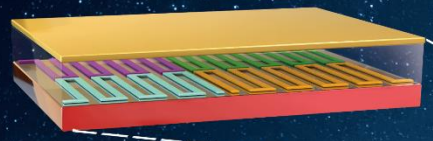


Demonstration of a Next Generation SLR Based on SNSPD Array

Labao Zhang[1*], Yuqiang Li[2], Zhulian Li[2], Jisi Qiu[3], Sen Zhang[1], Jiang Zhu[1], Xiachao Yan[1], Dongshen Zhai[2], Haitao Zhang[2], Xiaoqin Jia[1], Honglin Fu[2], Xiaoyu Pi[2], Lin Kang[1], Jian Chen[1], Biaobing Jin[1], Yang Liu[3], Yaoheng Xiong[2] and Peiheng Wu[1]

1. Research Institute of Superconductor Electronics of Nanjing University, Nanjing, China, 210043

2. Yunnan Observatories of National astronomical observatory of China, Kunming, China, 650216

3. Academy of Opto-Electronics of Chinese Academy of Science, Beijing, China, 100080

* Lzhang@nju.edu.cn

Outline

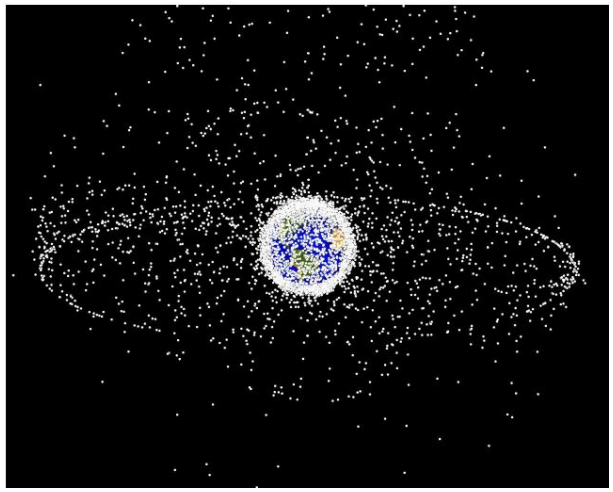
1. Background
2. SLR system and SNSPD
3. Laser ranging results
4. Conclusions

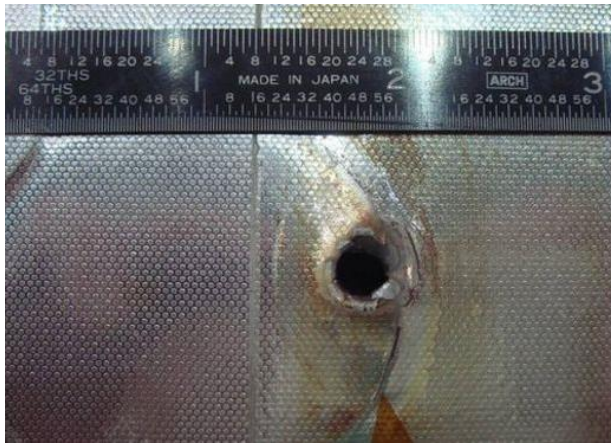
EUCAS

1. Background

Space debris is the collection of defunct human-made objects in earth orbit, such as old satellites, spent rocket stages, and fragments. From Wikipedia.

Satellite Laser Ranging (SLR) is most precise techniques for measuring space target such as satellites and space debris.



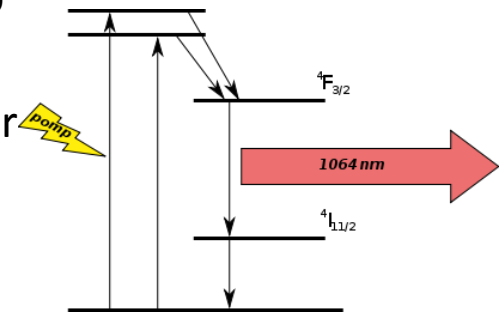


https://ilrs.cddis.eosdis.nasa.gov/index.html

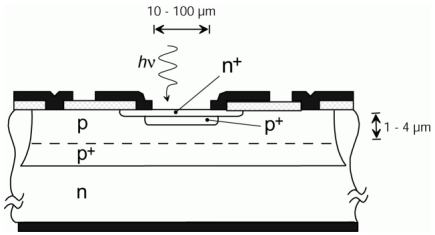
Brief history of SLR

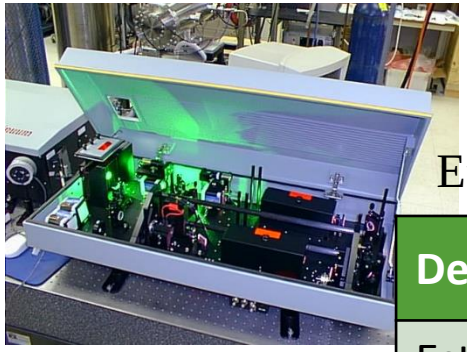
1970s Solomon, L.H. (1967) Some results at Baker-Nunn tracking stations. Smithsonian Astrophysical Observatory Special Reports, No. 244, 14pp

1990s Nd:YAG laser

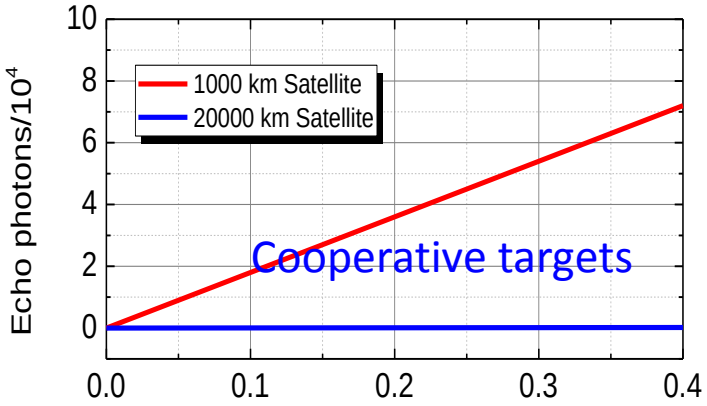


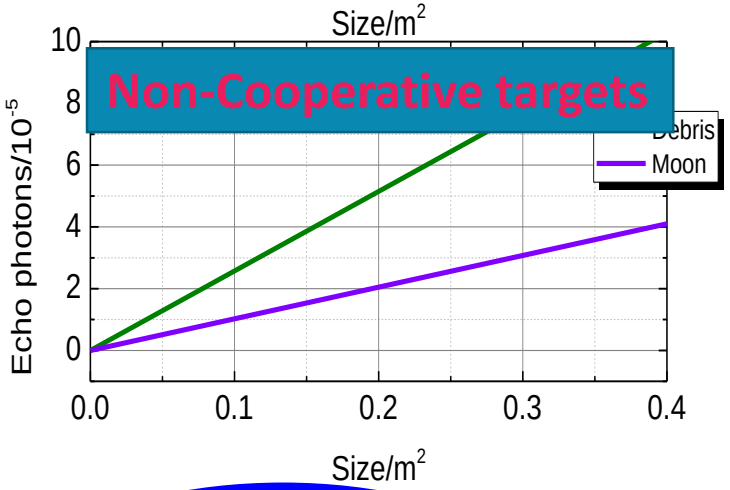
2000s **Single-photon avalanche diode**





Nd:YAG laser with lid open showing frequency-doubled 532 nm green light





Effective number of objects, 10 cm and larger.

Debris Size	0.1-1 cm	1-10 cm	>10 cm
Estimated amount[2]	150 million	650 000	22 000

dangerous

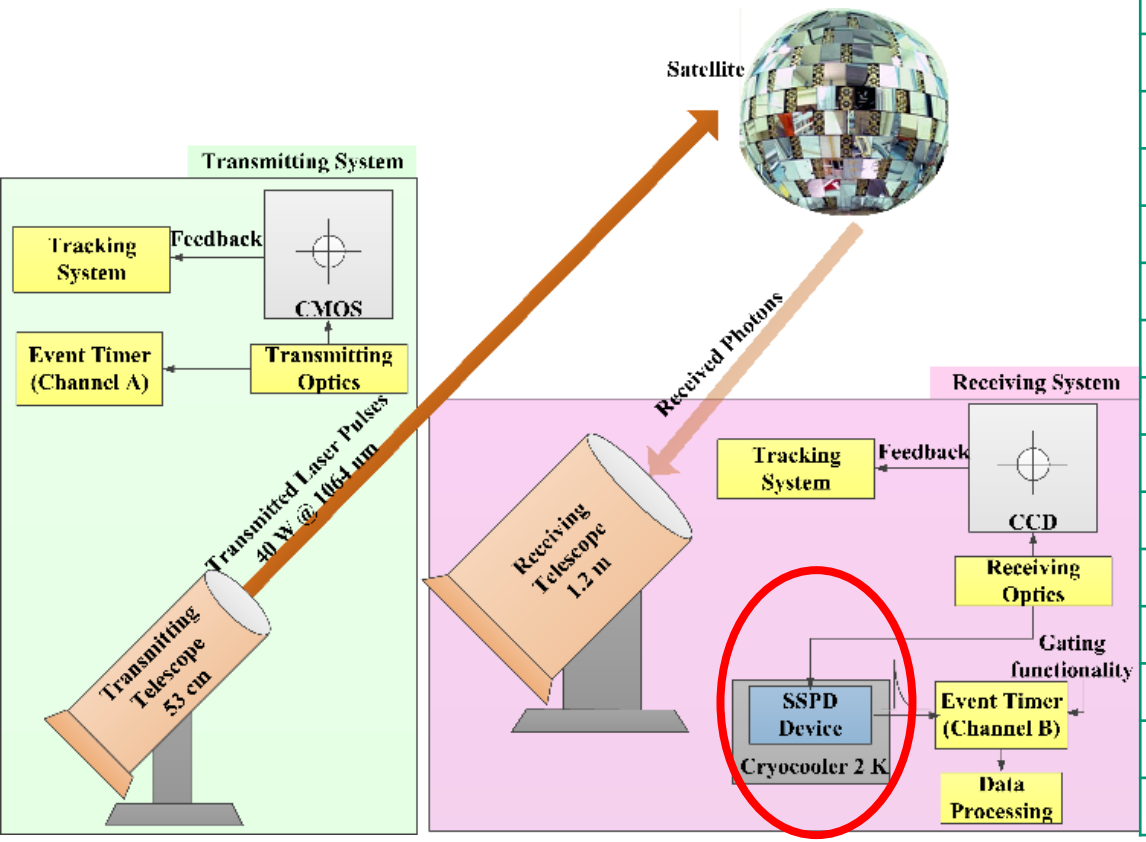
Difficult to measure with current SLR

[1] Liou, *el al.*, Science, 311(2006).

[2]Source: European Space Agency MASTER 2005 Debris Environment Model.

2. SRL system and SNSPD

Propose: 1064 nm laser + SNSPD



Parameters	values
Laser wavelength	1064 nm
Laser pulse energy	0.4 J
System equivalent focal length	2352 mm
Telescope aperture	150 mm
Laser divergence	85 urad
Divergence of transmitter-telescope	97 urad
Tracking error of transmitter-telescope	243 urad
Divergence of receiver-telescope	24 urad
Tracking error of receiver-telescope	243 urad
Detection area	40 μm×40 μm
Coupling fiber	Ø100 μm
Atmosphere transmittance	0.1
Transmitting optical system efficiency	0.8
Receiving optical system efficiency	0.6
Target reflection index	0.5

SNSPD array

Laser pulses were transmitted through a telescope with an aperture of 0.53 m. The echoes reflected from the targets were coupled to the SNSPD device through the 1.2 m-aperture telescope.

Schematics: SLR system
1064 nm SNSPD
Beam compression

Quasi-gated model

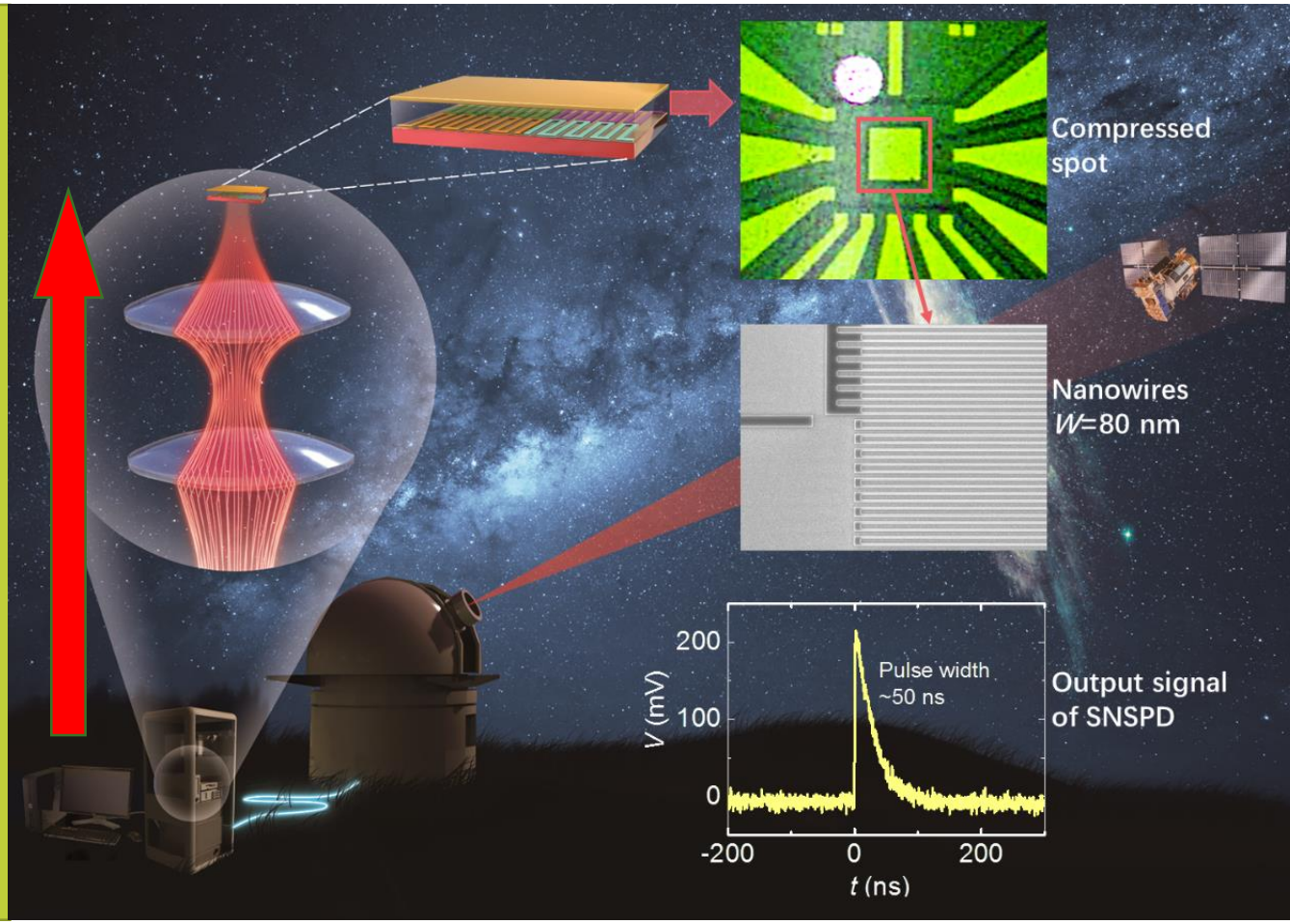
L. Xue, et al., Optics Letters **41** (16), 3848 (2016);
L. Zhang, et al., IEEE PLT, **28** (22), 2522 (2016)
L. Zhang, el al., Science Bulletin 60 (16), 1434 (2015)
L. Zhang, et al., IEEE Photonics Journal 6 (5) (2014)
L. Zhang, Sen Zhang, el al., IEEE TAS **27** (2), 2201206 (2017)

Detection area: 40 um

Beam compression: ~ 0.3X
NA: 0.8

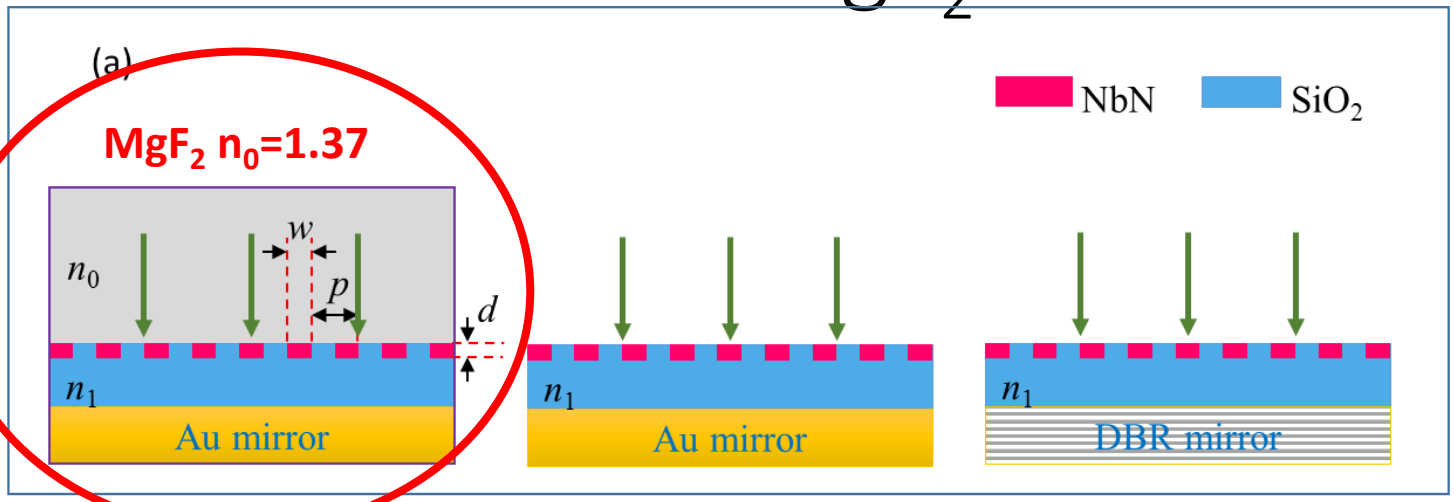
Coupling Fiber: 100 um
NA=0.22

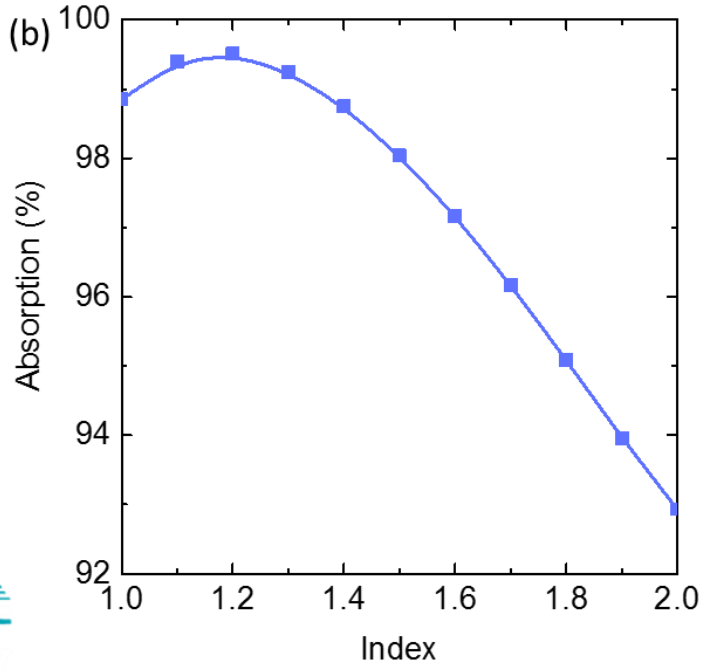
Telescope: 1050 mm
Diffraction Spot size: 37 um
Tracking error: 242 urad
Equ. focus length: 2352 mm

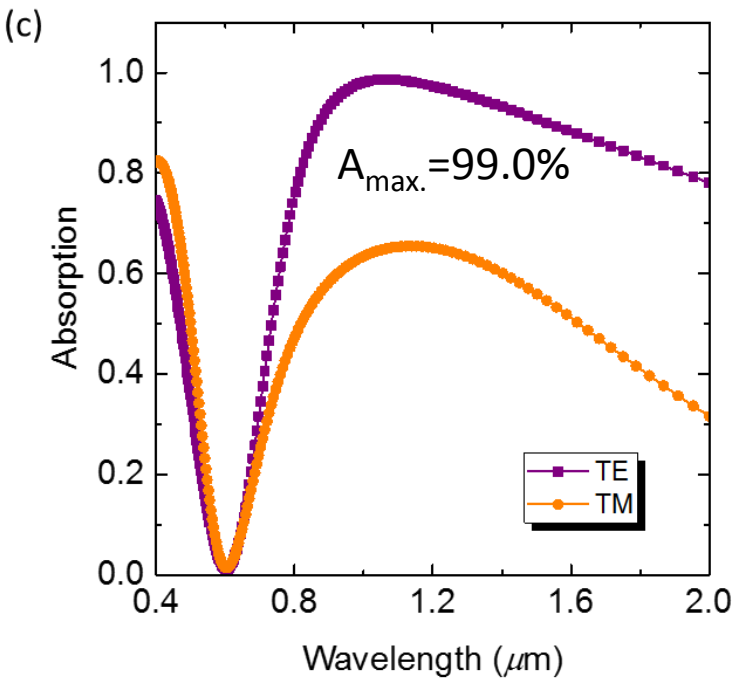


EUCAS 2017

1064 nm SNSPD on MgF_2 substrate

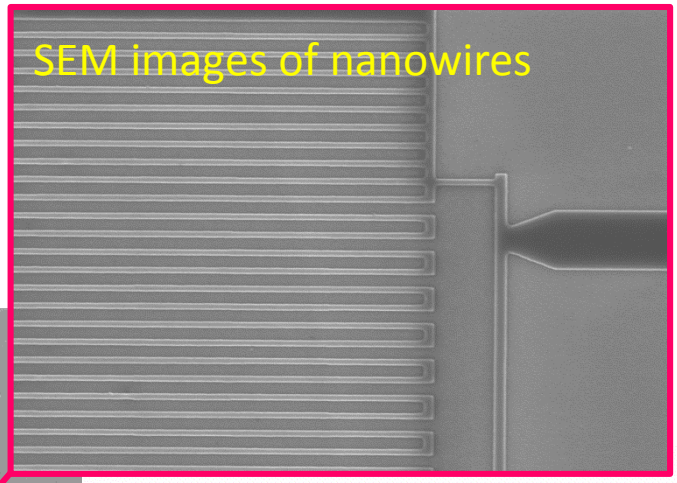


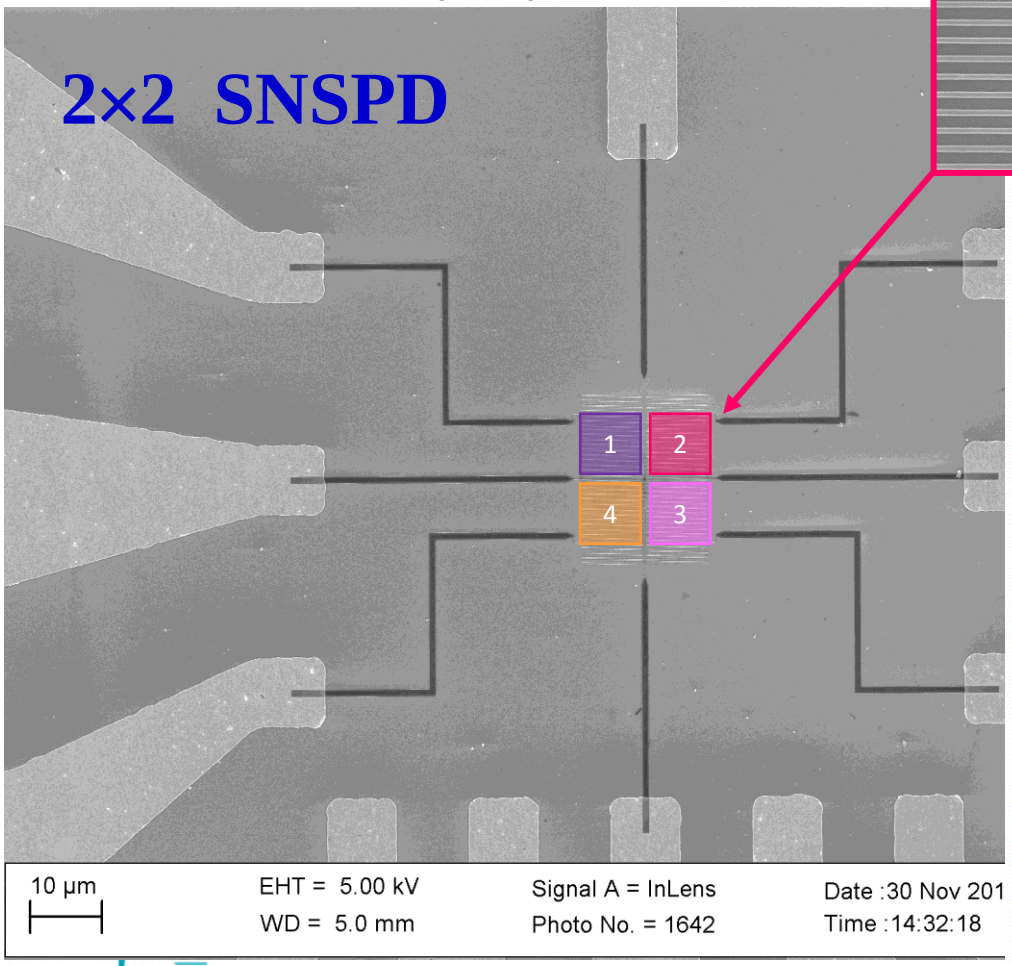


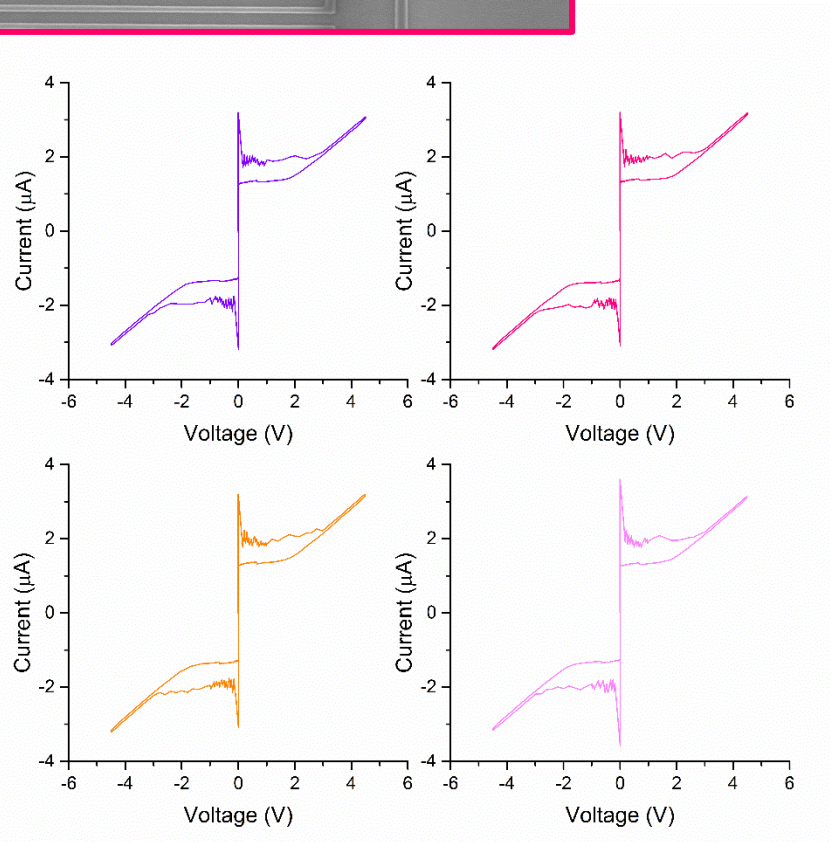


SNSPD array

- Uniformed geometric structure and electrical properties.

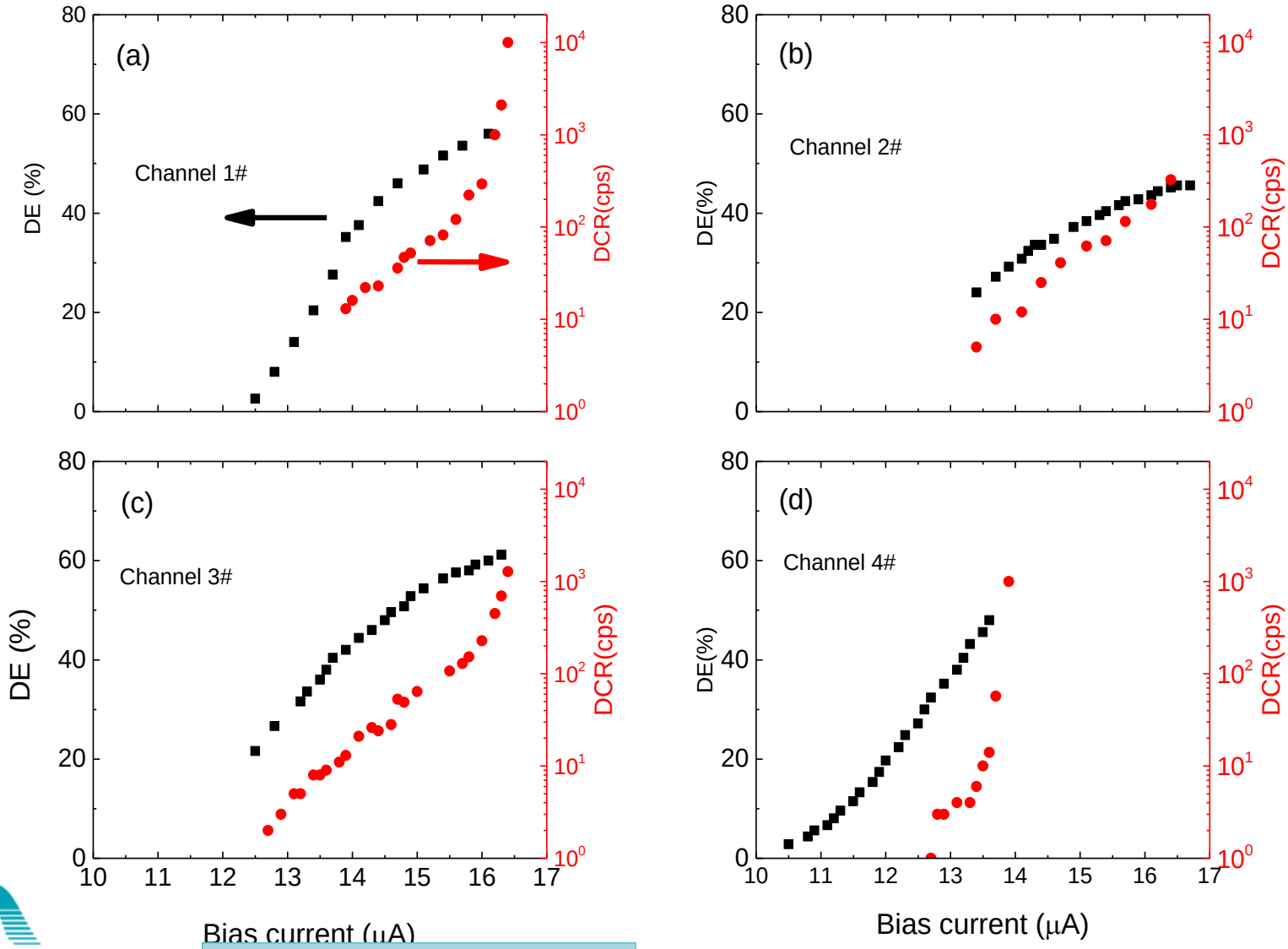






IV curves at 4.2K

System performance of SNSPD array

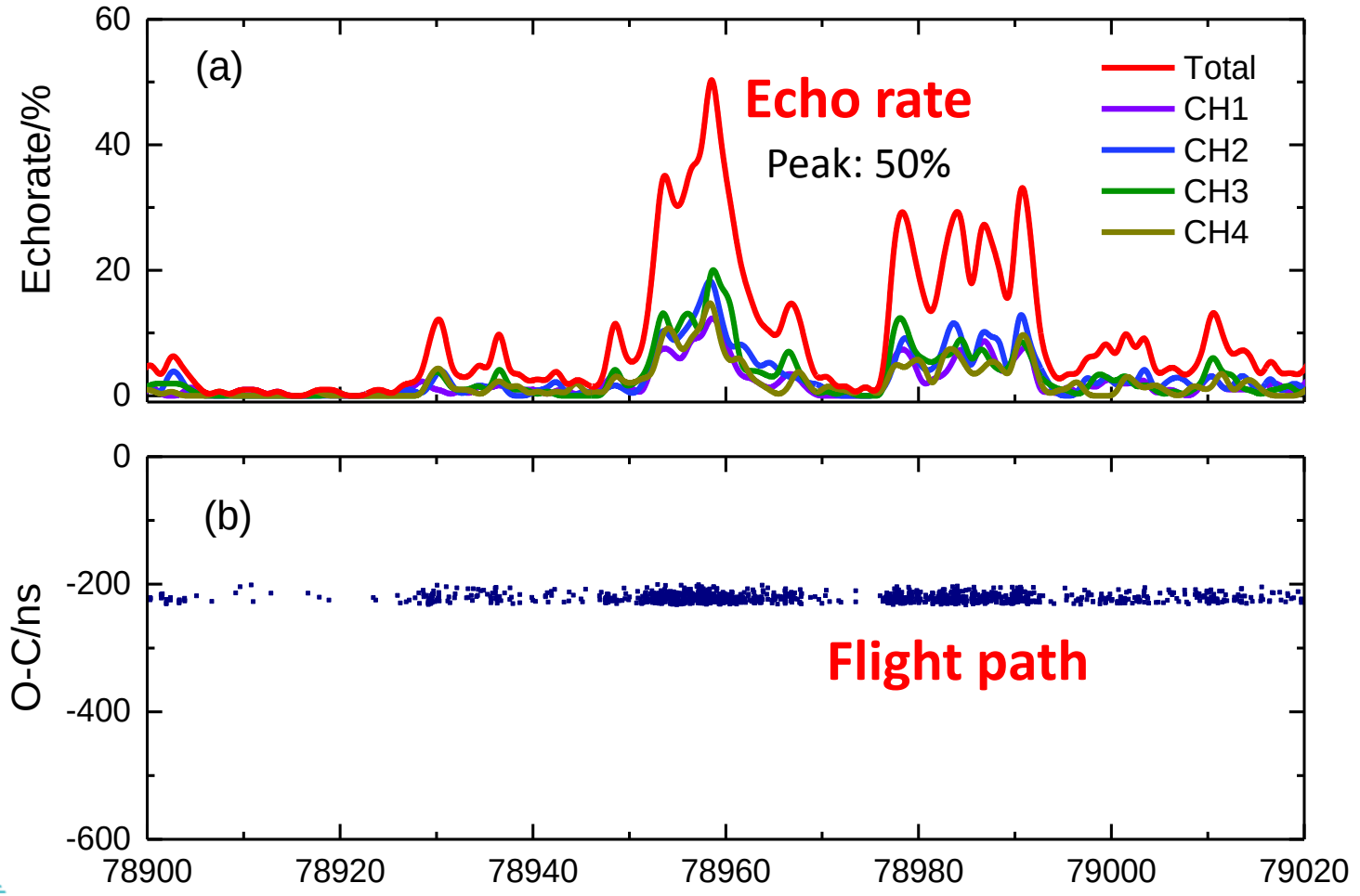


Time jitter: 140 ps

T=2.2 K

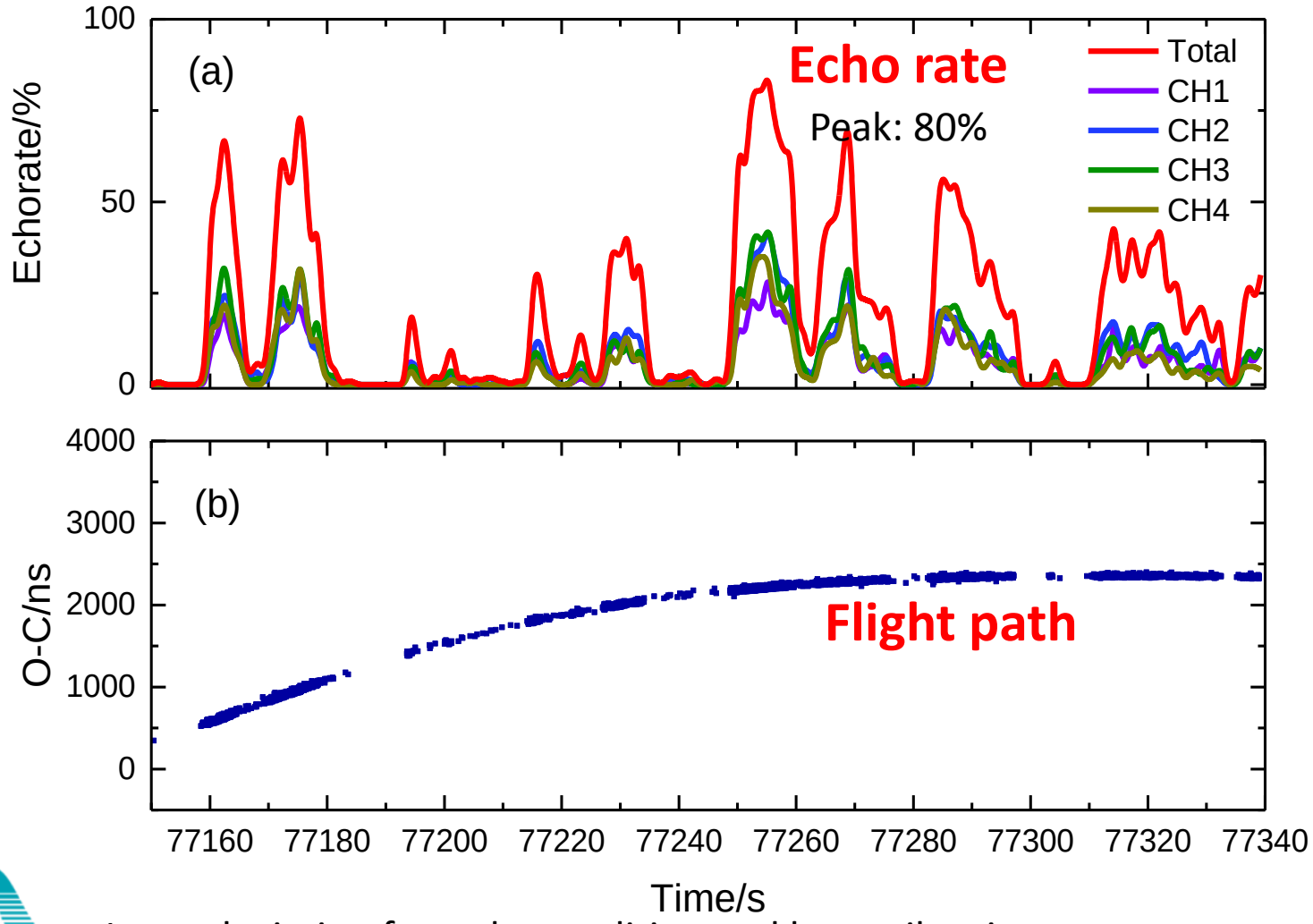
3. Laser ranging results

- Cooperative target: COMPASS I6B Satellite



altitude: 36 000 km

Non-Cooperative target: debris No. 37766

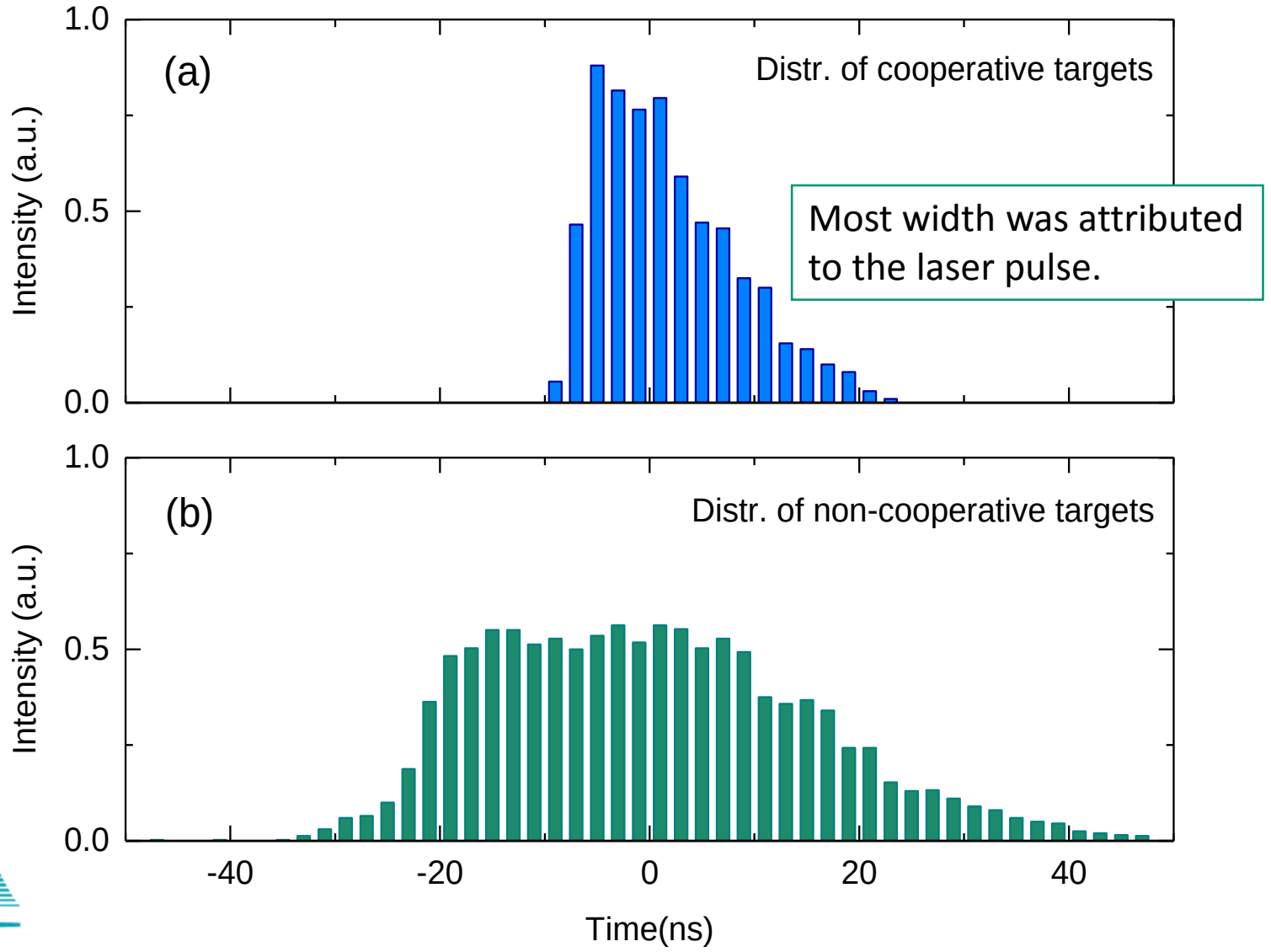


Large deviation from the perdition and large vibration.

altitude: ~700 km

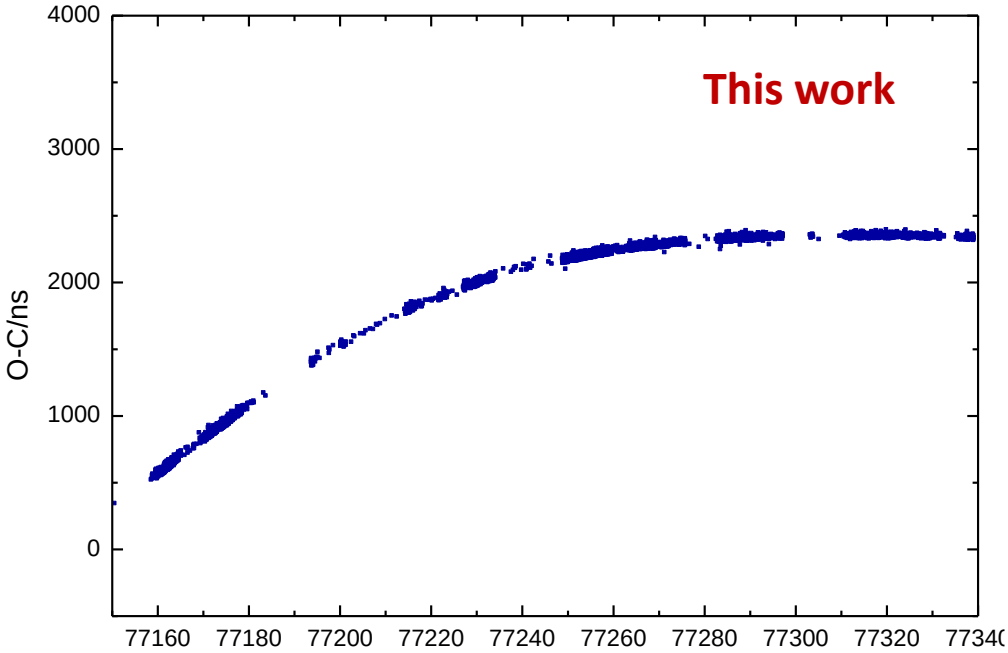
Resolution of SLR

Width of laser pulse: 6.7 ns

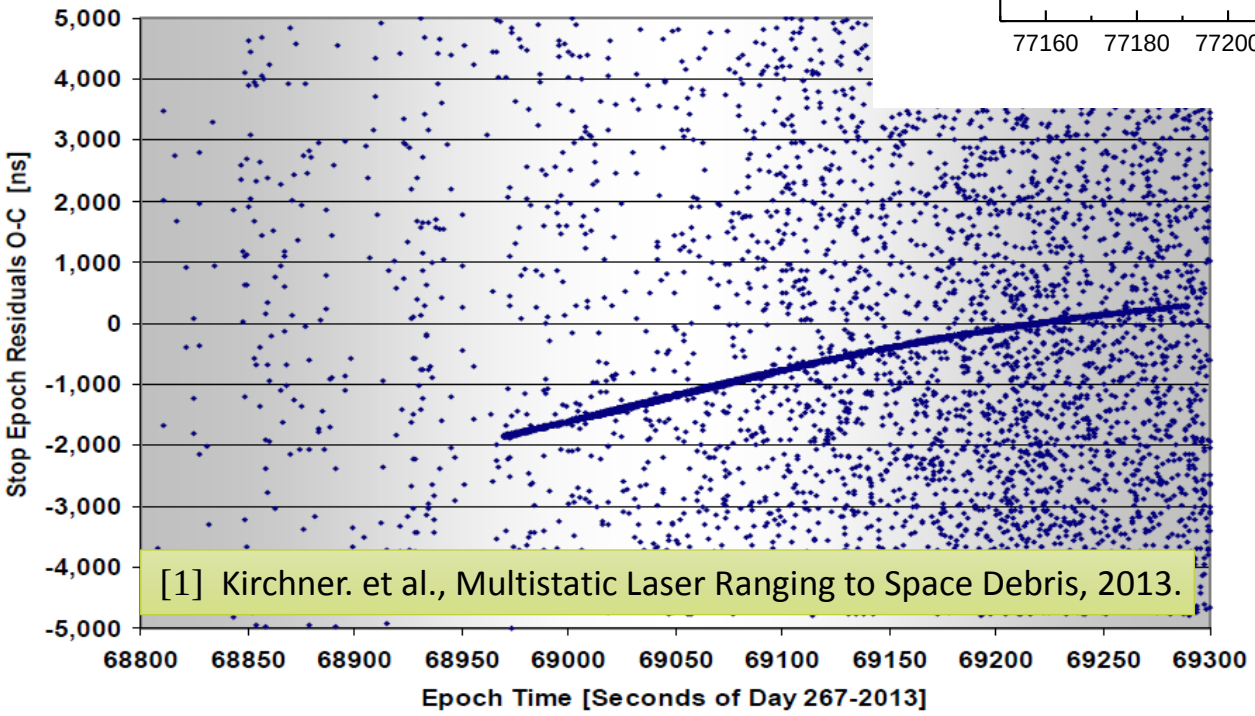


Most width was attributed to the laser pulse.

Comparison with previous results



An old rocket body (NORAD 23088) , detected at the SLR station Wettzell.

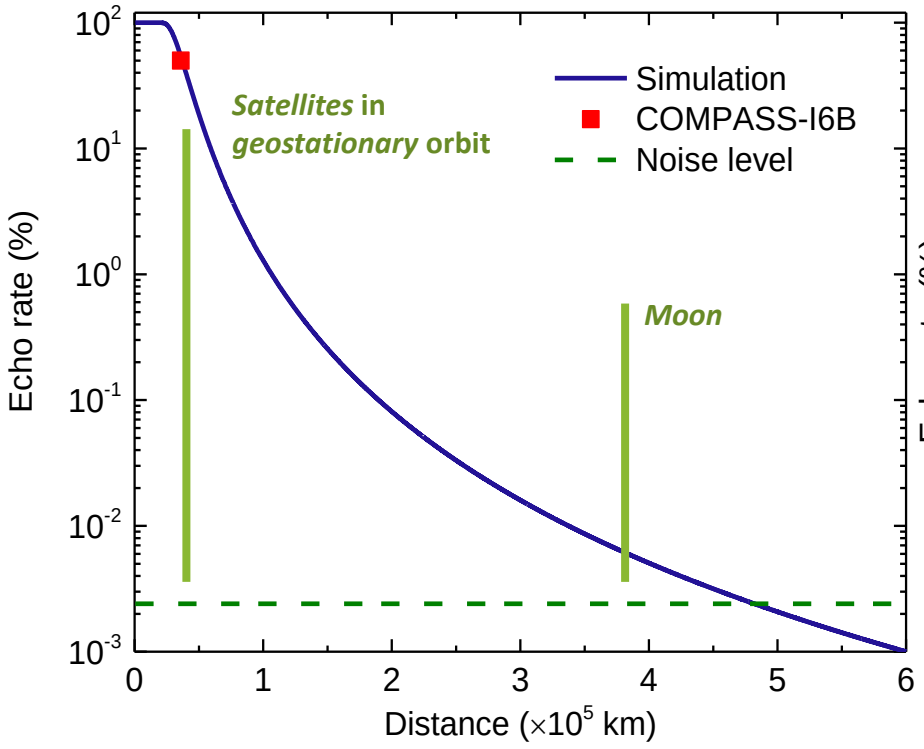


[1] Kirchner. et al., Multistatic Laser Ranging to Space Debris, 2013.

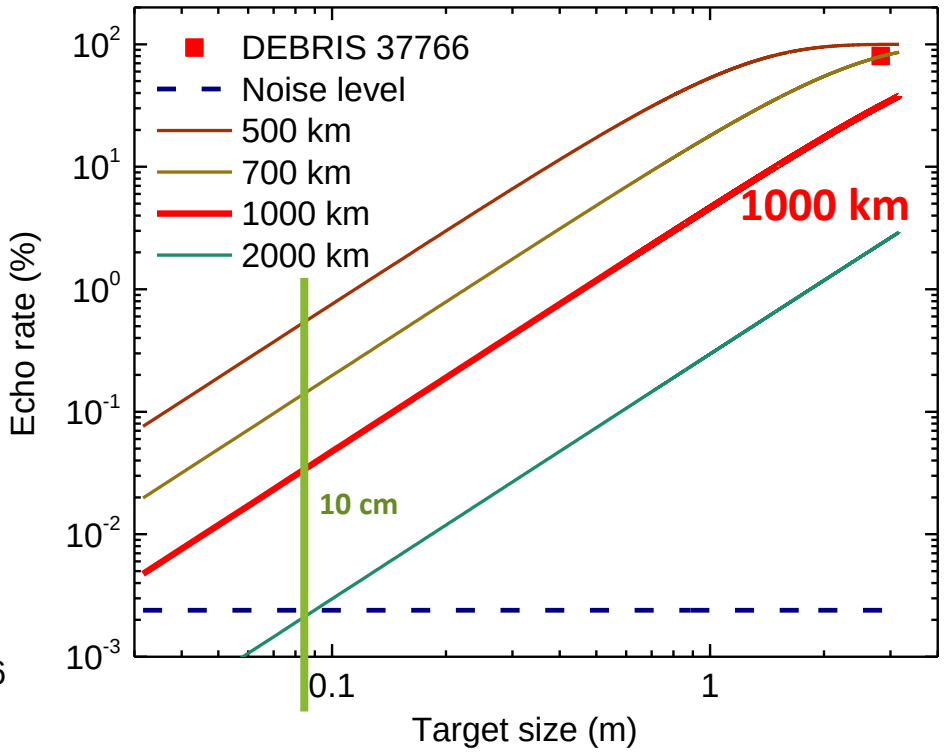
NOT only high efficiency, but also low noise and higher time resolution.

Analysis of ranging capability

Cooperative targets



Non-cooperative targets



Simulation was conducted based on Lidar equation.
The results was consistent with experimental data.

4. Conclusions

- **Demonstrated a next generation of SLR based on SNSPD.**

- **High echo rate for GEO satellite and space debris.**

  We have measured 170 targets up to now. (95% success)

  This system is possible to measure the debris with size < 10 cm.

- **The ranging capability can be further improved with a better telescope.**

Thank you!

Any comments are welcome.

Lzhang@nju.edu.cn

EUCAS 2017