

Single-photon detectors [1] for near-infrared and telecommunication-wavelength photons are fundamental devices for quantum key distribution (QKD). InGaAs avalanche photodiodes (APDs) are promising devices for realizing practical photon detectors since they are based on commercially available technology and can be used in the operating temperature range of Peltier coolers. The drawbacks of InGaAs APDs in Geiger-mode operation, which is the conventional operation mode for detecting photons using an APD, are a large dark count rate (DCR) and a high afterpulse probability. Usually, InGaAs APDs are operated in gated mode in which a periodic shot duration bias, synchronized to input photon timing, is applied. In the gated mode, however, InGaAs APDs cannot detect photons with a random input timing.

We have proposed a sub-Geiger-mode operation [2] as an alternative to realize free-running-mode operation of InGaAs APDs [3]. In the sub-Geiger-mode operation, the APD is operated continuously at a bias voltage below the breakdown voltage. This mode can considerably reduce the afterpulse probability, since the average number of charges generated by a detection event of 100–1000 electrons is much less than that in the above-Geiger-mode approaches. Moreover, since the output in this mode is not saturated, we can estimate the input light intensity. Therefore, the bright illumination attack may be prevented by using sub-Geiger-mode single photon detectors in QKD systems.

In this study, we assembled a sub-Geiger-mode single-photon detector using an InGaAs APD with a readout noise lower than that of the previously used charge sensitive amplifier to improve the single-photon detection efficiency (SPDE). As a result, we obtained an SPDE of 6.2% at a DCR of 3.5k counts per second (cps). This value is as high as that of a conventional gated-mode InGaAs APD.

References

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- [2] H. Dautet et al., *Appl. Opt.* 32, 3894 (1993).
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