Integrated high Q optical cavity on a low loss Si suspended waveguide for THz application

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***Abstract*: A free standing silicon waveguide with very low losses at THz frequencies is presented. By dry etching of an SOI wafer, the guiding channel is formed. This process allows to have a fully suspended Si (silicon) waveguide, where the air form it cladding. The absence of material as a cladding leads to have ultra-low losses. Another achievement of this work is also presented, where this guiding channel is etched in a way to form a high Q optical cavity.**

THz waves are used recently in many applications, and shows many interest in different domain as molecular spectroscopy, high data transmission, detection of organic molecules in space… But the integration of THz circuits for such applications is still a challenging point. In this work we demonstrate a new silicon millimetric waveguide to guide THz waves on chip, with very low propagation losses. As a complement to this achievement we show also a high Q optical cavity, formed by circular etching on the top of this waveguide.

The designed Si waveguide allows confined propagation of electromagnetic waves at THz frequencies starting from 500 GHz. A Si channel of 210µm in width and a thickness of 90µm form the core. The cladding material is absent in this design and replaced by the surrounded air in order to reduce the material losses. A highly confined fundamental optical mode represented in the insert of figure 1 is the result of this high index-contrast $n_{high\text{-}Res\ Si}/n_{air}$. The technique used here to fabricate this waveguide, consist of double face etching of an SOI (silicon-on-insulator) wafer with deep-reactive ion etching. The advantage of this technique, in contrast to previous reported ones[1], is that there is no necessity to have any other lossy material as Pyrex or glass to form the substrate. To experimentally test this waveguide, a free space S parameter measurements are done and extracted with a VNA (vector network analyzer). In order to excite the electric fundamental mode of the Si waveguide, metallic waveguide ports of the test setup are rotated by 90°. The two ends of the designed structure are adiabatically tapered, in order to reduce impedance mismatch between metallic waveguide and silicon waveguide, for an efficient smooth coupling.

An additional right angle (bending radius 3 mm) was included to the waveguide (see figure 1), helps to avoid direct coupling between transmitter and receiver ports.

Modal propagation losses are extracted by, transmission measurements on 5 waveguides of increasing length (3.87, 10.9, 14.9, 19.1 and 25.1 cm). Having a linear variation of the S_{21} parameter as a function of length, allows to extract the slope corresponding to the attenuation constant[2] (see Fig.2). An average of 0.7 dB/cm over the entire band is extracted which is at least 2 times better than the best demonstrated waveguides in this band up till now[3].

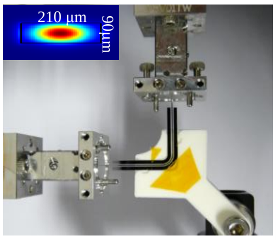

Fig. 1 Suspended Si waveguide on the VNA measurement setup; insert: fundamental electric mode

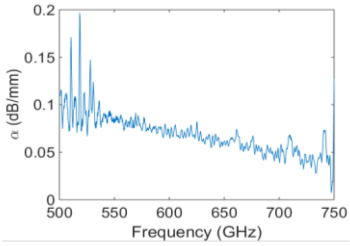

Fig. 2 Attenuation constant extracted from S parameter

Having demonstrated the potential of this very low loss waveguide, we benefited from this achievement to create a 1D photonic crystal cavity on the top of this waveguide (see Fig. 3), by making periodical circular etching in the core of the waveguide. Creating a defect in the etching periodicity allow us to create an optical cavity where the light is confined mostly in air at a predefined frequency.

3 different optical cavities with different etching radius size, are fabricated and measured. By increasing the etching radius of the photonic crystal, resonance frequency shifts toward highest frequencies.

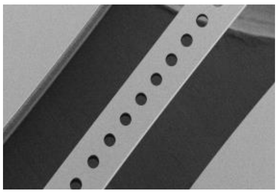

Fig. 3 Microscopic image of the photonic crystal

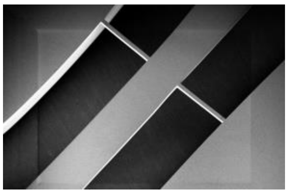

Fig. 4 Microscopic image of the suspended waveguide

Further results on this confined inline THz PhC cavities for sensing purposes will be shown. In conclusion, this demonstrated ultra-low-loss chipscale integrated THz photonic platform is a new tool integrated Thz spectroscopy with increased light-matter interation.

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