Application Note

Signal Recovery 7270 Lock-in Amplifier in Next-Generation Infrared Photodetector Research

Application Note: 2025

1. Introduction

Infrared (IR) photodetectors are at the heart of modern technologies spanning environmental monitoring, thermal imaging, medical diagnostics, and free-space optical communication. As applications demand higher sensitivity, broader spectral response, and room-temperature operation, the development of novel IR photodetectors has accelerated. However, the weak signals and high noise environments typical in IR measurements present significant challenges. Here, the Signal Recovery 7270 Lock-in Amplifier has become an indispensable tool, enabling researchers to extract faint photo responses with high precision and reliability.



Figure 1. AMETEK Singal Recovery 7270 DSP lock-in amplifier

This application note presents three significant recent studies utilizing the 7270 LIA to advance IR photodetector performance, demonstrating its essential contribution to measurement and device characterization.

2. Case Studies

2.1. Ultrabroad Spectrum Photodetectors (Wang et al., Advanced Science, 2019[1])

Device/Concept:

A hybrid photodetector combining 2D MoS_2 and ferroelectric P(VDF-TrFE), achieving a record ultrabroad spectral response from 375 nm (UV) to 10 µm (long-wave IR).

Measurement Challenge:

Detecting pyroelectric and photoconductive signals across a vast spectral range, especially in the mid- and long-wave IR where signals are weak and noise is significant.

Role of the 7270 LIA:

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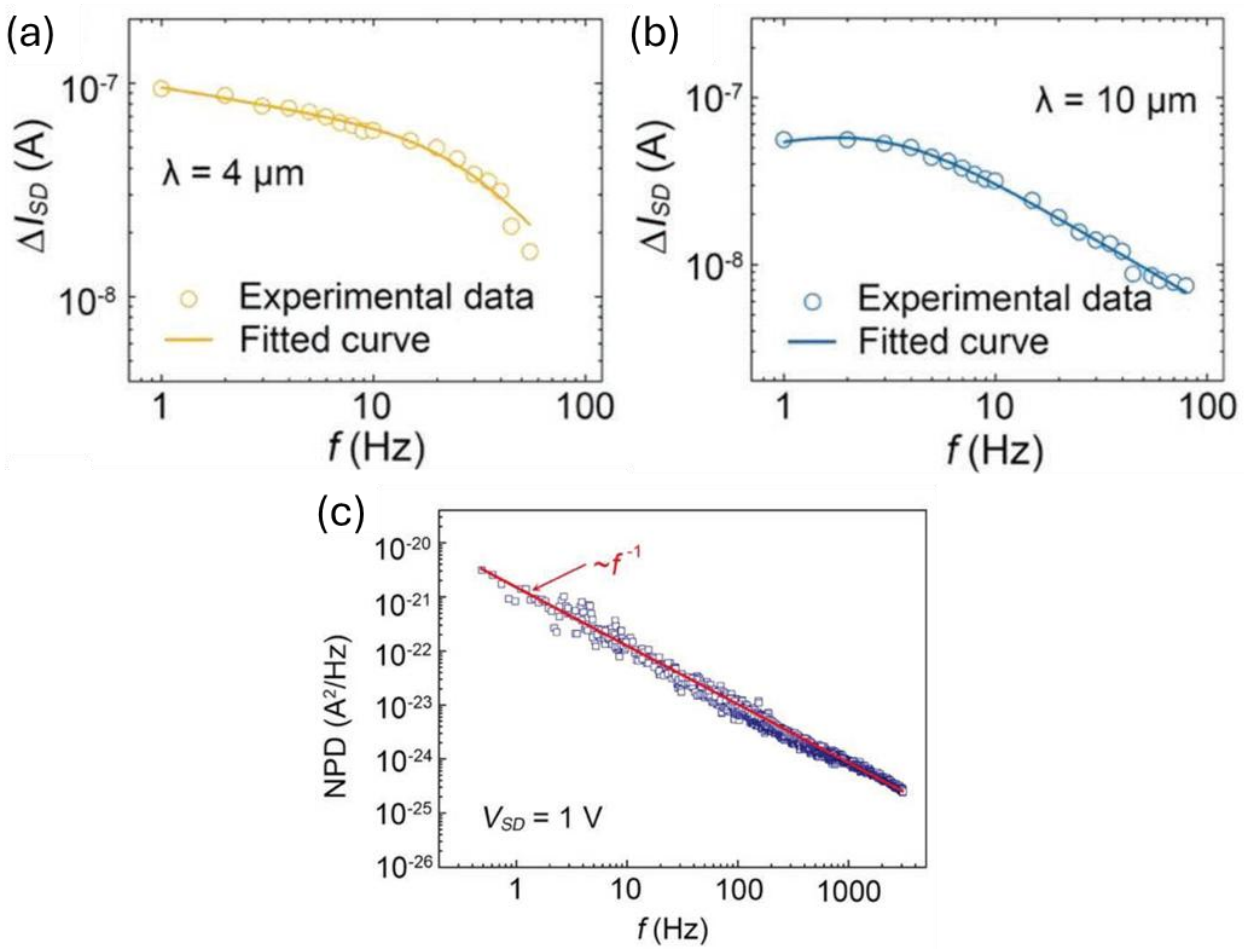


Figure 2. (a,b) Frequency-dependent photocurrent response (ΔI_SD) measured using a lock-in amplifier (Signal Recovery 7270) under chopped IR illumination, showing fast response times of 5.5 ms (4 μm) and 52.5 ms (10 μm). (c) Noise power density (NPD) of the photodetector measured as a function of frequency at room temperature and V_SD = 1 V, using the 7270 lock-in amplifier. Reproduced from (1)

- Used to lock-in to the modulated photocurrent signal generated by chopped IR laser illumination (2.76–10 μm).
- The current signal from the device was pre-amplified and then fed to the 7270 LIA, which demodulated the signal at the chopper frequency, dramatically improving the signal-to-noise ratio.
- Enabled frequency-dependent response measurements and accurate extraction of response times (as low as 5.5 ms at 4 μm), responsivity, and on/off ratios.

Impact:

The 7270 LIA was crucial for quantifying the fast, low-noise pyroelectric response and for mapping the device's performance across the IR spectrum, validating the device's suitability for room-temperature, broadband IR detection.

2.2. High-Performance Polarization-Sensitive MWIR Photodetector (Jiao et al., Science Advances, 2022[2])

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Device/Concept:

A van der Waals heterojunction of HgCdTe and black phosphorus, enabling room-temperature, polarization-sensitive midwave IR (MWIR) detection with high detectivity.

Measurement Challenge:

Accurate measurement of photocurrent and noise under modulated MWIR illumination, and extraction of polarization-resolved response in the presence of environmental noise.

Role of the 7270 LIA:

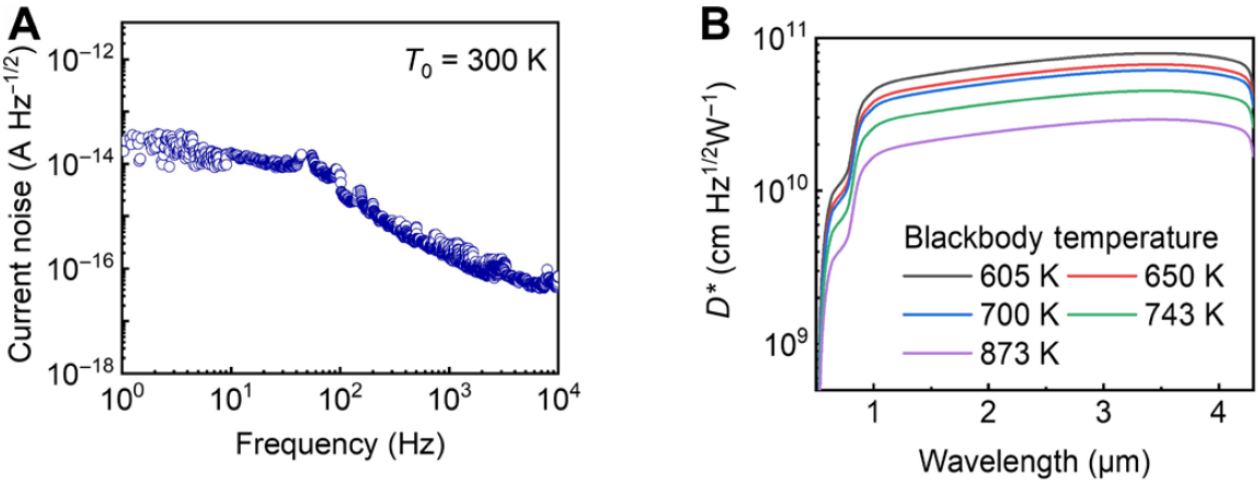


Figure 3. (A) Current noise spectrum of the HgCdTe/black phosphorus (bP) van der Waals heterojunction photodetector, measured from 1 to 10^4 Hz at room temperature and zero bias using the Signal Recovery 7270 DSP lock-in amplifier. (B) Detectivity as functions of wavelength at various blackbody temperatures measured at background temperature of 300 K. Reproduced from (2)

- Used in conjunction with a low-noise preamplifier (SRS SR570) to measure the modulated photocurrent at the frequency of a mechanical chopper placed in the IR beam path.
- Enabled precise mapping of photocurrent as a function of polarization angle and wavelength, as well as noise spectral density measurements.
- Facilitated blackbody response measurements, allowing the extraction of detectivity values up to 7.93×10^{10} Jones at room temperature.

Impact:

The 7270 LIA's sensitivity and phase-locked detection were essential for demonstrating the device's high performance and polarization sensitivity, even at zero bias and without cooling.

2.3. Two-Color IR Photodetector Based on 2D/3D Heterostructures (Wu et al., Light: Science & Applications, 2022[3])

Device/Concept:

A two-color IR photodetector using a vertically stacked black phosphorus/MoS_2/Si heterostructure, capable of simultaneous near-IR (NIR) and mid-IR (MWIR) detection with ultralow crosstalk.

Measurement Challenge:

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Simultaneous, independent measurement of weak NIR and MWIR signals, and accurate determination of detectivity and crosstalk at room temperature.

Role of the 7270 LIA:

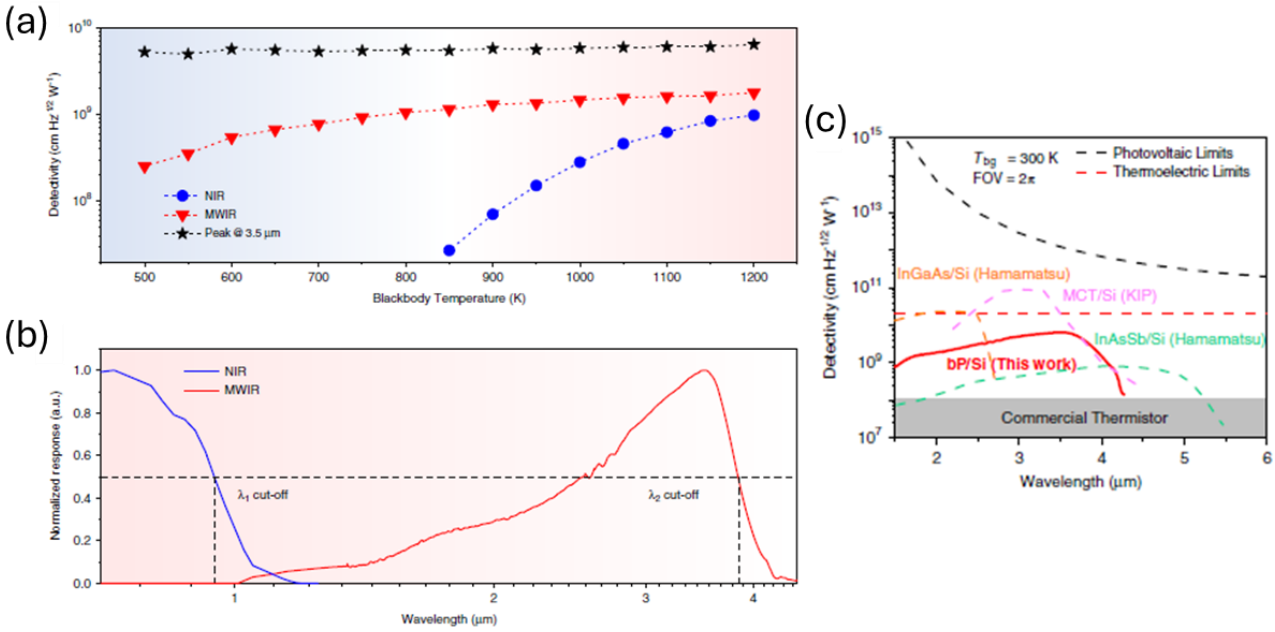


Figure 4. Performance of the bP/MoS_2/Si van der Waals two-color infrared photodetector. (a) Specific detectivity (D) at different blackbody temperatures, measured with a lock-in amplifier (Ametek 7270 DSP) under chopped blackbody illumination. (b) Normalized spectral response in NIR and MWIR bands. (c) D as a function of wavelength, compared to commercial two-color detectors.* Reproduced from (3)*

- The photocurrent signal, after preamplification (SR570), was recorded by the Ametek Model 7270 DSP Lock-in Amplifier.
- Used for spectral response measurements (with FTIR and laser sources), noise current measurements, and transient response characterization.
- Enabled the extraction of key device metrics such as specific detectivity (D*) and crosstalk ratios, even under low-signal conditions.

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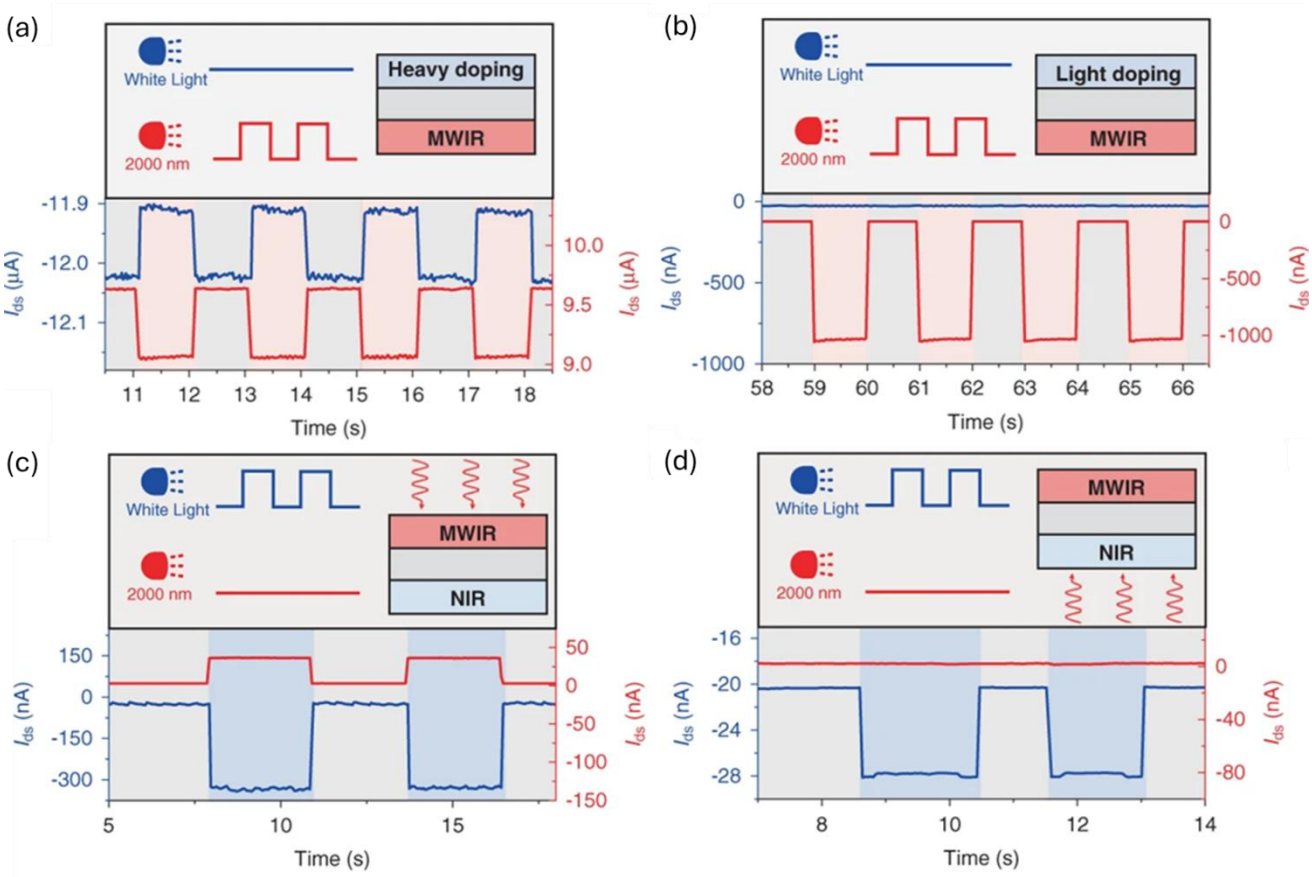


Figure 5. Photo current of doped Si two-color photodetector: (a) heavily doped, under a modulated illumination source (λ = 2 μm). (b) light doped under a modulated illumination source (λ = 2 μm). (c) light doped under a modulated illumination source (White light) in front radiation mode. (d) light doped under a modulated illumination source (White light) in back radiation mode. Red and blue line are MWIR and NIR photocurrents, respectively. Reproduced from (3)

Impact:

The 7270 LIA's ability to isolate and quantify weak, band-specific signals was pivotal in demonstrating the device's ultralow crosstalk and high detectivity, supporting its application in multispectral IR imaging and temperature sensing.

3. Conclusion

Across these cutting-edge studies, the Signal Recovery 7270 Lock-in Amplifier proved essential for:

- Extracting weak photocurrent signals from noisy backgrounds,
- Enabling frequency- and phase-sensitive detection,
- Supporting advanced device characterization (responsivity, detectivity, response time, crosstalk),
- Facilitating the development of next-generation IR photodetectors operating at room temperature and beyond.

For any research group aiming to advance IR photodetector technology, the 7270 LIA is not just a measurement tool—it is a key enabler of discovery.

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4. References

1) X. Wang, H. Shen, Y. Chen, G. Wu, P. Wang, H. Xia, T. Lin, P. Zhou, W. Hu, X. Meng, J. Chu, J. Wang, Multimechanism Synergistic Photodetectors with Ultrabroad Spectrum Response from 375 nm to 10 µm. Adv. Sci. 2019, 6, 1901050. https://doi.org/10.1002/advs.201901050
2) Hanxue Jiao et al., HgCdTe/black phosphorus van der Waals heterojunction for high-performance polarization-sensitive midwave infrared photodetector. Sci. Adv., 2022, 8, eabn1811. https://doi.org/10.1126/sciadv.abn1811
3) Wu, P., Ye, L., Tong, L. *et al.* Van der Waals two-color infrared photodetector. *Light Sci Appl*, 2022, 11, 6. https://doi.org/10.1038/s41377-021-00694-4

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