Photonic microsystem made by dynamic micro-assembly

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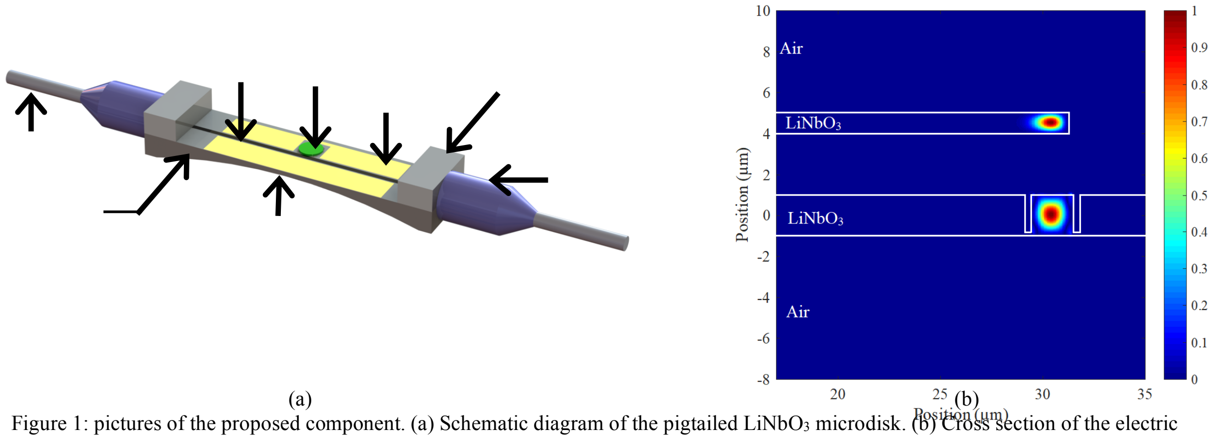
Abstract: We report on the production of hybrid photonic microsystem made by the dynamic structuration and assembly of photonic building blocks in F.I.B. (Focused Ion Beam) environment. More particularly, we show how to produce a low-loss integrated $LiNbO_3$ resonator composed of a free-suspended microguide and a microdisk, which shows great potential for electro-optic sensors or comb generators. The method opens the way toward new 3D electro-optical or mechanical hybrid photonic micro and nanosystems.

1. Introduction

While photonics is emerging as an attractive alternative to electronics in high-bit-rate telecommunication systems, sensors or signal processing devices, there is a need of specific 3D photonic architectures that cannot be easily engineered by clean-room processes. As an example there is a great interest in developing lithium niobate ($LiNbO_3$) integrated microresonators for applications as varied as integrated gyrometers, sensors, spectrometers, dynamic filters or modulators. However, the low-loss integration of $LiNbO_3$ micrometer scale resonators with an input/output waveguide is still a critical issue. A tapered fiber coupled with a microdisk [1] is too fragile to be envisioned as a commercial solution. The monolithic integration, where both the waveguide and the microresonator are produced on the same wafer by clean room processes, can lead to high quality factors ($> 10^5$) and low propagation losses (< 1 dB/cm) [2-5], but the insertion losses are usually higher than 10 dB due to the large mode mismatch between the fibers and the confined microguides. Here we propose to reduce significantly the coupling losses by dynamically structuring and assembling a pigtailed low-loss microguide [6] and a $LiNbO_3$ microdisk. The proposed method can advantageously be extrapolated to 3D electro-optical or mechanical photonic microsystems.

2. Model, fabrication and preliminary results

The proposed hybrid microsystem is depicted in Fig. 1(a). It is made of a locally thinned $LiNbO_3$ waveguide coupled with a microdisk. In the free-standing-section, the waveguide has a thickness of 2 µm. The waveguide is surrounded by electrodes allowing an electro-optic control of the operating point. A local etching is performed on both sides of the waveguide to confine the light laterally (see bottom of Fig. 1(b)), while measuring simultaneously the optical transmission. This approach allows to preserve low insertion losses, and to prepare a strong coupling with a photonic element placed at te top of the ridge. A microdisk is fabricated separately and is assembled dynamically at the waveguide top. Hence, the insertion losses and the microdisk coupling are optimized separately.



(a) (b)

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Figure 1: pictures of the proposed component. (a) Schematic diagram of the pigtailed $LiNbO_3$ microdisk. (b) Cross section of the electric fields in the disk (top) and in the suspended ridge (bottom). The calcultation are performed by finite element method (F.E.M.), COMSOL®.

F.E.M. based numeric calculations were performed for different photonic architectures. An overview of the

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calculated modes is seen in Fig. 1(b) for a 2 µm-thick waveguide and a 1 µm-thick microdisk. Noteworthy, a ridge configuration (see Fig. 1(b)) increases the coupling efficiency. Calculations also show that the coupling is optimal when the disk is positioned at the waveguide top.

Firstly, the microguide was fabricated through standard techniques (lithography, Ti-diffusion, deposition of electrodes), and then the substrate was locally thinned down to 2 µm by precise dicing as described in [6]. The tapers were obtained by lifting the blade before the end of the waveguide. The free-suspended waveguide was pigtailed to two SMF28 fibers, as represented in Fig. 1(a). The measured propagation losses are of 0.2 dB/cm for both propagating polarization, and the insertion losses are lower than 3 dB. Noteworthy, a high index UV-adhesive was used for pigtailing, so as to limit the Fabry-Perot effect between the input and output of the waveguide.

The micodisk was produced through precise dicing followed by Focused Ion Beam (FIB) milling, as seen in Fig. 2.

Finally, the pigtailed waveguide and the microdisk were assembled in the FIB environment. A lateral etching was performed on both sides of the waveguide by FIB milling, leading to a local ridge surrounded with tapers in the suspended section. A microgriper was used to grip the disk and to place it accurately at the top of the waveguide. The precise assembly can be optimized by measuring the transmitted response through the guide simultaneously with the positioning. This method has been validated for 1 µm to 4 µm-thick midrodisks, with diameters ranging from 50 µm to 300 µm. Preliminary results show a quality factor of 3887.

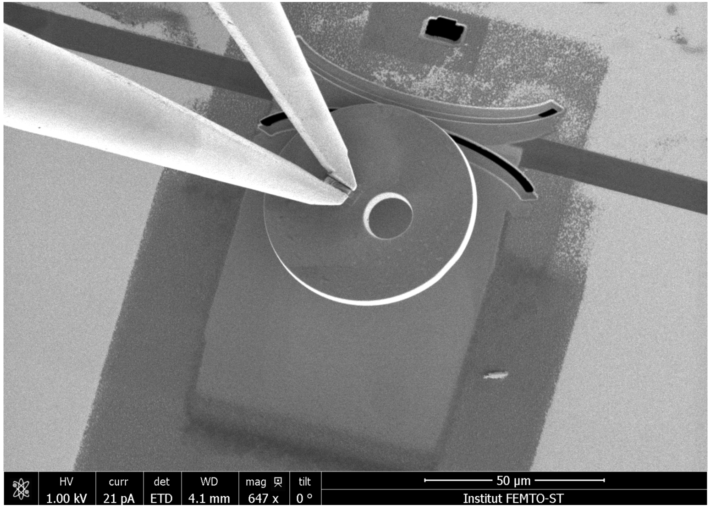

Figure 2: SEM image of a microdisk in a membrane before being micromanipulated with a needle.

3. Conclusion

We propose a micromanipulation-based technique to produce low-loss 3D photonic microsystems. In particular, a low-loss integrated $LiNbO_3$ microresonator is demonstrated, opening the way toward new 3D photonic architecture with dynamically optimized photonic responses.

4. References

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