**Note of REI list**

Quantum memories operate by reversibly mapping the quantum state of light onto the quantum transitions of a material system.

Due to a lack of a suitable storage material, a quantum memory that operates in the 1550 nm optical fiber communication band with a storage time greater than 1 us has not been demonstrated.

Developing such a (telecom) memory has proven very challenging. None of the proposed systems that operate directly in the low loss telecom band have the potential for long-term storage [4, 5]. For this reason, more complex ways of interfacing these candidate quantum memories with telecom are being investigated, including frequency conversion [6–9] or nondegenerate photon pairs.

REI in solids: The potential for developing practical memories in these systems has been highlighted through a series of recent demonstrations using non-Kramers ions (ions with an even number of electrons).

non-Kramers ions (ions with an even number of electrons): the electronic angular momenta of non-Kramers ions can be quenched by the crystal field for sites with sufficiently low symmetry. Therefore, these ions can exhibit the long ground-state hyperfine lifetimes necessary for efficient optical spin pumping and long hyperfine coherence times. Unfortunately for communication applications, none of the non-Kramers ions have suitable optical transitions in any of the fiber telecom bands.

Crystals doped with either praseodymium or europium have demonstrated storage on long lived spin states [15–17], multimode storage [15, 18], large efficiencies [19, 20] and hyperfine coherence times of 6 hours using the Zero First Order Zeeman (ZEFOZ) technique.

Compatibility with the telecom bands is offered by Kramers ions, with an odd number of electrons. In particular, erbium has an optical transition in the telecom band at 1538 nm. However, it is much more difficult to make quantum memories with Kramers ions, and not a single Kramers system has demonstrated an on-demand quantum memory. The root of the difficulty is that, unlike for non-Kramers ions, the electronic magnetic moment of Kramers ions cannot be quenched by a crystal field as they possess a half-integer spin. For these ions there is a rapid electronic spin relaxation which shortens the hyperfine state lifetimes. This is similar to the electron spin lifetime [23] and only an order of magnitude longer than the optical excited state lifetime, making efficient optical spin pumping very difficult.