High-Performance Negative Differential Resistance Oscillators and Combiners

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Abstract

Many emerging systems applications at submillimeter-wave frequencies critically depend on the availability of compact, reliable, and efficient sources of radiation with substantial amounts of power. Negative differential resistance (NDR) devices, such as GaAs tunnel-injection transit-time diodes [1] and InP Gunn devices [2] have been the most successful approach to fundamental oscillators. To exploit the favorable material parameters of GaN, such as the high breakdown electric fields, the relatively low dielectric constant, and, most importantly, the high electron drift velocity, a novel tunnel-injection transit-time device was proposed recently [3]. It uses the unique tunneling properties from piezoelectric and spontaneous polarization effects in GaN/AlGaN heterojunctions [3]. Its performance potential was initially evaluated with simulations using a hydrodynamic device model [4] and excellent performance characteristics were predicted around 160 GHz and 320 GHz [3]. The validity of the hydrodynamic model at higher submillimeter-wave frequencies is questionable. Therefore, an energy-momentum model was employed more recently together with refined GaN material parameters and heterojunction intraband-tunneling injection characteristics. These simulations predicted RF output power levels (and corresponding dc-to-RF conversion efficiencies) of more than 25 mW (> 2%) at 260–360 GHz and more than 5 mW (> 1%) at 350–490 GHz for operating active-layer temperatures well below 600 K.

Power combining is a well-known method if power levels higher than those of a single oscillator are needed in systems applications. Its viability and strong performance potential with milliwatts of output power was demonstrated for the first time at submillimeter-wave frequencies using InP Gunn devices [4]. In these initial experiments [4], the performance of the in-line waveguide combiner was limited by the fixed spacing between the two oscillators. More recently, waveguide washers were used to adjust the spacing and get closer to the optimum phase relationships at the fundamental and second-harmonic frequencies of the InP Gunn devices in the two cavities. Initial experiments already yielded a performance improvement of 25% and combined power levels of more than 7.5 mW with corresponding combining efficiencies of more than 85% were measured at 280 GHz. These experiments together with earlier experiments at lower frequencies indicate that this a very promising method to increase the output power levels from various NDR devices at submillimeter-wave frequencies including the GaN-based devices described above.

References

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