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A low-noise, high-gain, and large-dynamic-range photodetector based on a JFET and a charge amplifier

Key words: Quantum noise; Bell-state detection (BSD); Photodetector (PD); Junction field-effect transistor (JFET); Charge amplifier

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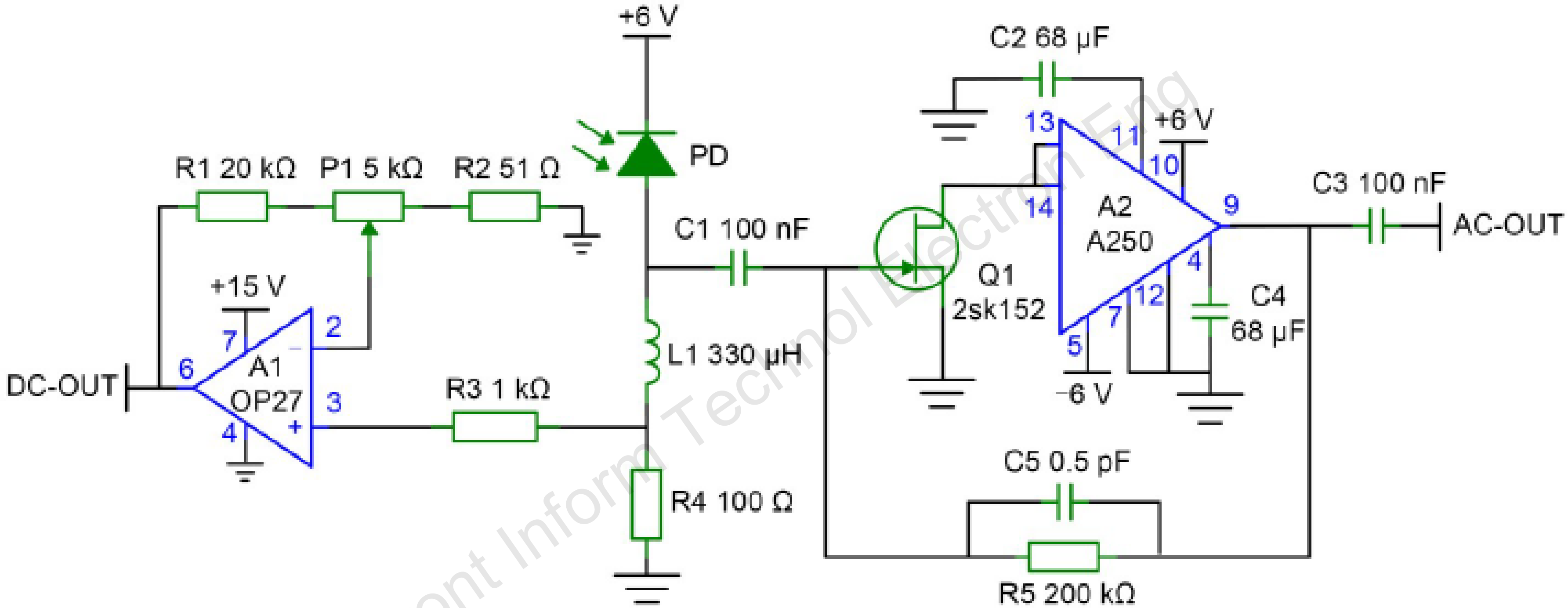
Motivation

As one of the most fundamental methods in detecting the optical noise at the quantum noise limit, a photodetector (PD) with a high signal-to-noise ratio (SNR) in the Bell-state detection (BSD) is urgently needed to enable the accurate detection of high-level squeezed light in a high-frequency range. The squeezed level of the squeezed light is dependent on the SNR of the PD. Existing researches tried to suppress the electronic noise and improve the SNR by adopting the bootstrap structure or introducing a junction field-effect transistor (JFET) buffering input based on the bootstrap structure. In pursuit of higher squeezed value, it is extremely vital to obtain higher SNR of the PD.

Framework

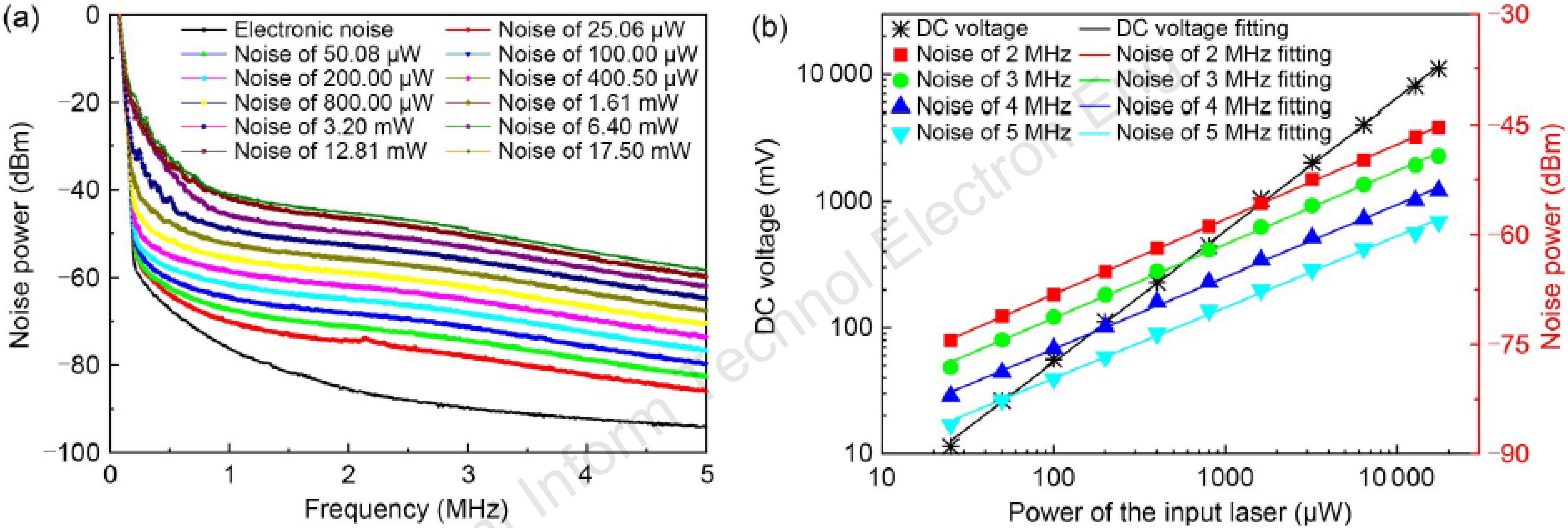


Circuit diagram of the photodetector

Method

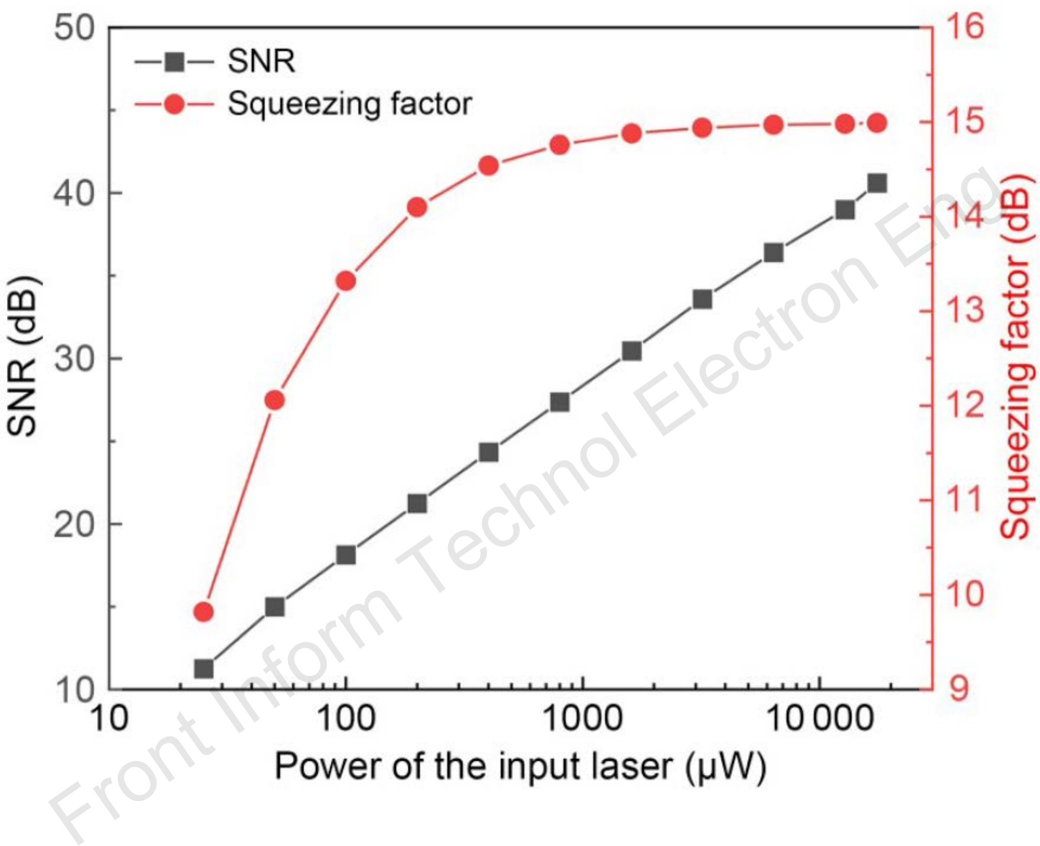
- We focus on the electronic noise and SNR and perform a comprehensive theoretical analysis of the SNR in high-frequency region based on the equivalent circuit of a typical transimpedance-based PD circuit with noise source.
- Particular photodiode junction capacitance allows the silicon N-channel JFET 2sk152 to be matched to the noise requirement for charge amplifier A250.
- By adopting the combination of an inductor and a capacitance, the AC and DC branches of the PD can operate linearly in a dynamic range of 25.06 μW–17.50 mW.

Major results



Noise power of the AC branch (a) and the linearities of the AC and DC branches (b)

Major results



Signal-to-noise ratio (SNR) of the AC branch and the corresponding measured squeezing factor for squeezed light of 15 dB obtained at 2.75 MHz

Conclusions

In conclusion, we have developed a low-noise, high-gain, and large-dynamic-range PD based on a JFET and a charge amplifier for the measurement of quantum noise in BSD. Based on the junction capacitance of 1 pF for a specially made InGaAs-PIN photodiode from Laser Components, the silicon N-channel JFET 2sk152 is preferred for satisfying the noise requirement for charge amplifier A250, and the electronic noise is effectively suppressed. By adopting the combination of an inductor and a capacitance, the AC and DC branches of the PD can operate independently and linearly in a dynamic range of 25.06 μW–17.50 mW. The maximum SNR reaches 15 dB in the range of 2–5 MHz for a coherent laser power of 50.08 μW. In addition, the DC branch provides a monitoring signal for laser beam alignment. The PD can completely meet the requirement of weak optical signal detection, quantum optics experiments, and relevant research.

Jinrong WANG received his BS degree from Yanshan University, China, in 2013, and MS degree from Shanxi University, China, in 2021. He is currently a college teacher in Lyuliang University. His research interest lies at precision measurement and optical quantum devices.