Changing Colours in Optical Fibres:
The Key to Long-Distance Quantum-Secured Communications

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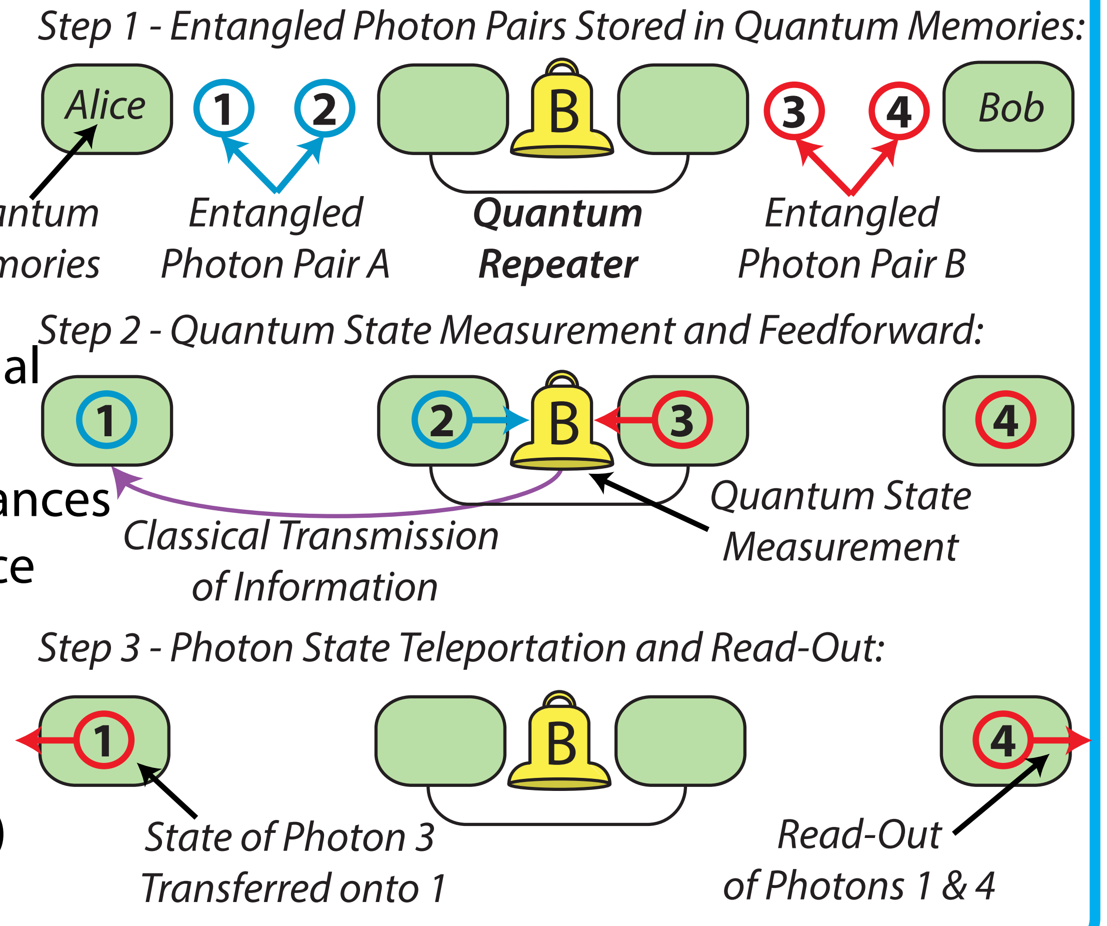
Motivation

The Quantum Internet: The Future of Secure Communications
- Current internet security relies on difficult maths to secure information
- The development of a quantum computer will make current security ineffective
- Quantum key distribution (QKD) offers absolute security of information transfer
- QKD relies on encoding 0s and 1s onto single particles of light ("photons")
- QKD's distance is limited to only a few hundred kilometers in optical fibre
- Unlike classical optical fibre networks (i.e., NBN) we cannot simply amplify the signal

Quantum Repeaters: Extending the Distance of Quantum Key Distribution
- Quantum repeaters use teleportation to reduce the loss of photons over long distances
- Including quantum repeaters in an optical fibre network will allow for long-distance quantum-secured information networks
- The key component of a quantum repeater is a "quantum memory" - a device that can freeze light in place
- The problem: quantum memories typically operate in the near infra-red (~800 nm) while fibre transmission is most efficient at 1550 nm

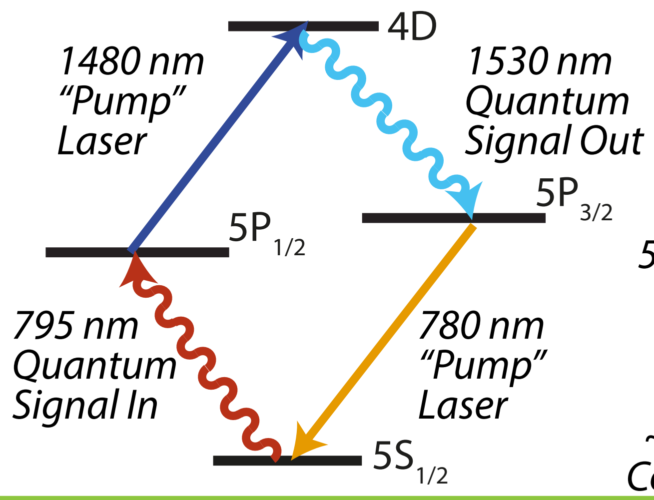
Quantum Repeater Protocol



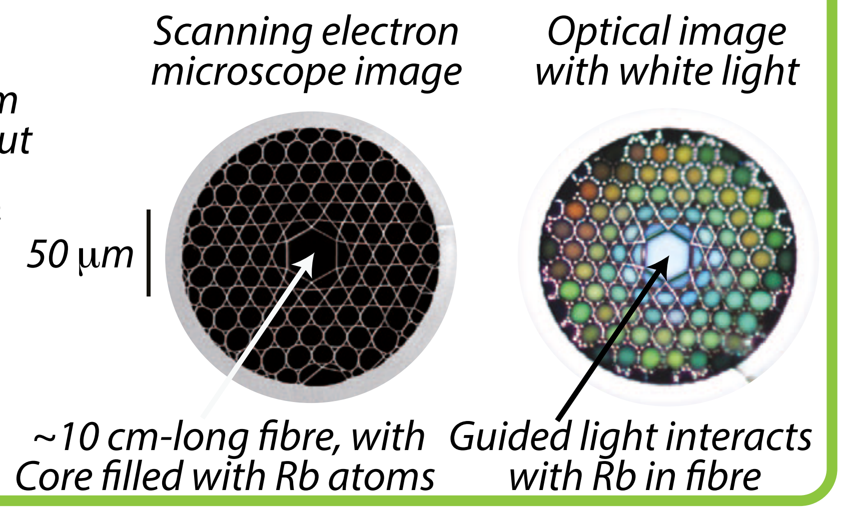
Changing Colours: Four is the Magic Number

Rubidium: the Atom that Keeps on Giving
- Rb is a Group 1 element with "simple" electron structure
- Strongly absorbs light, making for efficient quantum memories
- Ground-state absorption occurs for photons around 800 nm
- Has excited state energy levels within telecom band at 1530 nm
- Can use "four-wave mixing" (FWM) technique to change the wavelength of light from efficient storage to efficient transmission
- At the University of Adelaide we have loaded rubidium atoms into special hollow optical fibres to maximise FWM efficiency [1]

Rubidium Energy Level Scheme for Four-Wave Mixing



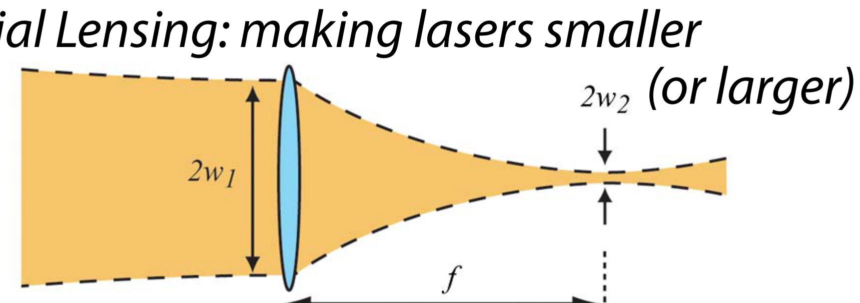
Hollow-Core Fibres - Enhancing FWM Efficiency



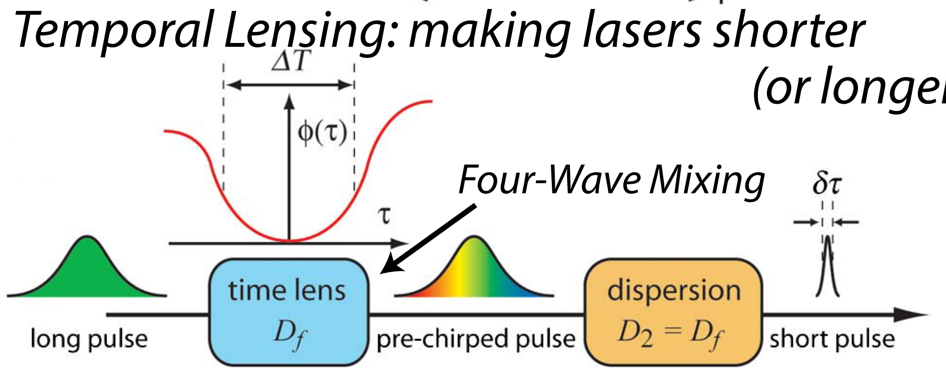
Fulbright Future Scholarship: Columbia University

Temporal Lensing: Breaking the Picosecond Barrier
- The Gaeta group at Columbia University are the only group to have demonstrated FWM in hollow fibres [2]
- For my Fulbright Future Fellowship I will learn key aspects of FWM and apply it to stretching pulses in time ("temporal lensing") in nonlinear fibres
- Our goal is to stretch picosecond pulses to nanoseconds, allowing for the detection of ultrashort pulses with the most efficient optical detectors available
- Applications include fields such as biology, spectroscopy and quantum optics

Spatial Lensing: making lasers smaller

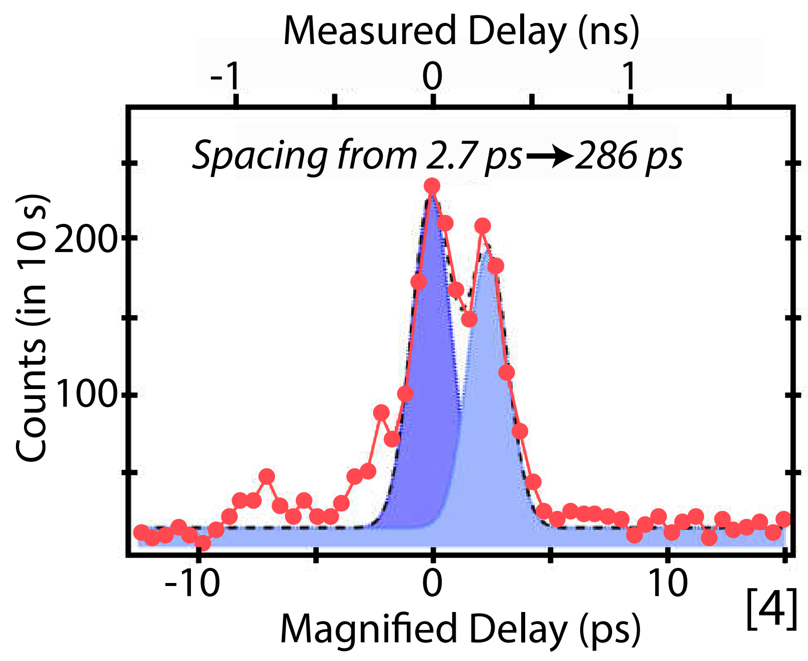


Temporal Lensing: making lasers shorter (or longer)



[3]

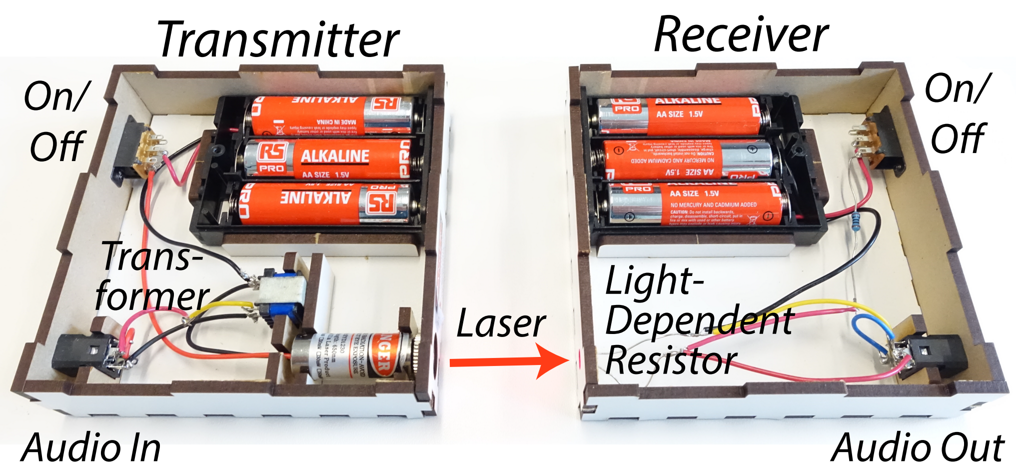
Initial Columbia Expansion Results:



[4]

Engagement

The University of Adelaide Laser Radio
- Aims to inspire & excite the next generation of scientists and engineers
- Students construct the device, which sends sound information over light



Greatest Hits:
- Appeared on ABC News & Scope (Ch 10)
- Presented to politicians such as Christopher Pyne & Tanya Plibersek
- Presented to Google co-founders Sergey Brin and Larry Page
- More info at *laserradio.wordpress.com*

References & Acknowledgements

FULBRIGHT
AUSTRALIAN–AMERICAN FULBRIGHT COMMISSION

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[1] A. Hilton *et al.*, Phys. Rev. Appl. **10**, 044034 (2018); [2] P. Londero *et al.*, Phys. Rev. Lett. **103**, 043602 (2009);
[3] R. Salem *et al.*, Adv. Opt. Photon. **5**, 274 (2013); [4] A. Forsi *et al.*, CLEO 2016 FW1C.2 (2016).

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