Nonlocal Dielectric Metasurfaces for Multi-channel SWIR Photodetection

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Short-wavelength infrared (SWIR) photodetectors with high spectral resolution and narrowband response are critical for applications such as chemical sensing, biomedical imaging, and free-space optical communication. Recent advances in nanophotonics have established dielectric metasurfaces as a powerful platform for subwavelength light manipulation, with diverse applications such as wavefront shaping [1], molecular sensing [2], and narrowband spectral filtering [3]. In particular, elliptical dielectric nanoresonators have been shown to support high-Q, polarization-dependent resonances, enabling precise control over both spectral position and polarization response [4].

Building on these foundational works, we propose a photodetector platform that transforms such high-Q resonances into functional, spectrally selective detection across multiple wavelength channels. Rather than directly patterning the absorptive layer—which increases surface recombination and reduces carrier lifetime—we spatially decouple the resonance generation from the photocarrier generation process. Our architecture consists of a dielectric metasurface placed above a planar absorptive layer. The metasurface supports nonlocal optical resonances, which emerge from long-range photonic interactions among subwavelength resonators [5,6]. These nonlocal resonances exhibit sharp spectral features and efficiently couple evanescent fields into guided modes of the underlying absorber, enabling strong, narrowband absorption without degrading the material's electrical properties.

By tailoring the metasurface geometry—such as ellipticity, periodicity, and orientation—multiple resonant channels across distinct wavelengths can be independently addressed, allowing for multichannel detection within the SWIR range. This approach provides a flexible and scalable pathway toward next-generation photodetectors that integrate nanophotonic precision with robust electronic performance.

References

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