



**HAL**  
open science

## High efficiency O-band SOA-UTC for access network

Risab Gnanamani, Hervé Bertin, Claire Besançon, Karim Mekhazni,  
Christophe Caillaud, Marina Deng, Mukherjee Chhandak, Cristell Maneux

► **To cite this version:**

Risab Gnanamani, Hervé Bertin, Claire Besançon, Karim Mekhazni, Christophe Caillaud, et al.. High efficiency O-band SOA-UTC for access network. Compound Semiconductor Week (CSW), May 2023, Jeju Island, Korea, South Korea. hal-04231573

**HAL Id: hal-04231573**

**<https://hal.science/hal-04231573v1>**

Submitted on 6 Oct 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# High efficiency O-band SOA-UTC for access network

R. Gnanamani<sup>1,2</sup>, H. Bertin<sup>1</sup>, C. Besançon<sup>1</sup>, K. Mekhazni<sup>1</sup>, C. Caillaud<sup>1</sup>, M. Deng<sup>2</sup>, C. Mukherjee<sup>2</sup>, C. Maneux<sup>2</sup>

III-V Lab, A Joint Lab between Nokia Bell Labs, Thales Research & Technology and CEA-LETI, 91767 Palaiseau, France

IMS Laboratory, University of Bordeaux, UMR CNRS 5218, 33405 Talence, France  
risab.gnanamani@3-5lab.fr

**Abstract**—This paper presents our latest result on high efficiency SOA-UTC receiver for access network. We demonstrate a very high responsivity of 140 A/W, with a PDL around 1 dB and a 3-dB bandwidth of 33 GHz, which is very promising for future access network above 50 Gbaud.

**Keywords**—High speed photodiode; SOA; PIC

## I. INTRODUCTION

50G PON and higher is a growing research subject for future high speed access network. One critical point is to achieve sufficient power budget for these high bandwidth links and receiver sensitivity is a key parameter. Avalanche photodiodes presents a degraded responsivity for bandwidth above 30 GHz and tackle to go above 50 GHz bandwidth. Therefore, pre-amplified receiver comprising a SOA preamplifier and a high-speed photodiode are facing a growing traction and we have demonstrated in 2018, a 33 GHz receiver with a responsivity of 90 A/W [1], but with a high PDL above 4 dB. A sensitivity of -26.3 dBm was demonstrated with this device using 50 Gbit/s burst mode signal [2]. In this paper, we demonstrate an optimized O-band SOA-UTC receiver with improved responsivity and energy efficiency and a PDL reduced below 1 dB.

## II. DEVICE DESIGN AND PERFORMANCES

Our SOA-UTC is based on MOVPE epitaxy for better manufacturability and use butt joint regrowth technique. SOA and passive waveguide are based on buried technology whereas the photodiode use deep ridge structure, as previously [1]. For better energy efficiency, we use a butt joint to couple directly the SOA waveguide to the passive waveguide and the input spot size converter is done with the passive waveguide. Therefore, current injection only occurs in straight waveguide and not in the taper, which greatly enhance energy efficiency of the device (Fig. 2). We measure the responsivity of our SOA-UTC with a lensed fiber (FMD 4.4  $\mu\text{m}$ ) at a temperature of 20°C. Using a SOA-UTC with a 500  $\mu\text{m}$  long SOA and a 4 $\times$ 15  $\mu\text{m}^2$  photodiode, we reach a record responsivity close to 140 A/W at 140 mA SOA drive current and already 80 A/W at 80 mA drive current, which is nearly 50 % improvement compared to our previous demonstration (90 A/W at 160 mA drive current). The PDL is also greatly reduced from more than 4 dB to around 1 dB, as shown in Fig. 3, which make our device usable in practical network. The noise figure is moderate, between 8.4 dB at 1290 nm and 7.6 dB at 1340 nm. The high efficiency of our SOA also allow us to reduce its length for lower power consumption and optimized noise figure. As shown in Fig. 4, using a 400  $\mu\text{m}$  long SOA, we have a peak responsivity above 40 A/W at 1310 nm, a low PDL below 1 dB (<0.5 dB at 1340 nm) and a lower noise figure, down to 6.8 dB. These performances are very promising for future use in next generation access network. The noise figure was calculated using Eq.1 [1], where  $n_{sp}$  the spontaneous emission factor,  $\eta_e$  the coupling efficiency between the SOA and the input optical fiber, R the responsivity of the SOA-PIN,  $I_{ASE}(\nu)$  the current generated in the PD by the ASE of the SOA at frequency  $\nu$ , integrated on a bandwidth  $B_o$ ,  $R_{min}$  and  $R_{max}$  the minimum and maximum responsivity respectively, with respect to polarization.

$$NF = \frac{2n_{sp}}{\eta_e} = \frac{I_{ASE}(\nu)}{h\nu B_o R_{max}} \times \frac{2}{1 + R_{min}/R_{max}} \quad (1)$$

We measure the responsivity of stand-alone UTC-PD using test photodiode structure, without the SOA. In Fig. 5, we see that for a 4 $\times$ 15  $\mu\text{m}^2$  photodiode at 1310 nm, the maximum responsivity is 0.41 A/W. Considering this as ideal photodiode, comparing this to the responsivity (140 A/W at 140 mA) of SOA-UTC of 4 $\times$ 15  $\mu\text{m}^2$  photodiode at 1310 nm, corresponds to 21.5 dB gain and internal SOA gain of 25.3 dB. From the test photodiodes, we also measure 3-dB bandwidth of 38 GHz for 4 $\times$ 10  $\mu\text{m}^2$  photodiode and 33 GHz for 4 $\times$ 15  $\mu\text{m}^2$  photodiode (Fig. 6). These high bandwidths are perfectly compatible with 50 Gbaud operation but are lower than the one we have obtained on stand-alone UTC-photodiode in C-band (70 GHz) [3]. This can be explained by the higher doping level in the absorber which induces dopant diffusion at the absorber collector interface. Therefore, electrons are slow down at this interface as they are not assisted by the electric field to pass through the potential barrier of the InGaAs/InGaAsP interface. This can be easily solved in a next iteration to deliver high bandwidth/high efficiency SOA-UTC receiver.

1. C. Caillaud et al., ECOC 2018, pp. 1-3
2. G. Simon et al., OFC2022, pp. 1-3
3. C. Caillaud et al., ECOC 2021, pp. 1-4

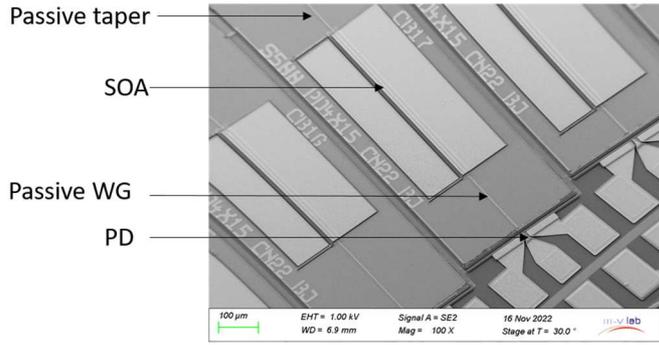


Fig. 1. SEM image of the SOA-UTC wafer

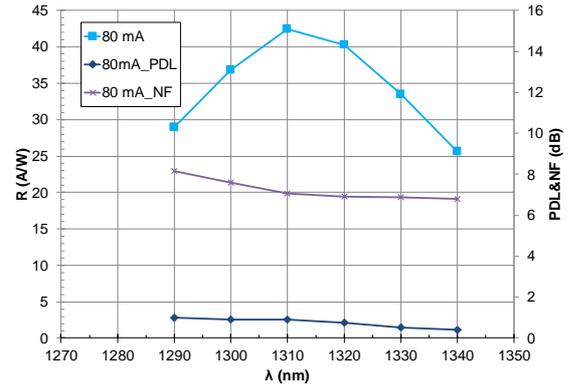


Fig. 4. PDL and NF versus wavelength of SOA-UTC with 400 μm long SOA

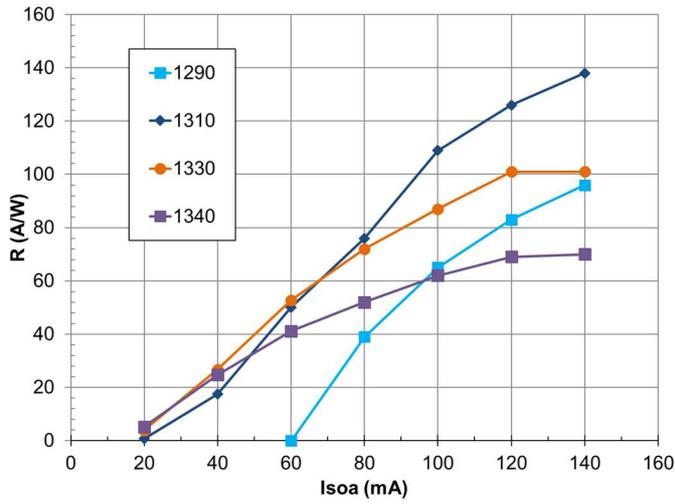


Fig. 2. Responsivity of SOA-UTC device with 500 μm long SOA

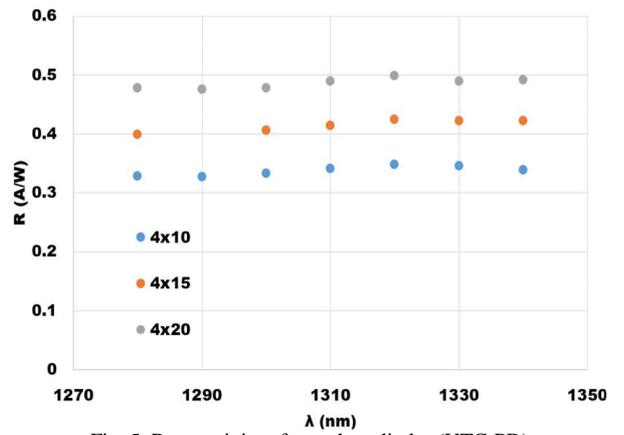


Fig. 5. Responsivity of test photodiodes (UTC-PD)

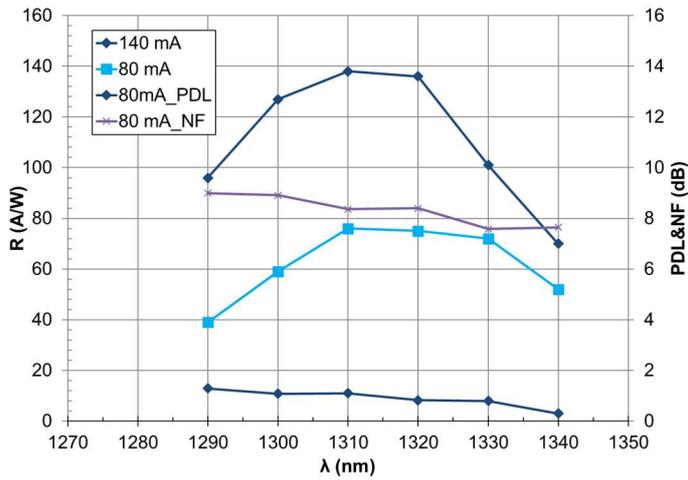


Fig. 3. Gain, PDL and NF versus wavelength of SOA-UTC with 500 μm long SOA

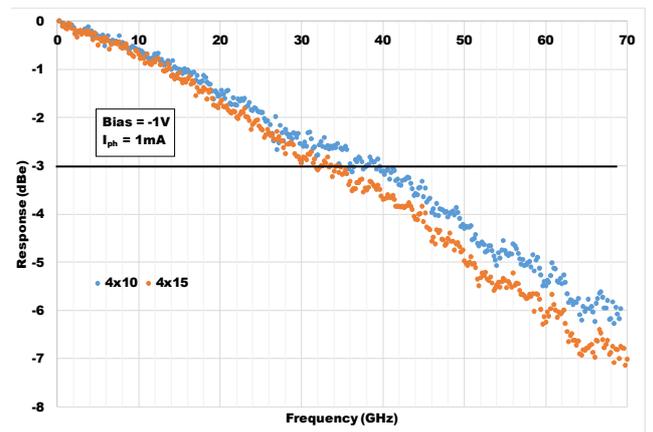


Fig. 6. 3-dB bandwidth of UTC-PD