

# Design of Fabry-Perot grating cavity based on Ge-rich graded SiGe waveguide for Mid-IR

Qiankun Liu<sup>1\*</sup>, Joan Mane Ramírez<sup>1</sup>, Vladyslav Vakarin<sup>1</sup>, Diego Perez-Galacho<sup>1</sup>, Carlos Alonso-Ramos<sup>1</sup>, Daniel Benedikovic<sup>1</sup>, Jacopo Frigerio<sup>2</sup>, Andrea Ballabio<sup>2</sup>, Giovanni Isella<sup>2</sup>, Laurent Vivien<sup>1</sup>, Delphine Marris-Morini<sup>1</sup>

<sup>1</sup> *Centre de Nanosciences et de Nanotechnologies, CNRS*

<sup>2</sup> *L-NESS, Dipartimento di Fisica, Politecnico di Milano*

\*correspondance to : qiankun.liu@u-psud.fr

In recent years, a large variety of reported works on silicon photonics related topics have shown the attraction of this platform, which is providing high performance, low cost, low power consumption and high reliability, as a promising alternative to enable the integration of passive and active components at chip scale. However, most of them only focus on a narrow window of operation wavelengths that spans from the visible range up to near infrared, typically up to the telecom wavelength 1.55  $\mu\text{m}$ . Currently, some research groups have proposed the use of silicon photonics not only for the visible-telecom range, but also at longer wavelengths located within the mid-IR window [1]. The strong molecular absorption experienced by several relevant chemical and biological substances [2, 3] is providing strong motivation to the development of new chip-scale integrated mid-IR sensors.

Moreover, Si and Ge offer an extended transparency window up to 8  $\mu\text{m}$  and 14  $\mu\text{m}$  respectively, which enables the design of new mid-IR devices in a broadband wavelength range. At the meanwhile, some recent works have proven the benefits of using  $\text{Si}_{1-x}\text{Ge}_x$  alloy as an attractive platform to realize active and passive mid-IR devices [4, 5]. However, in order to demonstrate the full potential of this platform some keys structures still need to be developed, such as resonant structures, which will be crucial when targeting devices for sensing applications and for the study of non-linear properties where strong light-matter interaction is desired for both. In that line, ring resonators entail strong challenges from a design view point taking into account the weak mode confinement in these structures. Alternatively a Fabry-Perot cavity using Bragg grating mirrors based on waveguide might be a promising option to develop mid-IR SiGe cavities with high performance. Therefore, in this work we design Bragg grating in graded  $\text{Si}_{1-x}\text{Ge}_x$  waveguides and evaluate the performances of integrated cavities at 7.3  $\mu\text{m}$  wavelength.

The waveguide design is based on a 6  $\mu\text{m}$ -thick graded  $\text{Si}_{1-x}\text{Ge}_x$  layer that departs from Si and increases its Ge concentration up to pure Ge. The rib height is 4  $\mu\text{m}$  and the width is 5  $\mu\text{m}$  as illustrated in Fig 1.b. The Bragg grating is obtained by patterning the top of the waveguide as illustrated in Fig 1.a. In order to avoid the leakage into substrate, a maximum etching depth of 400 nm is obtained. With 250  $\mu\text{m}$  grating length, the reflectivity per mirror up to 93% is obtained, within a 50 nm spectral bandwidth. The transmission of a 600  $\mu\text{m}$ -long cavity using these mirrors is plotted in Fig 1.c. The simulated Q-factor is around 7100. Furthermore, a double-period Bragg grating has also been designed to broaden the operation bandwidth of the device, providing an increase of the spectral bandwidth from 50 nm (single-period Bragg mirror) to 130 nm (double-period Bragg mirror). These cavities may be a fundamental building block for resonant structures targeting mid-IR integrated devices for sensing applications.