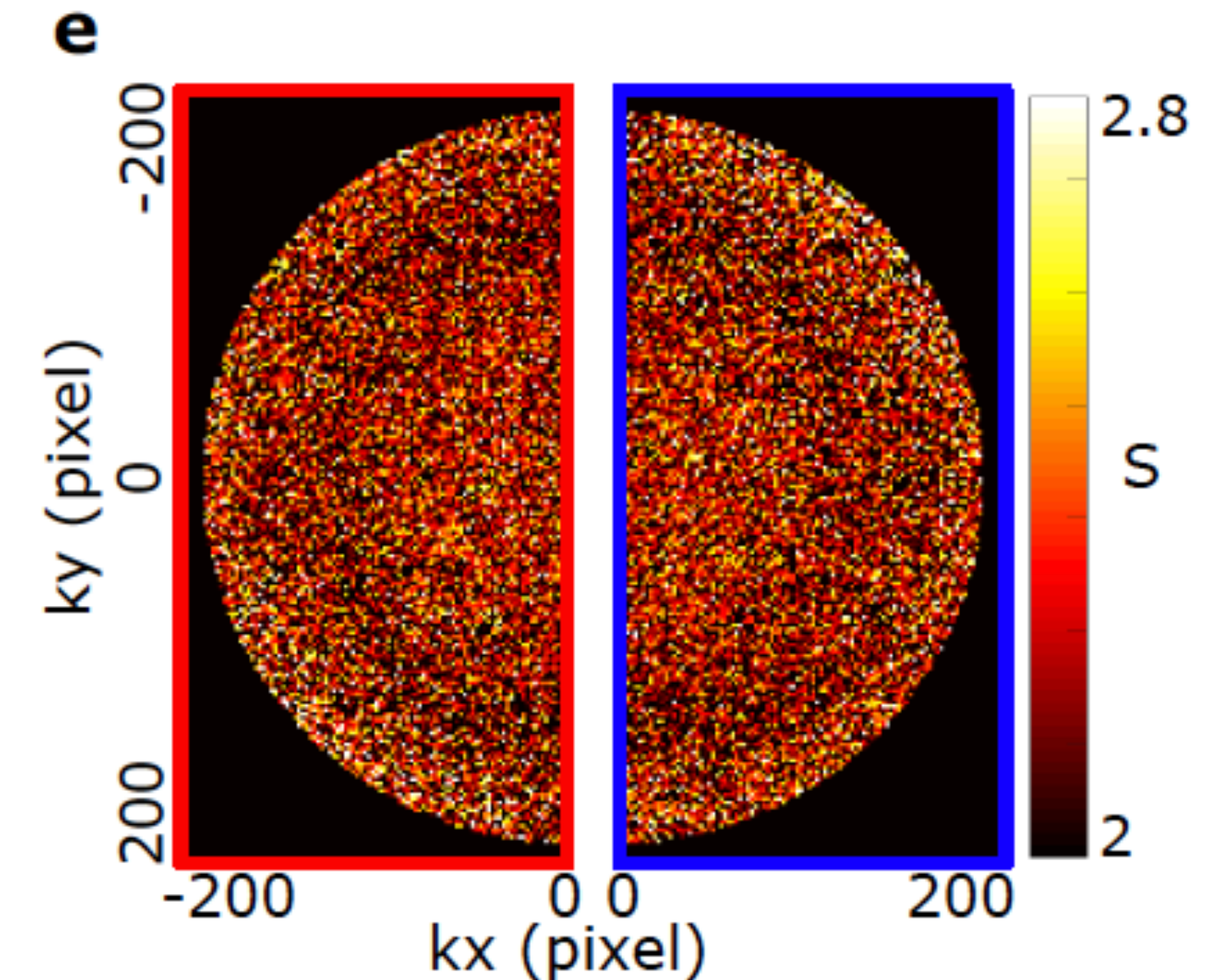
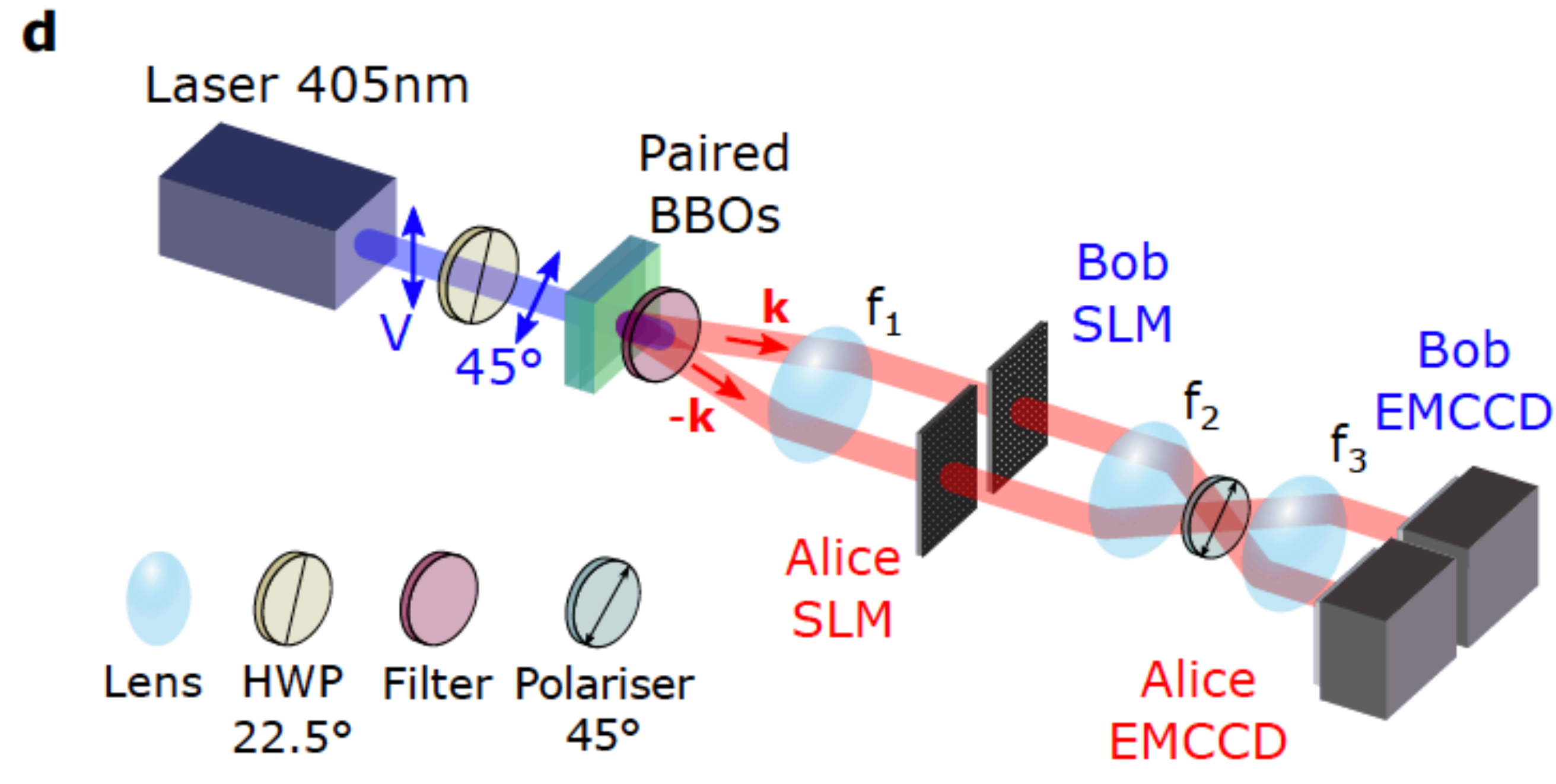


$$\sigma_r^{(c)} = 26.20 \pm 0.02 \mu m \quad \sigma_k^{(r)} = 17.00 \pm 0.01 \mu m$$

$$\approx 1.6 \text{ pixel}$$



## (b) Polarisation entanglement



$$E_{\theta_A, \theta_B} = \frac{R_{\theta_A, \theta_B} - R_{\theta_A, \theta_{B+\pi}} - R_{\theta_{A+\theta}, \theta_B} + R_{\theta_{A+\pi}, \theta_{B+\pi}}}{R_{\theta_A, \theta_B} + R_{\theta_A, \theta_{B+\pi}} + R_{\theta_{A+\theta}, \theta_B} + R_{\theta_{A+\pi}, \theta_{B+\pi}}}$$

$$S = |E_{\pi/2, \pi/4} - E_{\pi/2, 5\pi/4}| + |E_{0, \pi/4} + E_{0, 5\pi/4}|$$

Violation of the CHSH inequality

$$S > 2$$