Optical Coupling between Er^{3+} and Integrated Microring Resonators on Si

NTT Basic Research Labs.[1], Univ. of Otago[2], NTT Device Tech. Labs.[3],

Nihon Univ.[4], Yamato Univ.[5]

°(D)Masaya Hiraishi[1,2], Tomohiro Inaba[1], Xuejun Xu[1†], Haruki Sanada[1], Tai Tsuchizawa[3],

Atsushi Ishizawa[1], Takehiko Tawara[4], Hiroo Omi[5], Jevon Longdell[2], Katsuya Oguri[1], Hideki Gotoh[1],

[†]E-mail: xuejun.xu.xe@hco.ntt.co.jp

Optical coupling between atoms (ions) and a resonator has gained great interest in both classical and quantum applications. Among these atoms and ions, erbium ions (Er^{3+}) in solids are a promising candidate for laser-amplifiers and quantum memories. This is owing to its long coherence times and optical transitions within the telecommunication C-band, where optical fiber-based network allows for low-loss communication. The optical coupling of Er^{3+} ions with a resonator has been investigated mainly in bulk materials so far [1]. They are not suitable for on-chip devices, favored in fabrication process compatibility with Si-based technology. From this point of view, we have been developing SiN/$(ErGd)_2O_3$/Si strip-loaded waveguide with ultra-low loss of 4.7 dB/cm based on epitaxially grown single-crystal $(ErGd)_2O_3$ thin film on Si [2]. Here, we newly developed high Q-factor microring resonators based on this waveguide, and confirmed the optical coupling between Er^{3+} ions and the resonator at cryogenic temperature.

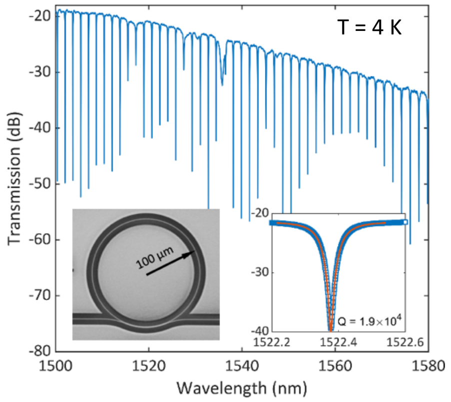

Fig. 1 Transmission spectrum of the waveguide-coupled resonator measured at T = 4 K. The insets are SEM image of the device and one of the resonances around 1522 nm with its Lorentz fitting curve.

Figure 1 shows a transmission spectrum of a waveguide-coupled microring resonator. Periodical dips indicate the resonator modes with about 2-nm free spectral range. A fit to one of the modes gives the quality factor Q ~1.9 $\times 10^4$. To confirm the coupling of Er^{3+} ions to microring resonant modes in both aspects of absorption and emission, we performed photoluminescence (PL) and photoluminescence excitation (PLE) measurements.

For PLE measurement, wavelength of the excitation laser was scanned in a range near an upper transition levels of the excited state ($^4I_{13/2}$) of Er^{3+} ions and PL spectra around lowest transition levels were recorded. The PLE spectrum in Fig. 2 shows periodic resonant peaks with same wavelengths in the transmission spectrum, indicating resonant absorption of excitation laser by Er^{3+} ions coupled with the resonator. The PL spectrum in Fig. 2 was recorded when the excitation laser was tuned to one of the resonant modes. Periodic resonant PL peaks were also clearly observed, indicating that light emission of Er^{3+} ions was also coupled to resonant modes.

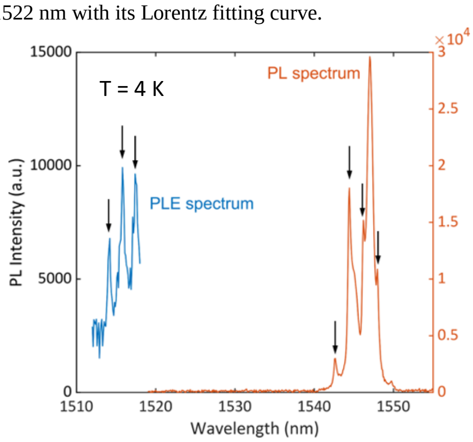

Fig. 2. PL and PLE spectra of the resonator measured at T = 4 K. Arrows indicate the resonator modes.

Our results represent an important step towards realization of rare-earth ion based classical and quantum photonic devices by using resonant-enhanced light-matter interactions.

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References:

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