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Resonant cavity-enhanced photodetector incorporating a type-II superlattice to extend MWIR sensitivity

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Abstract: Mid-infrared resonant cavity-enhanced photodetectors (RCE PD) present a promising technology for targeted gas detection. We demonstrate an RCE PD incorporating an InAs/InAsSb superlattice as the detecting element, extending the resonant wavelength beyond 4 µm. AlAsSb/GaSb mirrors and a unipolar barrier active region paralleling an nBn structure are also used, and performance is compared to a conventional broadband nBn detector incorporating the same superlattice. The RCE PD exhibited a Q-factor of ~90 and an extremely stable resonance wavelength. Peak responsivity was 3.0 A W^{-1} at 240 K, equalling 84% quantum efficiency, a 5.5 times increase over the reference nBn at the same wavelength. Dark current density was 3.3×10^{-2} A cm^{-2} at 240 K, falling to 2.7×10^{-4} A cm^{-2} at 180 K. The broadband BLIP limit is approached at 180 K with specific detectivity of 2.1×10^{11} cm $Hz^{1/2}$ W^{-1}, which presents the potential of achieving BLIP-limited operation in the thermoelectric cooling regime.

1. Introduction

III-V semiconductor compounds have seen increasing interest for use in infrared detection, as an alternative to the HgCdTe material system. In particular, antimonide-based alloys and quantum structures, characterised by small effective bandgaps, have gained significance in the technologically important mid-wave infrared (MWIR) and long-wave infrared (LWIR) regions of the spectrum [1], resulting in increasing commercial implementation of photodiode detectors utilising bulk InSb or InAsSb compounds [2,3] as well as emerging quantum-structured absorbers, such as nBn, multiple quantum well and superlattice structures.

One particular application of such infrared technology is detection of gases for important environmental, safety or diagnostic purposes using their characteristic narrow-band infrared absorption fingerprints. Broadband detectors can be adapted for this purpose with additional filters or the use of dual-band responses; however, their inherent broadband sensitivity is undesirable and at times deleterious. An alternative approach arises in the form of resonant cavity-enhanced photodetectors (RCE PDs), where the active photodetector element is embedded in an optical cavity formed between two distributed Bragg reflector (DBR) mirrors, creating a structure analogous to a vertical cavity surface emitting laser. The optical mode defined by the cavity leads to strong selectivity of absorption at the resonant wavelength and high specificity of gas detection when spectrally aligned with an absorption fingerprint.

In an RCE PD, high quality mirrors enable quantum efficiencies approaching unity [4], while the thinned absorber offers proportionately reduced Auger and generation-recombination dark current magnitudes due to their dependence on absorber volume. Additionally, the broadband background-limited performance (BLIP) limit of operation does not apply to RCE PDs as absorption at non-resonant wavelengths is suppressed. The study and demonstration of RCE