Linearity Improvement in Photodetectors by using Index-matching Layer Extensions

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Abstract: Uniform photocurrent densities can be achieved in waveguide photodetectors by tailoring the extension length of an index-matching layer in front of the diode. We demonstrate up to 9dB improvement in RF linearity at 20GHz.

Introduction: Spur free Dynamic Range (SFDR), RF insertion loss and signal to noise ratio of analog fiber optic links improve with increasing maximum linear photocurrent [1]. The maximum linear photocurrent of photodetectors is limited either by thermal failure or by charge screening and can be increased by either tailoring absorption in the diode [2,3] or by tailoring carrier transport [4]. Standard waveguide photodetectors have an exponential distribution of photocurrent along the wave propagation direction. More uniform photocurrent distribution increases the effective absorption volume and therefore maximum linear photocurrent. A matching layer of intermediate refractive index can increase coupling between the waveguide and the photodetector [5]. This has been used to increase responsivities of the photodetectors [4-7]. Deri, et. al, also proposed extending the matching layer in front of the diode, to reduce the length of the photodiode as light first couples into the matching layer from the core and then into the detector. Varying the extension of the matching layer also changes the absorption profile along the length of the photodetector and can be use to achieve high linear photocurrents. In addition, fabrication is simpler compared to [2] which requires fabrication of a tapered waveguide. In this paper, we report on the fabrication of waveguide photodetectors with various lengths of matching layer extensions and the correlation between the maximum linear photocurrent and the extension layer length. We show that up to 9dB improvement in the maximum linear RF output signal at 20 GHz is achieved in waveguide photodetectors with optimum matching layer design.

Results: Our detectors are fabricated in the InGaAsP/InP system and the epi-layer schematic is shown in Fig. 1. BeamProp simulation of the absorption along the diode length is shown in Fig. 2 for different matching layer extensions. We fabricated two designs of 30μm x 6 μm diodes with 8μm (detector A) and 18μm (detector B) extensions respectively. Both designs have the same dimensions in order to have similar responsivities and bandwidths. The DC responsivity, without AR coating, of detector A is 0.29A/W and that of detector B is 0.27A/W respectively. The RC limited bandwidth of both detectors is ~30GHz (Fig. 3). The RF linearity is measured using a heterodyne setup to generate a 20GHz signal. The plot of RF output with varying optical input power is shown in Fig. 4 with the photodetector biased at –2V. The RF output of detector A compresses by 1dB at –19dBm while the output of detector B is linear up to –10dBm.

Conclusion: We have proposed and successfully demonstrated using an index matching layer extension to increase maximum linear photocurrent in waveguide photodetectors. Our measurements show up to 9dB improvement in the maximum linear photocurrent.

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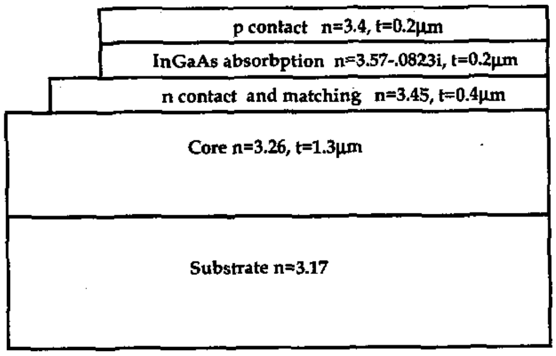

Fig. 1. Schematic of layer structure showing matching layer design

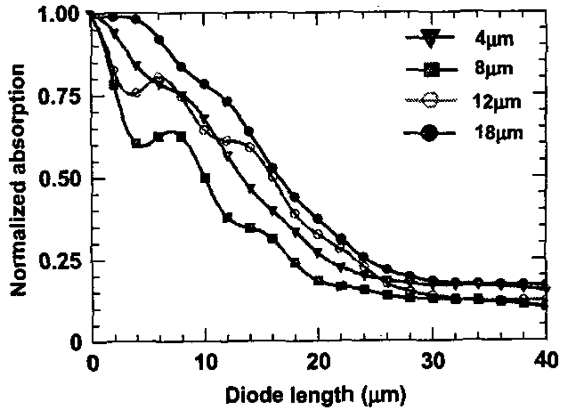

Fig. 2. Absorption profile for different matching layer extensions

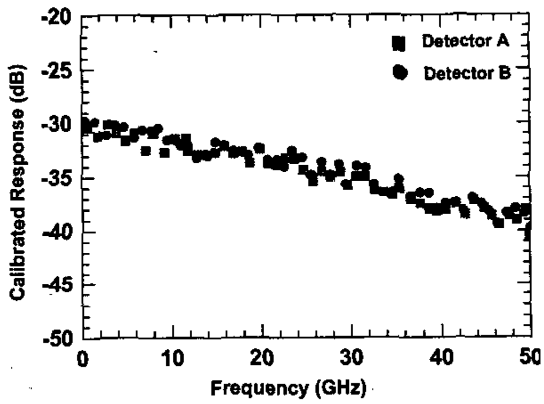

Fig. 3. Heterodyne frequency response. The bandwidth is 30GHz for both detectors

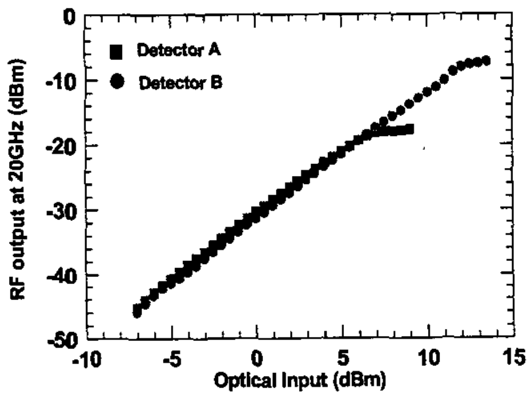

Fig.4 AC linearity measurement with 20GHz heterodyne signal. Maximum linear RF power shows 9dB improvement

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