Broadened Photoresponse of Metasurface Quantum Well Infrared Photodetectors Using a Patchwork of Cavities within a Subwavelength Period

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

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

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

The integration of quantum well infrared photodetectors (QWIPs) with plasmon cavities has allowed for demonstration of sensitive photodetectors in the mid-infrared. These detectors typically use only a single type of plasmon cavity to match the cavity and quantum well absorption peaks. In contrast, metasurface absorbers combining multiple cavities in a single subwavelength period can generate complex photoresponses such as multi-band or broadband absorption. Here, we use a simple square cavity design as a building block for demonstrating detectors with a broadened photoresponse. For square cavities with L = 0.99 μm, we observe a maximum responsivity of 3.9 A/W at 7.04 μm and a detectivity of 3.7×10^{10} cm Hz$^{1/2}$/W, comparable to previous high-detectivity designs[1-3] (3.9×10^{10} cm Hz$^{1/2}$/W).

This high performance suggests that we can adopt more complex cavity designs to our detectors. By adopting a patchwork of square cavities with different resonances[4], we can use resonant photon sorting to broaden the detector photoresponse. We realize a maximum responsivity of 4.3 A/W at 6.78 μm in a 4 Patch detector and photoresponse 1.5 times broader than a 1 Patch detector. Absorption behavior is analogous to initial reports on simple metasurface absorbers[4], and suggests integration of metasurface cavities with complex photoresponses should allow detectors with greater functionalities to be realized.

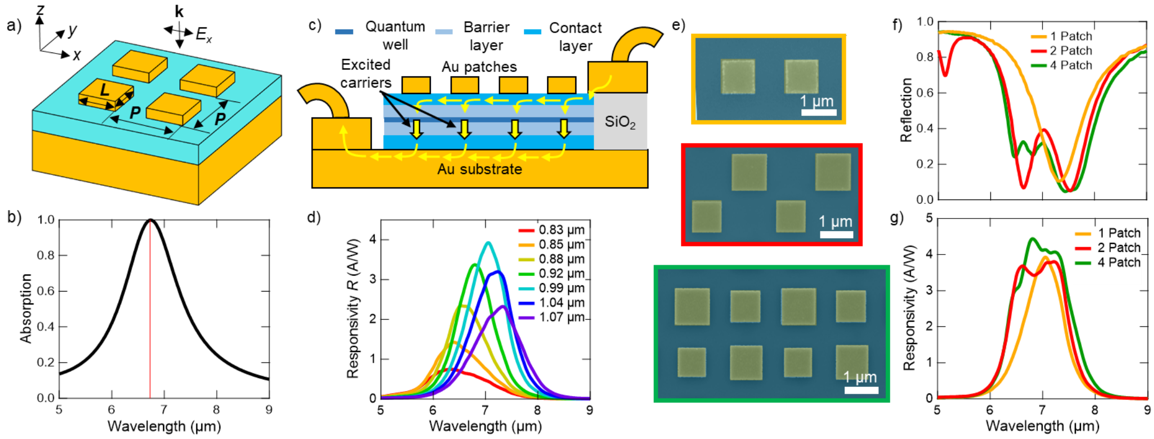

Figure 1 – a) Schematic of square patch structure. b) Calculated absorption used for cavity design. L = 0.89 μm and P = 1.8 μm gives resonance that matches quantum well absorption peak at 6.73 μm (red line). c) Schematic of device operation. d) Responsivity spectra of square cavity detectors with increasing L values. e) SEM images of 1 Patch (L = 0.99 μm, P = 1.8 μm), 2 Patch (L_1 = 0.90 μm, L_2 = 1.06 μm, P = 2.8 μm), and 4 Patch (L_1 = 0.87 μm, L_2 = 0.94 μm, L_3 = 1.01 μm, L_4 = 1.07 μm, P = 3.3 μm) detectors. f) Reflectivity and g) responsivity spectra of all three detectors.

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

1. H. T. Miyazaki *et. al.*, *Nature Commun.* **11**, 565 (2020).
2. M. F. Hainey, Jr. *et. al.*, *Nanophotonics* (in press) (2020).
3. M. F. Hainey, Jr. *et. al.*, submitted.
4. P. Bouchon *et. al.*, *Optics Letters* **37**(6), 1038-40 (2012).