

Optical communication with spatial modes of light

Andrew Forbes

Structured Light Laboratory, School of Physics



- **Past:** Russian partner got no funds and the Indian partner got funds 18 months late. Later we added a Chinese partner but there was no obvious way to formally include them;
- **Present:** Indian partner requests an 8 month extension and a transfer of funds from travel to consumables, both due to COVID;
- **Future:** We are ready to move on to the next stage, e.g., develop devices, so funding options for advanced projects and prototyping would be welcome.
- **Exchange:** Quantum (SA to China), Fibre Optics (China to SA), Adaptive Optics (Russia to SA), Structured light (SA to India), Binary Optics (India to SA), turbulence (SA to Russia)

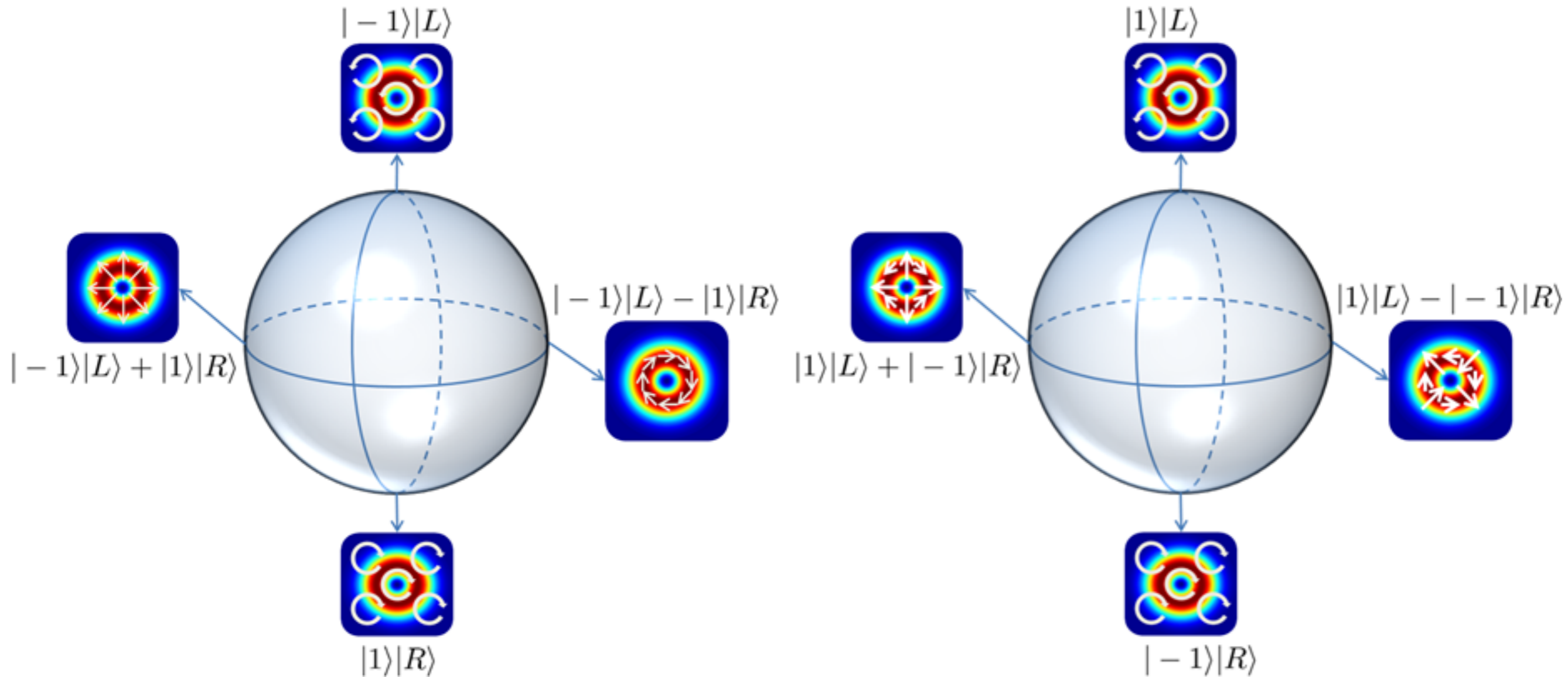
Issues and suggestions

Past, present and future

By combining degrees of freedom, we create a larger encoding space

$$\{|R\rangle, |L\rangle\} \xleftarrow{\text{Polarization}} \otimes \text{OAM} \xrightarrow{\text{OAM}} \{|-\ell\rangle, |\ell\rangle\}$$

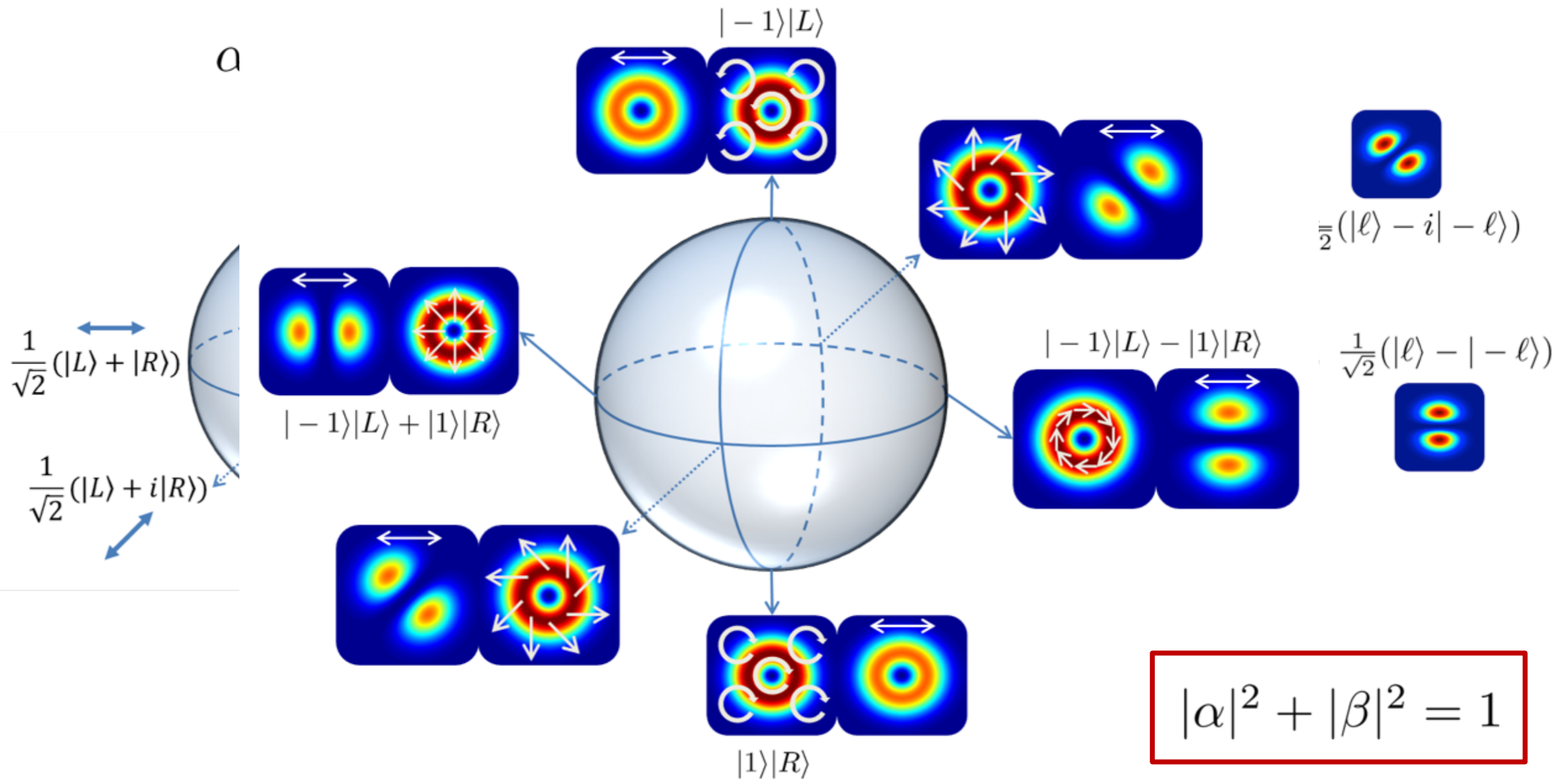
$$\{|-\ell, R\rangle, |\ell, R\rangle, |-\ell, L\rangle, |\ell, L\rangle\}$$



Vector states of light can be mapped on a higher-order Poincaré sphere

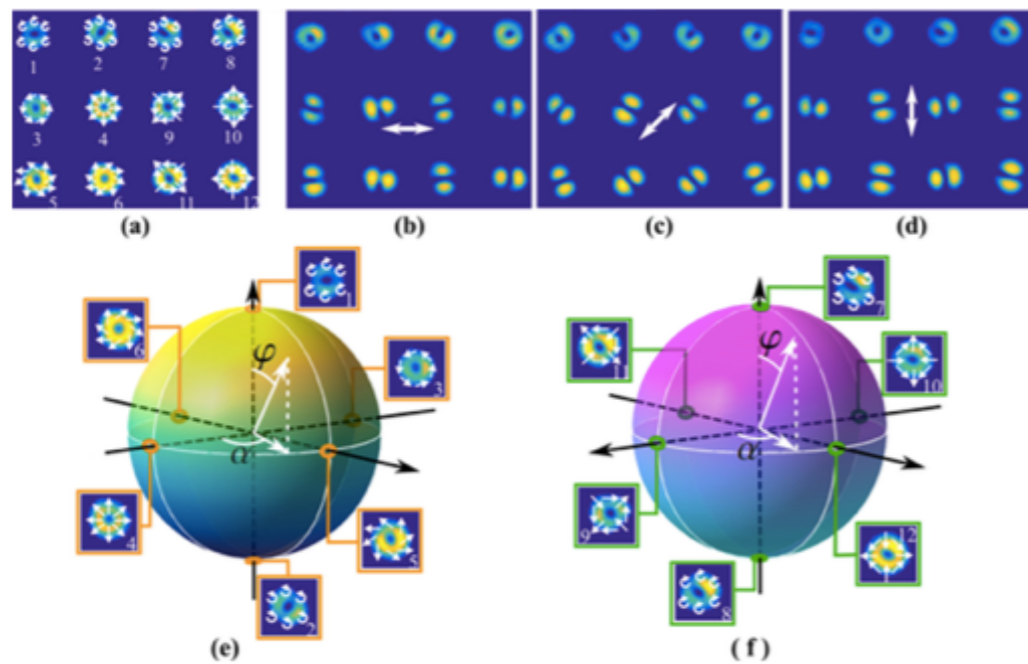
$$|U\rangle = \alpha|-\ell\rangle|L\rangle + \beta|\ell\rangle|R\rangle$$

a



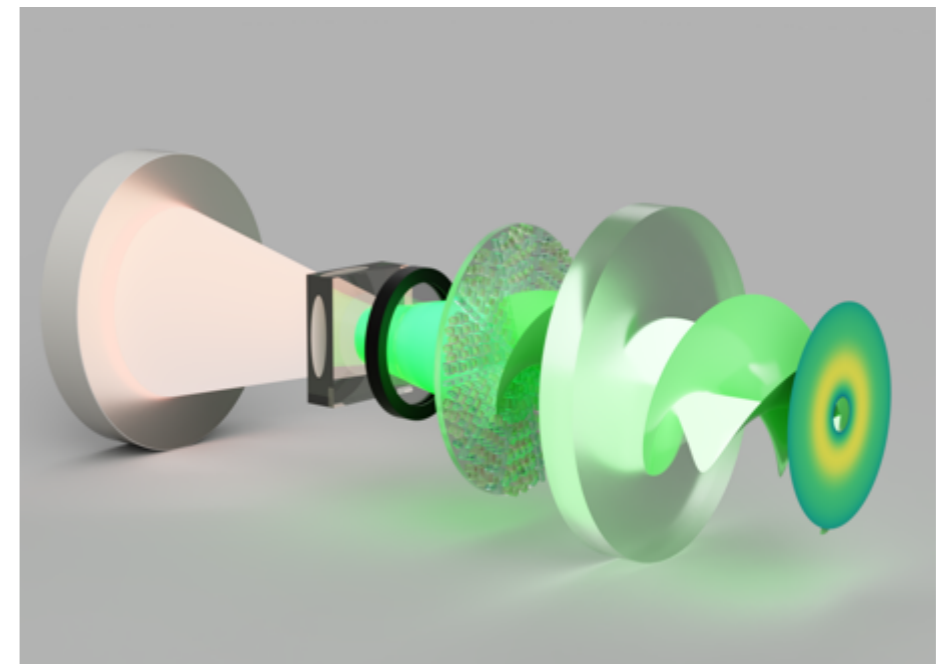
We tailor the optical fields
both inside and outside the laser

200 modes on an SLM



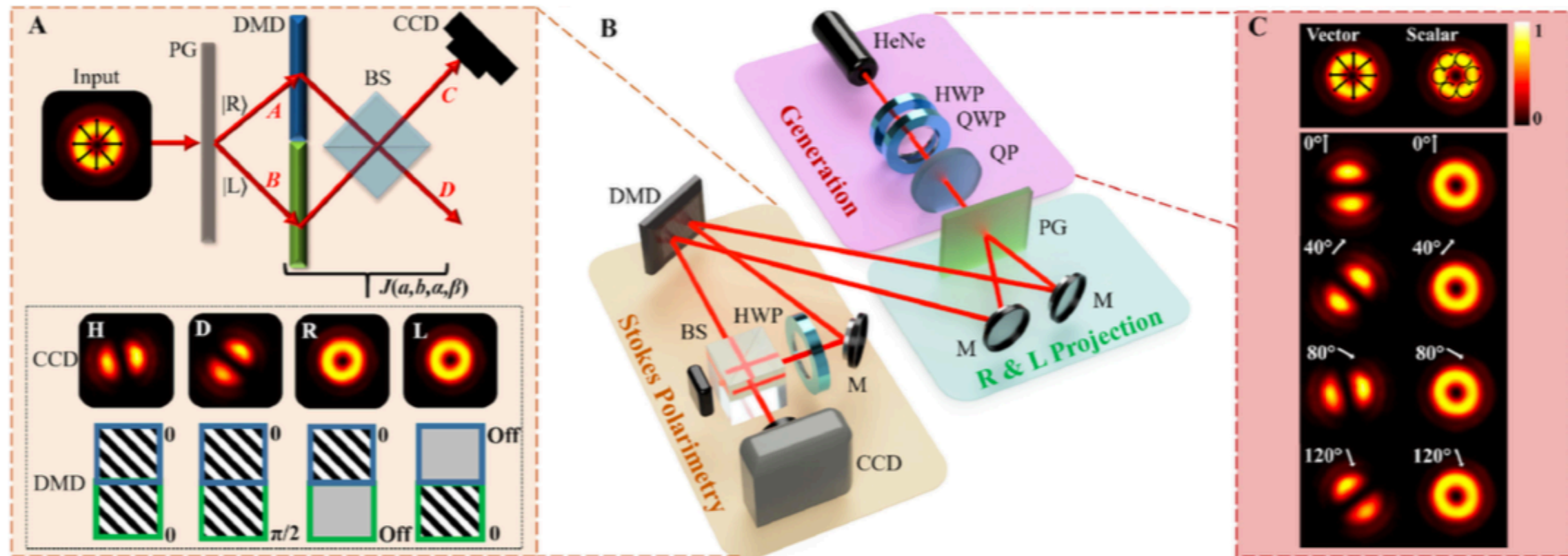
Optics Express **25**, 25697 (2017)

Super-chiral light



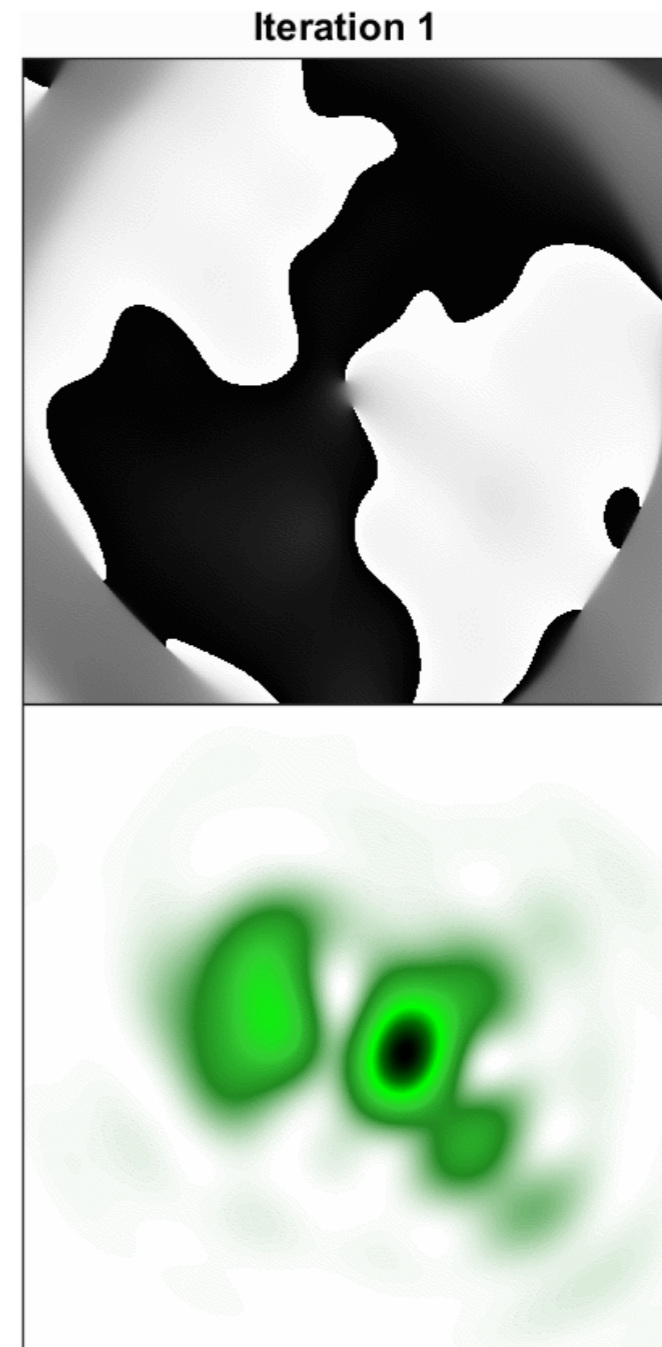
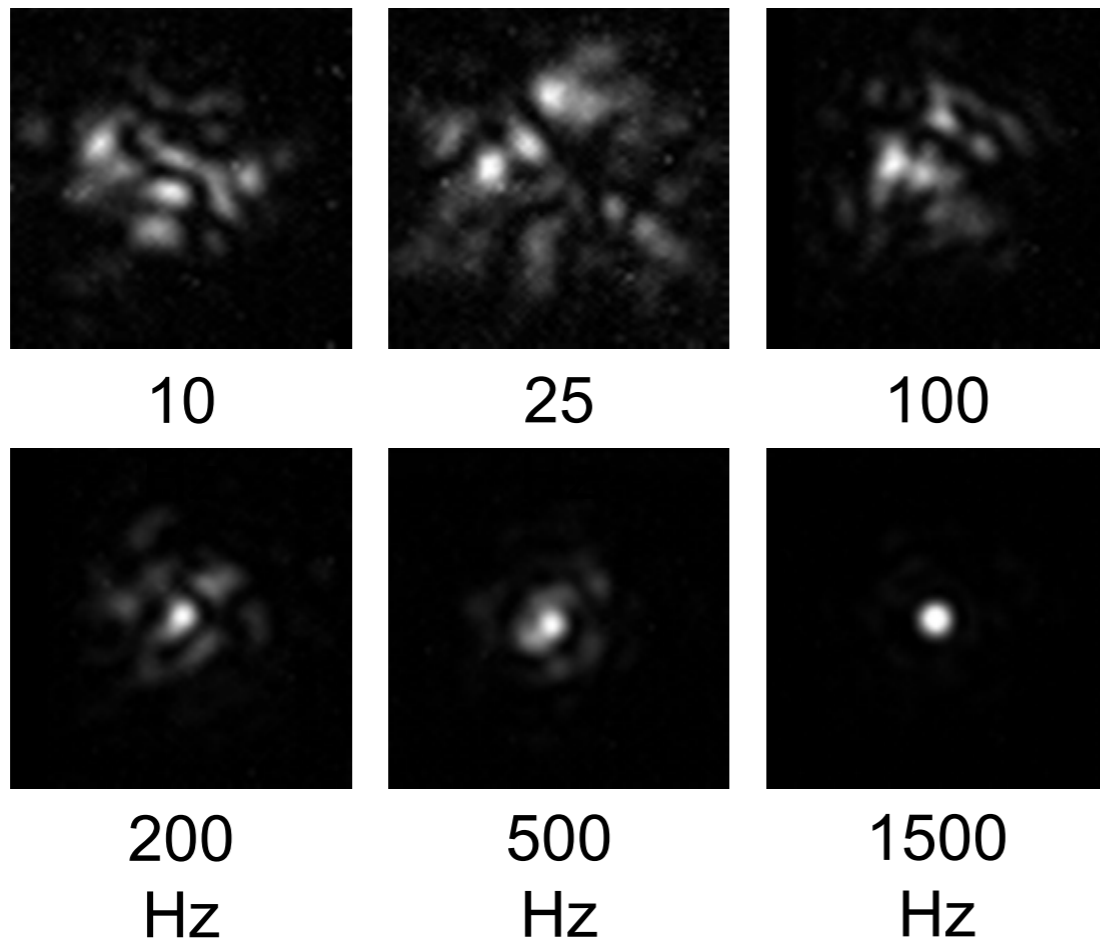
Nature Photonics **14**, 498 (2020)

And detect them with DMDs in a fast and cheap manner



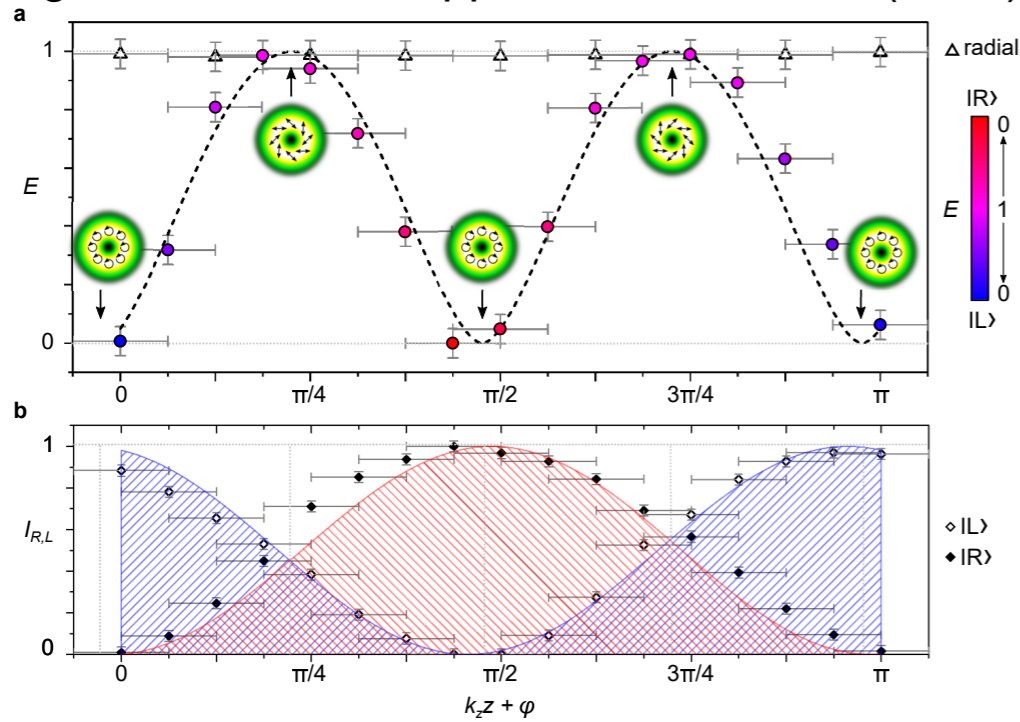
We have created devices for correction too

Applied Optics **58**, 6019 (2019)

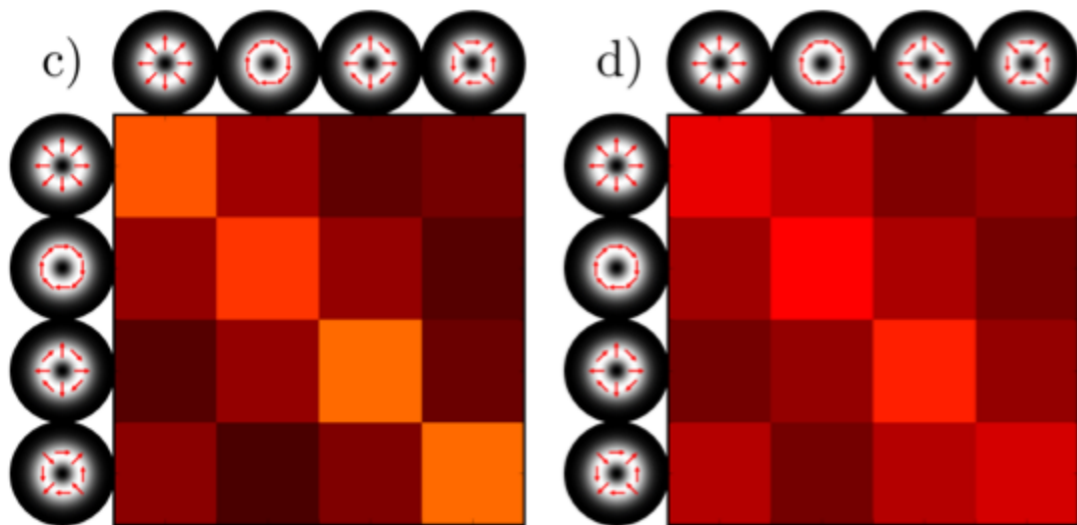


We deployed these tools in a variety of applications

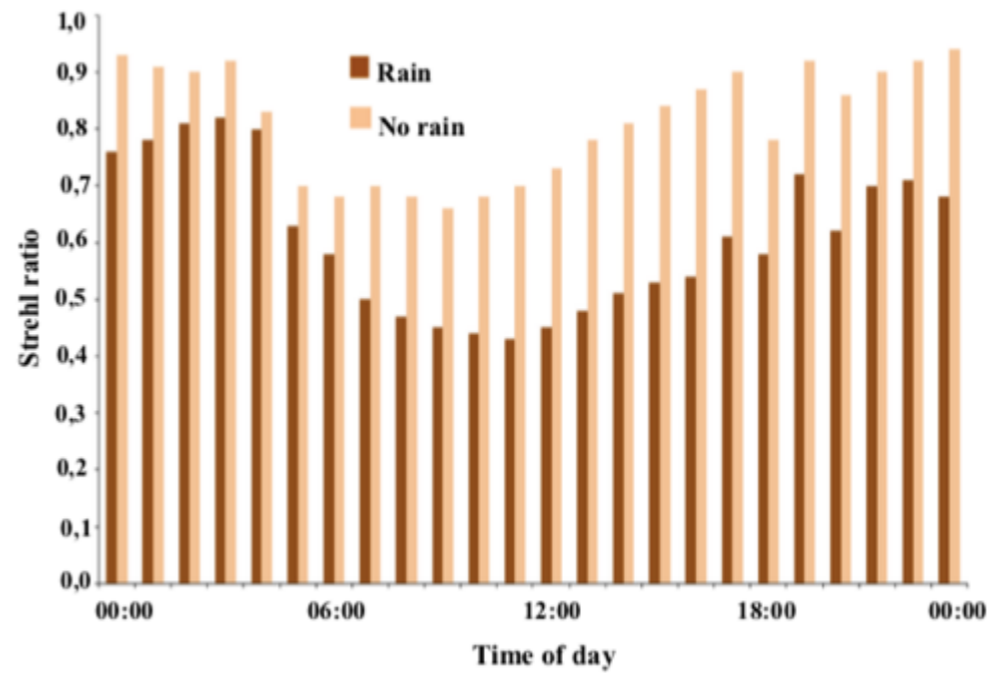
Light: Science and Applications **7**, 18009 (2018)



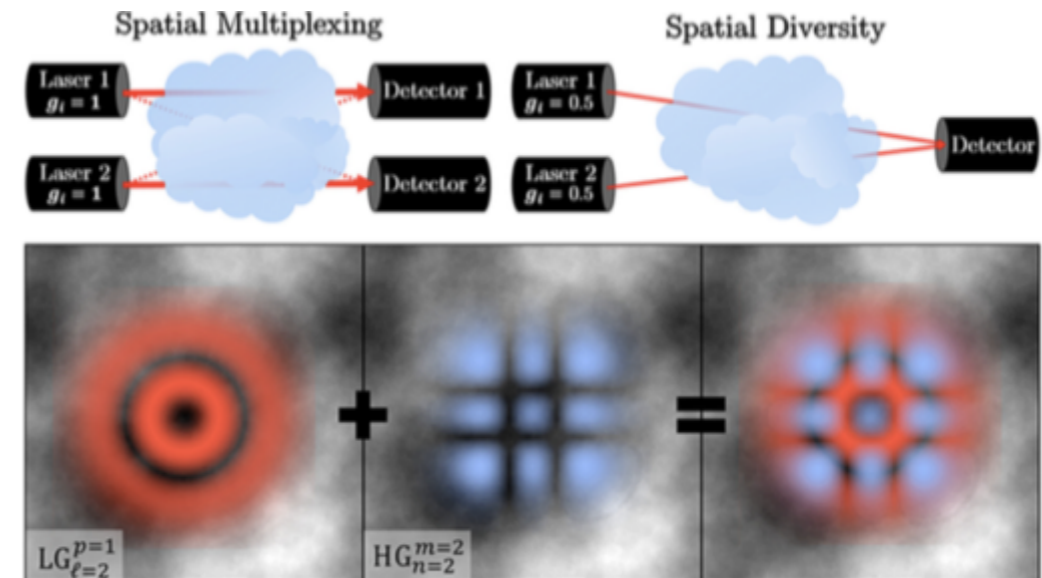
J. Lightwave Tech. **36**, 292 (2018)



Applied Optics **58**, 4258 (2019)

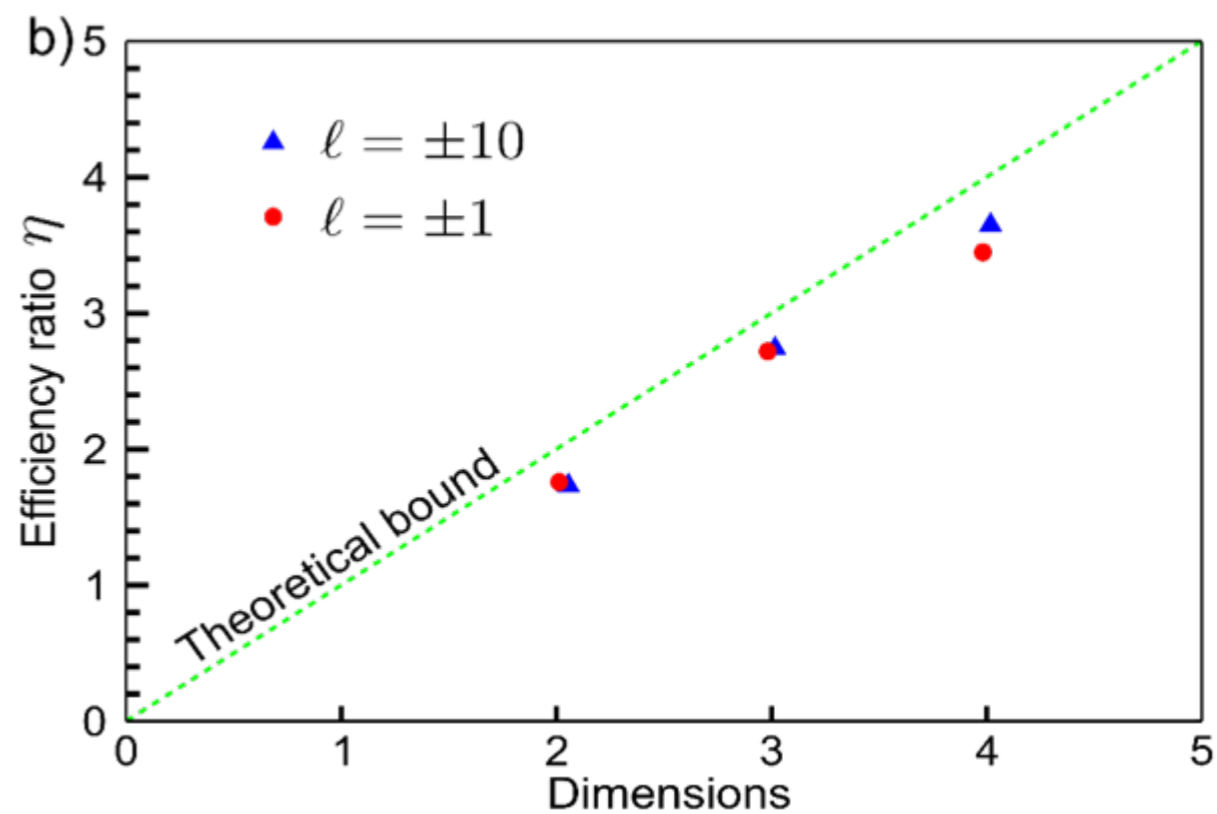
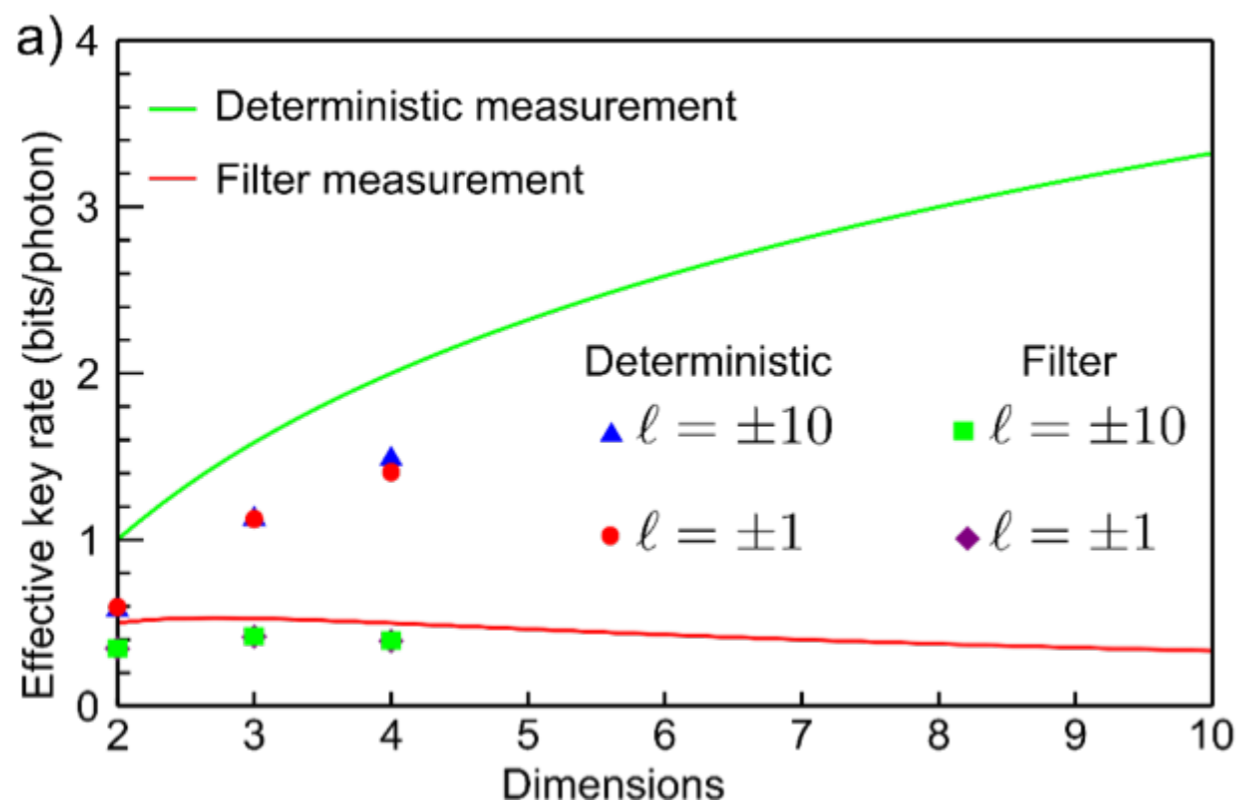
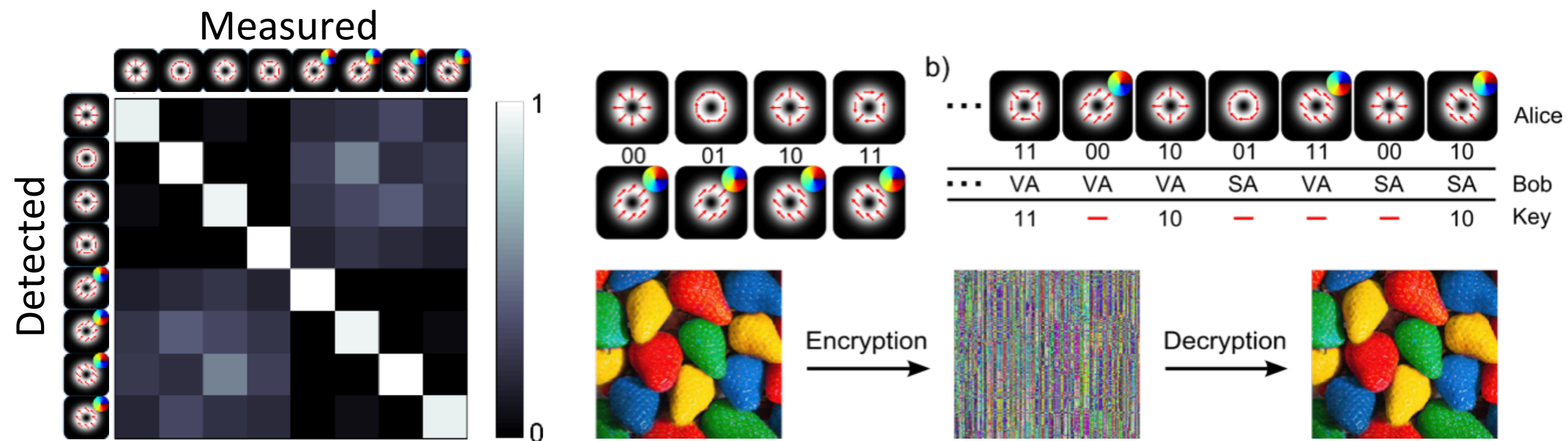


Phys. Rev. Appl. **10**, 024020 (2018)

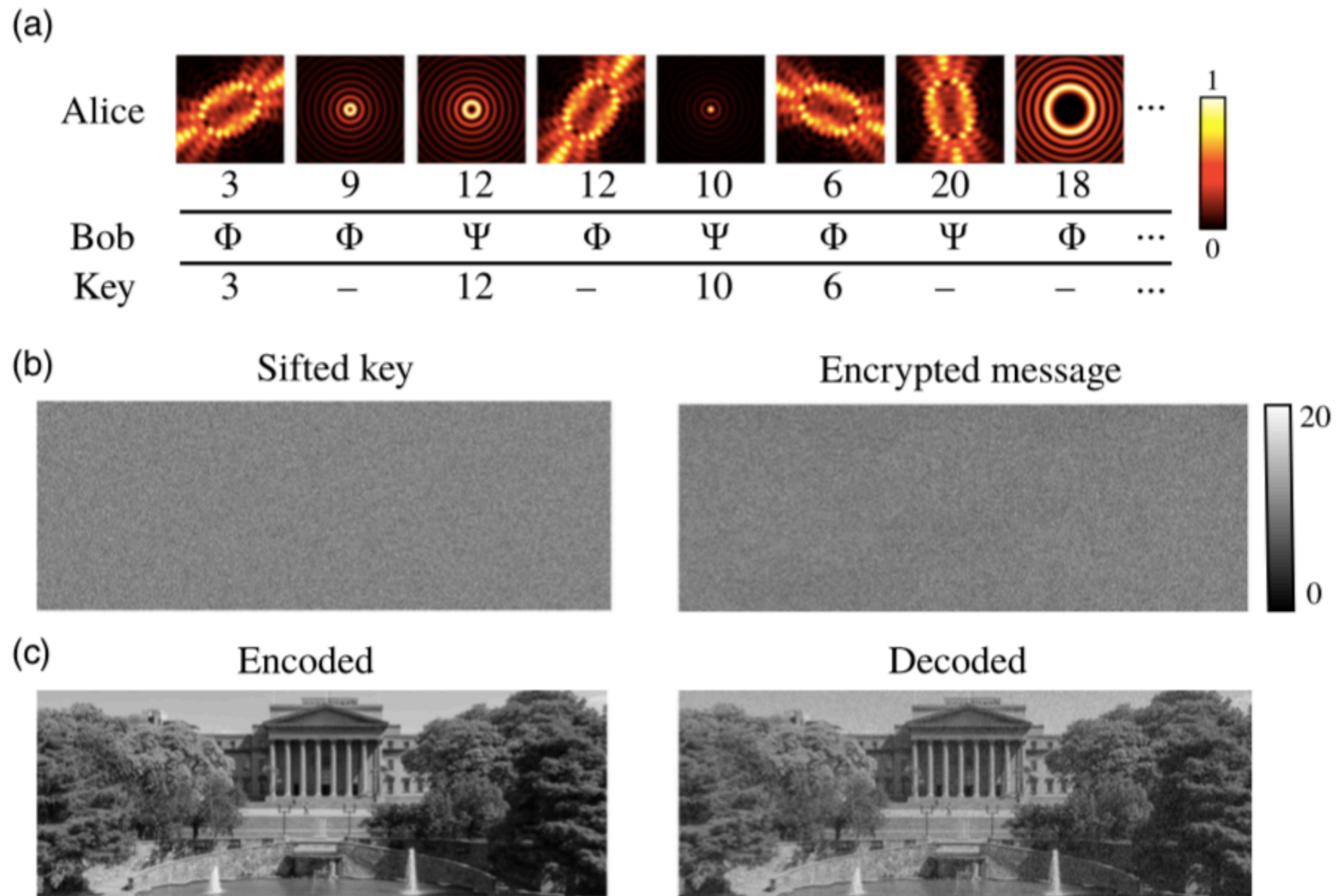


Vector mode QKD

Scientific Report 7, 13882 (2017)



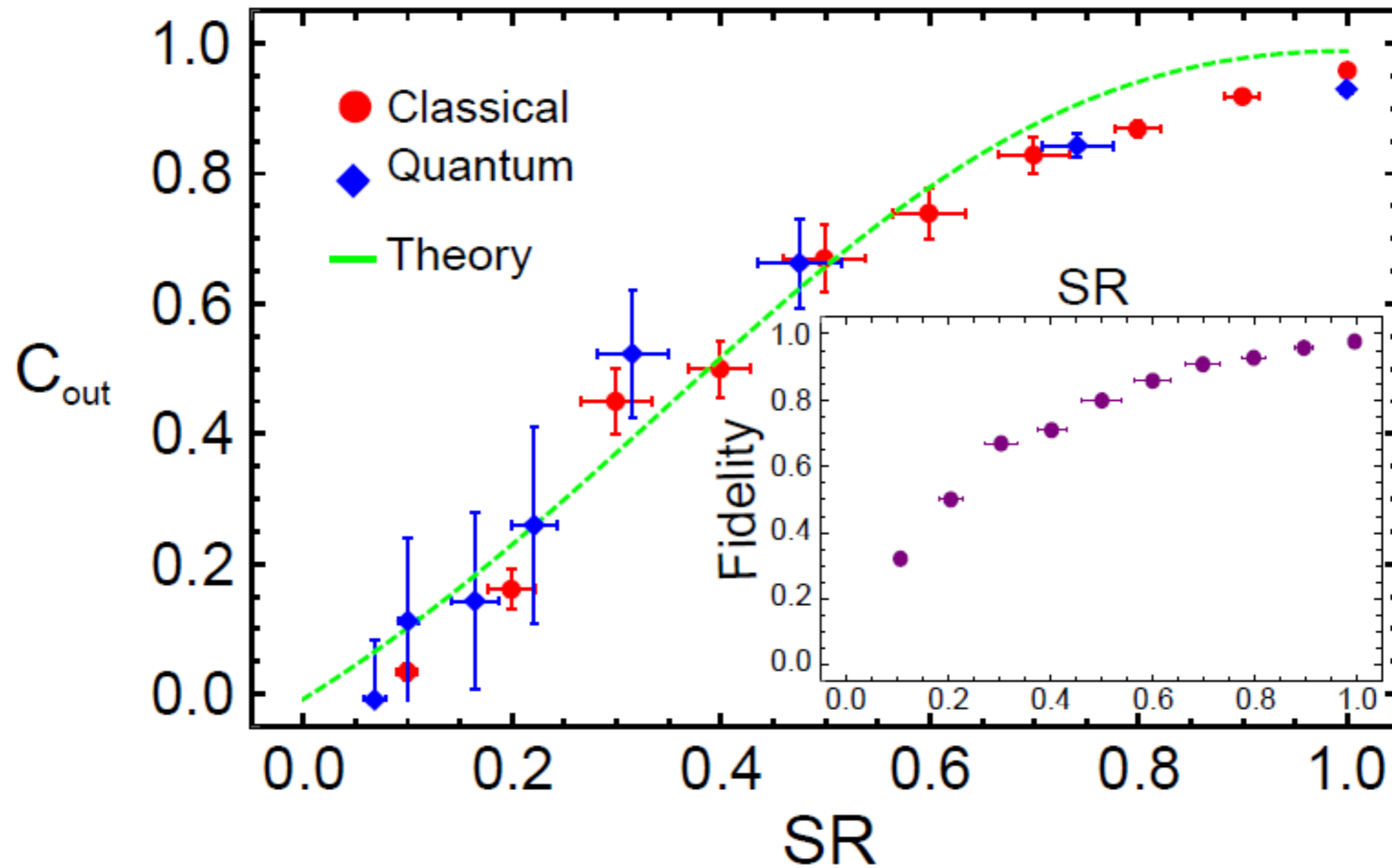
Now one can do a range of things with such beams, including self-healing QKD



For a good tutorial, see: JOSA B **37**, A309 (2020)

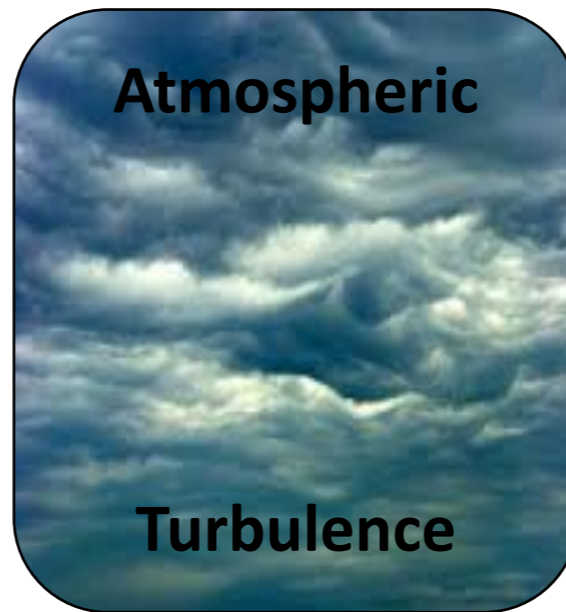
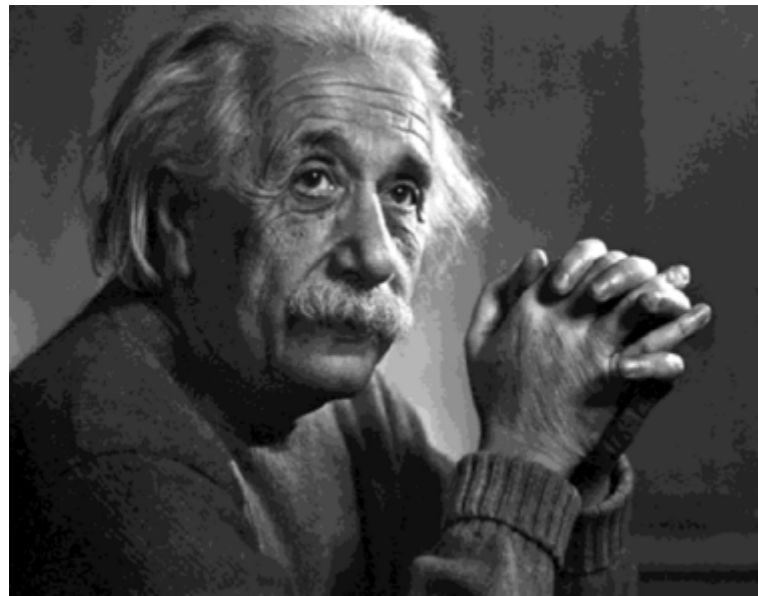
Optics Express **26**, 26946 (2018)
Phys. Rev. A **98**, 053818 (2018)

Nature can't distinguish between the decay of non-separable classical states and quantum entangled states

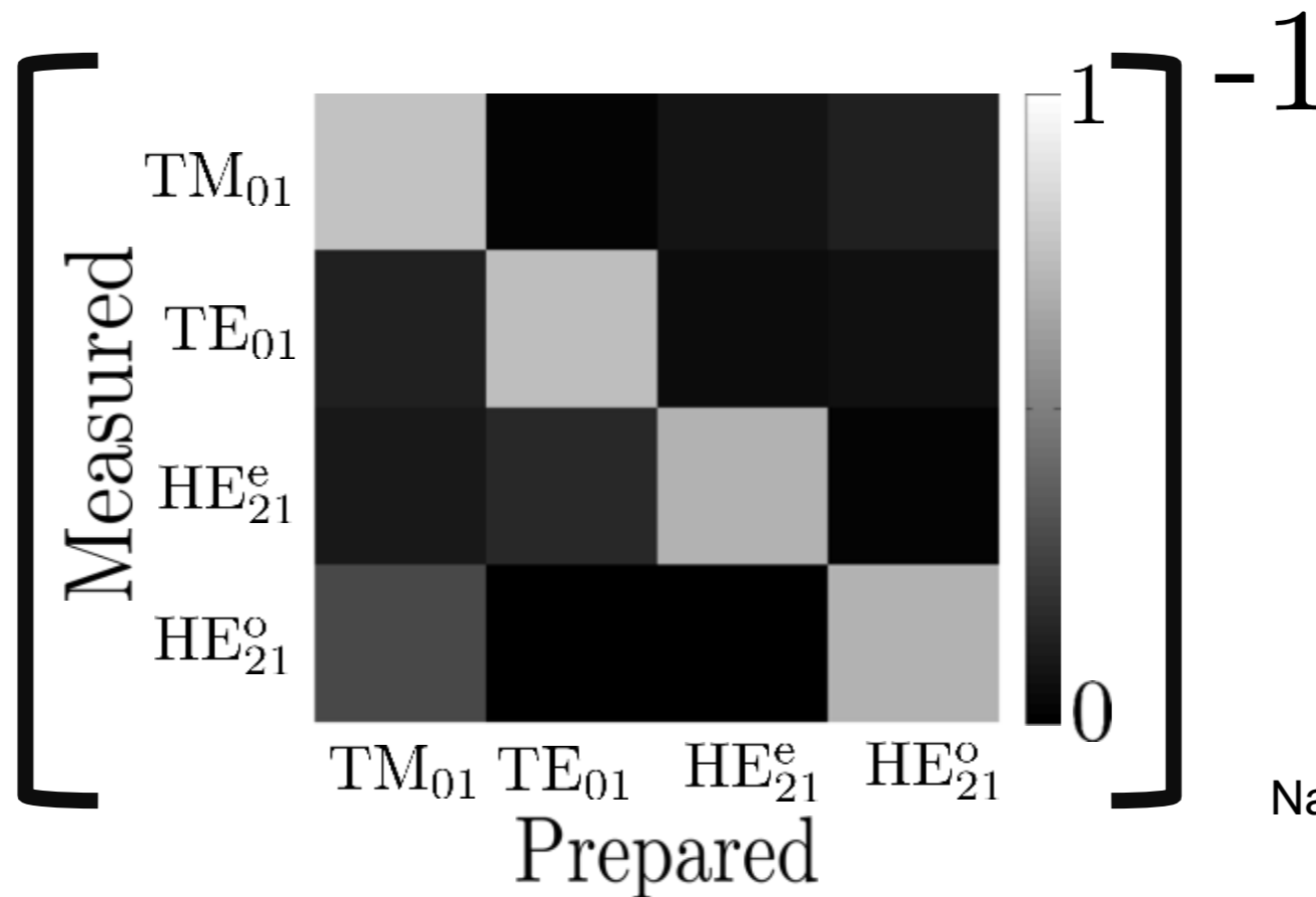


Data transfer through a noisy channel (atmosphere/fibre)

Sent



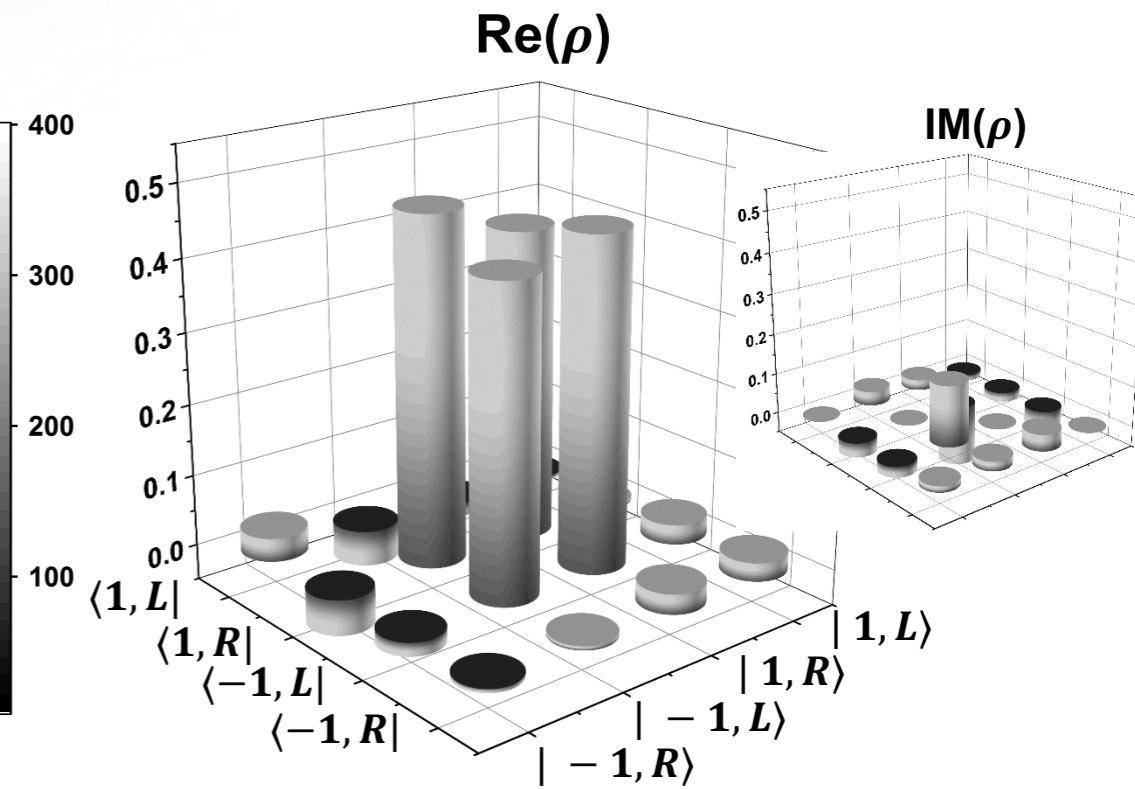
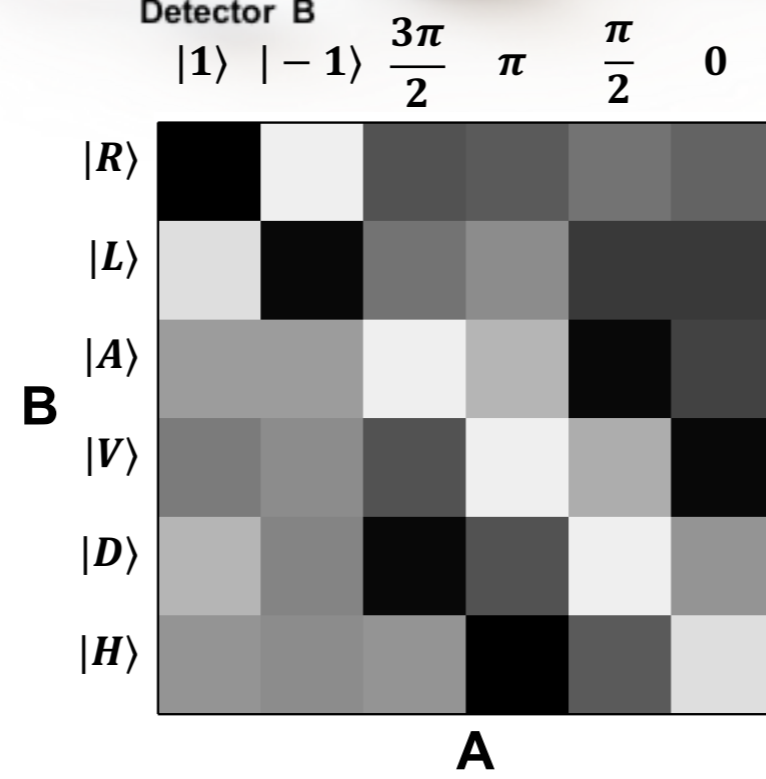
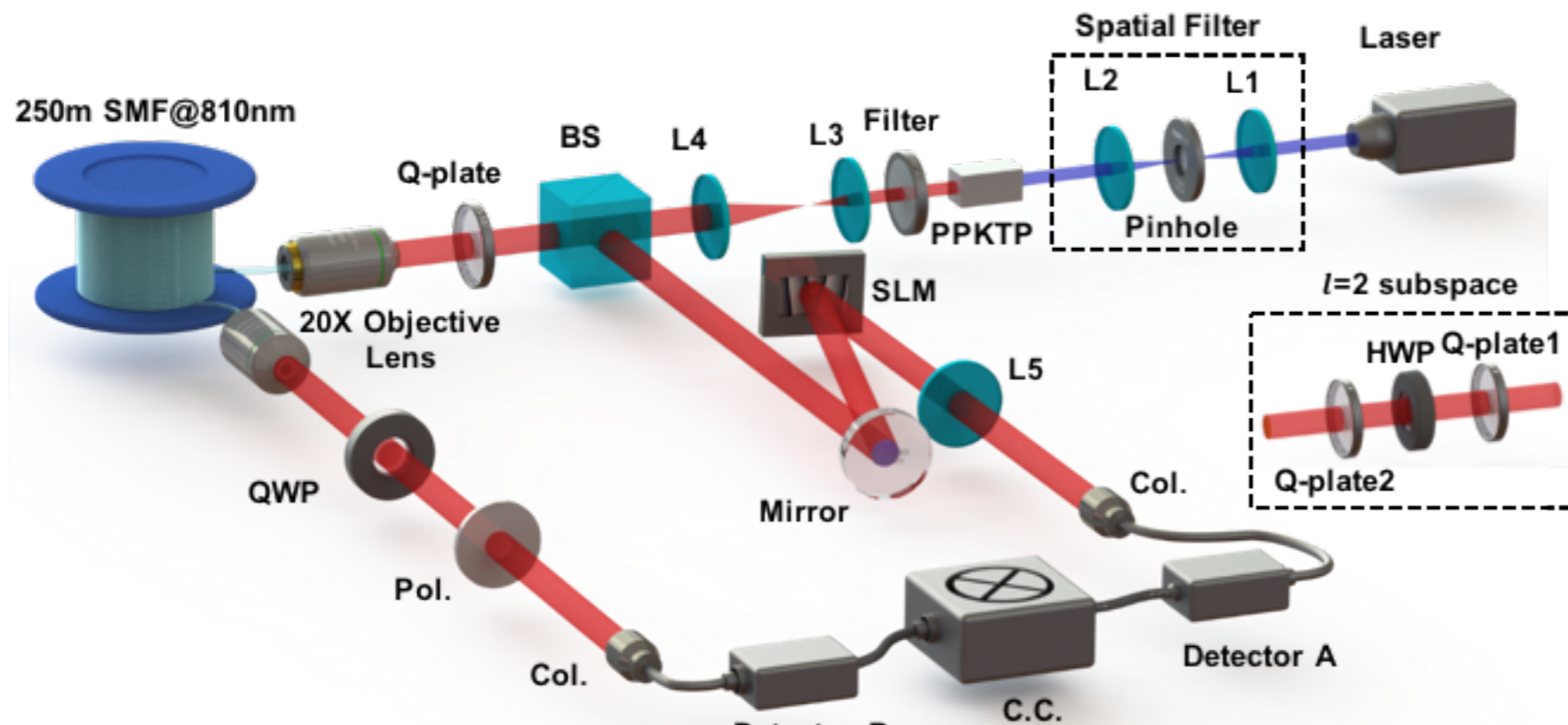
Received



Nature Physics **13**, 397 (2017)

We could play with hybrid entanglement to trick out way through the medium

Science Advances 6, eaay0837 (2020)



LASER & PHOTONICS REVIEWS

Quantum secret sharing

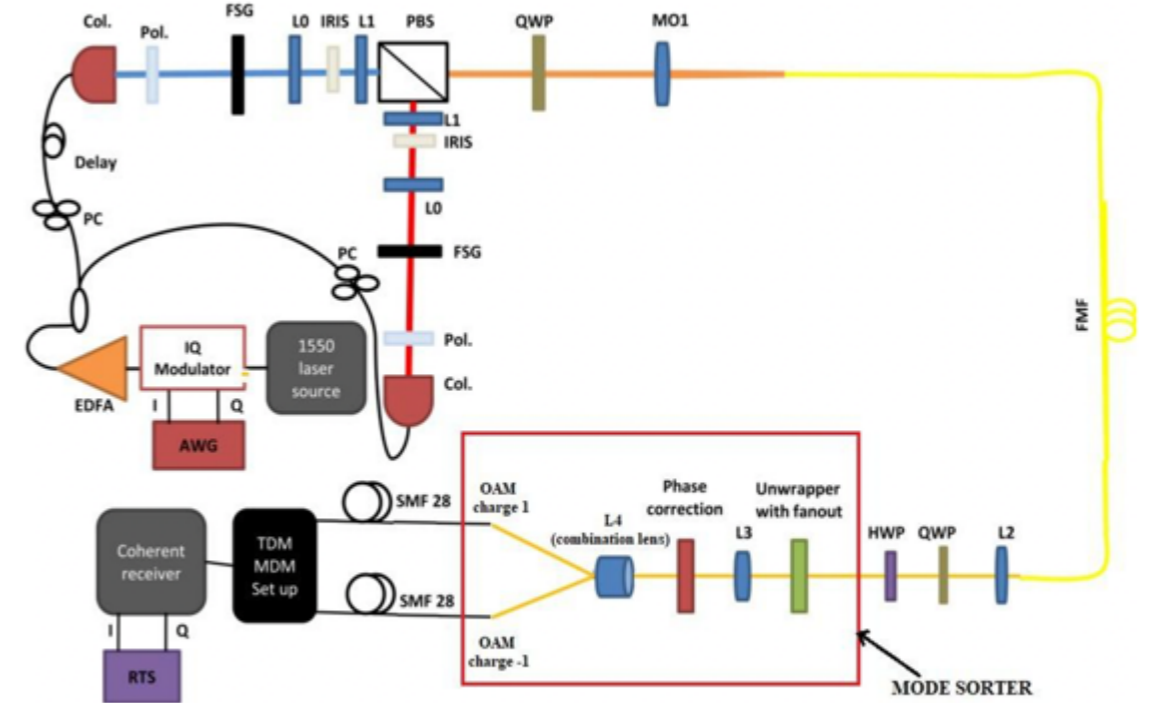
In 11 high-dimensions and
across 10 parties



**Experimental Demonstration of 11-Dimensional
10-Party Quantum Secret Sharing**

Jonathan Pinnell, Isaac Nape, Michael de Oliveira,
Najmeh TabeBordbar, and Andrew Forbes

OAM MDM set-up



Still to come

Exciting outcomes on devices,
fibre optics and quantum

2 kHz aberration correction



ACTIVE OPTICS NIGHTN LTD.
MOSCOW, RUSSIA
activeoptics.ru

IN COLLABORATION WITH
AKA OPTICS SAS
MARSEILLE, FRANCE
akaoptics.com

PRODUCT
BROCHURE



science
& technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



Thank you

andrew.forbes@wits.ac.za

