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Waveguide coupled high-Q micro-optical resonators

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For practical applications, in order to fully exploit the unique properties of Whispering Gallery Mode (WGM) micro-optical resonators, a critical point is an efficient and robust coupling of the light to the cavity [1,2]. We present the results of our studies on coupling methods based on integrated waveguides, with particular reference to the case of crystalline waveguides ($LiNbO_3$) and polymeric waveguides (SU8 photoresist). In both cases the WGM resonators were made of the same material of the waveguides and Fig. 1 shows pictures of the two systems with a $LiNbO_3$ disk (Fig. 1a), and a SU8 bottle resonator (Fig. 1b).

After the first demonstration of waveguide based coupling obtained by using an ion-exchanged waveguide (fabricated in BK7 glass and coupled to a BK7 microsphere [3]), we have been working on this type of approach mainly for two different applications, RF photonics and biosensing. In the first case, in order to develop innovative optoelectronic oscillators we have fabricated high-Q $LiNbO_3$ disk resonators of few millimeters in diameter. Aiming to achieve improved device compactness and robustness we have implemented coupling from fiber pigtailed $LiNbO_3$ waveguides, successfully developing a system which is all in guided optics architecture [4]. The waveguides are made by Ti:diffusion in X-cut lithium niobate substrates while the high-Q disks are made from commercial Z-cut lithium niobate wafers by polishing the edges into a spheroidal profile. An example of high-Q resonances in excess of 10^8 around 1550 nm is shown in Fig. 2a.

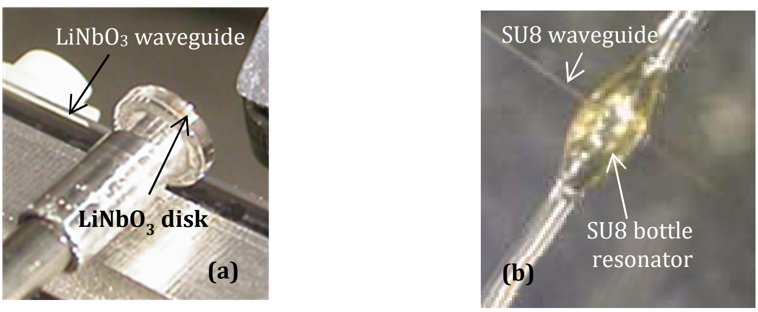

Fig. 5. Photo of a $LiNbO_3$ disk coupled to a Ti:diffused $LiNbO_3$ waveguide (a), and of a SU8 bottle resonator coupled to a ridge SU8 polymer waveguide made on PMMA substrates (b).

The experience developed using WGM resonators as micro-optical transducer for biosensing suggested us that a polymer based integrated platform could be an ideal approach for such application. We have recently implemented and optimized a simple, self-assemble process to fabricate bottle micro-resonators in SU-8 polymer [5]. The method is based on dispensing a droplet of SU-8 polymer photoresist on a fiber stem by a syringe pump followed by an UV curing step. In order to excite the WGMs in the microbottle resonators, we fabricated single mode SU-8 ridge waveguides by SU-8 spin coating on a PMMA substrates followed by a standard photolithograpic process. The waveguides were designed and fabricated 3 µm wide × 2 µm thick in order to be single mode at 1550 nm. The development of this solid, fully polymeric platform based on integrated waveguide is essential for implementing a convenient and reliable WGM-based sensing device (which could be critical to implement with standard silica fiber taper based couplers because of their inherent instability and mechanical fragility). The measured Q factors were in excess of 10^4 (see spectrum of Fig. 2b), which represents the basic limit due to material absorption.

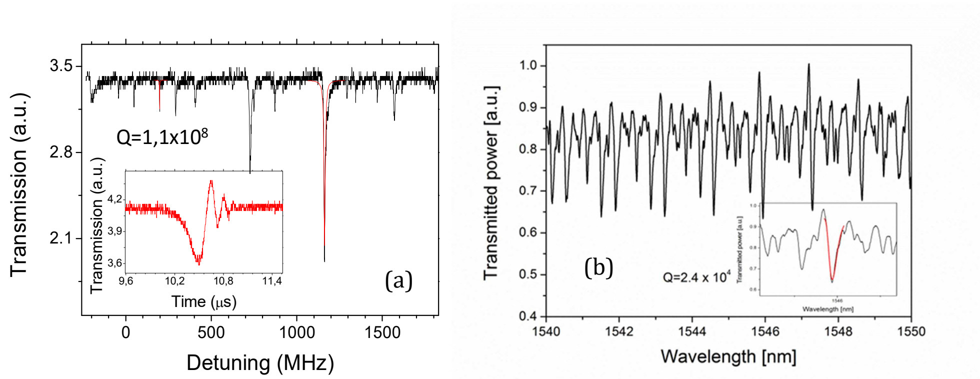

Fig. 2. WGMs spectra around 1550 nm of a waveguide coupled high-Q $LiNbO_3$ disk (with a resonance ringdown measurement in the inset) (a) and of a SU8 bottle resonator (with a magnified resonance in the inset) (b).

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