Broadband 145GHz Photodetector Module Targeting 200GBaud Applications

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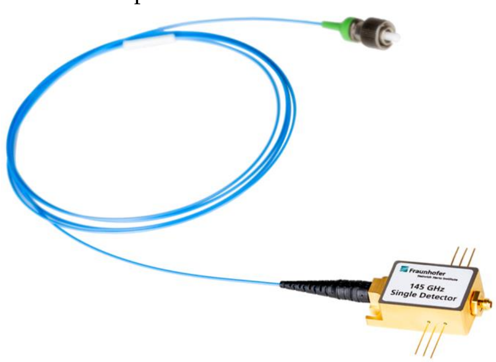
Abstract: We demonstrate a photodetector module with a 0.8mm-RF connector and an estimated 3dB-bandwidth of 145GHz. The bandwidth of the module exceeds all other state of the art photodetector modules. The intended application of the module is for test and measurement equipment of next generation optical networks with 200GBaud.

1. Introduction

Recent publications show more and more transmission experiments with high symbol rates of 200GBaud and coherent or direct detection schemes [1, 2]. The intention of this trend is to double the data rate without increasing the number of transceivers and thereby keeping the cost low. According to classical theory, the needed component bandwidth can be approximated with 0.7-times of the targeted symbol rate. For the case of 200GBaud this corresponds to a bandwidth of 145GHz. So far, only few electrical components have been presented for this symbol rate [3, 4]. Most experiments are demonstrated with optoelectronic components with a bandwidth significantly below 145 GHz [5, 6], requiring more complex digital signal processing (DSP) algorithms to compensate for the low component bandwidth.

In this contribution, a photodetector module with approx. 145GHz 3dB-bandwidth is presented (Fig. 1). Due to the 0.8mm-RF connector [4], the module performance of high bandwidth photodetector chips is no more limited to 110GHz bandwidth of previous 1mm-RF connectors.



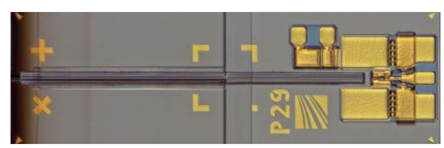


Fig. 1. Fabricated high-speed photodetector module (left) and top view of the photodetector chip inside the module (right)

2. Design and Fabrication

One of the major photodetector design challenges is the trade-off between bandwidth and responsivity. A high responsivity requires a large active region area, which in turn increases the capacitance of the photodiode, resulting in a reduced bandwidth of the photodiode. For developing the new photodetector chip with increased bandwidth, we were able to remain the responsivity by trading in the low PDL of our waveguide integrated photodetectors [5].

Photodetector modules according to Fig. 1 have been fabricated. The photodetector module comprises a polarisation maintaining fibre (PMF), an InP based waveguide integrated photodetector chip, a RF interposer and a 0.8mm-RF connector. The photodetector chip includes a single mode fibre spot-size converter and a photodiode. A DC reverse bias voltage is applied to the photodiode using an integrated electrical bias network consisting of integrated capacitors and resistors. The photodetector chips have been fabricated on a 3-inch InP wafer. Semi-insulating InGaAsP/InP waveguide layers and the doped detector layers are grown by single-step MOVPE. The photodiodes and the waveguides were structured using standard photolithography and dry (RIE and ICP) and wet etching technique. Photoresist and SiN_x served as etching masks. The waveguide integrated photodiode comprises an InGaAs absorption layer and heterostructure contact layers in order to allow high responsivities and high bandwidths. The optical facet of the chips is AR coated to reduce insertion loss and to avoid back reflection into the local oscillator.

3. Measurement Results

In this section, the measurement results of the photodetector module are presented. One of the main challenges is to characterize the high-speed RF performance of the photodetector module with the measurement equipment being currently still limited to lower bandwidths.

Fig. 2 shows the responsivity measurement of the photodetector module. Over the entire C-band the responsivity is almost 0.4A/W and for the entire L-band above 0.4A/W. For some devices, we were even able to measure responsivities up to 0.45A/W. The measured polarisation dependent loss (PDL) is shown in Fig. 2. Since the PDL is high compared to state of the art waveguide integrated photodiodes [5], we chose a PMF as optical input. Furthermore, the optical return loss of the photodetector module was measured below -25dB over the entire C- and L-band when coupling into the FC-APC fibre connector (Fig. 2). The ORL is dominated by the fibre components, because the ORL of the photodetector chip is measured below -40dB.

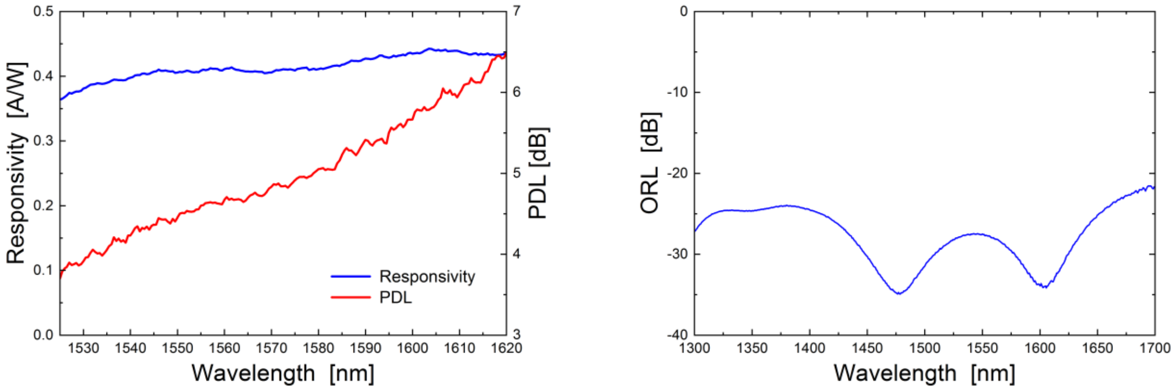


Fig. 2. Responsivity and polarisation dependent loss measurement (left) and optical return loss measurement (right)

We also measured the dark current of the photodetector module being an important parameter for the SNR in direct detection schemes. Up to a reverse bias voltage of 5V, the dark current remains below 40nA. The dark current measurements of the photodetector module include the dark current of the photodiode, the leakage current of the RC-bias network, and all leakage currents inside the module.

The RF transmission response shows an excellent 3dB-bandwidth (Fig. 3). The injected light into the photodetector module was TE polarised at a wavelength of 1550nm. The measurements were made at a reverse bias voltage of 2V. Due to a lack of high-speed measurement equipment, we were only able to measure the module with an additional RF-adapter up to 110GHz with our heterodyne measurement setup. Within this frequency range the 3dB-bandwidth is still not reached. Therefore, we had to extrapolate the 3dB-bandwidth of the photodetector module from simulations. In order to better rely on the simulated bandwidth the simulated performance should not only be fitted to one measurement. Hence, the RF reflection $|s_{22}|$ was measured up to 145GHz with an Anritsu VectorStar ME7838D network analyser. The simulation results are also plotted into the measurement figures. Simulations and measurements are in a good agreement, so that a 3dB-bandwidth of 145GHz can be approximated from the simulation.

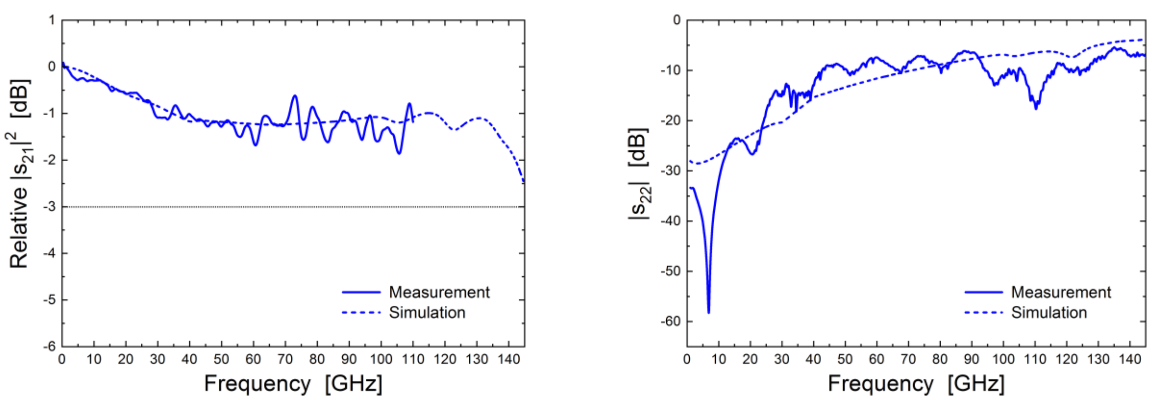


Fig. 3. RF transmission response (left) and electrical reflection (right) for a reverse bias voltage of 2V

Fig. 4 shows the linearity measurements from our heterodyne setup for different frequencies and reverse bias voltages. With increasing reverse bias voltage, the saturation RF output power increases. At 3V a saturation RF output power of -9.3dBm, -8.6dBm, and -9.8dBm has been measured for the frequencies of 75GHz, 90GHz, and 105GHz, respectively. In general, one would expect that the saturation power decreases with increasing frequency. However, the result is in accordance with the transmission response showing ripples in this frequency range, indicating similar to [7] the dominate influence of the RF response on the linearity measurements. The maximum RF power is obtained for a DC current of 7mA corresponding to an optical input power of approximately 12dBm.

Finally, the pulse response of the photodetector module was measured. For the setup, a Pritel fs-pulse source with a pulse repetition rate of 20MHz was used to inject the light into the photodetector module. Due to a lack of DCFs, the optical pulse blurred while propagating through the setup to a pulse width of 3.5ps. The electrical signal at the output was recorded with a Keysight sampling oscilloscope N1046A with a bandwidth of 100GHz. The measurement results are shown in Fig. 4. The pulse power was varied with an optical attenuator in order to do not change the pulse shape by changing the operation point of the laser. The applied optical power on the photodetector module is indicated by the measured DC bias current of the photodetector module. The measured voltage increases approx. linearly with the optical input power. Furthermore, the ringing of the pulses becomes less with increasing optical input power.

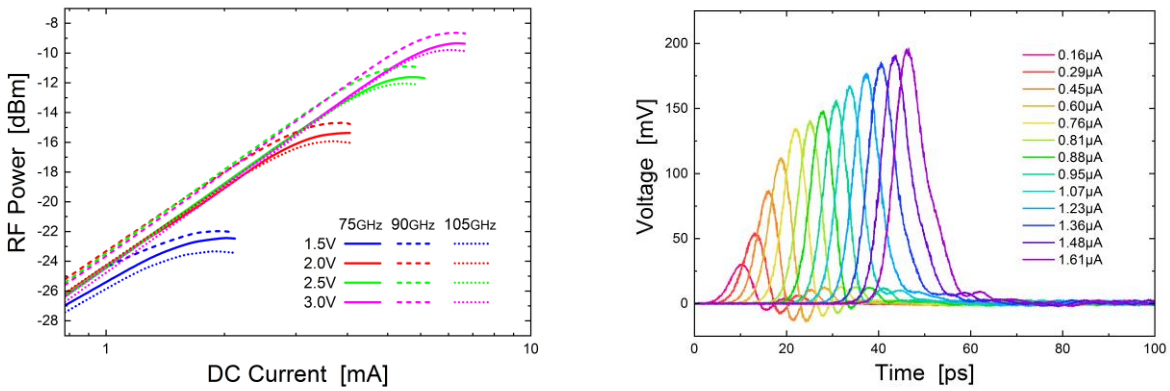


Fig. 4. Linearity measurements for different reverse bias voltages and perturbation frequencies (left) and pulse response for different optical input powers at a reverse bias voltage of 2V (right); legend of pulse response measurement indicates measured average DC-bias current at the photodetector module for different power of the pulses

4. Conclusion

We demonstrate a broadband photodetector module with an estimated 3dB-bandwidth of 145GHz and a responsivity of 0.4A/W. The photodetector module shows excellent performance with respect to the RF bandwidth. The intended application of this detector module is the test and measurement market with 200GBaud signal detection.

The next development for this photodetector module will be to design the photodetector chip polarisation independent (|PDL| < 0.5dB), without trading in responsivity nor bandwidth. However, the current module can already be used for coherent detection or RF-signal generation in single polarization microwave photonics.

5. Acknowledgement

The authors would like to thank the BmBF for funding equipment within the Forschungsfabrik Mikroeletronik Deutschland (FMD). Furthermore, the authors would like to thank Özkan Karpuzi, Fabio Galetti and Steve Reyes from Anritsu for their support.

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