1064nm Laser Ranging Experiments at Kunming SLR Station using Superconducting Nanowire Single Photon Detector

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Outline

- Introduction
- 1064nm laser ranging system development
- Experiment results
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Introduction: 1064nm Laser

- Why we use the 1064nm Laser?

(Compared with 532nm)

- Larger photon quantity

  532nm laser is generated by second harmonic of 1064nm laser, second harmonic efficiency less than 60%

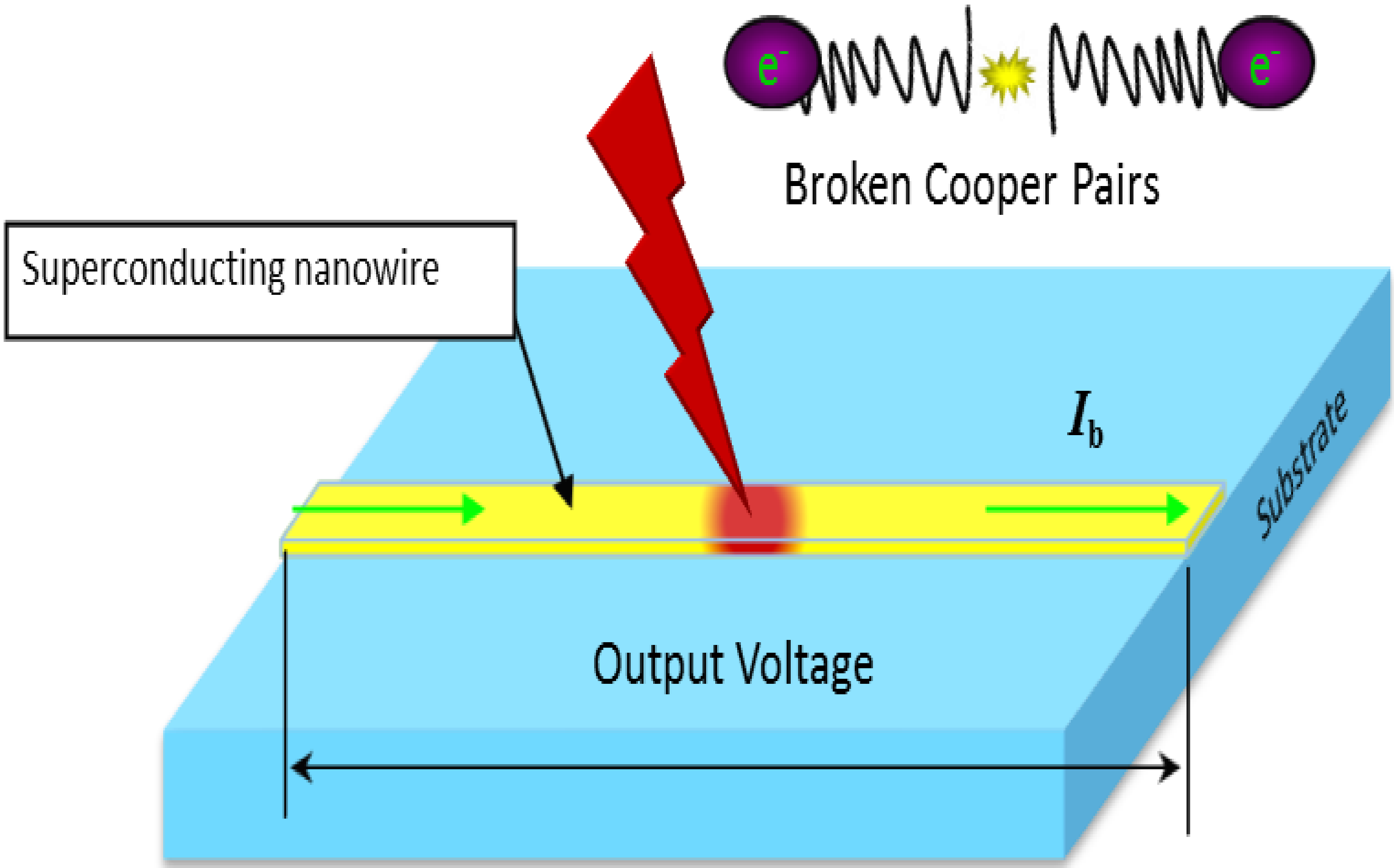
  photon energy of 532nm laser is twice compared with 1064nm laser

- Less impact from disturbance and attenuation effects from atmosphere

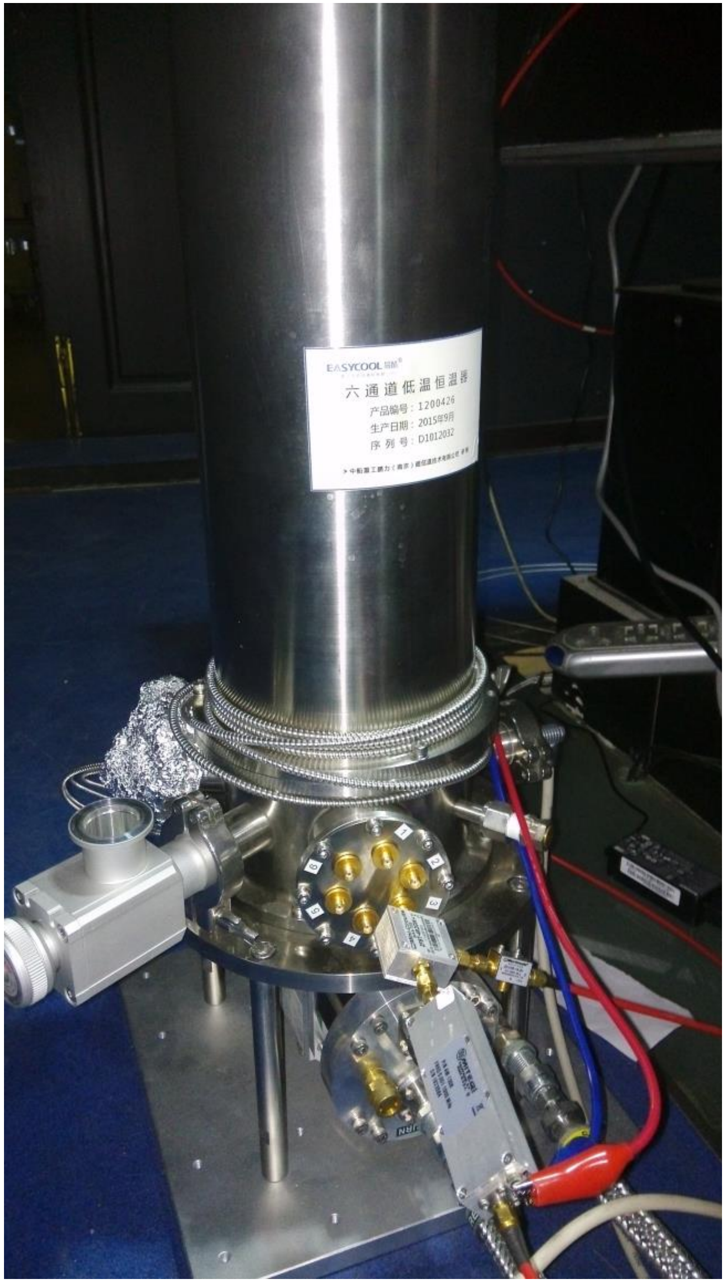
- Flexible hardware adaption

Introduction: SNSPD

- Principle of the Superconducting Nanowire Single Photon Detector



Introduction: SNSPD



The Characteristics of SNSPD:

- Low dark counts

< 100cps

- Wide response bandwidth

500nm~1700nm, adjustable according to demands

- High repetition rate
- Time jitter round 50ps

Introduction: Preliminary

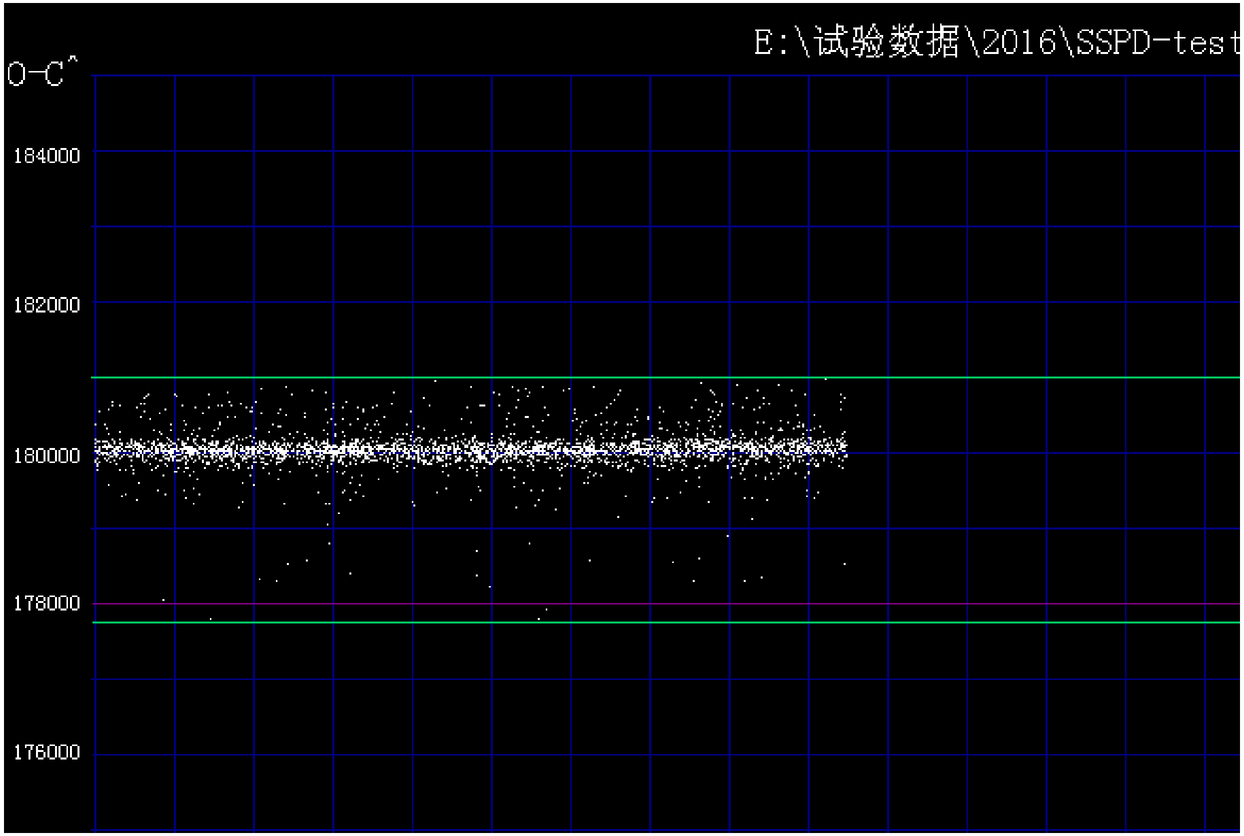
The preliminary ground target test using 30ps laser in April 2015 has a precision less than 1cm, similar to the C-SPAD's. The single shot accuracy is 5~7cm

SNSPD:
- developed by NJU
- response up to 1550nm wavelength.

Laser:
532nm, 0.8mj, 30ps, 1KHz, Common path

Echo from target in distance of 200m, were received, which single shot accuracy was less than 1cm.

Another target 18km away was ranged successfully.



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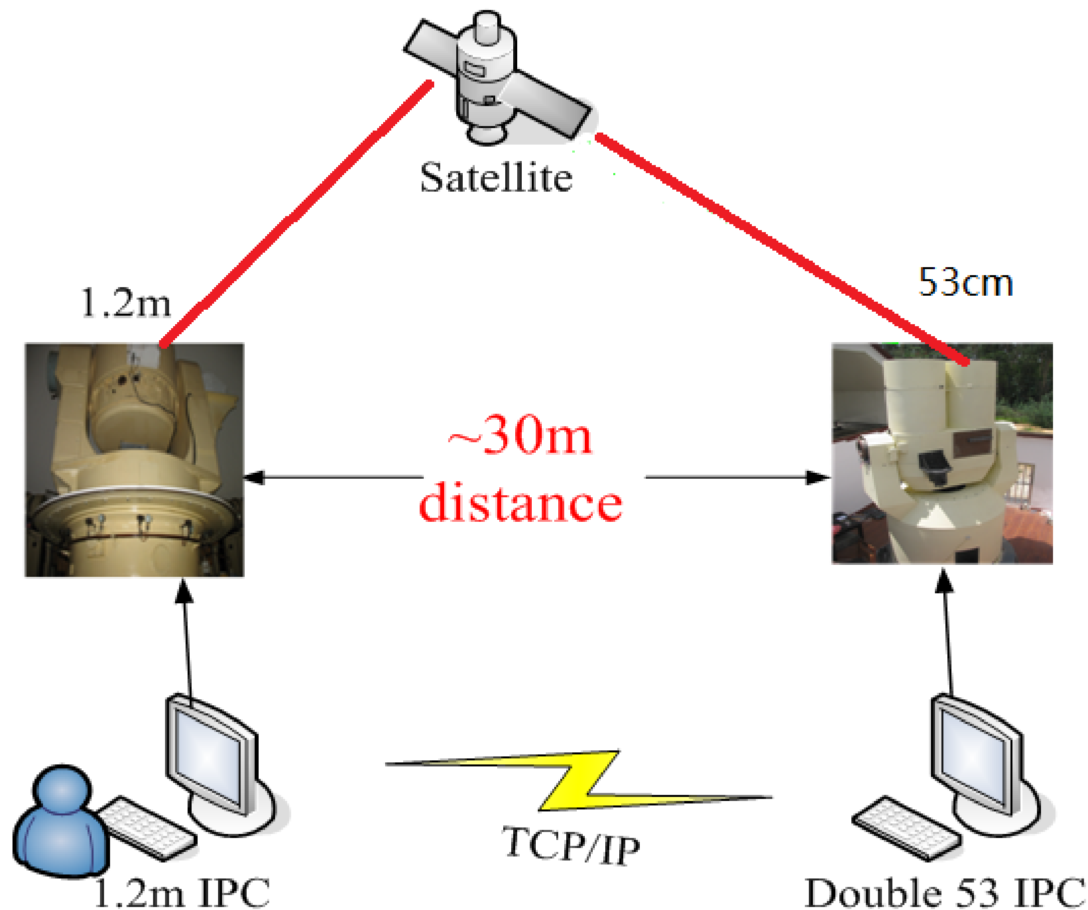
System Development

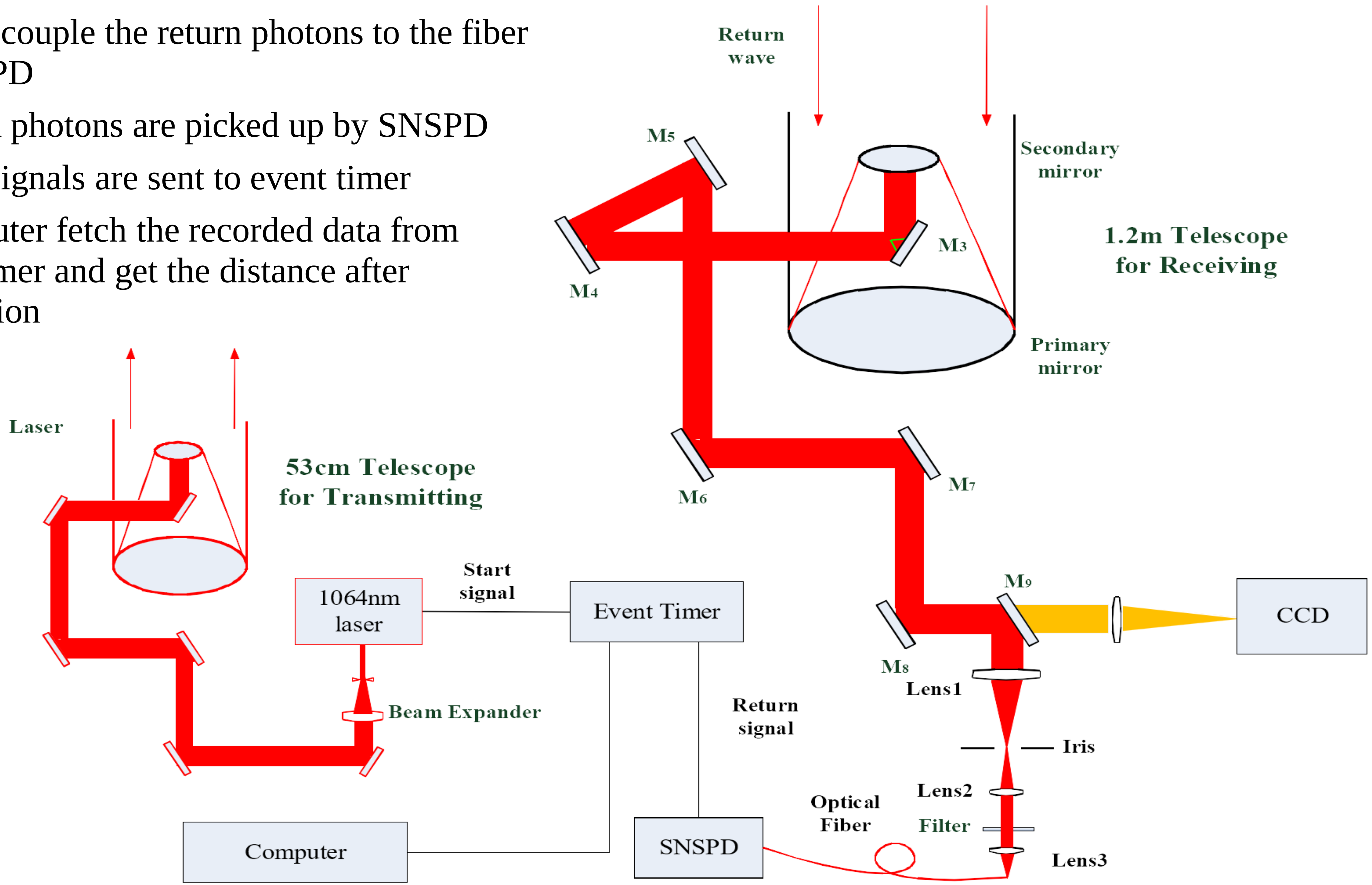
In February 2016, a new SNSPD from NJU focusing on 1064nm with system quantum efficiency of 20% and fiber diameter 65µm arrived and was prepared for satellite laser ranging experiments.

Transmitting and receiving

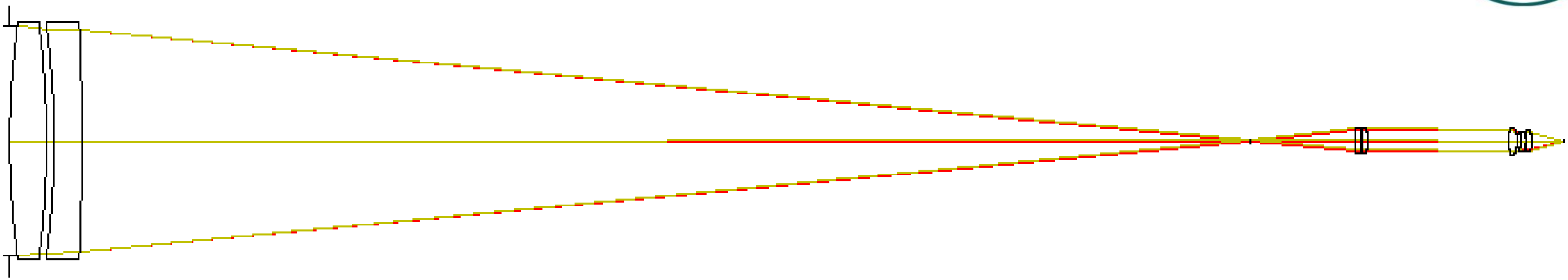


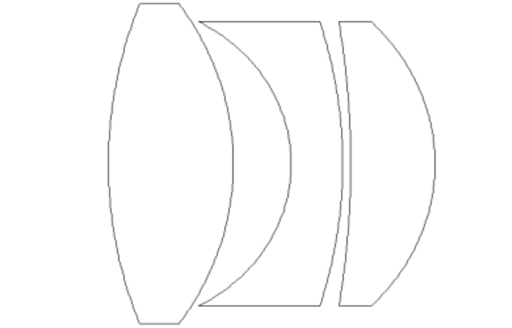
Structure

- Lens1, lens2, iris and narrow band pass filter(10nm) for collimation and filtering
- Lens3 couple the return photons to the fiber of SNSPD
- Return photons are picked up by SNSPD
- Echo signals are sent to event timer
- Computer fetch the recorded data from event timer and get the distance after calculation



About the receiving optic path





- Lens1 and lens2 are double lens
- Lens3 is triple-lens combination
- Chromatic aberration of 532nm and 1064nm is eliminated
- Receiving optic path is for both 532nm and 1064nm wavelength
- Receiving fiber is fixed on a precise 5-axis kinematic mount, where the fiber can be coupled to the focus of lens3

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Failure in 532nm SLR

As previous 532nm laser ground target ranging was successful, 532nm SLR experimets was carried out first.

Result: Failure

Reason: Severe influence from the 80MHz laser from mode lock oscillator

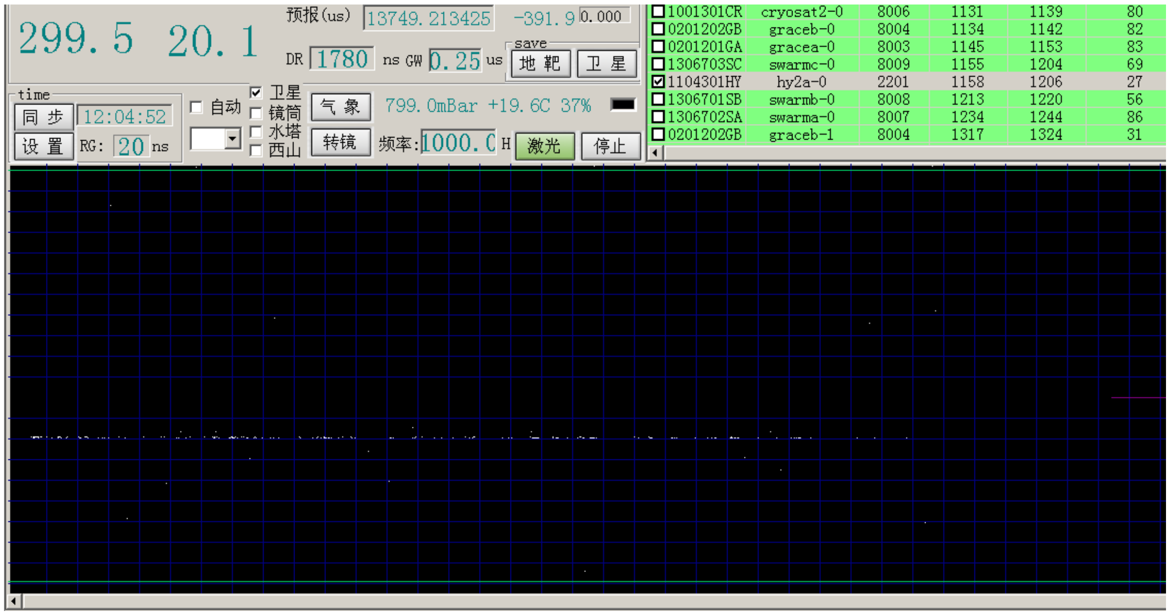
Solution: To use 1.2m telescope to pick up return wave while the 53cm binocular transmitting the 1064nm laser for the ranging experiments

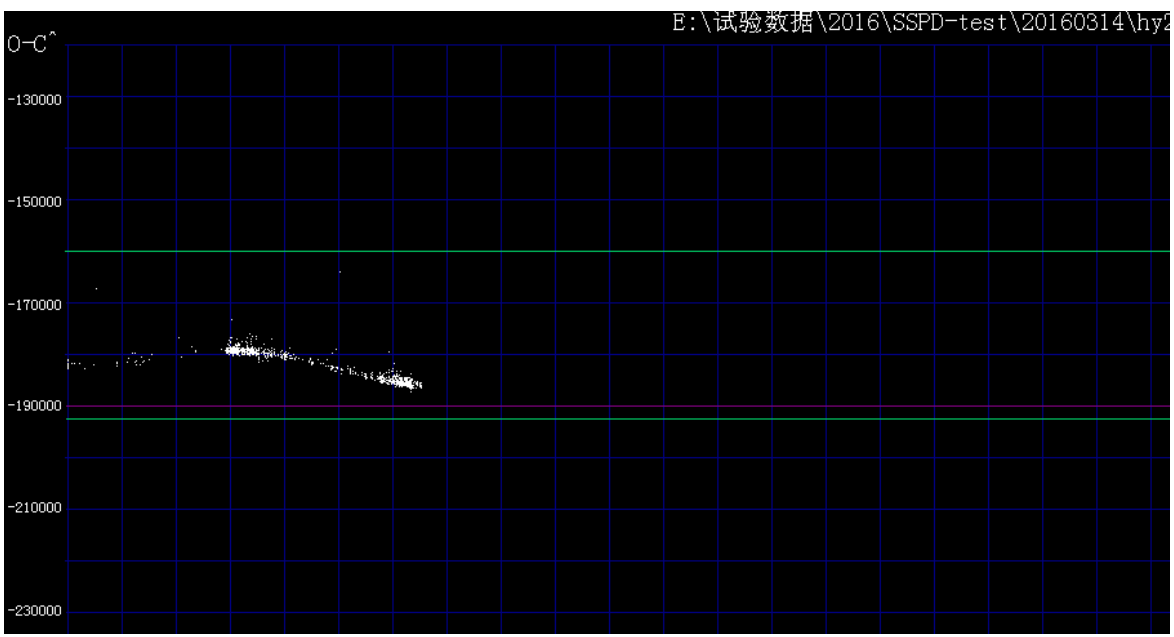
New Approach:

The laser is transmitted by 53cm binocular, its mirrors are coated with material fitting both 532nm and 1064nm laser.

Return waves are received by 1.2m telescope

1064nm SLR Result





The accuracy of single shot lies between 5~7cm, depending on laser pulse width.

The two figures shows ranging results of Hy2a on March.14.2016

1064nm SLR Result

date	satellite	Distance (ms)	Distance (km)	RMS(cm,2σ)
March 3, 2016	ajisai	9.154	2746.2	6.7
March 9, 2016	ajisai	9.722	2916.6	~
March 9, 2016	lares	5.381	1614.3	6.5
March 9, 2016	Glonass118	64.5845	19375.35	6.2
March 11, 2016	beaconc	5.482	1644.45	5.7
March 14, 2016	Hy2a	6.8745	2062.35	5.1
March 15, 2016	beaconc	7.767	2330.22	5.9
March 15, 2016	cryosat	4.981	1494.3	~
March 16, 2016	ajisai	10.1045	3031.35	6.9
March 17, 2016	cryosat	5.114	1534.31	6.2

During March.3~17, totally 10 groups of SLR data were acquired, including low orbit satellites like Ajisai, Hy2a, Cryosat and so on, as well as high orbit satellite the Glonass118

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- **Summaries of the experiments:**

Noise laser from mode lock oscillator fills the common optic path, the detector and event timer could not work properly at Kunming Station.

In the experiments the laser energy of 40mJ, 1kHz is applied. But the optical units in 1.2m telescope has not been coated in the past 4 years, resulting in low optical transfer efficiency of receiving path less than 10% (which is going to be solved by a recent upgrading). Thus, the application of strong laser does not contribute too much in the experiments.

1064nm is invisible, makes it hard to adjust the optic path. An IR electroviewer is necessary for adjustion.

Conclusions

- **Ad-/disadvantages of SNSPD application:**

+ very low dark noise level: <100cps
+ high precision: 1cm - ground target; 5~7 - satellites
+ high repetition rate and fast responde: recovery - 50ns
+ Large bandwidth range: 500~1700nm laser

- thin fiber for coupling
- low detect efficiency: QE of round 20%

SNSPD is quite a promising detector device. Its properties like low dark noise, fast respond, high detective repetition and so on are very good for SLR; But small coupling fiber diameter, low detect efficiency are its disadvantages, which need to be solved for further application of SNSPD in SLR.

Thank you!