

Rare-Earth Ion-Doped Crystals as Quantum Memories

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UNIGE Young Researchers Day 2022

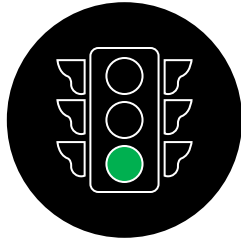


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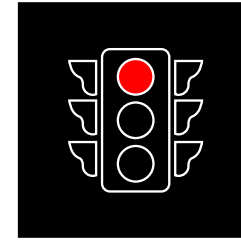
A Tale of Two Qubits

Flying Qubit



- Good at propagating
→ Photons

Stationary Qubit

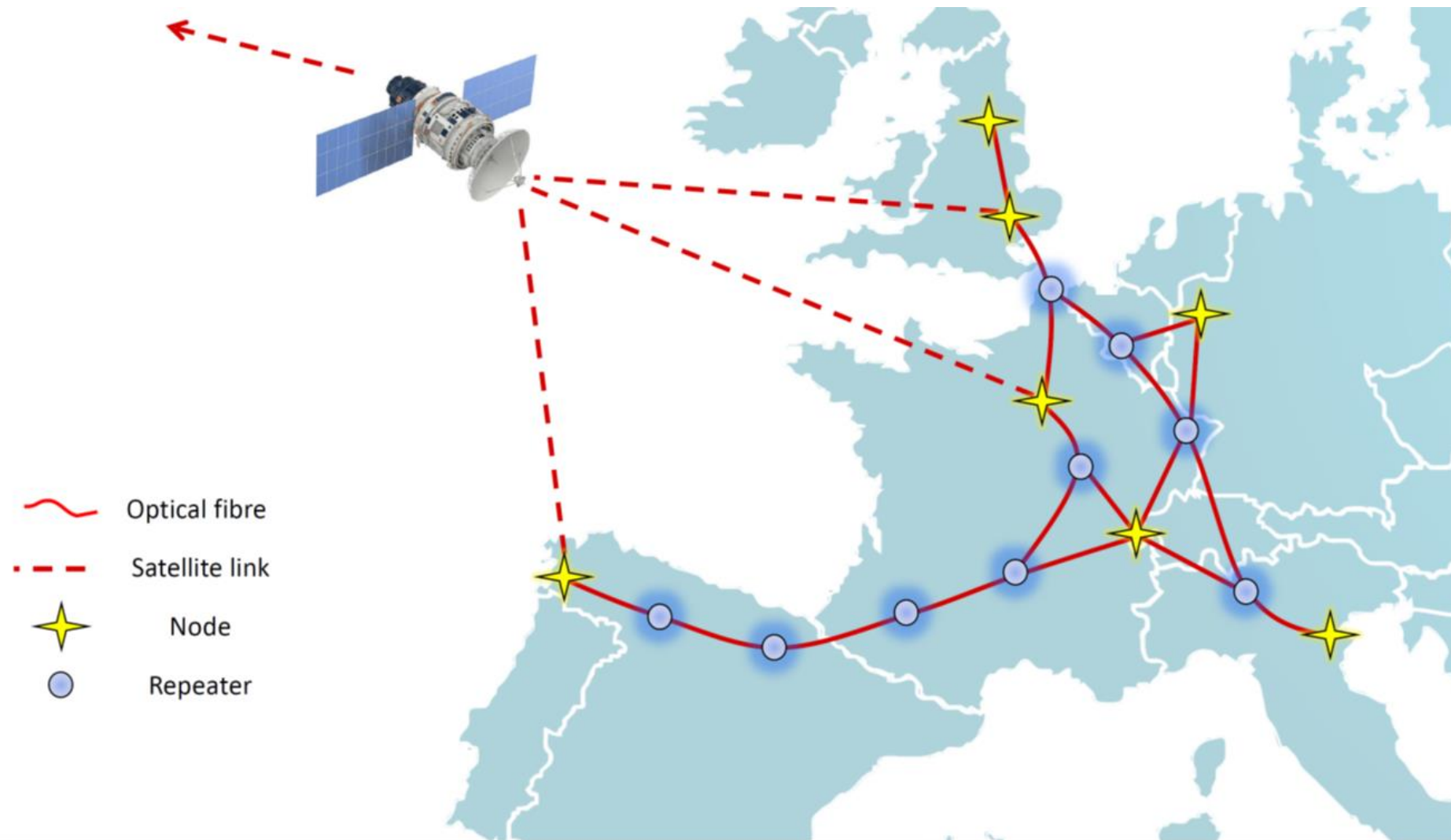


- Good at performing operations
→ No Comment

Limited by Distance



The Quantum Repeater

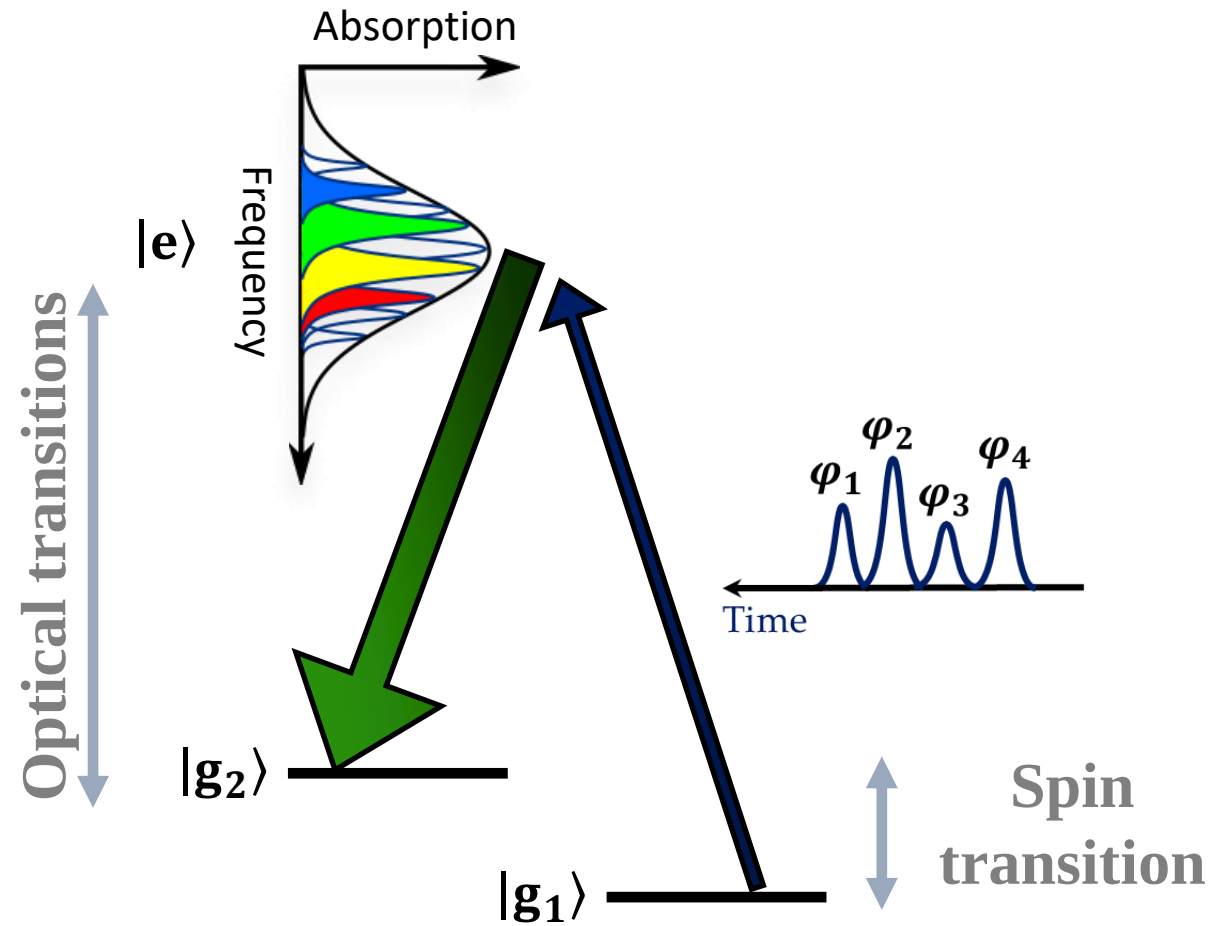


The Quantum Repeater



- Storage efficiency
- Storage fidelity
- Storage time – to reach the next node at longer distances
- Multimode capacity – to achieve high data rates in quantum communication network

The Lambda System



$\text{Eu}^{3+}:\text{Y}_2\text{SiO}_5$ - Magnetic Field

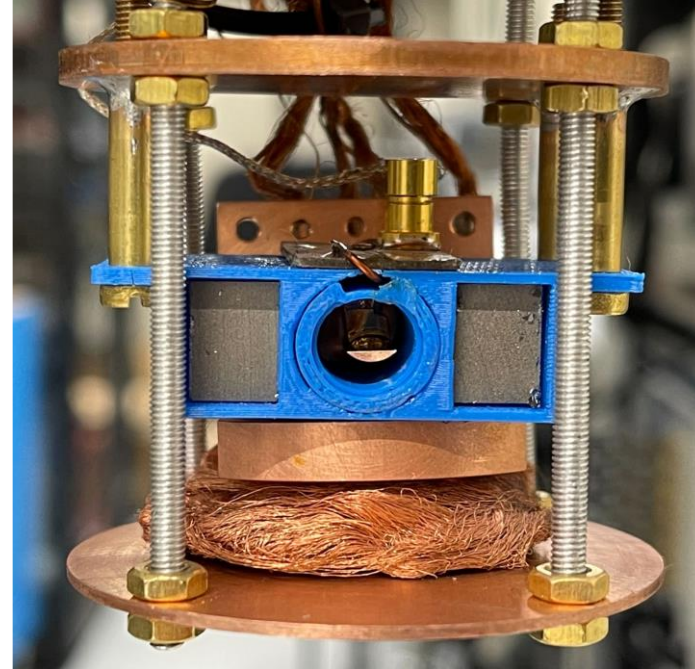
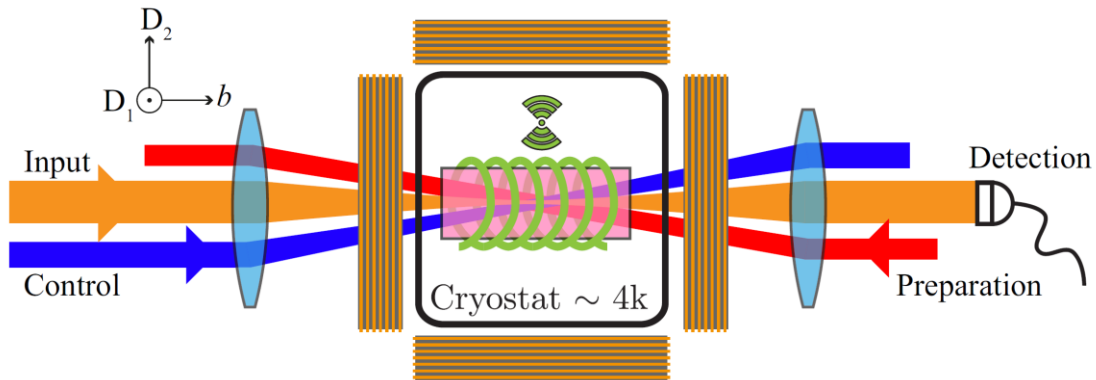


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$\text{Eu}^{3+}:\text{Y}_2\text{SiO}_5$ - Magnetic Field

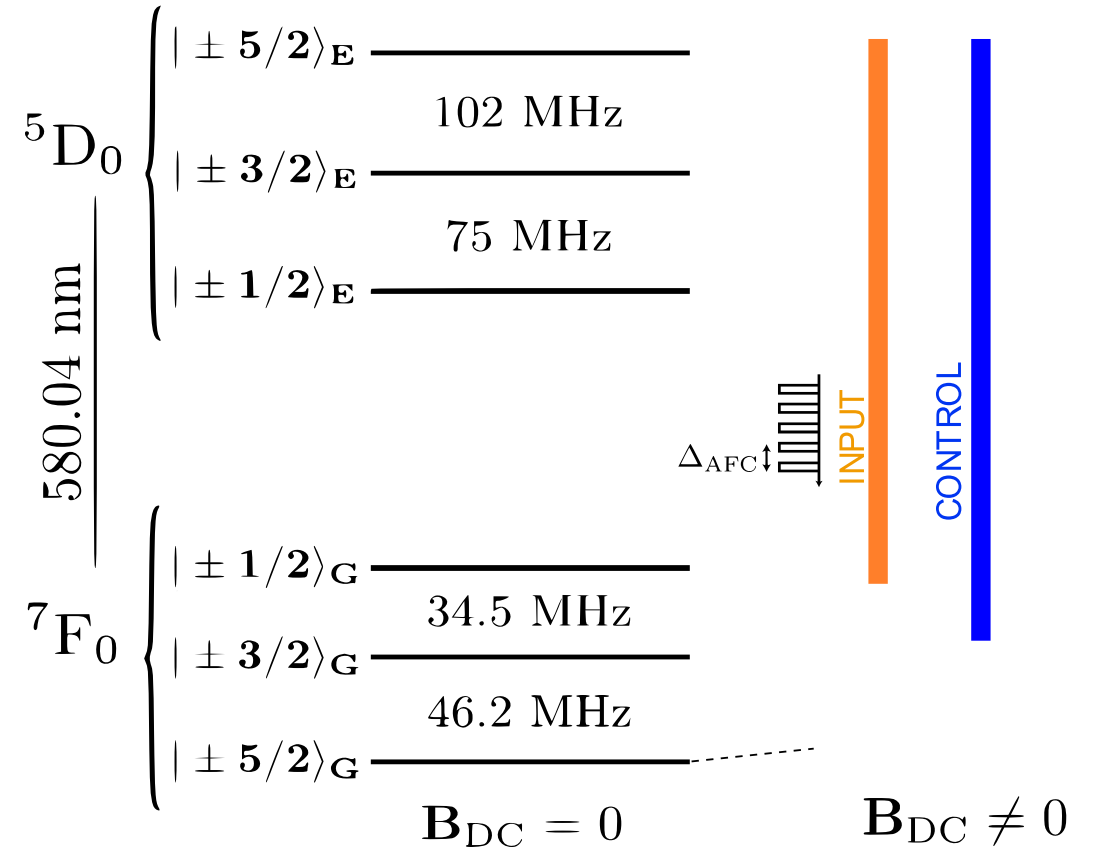
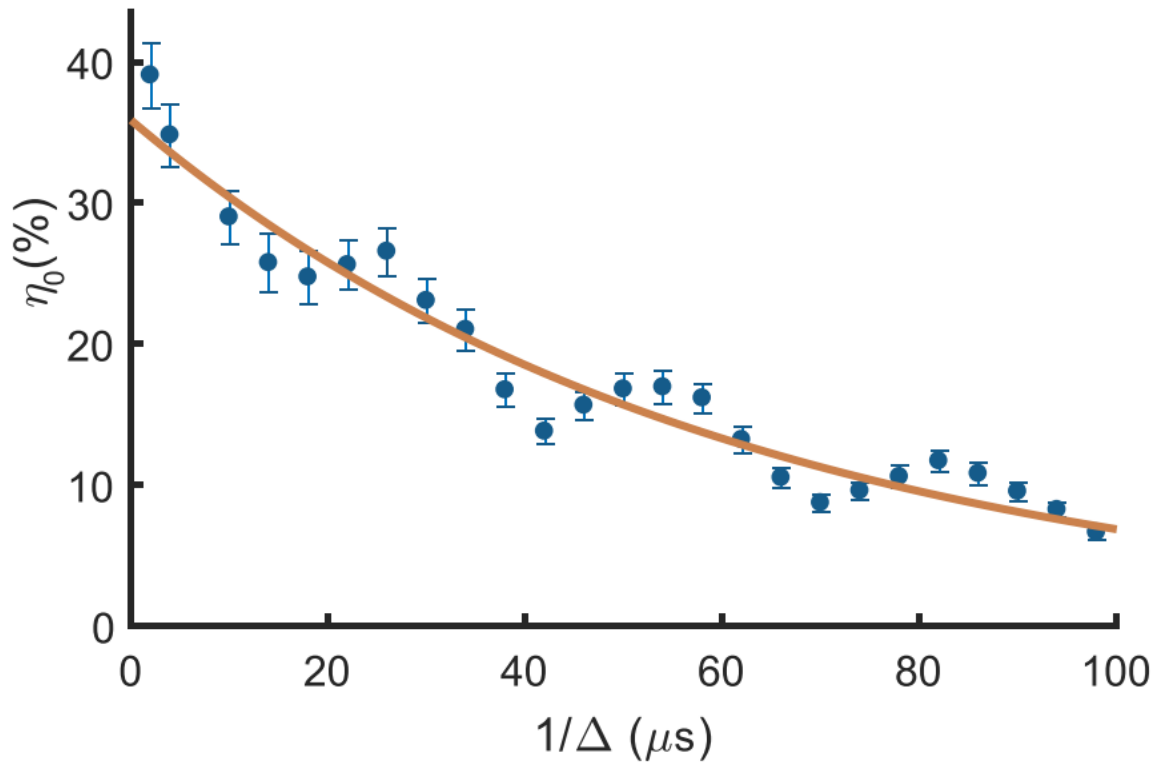
- Crystal is sandwiched by two permanent magnets to provide a magnetic field of $\sim 250\text{mT}$
- Customised crystal mount thermally and vibrationally isolated from other components

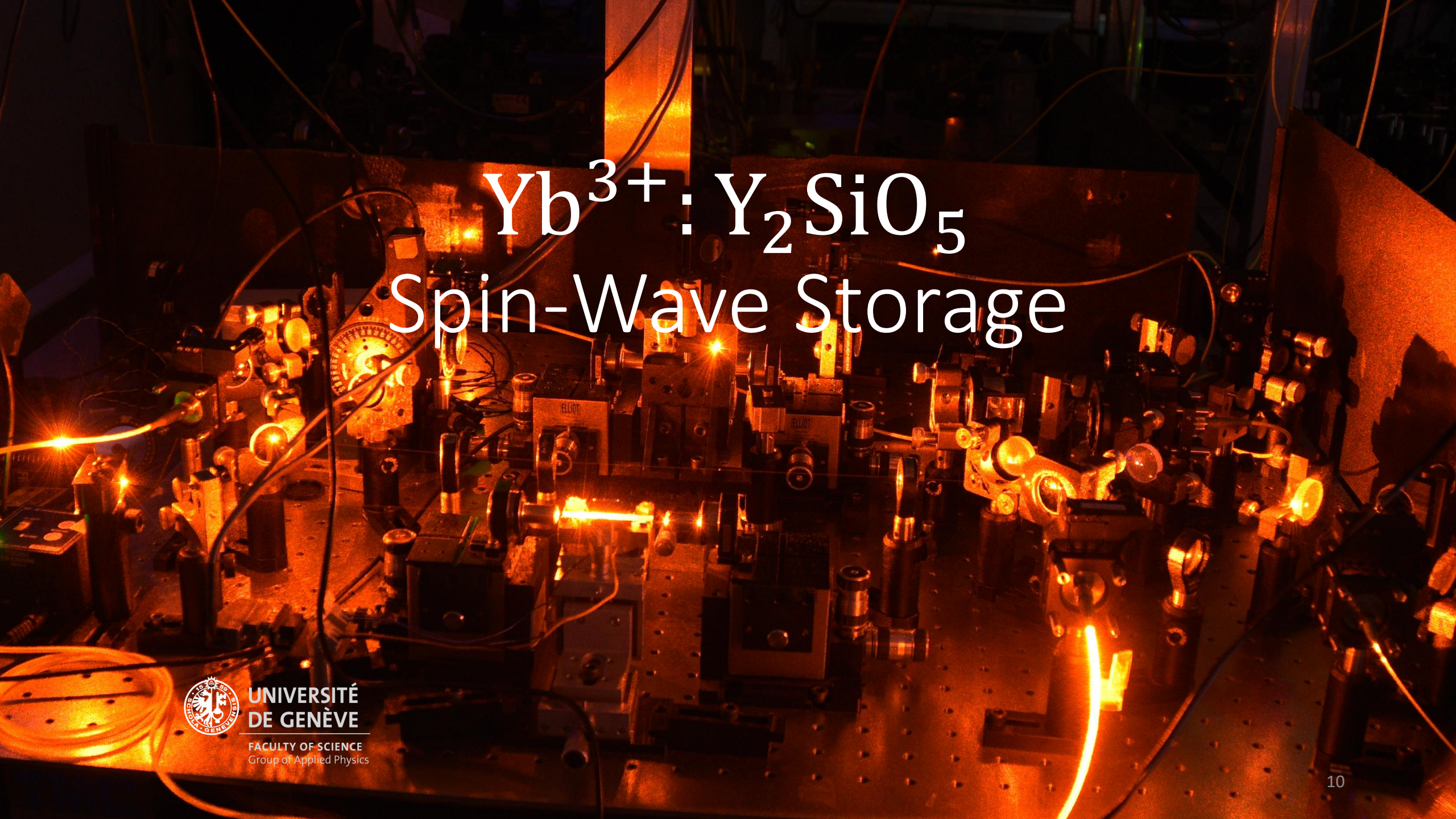


Custom crystal mount
RF coils
Permanent magnets
(NdFeB)

Vibration isolation
copper cushion

Eu³⁺: Y₂SiO₅ - Magnetic Field



A complex optical setup for spin-wave storage in Yb3+:Y2SiO5. The setup is mounted on a perforated metal plate and includes various optical components such as mirrors, lenses, prisms, and waveplates. A bright orange-red laser beam is visible, reflecting off several surfaces and passing through a central component. The background is dark, and the overall lighting is dominated by the warm glow of the laser light.

$\text{Yb}^{3+}:\text{Y}_2\text{SiO}_5$ Spin-Wave Storage



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$\text{Yb}^{3+}:\text{Y}_2\text{SiO}_5$ - Spin-Wave Storage

Remote distribution of non-classical correlations over 1250 modes between a telecom photon and a $^{171}\text{Yb}^{3+}:\text{Y}_2\text{SiO}_5$ crystal

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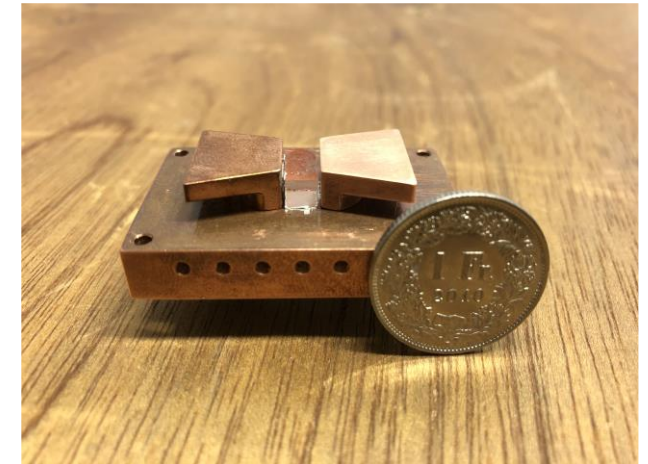
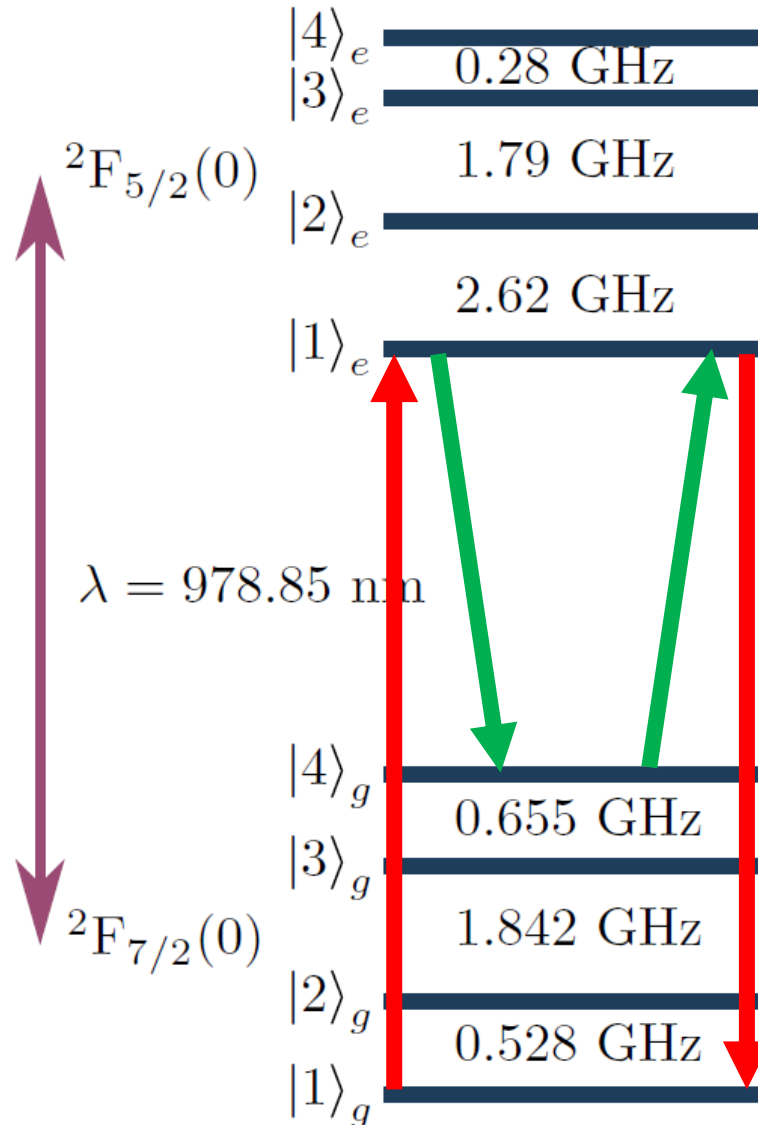
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Our number of modes is great, but we don't store them for nearly long enough!!!

Yb³⁺: Y₂SiO₅ - Spin-Wave Storage

	E//D ₂			
	1e	2e	3e	4e
1g	0.15	0.06	0.08	0.71
2g	0.06	0.19	0.71	0.04
3g	0.07	0.71	0.16	0.06
4g	0.72	0.04	0.05	0.19

	E//b			
	1e	2e	3e	4e
1g	0.54	0.19	0.03	0.24
2g	0.21	0.57	0.21	0.01
3g	0.01	0.18	0.66	0.15
4g	0.23	0.06	0.10	0.61



Microwave pulses can be added to even further increase the lifetime

Questions



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