Dual-band Metasurface Quantum Well Infrared Photodetectors Based on Resonant Photon Sorting

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Conventional dual-band infrared photodetectors have typically been developed following crystal engineering principles—the spectra of each band are determined by the band structure of the stacked crystals. Here we employ a nanophotonic principle, resonant photon sorting[1, 2], to develop a novel dual-band photodetector. When two plasmon cavities sandwiching quantum well infrared photodetectors (QWIPs) with distinct fundamental resonances (dimensions L_1, L_2) are alternately arranged in a subwavelength period P, each cavity realizes nearly perfect absorption of light at its resonance wavelength without significant interference from its counterpart. Because each deep subwavelength cavity has an absorption cross section much larger than its geometrical area, incident photons can be sorted laterally by wavelength. Thus, the function of two optimized detectors can be realized in the footprint of one.

Our dual-band detector can realize external quantum efficiencies up to 37% (responsivity 2.1 A/W, peak wavelength 7.06 μm) at 78 K, competitive with conventional detectors[3-6], and we can confirm clear manifestations of photon sorting. Each cavity absorbs selectively at its resonance wavelength while suppressing non-resonant absorption in its counterpart. By tailoring one resonance to an absorption peak of NO_2 molecule (6.25 μm) and the other to a non-absorbing reference wavelength (7.06 μm), we can measure NO_2 gas concentrations in a single device using the signal ratio of the resonant and non-absorbing detectors. Our device demonstrates accuracy on the order of 10 ppm and ms response times.

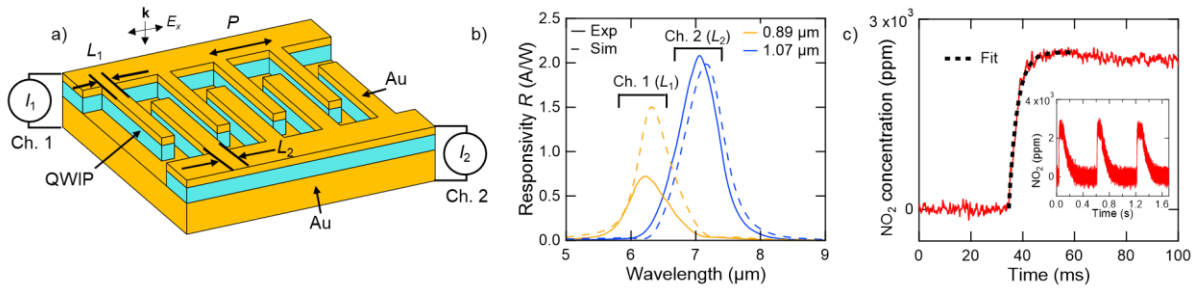

Figure 1 – a) Design of dual-band metasurface QWIP. Two electrically isolated, interdigitated stripes with different dimensions (L_1, L_2) in one subwavelength period P generate independent photocurrents (Ch. 1, Ch. 2). b) Experimental and simulated responsivity for individual detectors from a dual-band device (L_1 = 0.89 μm, L_2 = 1.07 μm, P = 3.1 μm). c) Rapid changes of NO_2 concentration measured with a dual-band device. Fit gives a time constant of 3.2 ms.

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