Polarization Penalty in Log-Periodic Toothed Antennas with integrated Waveguide Triple Transit Region (TTR) Photodiodes within 30-300 GHz

Vitaly Rymanov, Sebastian Dülme, Melanie Wachholz, Sebastian Babiel, and Andreas Stöhr

Universität Duisburg-Essen, Lotharstraße 55, 47057 Duisburg, Germany
*Corresponding author: andreas.stoehr@uni-due.de

Abstract

In this work, we report on compact (2x2 mm²) on-chip antenna-integrated continuous wave (CW) photonic transmitters (PTs) employing an integrated millimeter wave (mmW) InP-based 1.55 µm waveguide triple transit region photodiode (TTR-PD) structure. The applied TTR-PD structure exhibits three drift regions. More precisely, the structure features an active (i.e., absorbing) InGaAs double layer, introducing an undepleted material as well as a depleted material, in combination with a depleted collector InP layer to enhance the transit time of both photogenerated carriers, i.e., electrons and holes. Thus, even velocity overshoot impacts the electron drift supported by a high-frequency mushroom-type active waveguide architecture [1]. For attaining wide frequency tunability, the TTR-PD was integrated at the feeding point of a broadband planar log-periodic toothed antenna (LPTA) structure. The heterodyne optical signal from a single-mode fiber is guided to the active TTR-PD section thanks to an additional ridge-type InGaAsP/InP passive optical waveguide (POW). The generated mmW beam is focused by means of a high-resistivity float zone (HRFZ) silicon spacer and a hemispherical HRFZ-silicon lens [2].

The radio frequency (RF) power generated by the developed PT device was measured by a power detector array including six waveguide-coupled (i.e. WR-22, WR-15, WR-10, WR-8, WR-5, WR-3) Schottky barrier diodes (SBDs) with attached horn antennas, covering the entire frequency range between 30 GHz and 300 GHz. Besides the frequency response with an overall power drop-off of around 20 dB over the entire mmW frequency regime, polarization dependency between the LPTA-integrated PT and appropriate horn antennas was investigated, performing chip-level measurements. The achieved results, e.g. at frequencies of 37 GHz, 60 GHz, 73 GHz, 84 GHz, 94 GHz, 120 GHz, 200 GHz and 300 GHz, are shown in Fig. 1. A polarization-dependent power variation in the order of 2-6 dB can be observed within the entire mmW frequency range. For comparison, all PT chips were measured at a photocurrent level of 1 mA. Without cooling, peak photocurrent levels of about 18 mA along with a responsivity of up to 0.5 A/W have been experimentally achieved for integrated TTR-PDs, even without anti-reflection coated POW front surfaces.