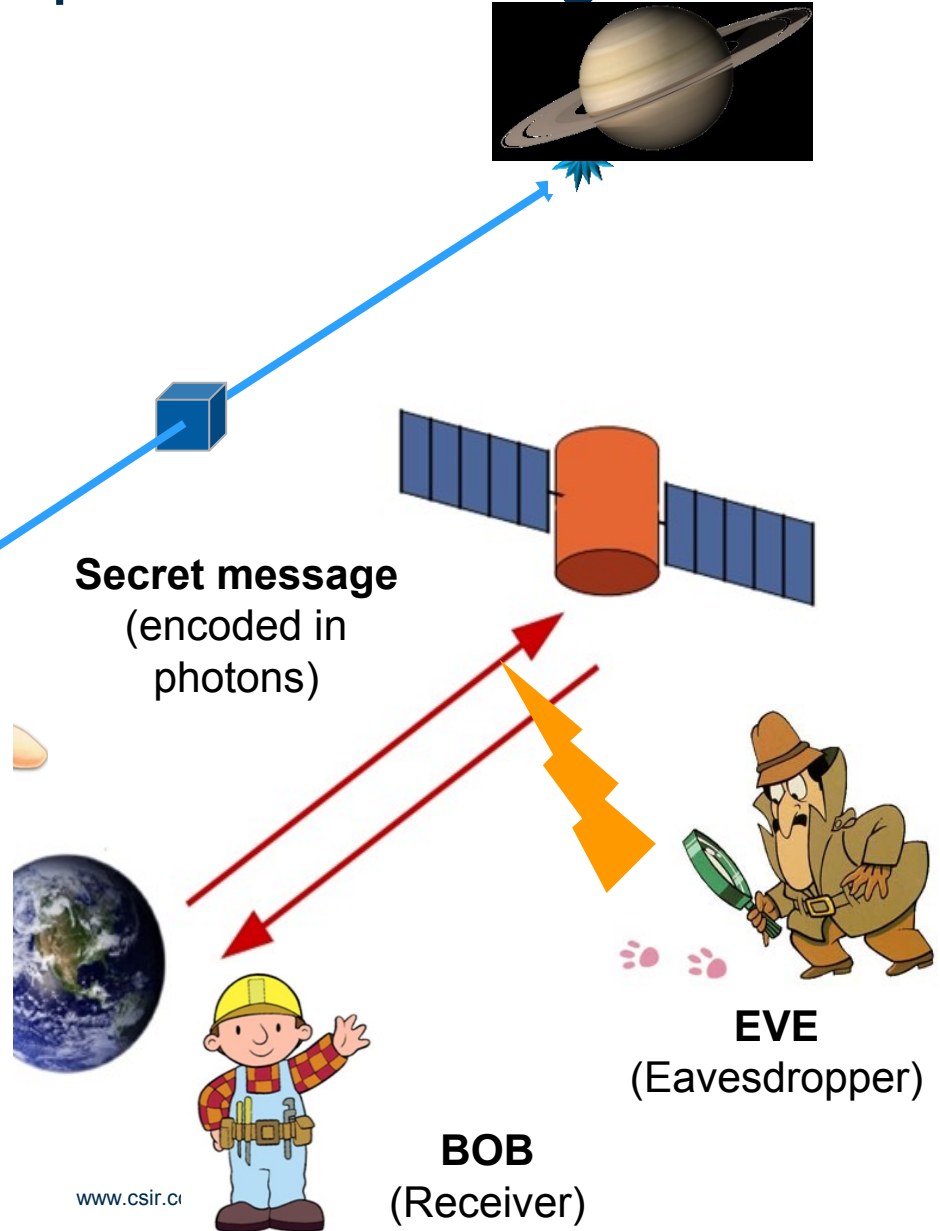
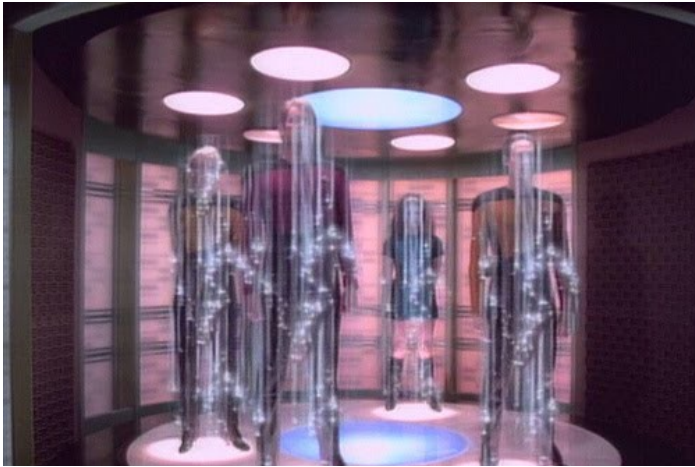


High dimensional entanglement

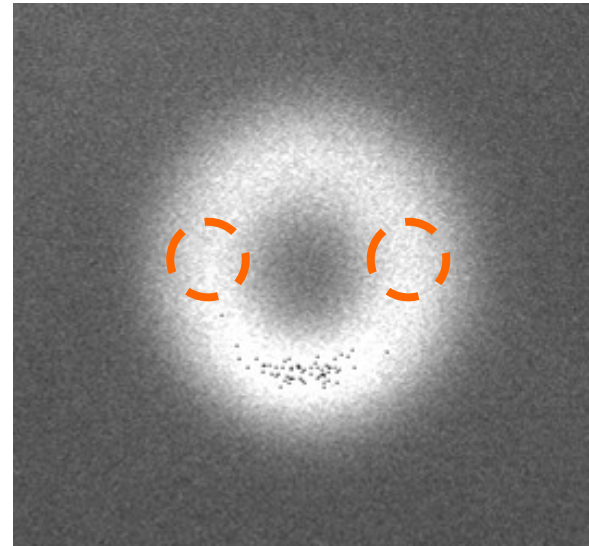
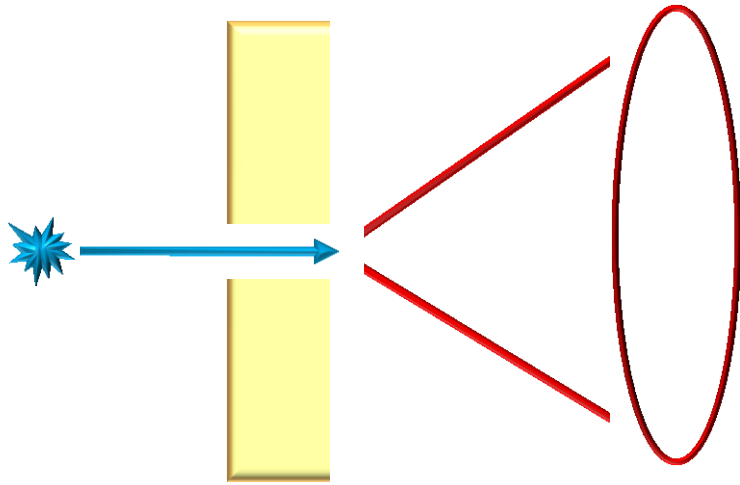
M. McLAREN^{1,2}, F.S. ROUX¹ & A. FORBES^{1,2,3}

1. CSIR National Laser Centre, PO Box 395, Pretoria 0001
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Increasing interest in quantum entanglement

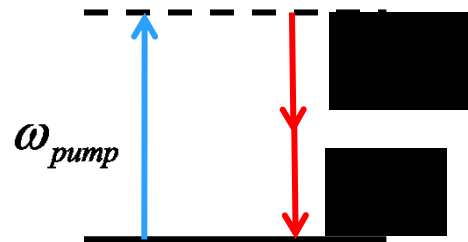
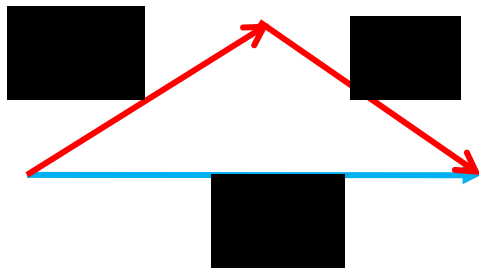


Spontaneous parametric down conversion – generating entangled photons



EMCCD image

Conservation of momentum & energy

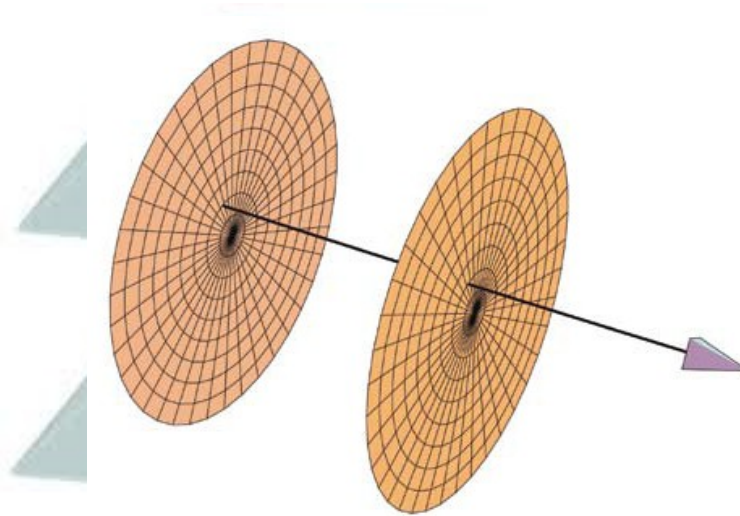
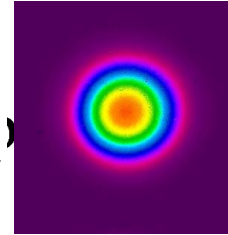


Azimuthally-phased beams have helical wavefronts and consequently carry OAM.

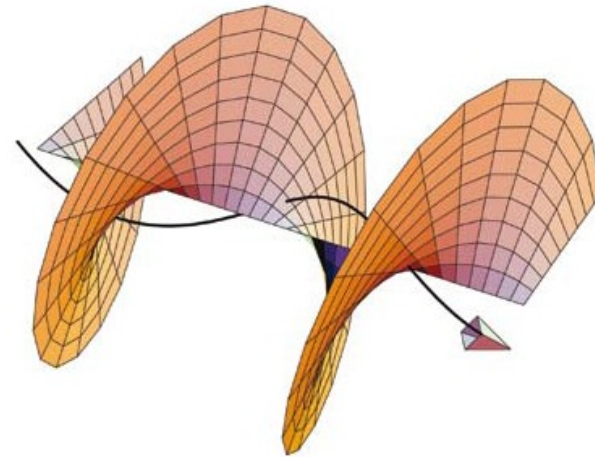
Spin Clockwise: 1

Spin Anticlockwise: 0

$$u(r, \theta, z) = u_0(r) e^{i\ell\theta} e^{-ikz}$$



GAUSSIAN BEAM



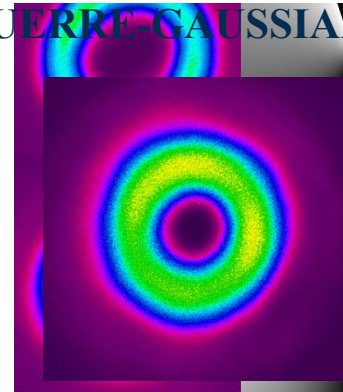
LAGUERRE-GAUSSIAN BEAM

Message Received:

101110 = A

3

4



A

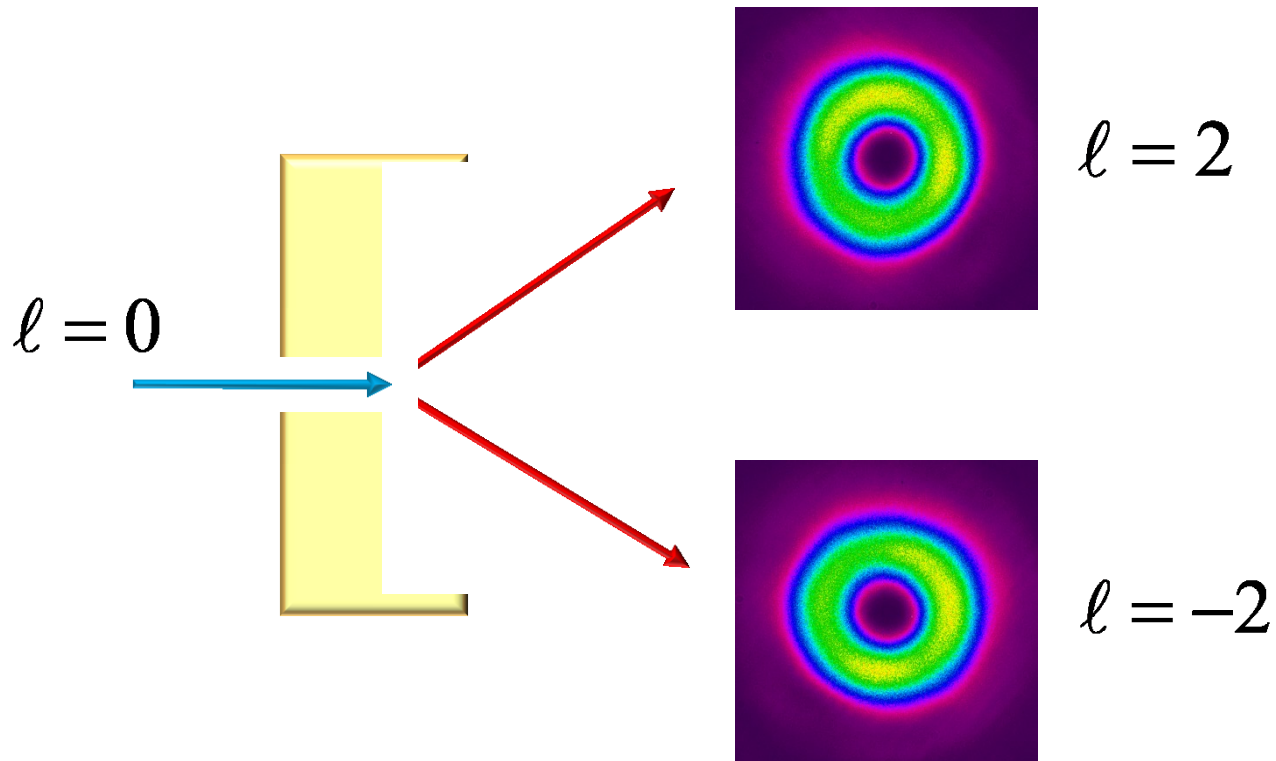
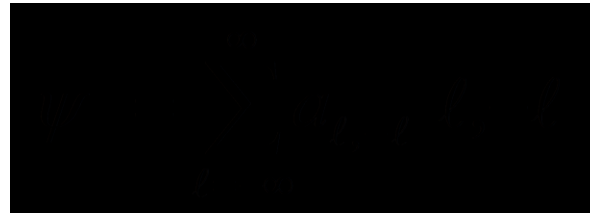
B

C

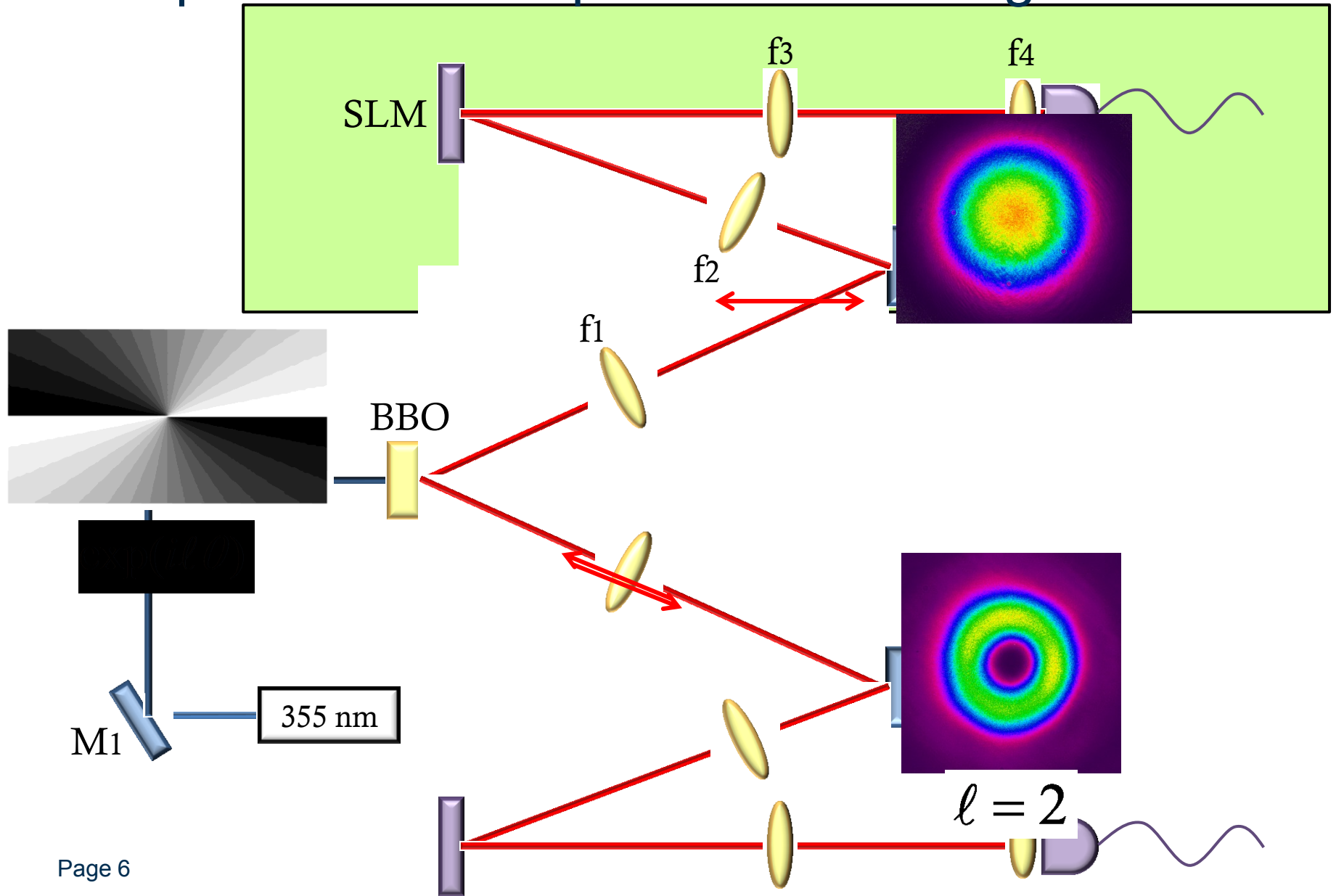
D

E

Entanglement in orbital angular momentum basis

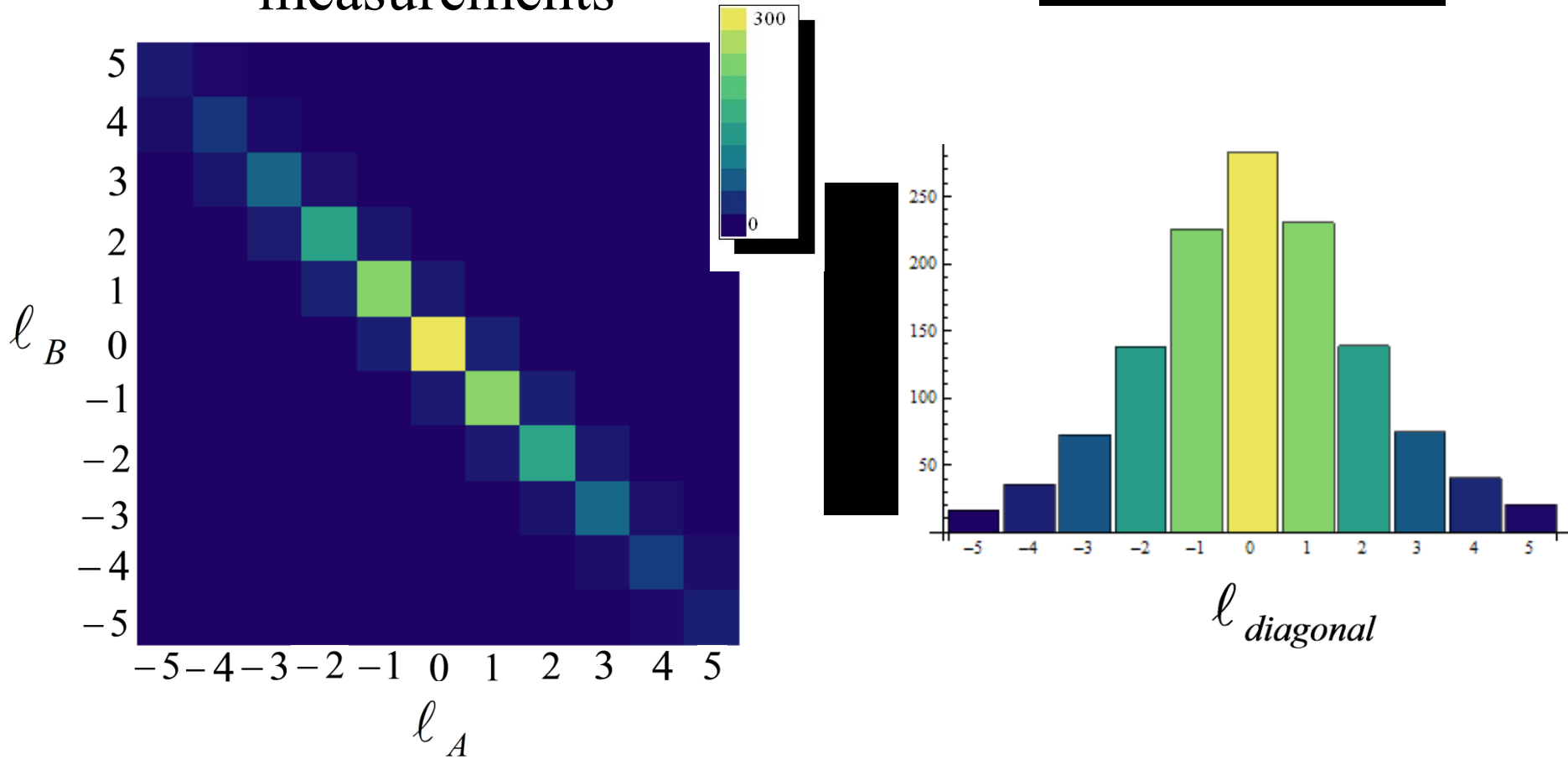


Experimental setup to detect entanglement

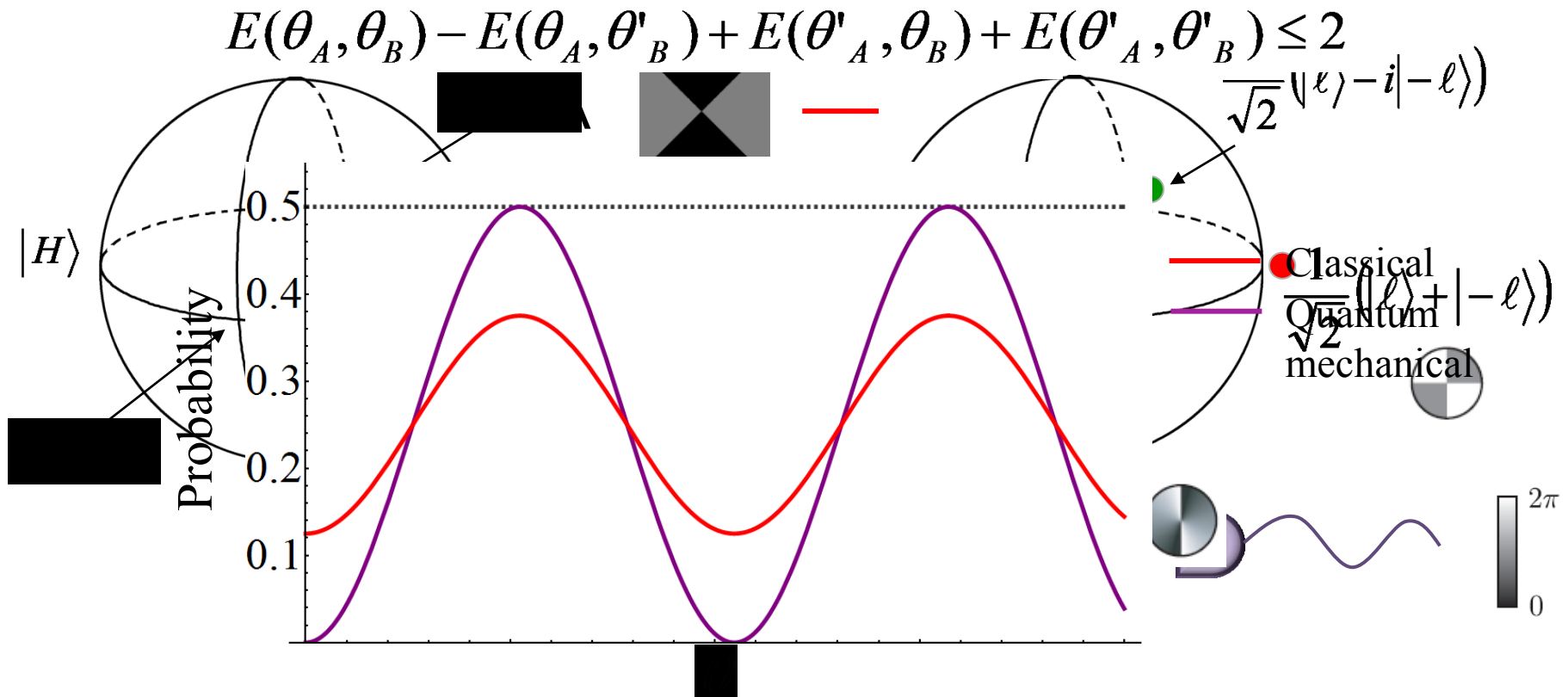


Conservation of OAM

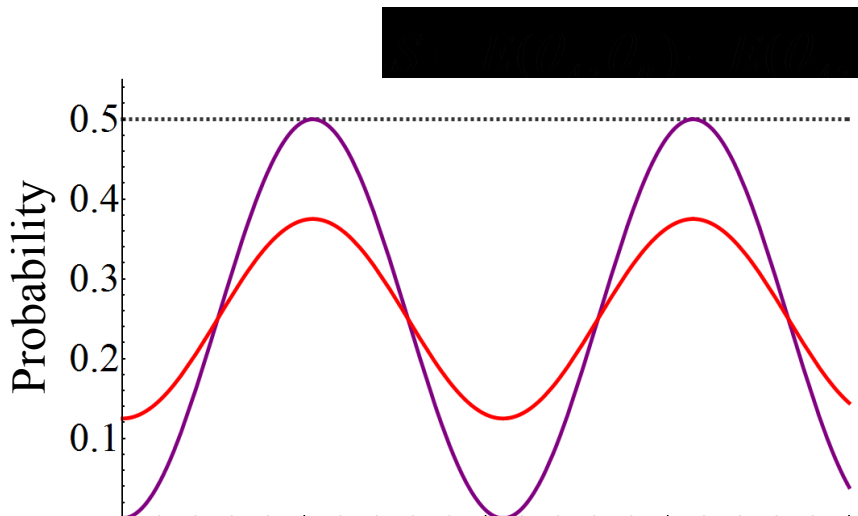
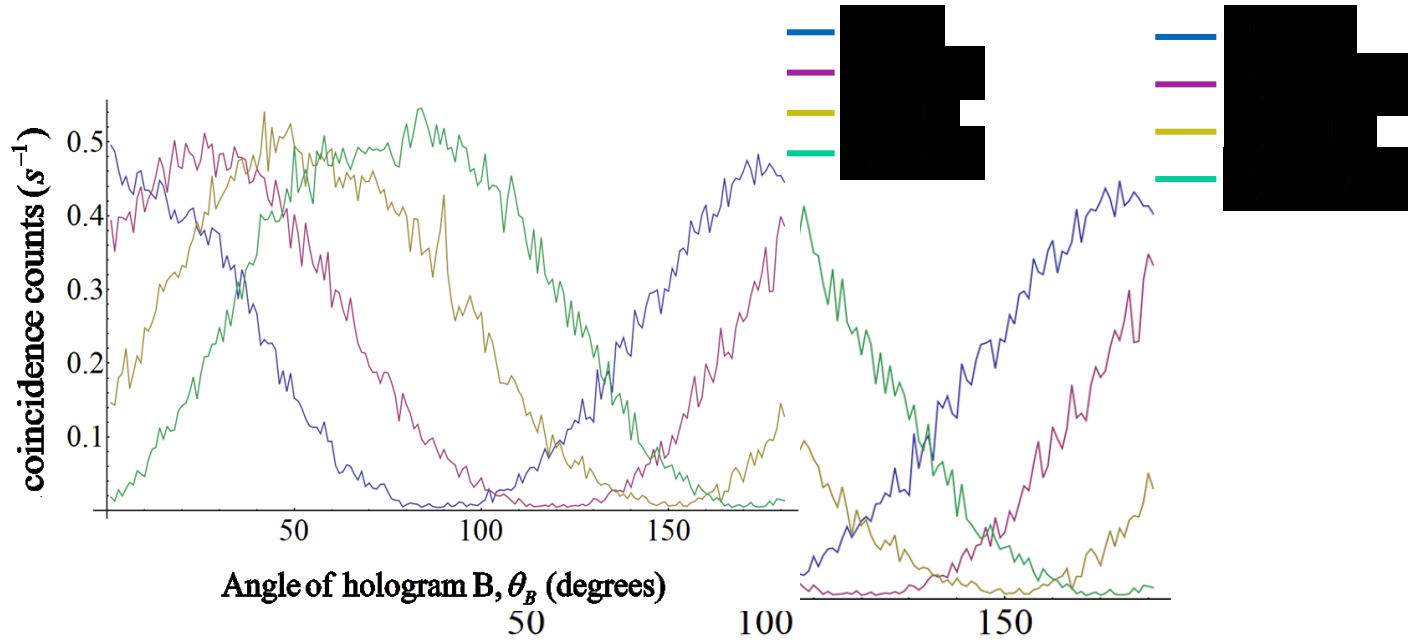
Array of coincidence measurements



Entanglement is verified by violating Bell's inequality



Do we have entanglement?



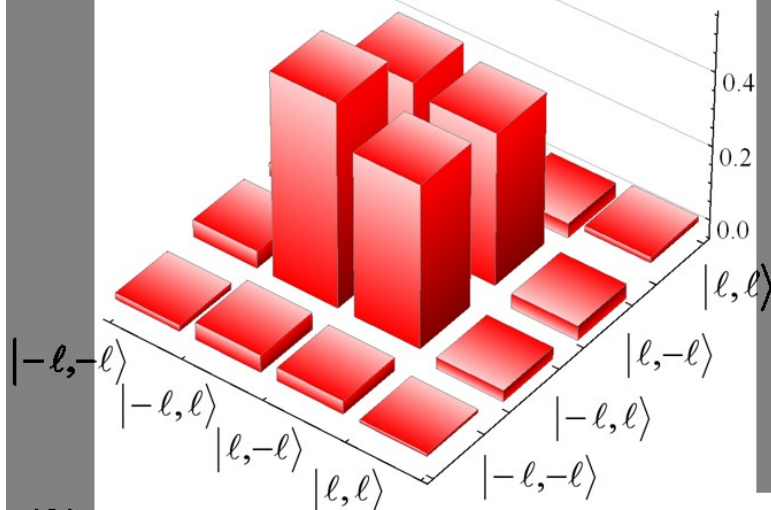
S	Violation by σ
± 0.06	10
± 0.09	7

Quantifying entanglement

$$\rho = \begin{pmatrix} 0.0009 & 0.0060 & 0.0025 & 0.0008 & 0 & -0.0051 & -0.0013 & -0.0017 \\ 0.0060 & \blacksquare & \blacksquare & \blacksquare & 0.0051 & 0 & \blacksquare & -0.0033 \\ -0.0025 & \blacksquare & 0.5085 & 0.5000 & 0.0018 & 0.0013 & 0.0045 & 0 & 0.0041 \\ 0.0008 & 0.0023 & 0.0018 & 0.0016 & 0.0017 & 0.0033 & -0.0041 & 0 & 0 \end{pmatrix}$$

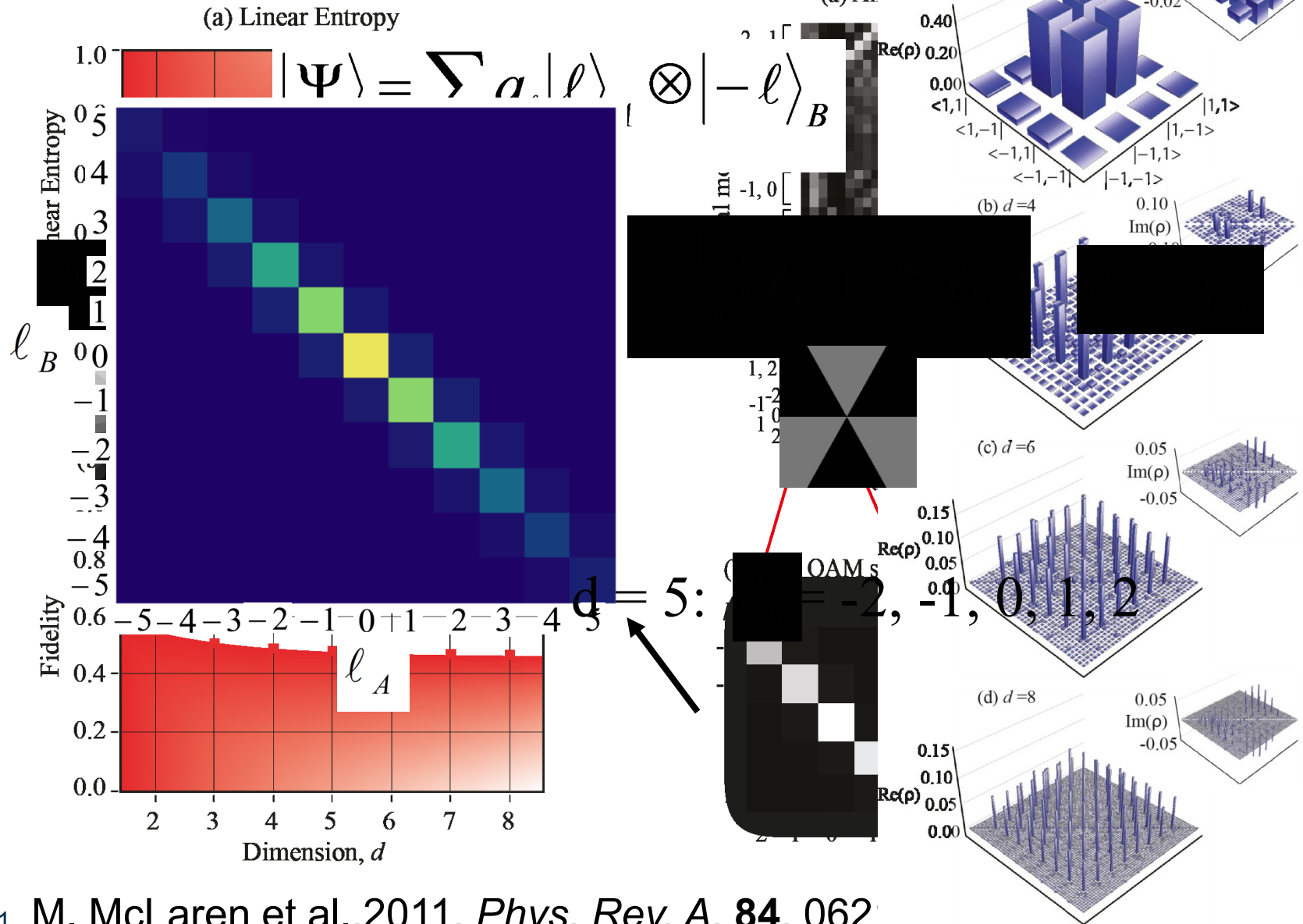


(a)

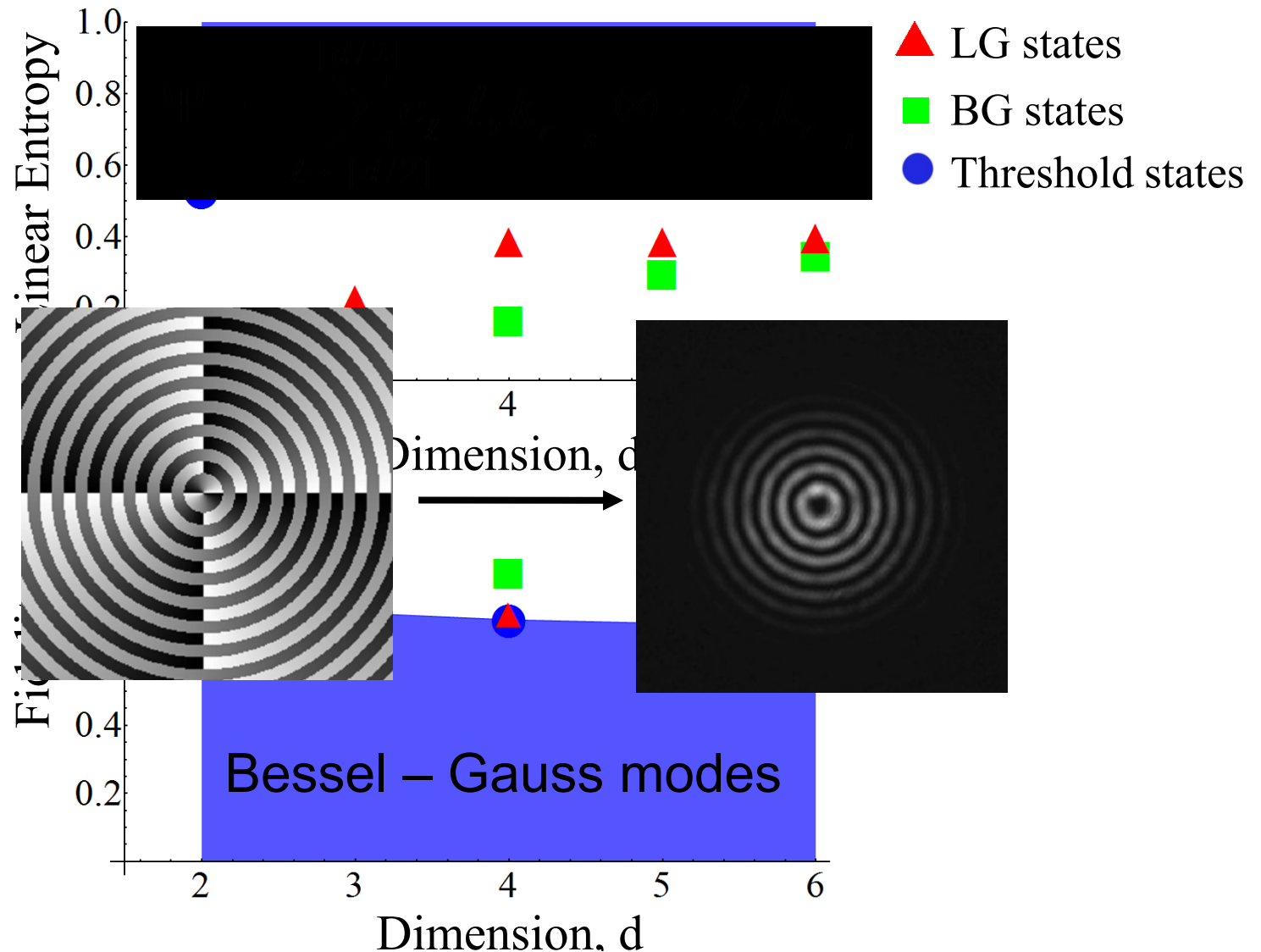


$$\text{Fidelity, } F = \left[\text{Tr} \sqrt{\sqrt{\rho_T} \rho \sqrt{\rho_T}} \right]^2 = 0.96 \pm 0.01$$

Entangling in higher dimensions

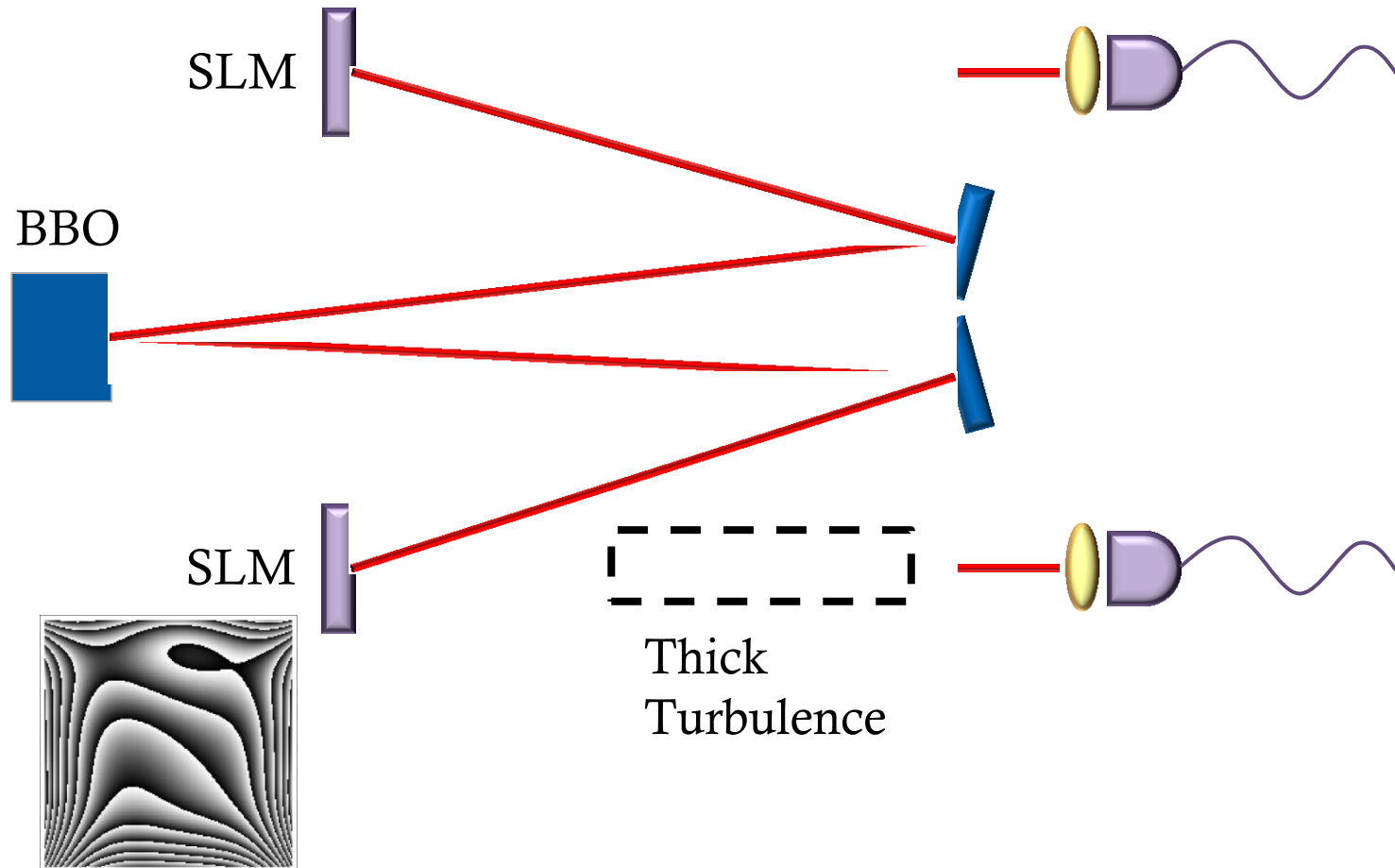


Entanglement using a different basis



Future Work

Effects of turbulence



Thank you

