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

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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.

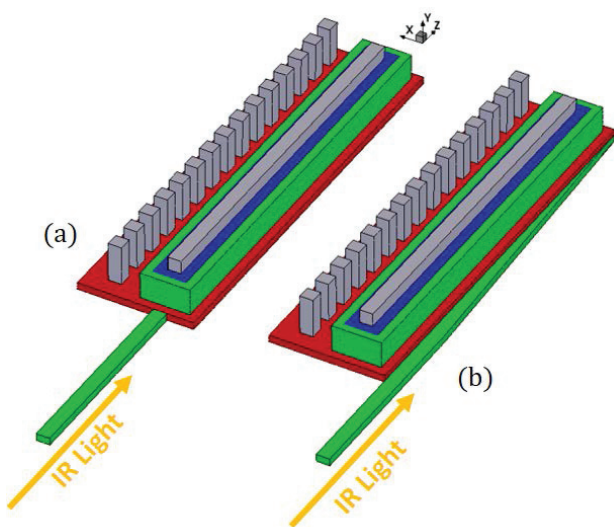


Fig. 1. Perspective view of a BC (a) and MEC (b) detector.

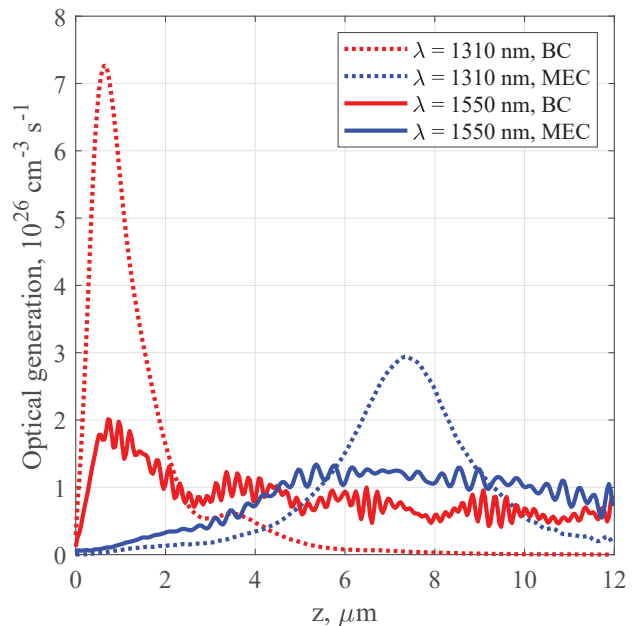


Fig. 2. Optical generation rate in Ge averaged over the WPD cross-section as a function of z , for the BC and the MEC detector.

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 $12 \mu\text{m}$ 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 $N_A = 10^{19} \text{cm}^{-3}$ is assumed at the W/Ge interface, and the Si base has a uniform n -type doping $N_D = 10^{18} \text{cm}^{-3}$. 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

