Enhanced dynamic properties of Ge-on-Si mode-evolution waveguide photodetectors

A. Palmieri*, A. Shafiee*, M. G. C. Alasio*, A. Tibaldi*†, G. Ghione*, F. Bertazzi*†, M. Goano*†, M. Vallone*
* Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, corso Duca degli Abruzzi 24, 10129 Torino, Italy
† IEIIT-CNR, corso Duca degli Abruzzi 24, 10129 Torino, Italy
E-mail: michele.goano@polito.it

***Abstract*—This work discusses coupled three-dimensional electromagnetic and electrical simulations of a Ge-on-Si waveguide photodetector where light is fed through a lateral waveguide. The numerical results show that this coupling solution leads to more uniform photon and carrier distributions along the Ge absorber compared to a conventional butt-coupled detector, allowing a broader electrooptical bandwidth for high input power levels in good agreement with available experimental measurements.**

I. Introduction

The computer-aided design and optimization of next-generation Ge-on-Si waveguide photodetectors (WPDs) for silicon photonics [1] requires a three-dimensional multiphysics picture describing the interplay between optical field propagation and transport of photogenerated carriers. Evanescent coupling of light in the Ge absorber by means of a lateral waveguide (mode-evolution coupling, MEC) has been proposed as a promising alternative to conventional butt-coupled (BC) WPD structures to minimize the impact of screening effects related to high-carrier injection [2]. This work presents a comparative simulation study of the BC and MEC WPDs proposed in [2], demonstrating the ability of a multiphysics approach to reproduce the broader electrooptical bandwidth at high optical power levels allowed by the MEC solution.

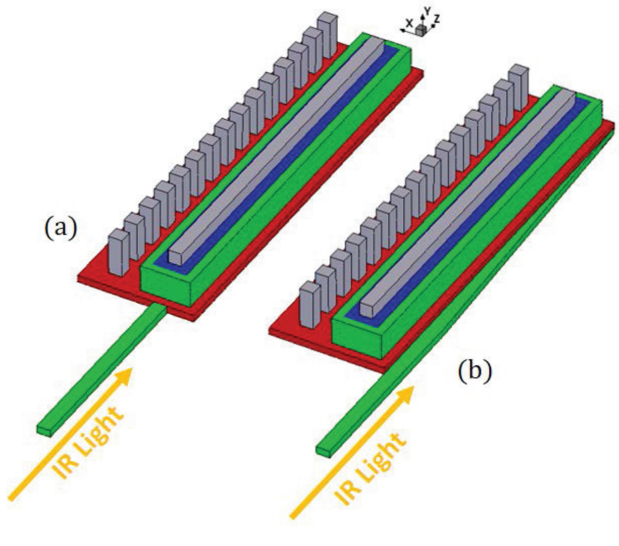

Fig. 1. Perspective view of a BC (a) and MEC (b) detector.

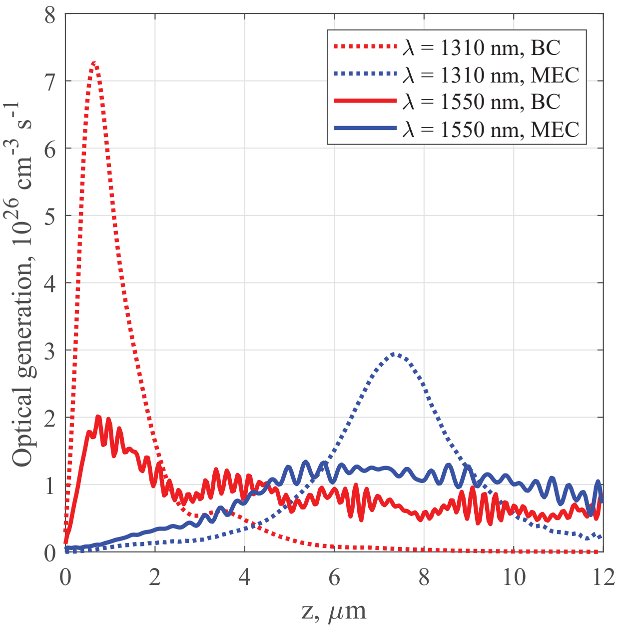

Fig. 2. Optical generation rate in Ge averaged over the WPD cross-section as a function of z, for the BC and the MEC detector.

II. Photodetector structure and modeling approach

Fig. 1 shows the photodetector structures proposed in [2]: on top of a SiO_2 substrate, an intrinsic Ge region 800 nm thick and 12 μm long lies over a thin Si base; both metallic contacts are in tungsten. In the simulated structures a steep, error-function-shaped p-doping profile with peak $N_A = 10^{19}\,\mathrm{cm}^{-3}$ is assumed at the W/Ge interface, and the Si base has a uniform n-type doping $N_D = 10^{18}\,\mathrm{cm}^{-3}$. The transport properties of Ge, including doping-dependent mobilities and high-field carrier velocity saturation, are described as in [3], while the optical properties of Ge are taken from [4].

Electrical simulations are performed in the drift-diffusion framework taking into account Fermi-Dirac statistics and incomplete dopant ionization, and considering Shockley-Read-Hall (SRH), radiative and Auger processes as generation-recombination terms.

Geometry and doping of the detector are defined with the Sentaurus TCAD suite by Synopsys [5], also used to