Enhancement of microwave to optical spin-based quantum transduction via a magnon mode

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The highly localized 4f electrons of rare-earth-doped materials provide a simple atom-like level structure with a spin-photon interface, telecom-wavelength optical transitions, potential for long spin and optical coherence times, and the ability to realize high-density doping. Proposals for microwave to optical quantum transduction using rare-earth ions[PRL113,203601(2014)] rely on spin-flip transitions from microwaves that couple to optical inter-4f transitions. An example is the Er^{3+} ion's transition $|J=15/2\rangle$ to $|J=13/2\rangle$ at telecom wavelength. The oscillator strengths ($\boldsymbol{g_b}$) of the microwave excitations of the Er^{3+} are particularly weak leading to poor transduction efficiencies. We describe an approach to dramatically enhance the microwave coupling without diminishing the optical oscillator strength ($\boldsymbol{g_a}$) for Er^{3+} ions. The microwave excitation is coupled to a magnon ($\boldsymbol{g_m}$) of a magnetic material, e.g., yttrium iron garnet (YIG). The Er^{3+} ions are embedded in an insulator and live close to the interface with the magnet. The iron lattice of the YIG will strongly couple to the Er^{3+}. We predict that the microwave-magnon coupling allows higher transduction rates that dramatically exceeds the previous set up.

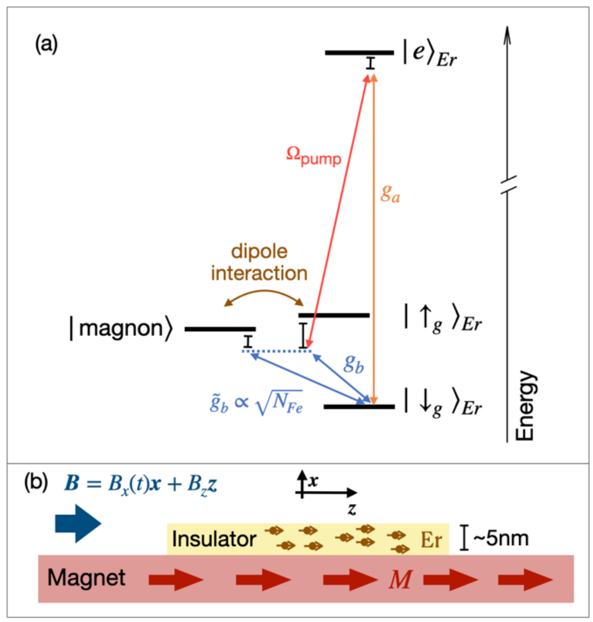

Figure 1. (a) Erbium level structure and its dipole interaction with a magnon mode. Coupling strengths are indicated next to optical ($\boldsymbol{g_a}, \boldsymbol{\Omega_{pump}}$) and microwave transitions ($\boldsymbol{g_b}, \boldsymbol{g_m}$). (b) Erbium ions implanted in an insulator that shares interface with a magnet. The microwave excitation $\boldsymbol{B_x(t)}$ drives the magnon mode that induces erbium spin transitions.

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