Quantum Dots Photonic Crystal Detectors

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Abstract

Quantum dot infrared photo detectors have been explored extensively in the past few years due to their potential to provide a major improvement in the device performance. Though the incorporation of quantum dots enhances the performance by discretizing the density of states in three dimensions with lower dark current, it suffers from low responsivity and quantum efficiency. This leads to a low operating temperature. In this paper we propose to use a photonic crystal resonant cavity to improve the quantum efficiency and the operating temperature of the device without affecting the dark current.

The photonic crystal cavity is inscribed in a InAs/InGaAs/GaAs dots-in-well (DWELL) structure, sandwiched between highly doped GaAs contact layers grown using Molecular Beam Epitaxy. The DWELL active region consists of 15 stacks of 2.2 monolayers of n-doped InAs quantum dots placed in an $In_{0.15}Ga_{0.85}As/GaAs$ quantum well [1]. E-beam lithography is used to make the hexagonal pattern of air holes in the active region. Using the spectral response and calibrated blackbody measurements, the conversion efficiency of the quantum dot photonic crystal is found to be 57% at –2.5 V while the normal DWELL detectors have quantum efficiency of 7% at the same bias. We observed no significant increase in the dark current of the photonic crystal devices compared to the normal structure. The generation-recombination D* for these samples at 77K operating temperature, when facing a 300K blackbody is estimated to be 2.92×10^{10} Jones at –2.5 V bias, which is higher than the DWELL structure without resonant cavity by a factor of 10. The increase in the quantum efficiency and D* almost by the same factor allows us to conclude that the noise remains the same by introducing the photonic cavity which is supported by the dark current measurements. The BLIP temperature for the photonic crystal devices is 20% more compared to the Quantum dot infrared photo detectors.