Giant Responsivity in Metasurface Quantum Well Infrared Photodetectors at High Applied Bias

NIMS[1], Nihon Univ.[2], Tohoku Univ.[3]

◦ (P) M.F. Hainey, Jr. [1], T. Mano[1], T. Kasaya[1], T. Ochiai[1], H. Osato[1], Y. Sugimoto[1], T. Kawazu[1], A. Shigetou[1], Y. Jimba[2], H. Miyazaki[3], and H. T. Miyazaki[1]

E-mail: HAINEYJR.Mel@nims.go.jp

Metasurface quantum well infrared photodetectors are highly tunable and sensitive infrared photodetectors integrating quantum well infrared photodetectors (QWIPs) and metal-dielectric-metal plasmon cavities. The resonances of the QWIP and cavity can be fully controlled[1,2], enabling responsivities up to 4 A/W at 7.06 μm in detectors using single-quantum-well QWIP layers and unetched square cavities[3].

Here, we report unique behavior in metasurface QWIPs with unetched square cavities and a three-quantum-well QWIP layer (Figure 1a). Compared to single-quantum-well metasurface QWIPs, maximum responsivity at low bias voltages is reduced, ~2 A/W at 7.06 μm for both negative and positive applied bias (-0.8V or +0.9V) (Figure 1b). However at negative bias, after initially decreasing beyond ~1 V of applied bias, responsivity dramatically increases above -2.0V (~100 kV/cm). A peak responsivity R_{peak} of 14.6 A/W is reached at 7.06 μm and -2.7 V bias (~135 kV/cm) (Figure 1c), corresponding to a 257% quantum efficiency and suggesting that the giant R_{peak} arises from avalanche carrier multiplication[4]. R_{peak} at -2.7 V is six times larger than the corresponding R_{peak} at the low bias peak for the same detector, and more than three times larger than R_{peak} for metasurface QWIPs using a single quantum well. Due to increased dark current and noise—also characteristic of avalanche multiplication[4]—detectivity at -2.7 V is reduced to 5.4×10^{8} cm Hz$^{1/2}$/W compared to detectivity at low bias (2.4×10^{10} cm Hz$^{1/2}$/W at -0.9 V).

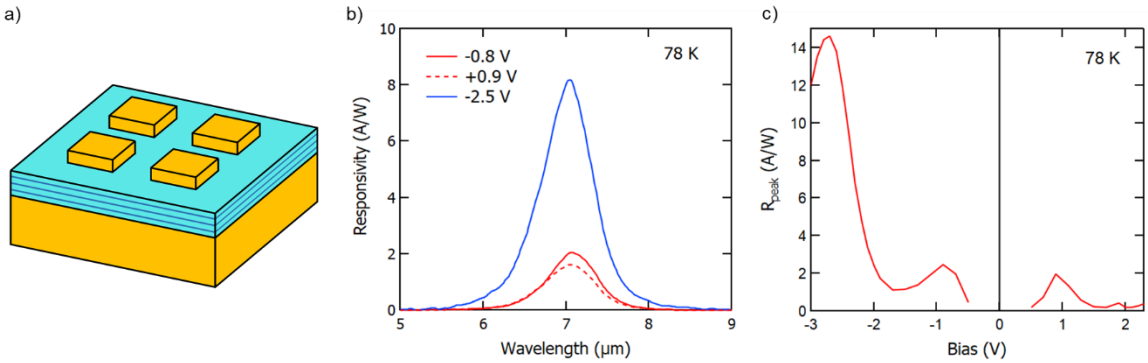

Figure 1 – a) Schematic of 3-quantum-well detector with square cavities. b) *R* spectra for 3-well detector at both low (red lines) and high bias (blue). c) R_{peak} vs bias for 3-well detector.

We thank the JSPS (JP19H00875), an anonymous company, the Project for Functional Sensors and Actuators, and the NIMS Nanotechnology Platform for support.

[1] D. Palaferri et al., Nature **556**, 85 (2018).
[2] H.T. Miyazaki et al., Nat. Commun. **11**, 565 (2020); M.F. Hainey et al., Nanophotonics **9**, 10 (2020); M.F. Hainey et. al., Nanophotonics **9** , 16 (2020).
[3] M.F. Hainey et al., Opt. Express **29**, 59 (2021).
[4] B.L. Levine et al., Appl. Phys. Lett. **51**, 12 (1987); R. Rehm et al., Appl. Phys. Lett. **82**, 17 (2003).