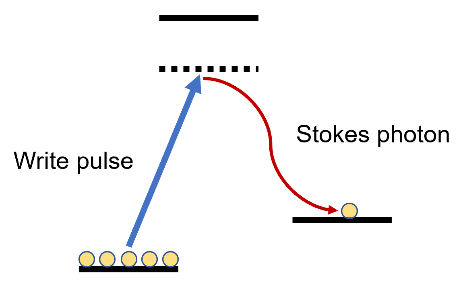
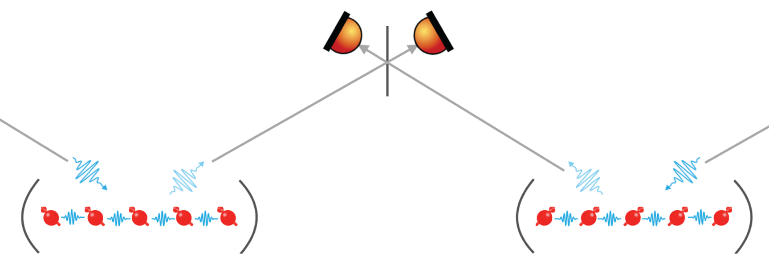
**On-chip quantum repeater nodes based on a coherent Er:Si spin-photon interface**

**Motivation**: Spins associated with defects in solids provide promising candidates for quantum-information science and quantum networks, among which the optical active ones are pursued extensively. The spin-dependent optical transitions coherently map between the quantum states of local spins and propagating photons, and their polarization selection rules form the basis for spin–photon entanglement1. Specifically, erbium (Er3+) and its coordinating oxygen complexes in Si links long spin coherence times and telecom optical transition at 1.54 μm to the advantage of the integrated-circuit and integrated photonics2 fabrication pedigree of silicon. With the evidence of required microwave and optical transitions from a PL-active Er center with orthorhombic symmetry3, we propose a quantum repeater scheme based on Er spin ensembles in silicon.

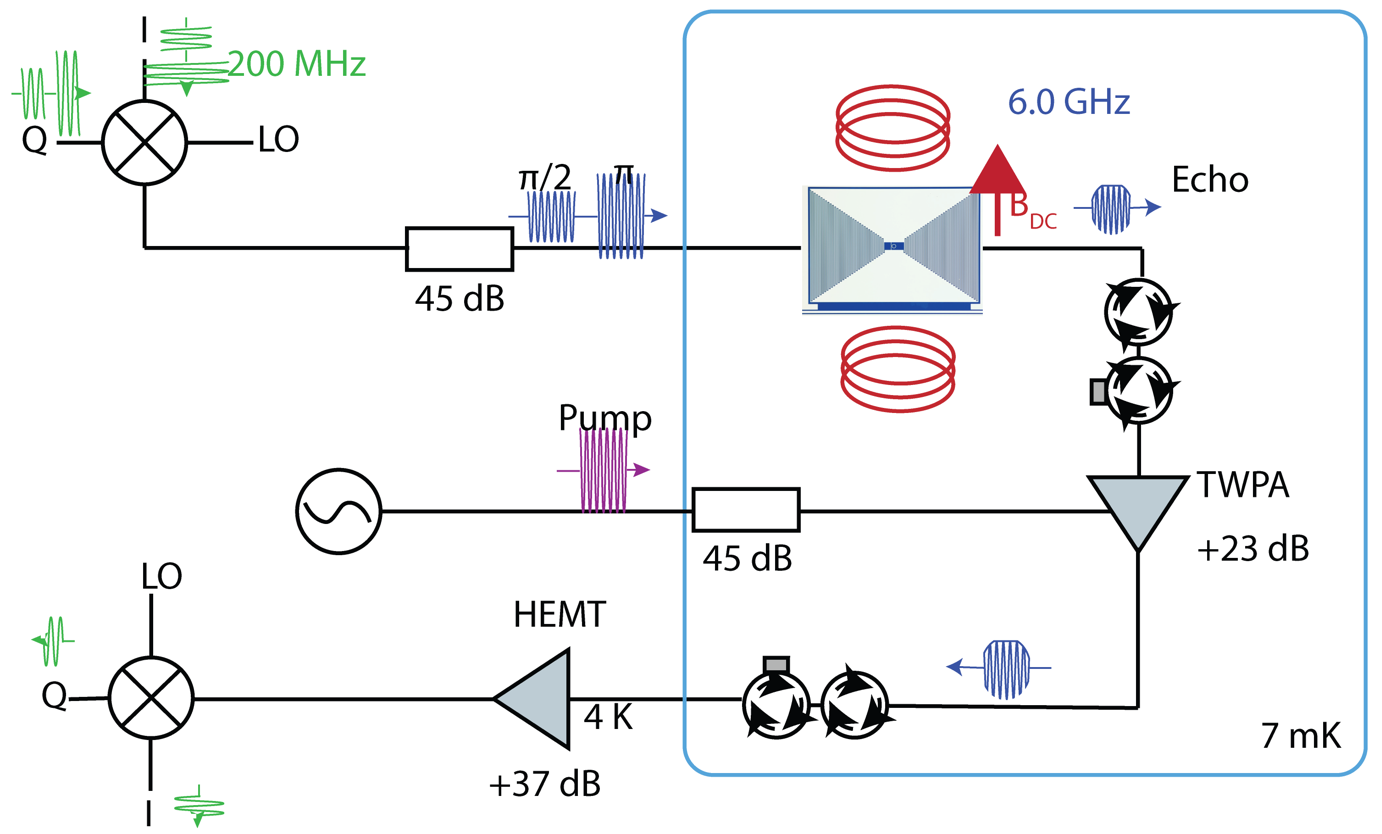
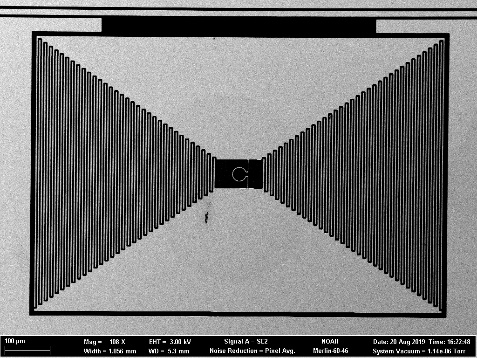
**Description**: As one of the most widely implemented schemes in various quantum repeater approaches, DLCZ protocol utilizes atomic ensembles and linear optics4. However, DLCZ-type photon sources do not offer much flexibility with the photon wavelength. On the demand of telecom photons for long-distance transmission in optical fibers and in the pursuit of telecom memories5, we consider cavity-enhanced photon pair source combined with absorptive quantum memories, and temporal multiplexing with inhomogeneously broadened rare earth ensembles in solids.

(Add legends later)

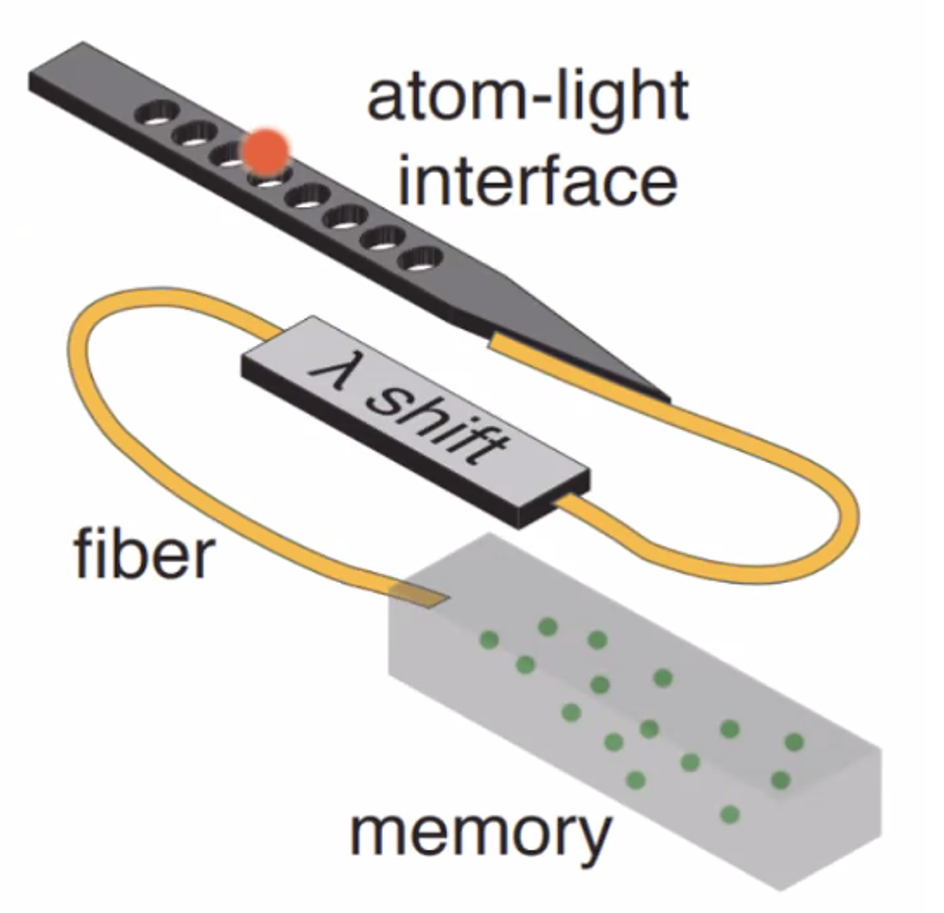
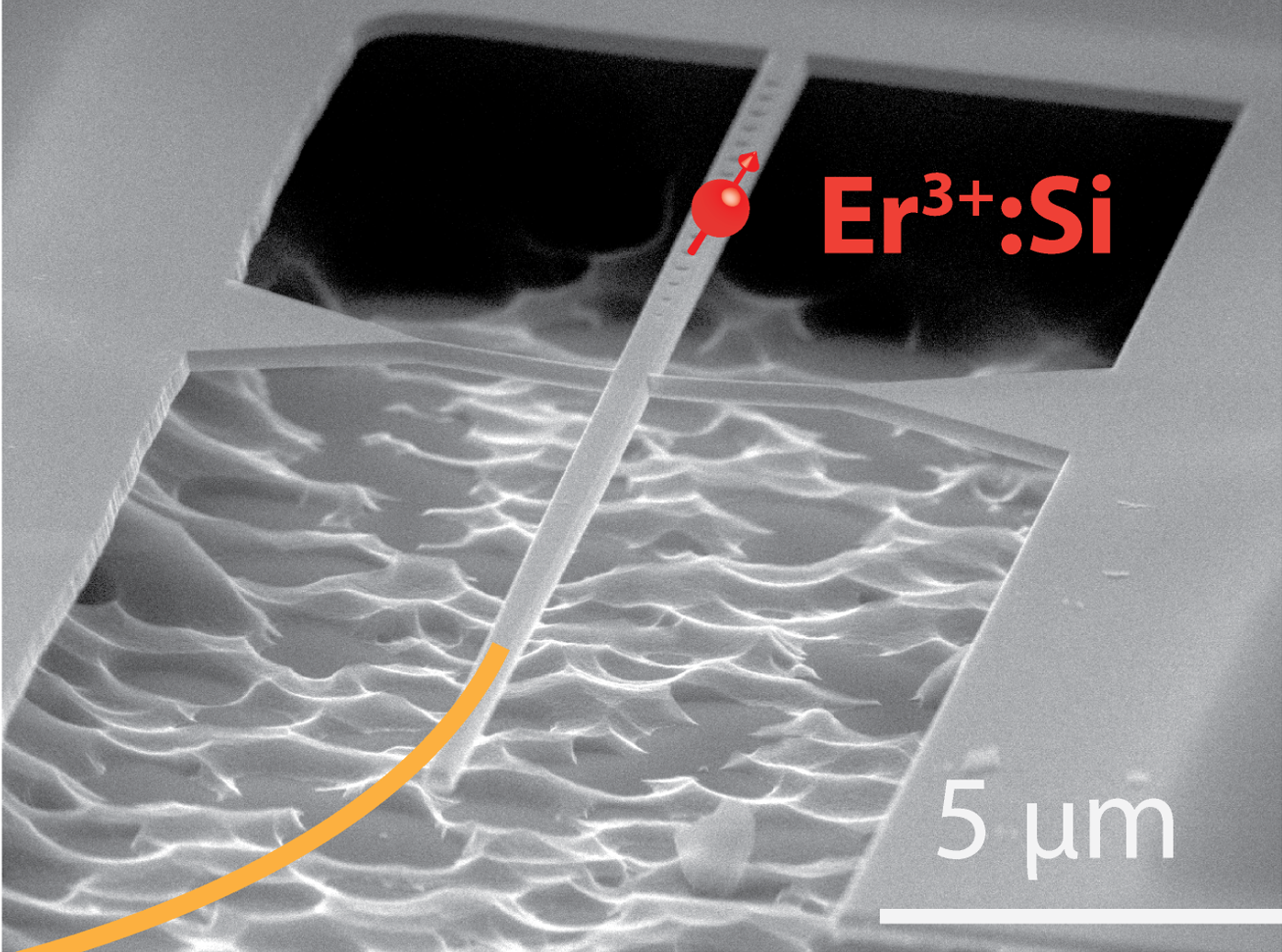
**Fig 1. Quantum repeater protocol**. Ensembles of Er and Er-O complexes in Si with Λ-type energy level configurations are simultaneously excited with a write pulse, leading to the emission of Stokes photons, and at the same time creating collective spin excitations in solids. Bell measurement of emitted photons heralds the storage of a single excitation and entanglement generation of distant quantum memories, which form the basis of long-distance entanglement distribution.

**Methods:** We build electron spin resonance (ESR) spectrometer operating at milli-Kelvin temperatures and apply Hahn echo sequence to study the spin properties of various material platforms6. Microwave is tailored in time domain and confined spatially within our superconducting resonator, coupling to spins. It is essential that we apply this technique to measure the EPR spectrum and spin coherence of Er in Si, to confirm the existence of a coherent spin-photon interface, and estimate its potential to function as a quantum memory for quantum repeater nodes using above protocol.

**Fig 2.** **ESR setup in Zhong Lab6**. Frequency-modulated, enveloped pulses are sent through the spectrometer and echo signal containing information of spins is dispersively readout; SEM image of 2D superconducting resonator, devised in a low-impedance manner for better magnetic field confinement.

Aiming at an integrated quantum repeater node, we are combining cavity-enhanced photon pair sources and quantum memory on a same chip. With theoretical proposal of photon pair sources based on inhomogeneous broadening of rare-earth doped solids7, which opens an avenue towards the heralded entanglement of remote ensembles, we will come up with our own theory concerning the write and readout schemes, and temporal/spacial multiplexing methods using our own photon pair sources. With the measured spin coherence properties on mind, we will also design our own photon-echo absorptive quantum memories using atomic frequency combs8 (AFC).

(Something like this, should draw my own picture later)

**Fig 3. Components of on-chip quantum repeater nodes8,9**. A silicon-on-insulator (SOI) nano-beam waveguide fabricated in Zhong Lab, which evanescently couples to a tapered fiber, confines light in the tiny structure, significantly enhancing the photon-matter coupling and the emission rate of emitters.

**Ancillas:** Coupling to adjacent nuclear spins might lead to decoherence and cause limitations in storage time of quantum memories, should study the properties of this kind of noise sources and design protocols to alleviate their diminishing of coherence, or directly utilize the coherence properties of nuclear spins as quantum memories.

The on-chip nature of Er:Si platform gives us the chance to combine photonic devices with microwave manipulations. By patterning superconducting resonator sharing a same region of mode volume with photonic cavities, we gain more manipulation modalities and functionalities.

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