Demonstration SLR Experiment using Superconducting Nano-wire Single Photon Detector at 532 nm

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Overview

1. Introduction

2. Superconducting Nanowire Single Photon Detector (SNSPD)

3. Application in 1KHz SLR experiment

4. Conclusion
1. Introduction

- SPAD made by Czech Technical University with the chip diameter of 0.1mm are used in Shanghai SLR station in 1991.
- And the one with time walk compensation (C-SPAD) is being used since 1997 and the measuring precision with ps-laser is about 1.0 cm for LAGEOS.
- With the development of space debris laser ranging in Shanghai, it makes the demand of laser detector with low dark noise, high QE.
- The breadboard APD detector with the diameter of 0.5mm, QE ~ 40%, dark noise ~1kHz (200Hz gate signal), jitter ~500ps is developed by group of SHAO and East China Normal University for detecting echo from space debris.
1. Introduction

- The demonstration APD detector have been applied to laser measurement to space debris and validate its performances.
- C-APD detector developed by Czech Technical University is also used by for debris ranging.
  - Chip diameter of 0.5mm
  - QE ~ 40%
  - Dark noise ~18kHz (200Hz gate signal)
  - Jitter ~500ps.
- For further developing and testing the performance of new type detector in the observation to space targets, the attention of Superconducting Nanowire Single-photon Detector (SNSPD) is paid in order to make a trial in the laser ranging.
2. SNSPD

- In the last decade superconducting nanowire single-photon detector (SNSPD) have been largely improved and received considerable attention due to its outstanding performance, high QE, low noise, lower jitter.

- SNSPD with 1550nm wavelength have been used in:
  - long-distance quantum key distribution (QKD)
  - space-ground laser communication
  - depth imaging
  - on-chip characterization of nanophotonic circuits

- SNSPD may have excellent performance at shorter wavelength since the photons of shorter wavelengths have larger photon energy which cause high detection probability:
  - fluorescence spectroscopy detection at 635nm
  - Singlet oxygen luminescence detection at 1270 nm
2. SNSPD

- Cooperation with Chinese institute of CAS-----Shanghai Institute of Microsystem and Information Technology (SIMIT), the first version for 532nm laser detection is designed and developed.

- SNSPD dedicated for 532nm:
  - Coupled with multimode fiber (MMF) with 50µm diameter (ϕ = 50 µm)
  - Diameter of sensitive chip: 42 µm
  - Chip working temperature: near 4K
  - Maximum system detection efficiency (DE) of 75%
  - Extremely low dark count rate of 0.1 Hz.
  - Timing jitter is about 60ps
  - No gate
Fiber input

vacuum chamber

Fiber coupling

SNSPD device

Cooler control

Temperature ~4K

Electronic systems
(Temperature monitor
Power module
...

Bias module
(Current limiter
Bias-Tee
Amplifier)

Current signal

Temperature ~4K

output

Cooler control
(a) DE (left) and DCR (right) versus bias current. The DE is approximately 75% with DCR less than 1Hz.

(b) Histograms of the time-correlated photon counts measured at a wavelength of 532 nm. The red lines are the fitted curves using the Gaussian distribution.

(c) Oscilloscope persistence map of the response at a bias current of 10.0 µA. Recovery time of approximately 300 ns (dead time).
3. Application in SLR experiment

Confocal optics \(\rightarrow\) small field of view
**Receiving FOV of SNSPD**

Limited by

1) Diameter of MMF (Multimode fiber): 50µm

2) N.A (numerical aperture) of the fiber: \( \sin(\theta/2) = 0.18\sim0.23 \)

SLR experiment has a fairly limited detector

**FOV of \( \sim 10" \).**
Laser Ranging control room
Dome and 60cm SLR telescope
Downstairs
Upstairs
Fiber
Cable line
SNSPD
stairs
Laser
Ranging control room
Calibration test

- **Laser:**
  - 532nm wavelength
  - 1 kHz repetition rate
  - 1 mJ per pulse
  - 30 ps pulse width
  - 0.6 mrad divergence

- **Event timer:**
  - ET-A033

- **Calibration Precision (RMS):** 0.7cm
3. Application in SLR experiment

- Due to the small receiving FOV for the demonstrated SNSPD, it is difficulty to make the collimation of transmitted and received laser signal.
  - Measuring the sensitive area of detector by counting the number of stop pulse through tracking star
  - Adjusting coude path of laser beam to make the stability of pointing
  - Improving the telescope tracking performance

- Due to no gate control, many stop pulses will be recorded by ET to make data processing difficult.
  - Setting the gate control on ET to make less stop pulses recorded.
  - The first two stop pulses within each measuring period (1kHz) are used for data processing in order to increase the number of laser echoes.
3. Application in SLR experiment

After the preparative works have been done, laser measurement to satellites was performed.

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- Target: Lares
- Receiving telescope: 60 cm
- Transmitting telescope: 21 cm
- Pointing accuracy of the telescope after star calibration is about 5"
Due to the major coupling loss from telescope receiving terminal to MM Fiber to detector, the return ratio is not high, much lower than the expected one.

The precision of measuring satellites is about 8.0 mm.

BUT the noise is much lower than C-SPAD and APD to help enlarge gate width for measuring to space debris.
4. Conclusion

- SNSPD is firstly applied in SLR
- The measuring precision achieves around 8.0 mm
- Due to low fiber coupling efficiency the return rate do not achieve the expected goal.
- The way of fiber coupling link will
  - make the detector be set in the stable condition to improve stability.
  - make less noise from background
- Ultra low dark-counts also make high SNR.

Low noise, High DE and high measuring precision
4. Conclusion

- Next step:
  - Fiber coupling in the detector and telescope should be strictly aligned in the future for weak photon.
  - 100 µm or 200 µm fiber for SNSPD with the diameter of sensitive chip 50 µm is being developed.
  - The detector with the larger sensitive chip (100 µm - 200 µm) will be considered to make larger FOV observation.
4. Conclusion

- **Prospect:**

  - The detector with the characteristics of High EQ, Low noise, Low jitter is perfect for laser measurement, especially for high repetition SLR, lunar ranging.
  
  - Much better performance than APD in the wavelength of 1064nm, which is a good choice for 1064nm laser ranging to space debris or other applications.
  
  - Fiber coupling may lead to better results in daylight ranging for its coupling to prevent background noise into the fiber.
Thank you