

## Design of a tunable optical resonator to enhance the single-photon emission of rare-earth ions

In the future, quantum networks could change the way we communicate, run apps in the cloud, and help scientific tools and sensors. In such networks, distant qubits can be connected via entanglement generation using single photons.

Individual rare-earth ions (REIs) doped in host crystals are suitable qubits for these networks as they offer a qubit-photon interface. While REIs exhibit very coherent optical transitions, their single-photon emission is weak. In the last few years, several research groups have demonstrated enhancement of the photon emission rate using the Purcell effect by coupling single ions to optical resonators (Fig 1a) [1], [2]. For successful Purcell enhancement, the resonator's frequency needs to match the REI transition frequency. However, the exact resonance frequency of fabricated devices varies on the order of a few nanometers. Therefore, post-fabrication tuning methods are required. Current techniques (for example gas tuning) are difficult to scale up, especially when there are more resonators on the chip.

Lithium Niobate on Insulator (LNOI) offers an alternative solution. This integrated photonics platform has a unique property: LN experiences a large electro-optic effect. This means that the refractive index of the material can be changed by applying an electric field, enabling in-situ and rapid tuning of the resonators' frequency, see Fig 1b, which can be designed in different crystal orientation cuts (X-cut [3],[4],[5] and Z-cut [6], [7]).

In this joint project offered by the Rajabali and Hermans Lab, you will study the feasibility of such a hybrid device by modeling different designs, where an LNOI resonator is evanescently coupled to REIs in a host crystal (Fig 1c).

To study the feasibility of such devices, we need to answer several questions:

- What is the tuning range of the resonance frequency (in pm/V or MHz/V)?
- What is the coupling between the evanescent light field to the REI?
- What is the expected Purcell enhancement of the optical transition?
- How to increase the tuning range by photonic engineering?
- How do fabrication uncertainties affect our design tolerance?

Are you a QIST, Applied Physics, or Electrical Engineer student and looking for an MSc thesis project? Are you up for a challenging project? Do you want to learn more about quantum optics and nanophotonics? Do you want to be part of not just one but two research groups? If so, reach out to Shima Rajabali ([S.Rajabali@tudelft.nl](mailto:S.Rajabali@tudelft.nl)) and/or Sophie Hermans ([S.L.N.Hermans@tudelft.nl](mailto:S.L.N.Hermans@tudelft.nl)).

### Literature

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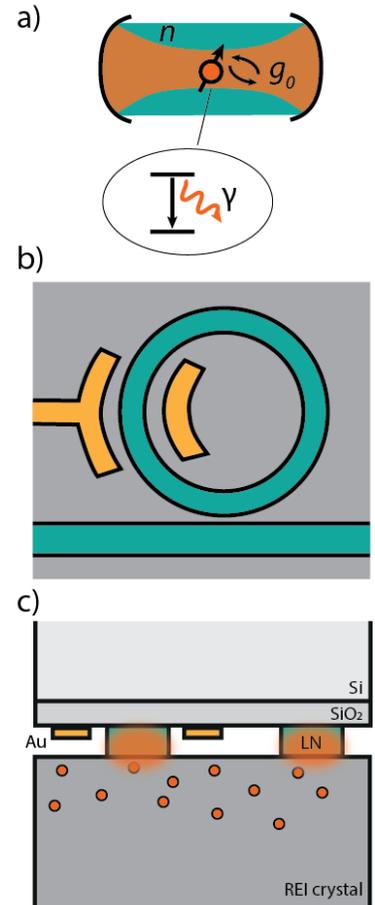


Fig 1 – a) Schematic of an optically active qubit coupled to a resonator. b-c) Example of a tunable LNOI resonator (top view in b), and side view in c)).