Metastable Helium Lidar in Hainan, China

Ruocan Zhao [(a)], Zhenwei Liu [(a)], Hang Zhou [(a)], Zhaofeng Wang [(a)], Jiangtao Li [(a)], Yingyu Liu [(a)], and Xianghui Xue [(a)]

[(a)] School of Earth and Space Science, University of Science and Technology of China
No 96, Jinzhai road, Hefei, Anhui, China
canlan@ustc.edu.cn

Abstract: Metastable helium He (2^3S) is a potential tracer for lidar detection of thermosphere and even exosphere. The lidar group in University of Science and Technology of China has been developing a large metastable helium lidar system since 2019. In the summer of 2023, the lidar system was initially assembled in Danzhou, Hainan Province of China. This system consists of 3 1083nm pulsed lasers with energy of more than 70 mJ and an array of 6 telescopes with diameter of 1m. The detector is a superconducting nanowire single photon detector (SNSPD). Observations are performed in case of clear night since November and more than 30 days of valid data was collected. More data processing and retrieval methods will be conducted in the future.

1. Introduction

The density, wind and temperature of neutral atmosphere of thermosphere and exosphere is related to the solar activity and the coupling of difference layers. It affects the safety of space activity. In this region, lidar can hardly get enough Rayleigh signals because of low density. Metastable helium becomes a potential tracer for fluorescence resonance lidar detection above height of 200 km.

The metastable helium lidar was initially proposed by Gerrard in 1997 [1]. After that, Carlson et al. in University of Illinois reported a bistatic lidar system with a continuous-wave 1083nm laser [2,3]. In 2022, German Aerospace Center developed a metastable helium lidar with a pulsed 1083nm laser and firstly reported the measurements of metastable helium density up to 750 km [4]. The result shows good agreement with the model prediction of the spatial-and-temporal distribution of metastable helium in thermosphere.

In this paper, we will introduce the under-developing metastable helium lidar in Danzhou, Hainan Province of China. This is a project conducted by the lidar group in University of Science and Technology of China since 2019 [5].

2. Instrument

The 1083nm pulsed laser has a repetition frequency of 50 Hz. It consists of three same independent systems. Each system has a 50 Hz 532nm pulsed laser, an optical parametric generator (OPG) and an optical parametric amplifier (OPA). OPG is pumped by a small part of the 532nm laser and generate 1083nm laser pulses with energy of 5-10 mJ. OPA is pumped by the major part of 532nm laser and amplify the 1083nm pulse into energy of about 70-140 mJ. Considering the lifetime of the KTP crystals and the Nd:YAG lasers, in the routine working condition, the power of the laser is usually tuned lower than the best performance. The 1083nm laser beams' divergence is around 1 mrad. The three beams are combined parallelly and emit into the 1-meter-diameter beam expander. They are expanded by a factor of 30.

The array of telescopes consists of 6 1-meter telescopes. They are separated by a distance of 1.75 m. In the focal plane of each telescope, a fiber (62.5um, NA=0.27) is mounted on a 6-axis translation stages, which helps accurate positioning of the fiber and furtherly fine tuning the field-of-view (FOV) of the telescope. The 6 fibers are merged into a fiber array and finally connected with a 200μm fiber. The 200μm fiber is connected with a superconducting nanowire single photon detector (SNSPD). By optimizing the electric current of the detector, it reaches a

performance of 20% efficiency and 100 cps dark counts.

Figure 1. Picture of the telescope array

Figure 2. Picture of the 1083nm pulsed laser

3. Observations

Observations are performed in case of clear night since November 2023 and more than 30 days of valid data was collected. Multi verification experiments are conducted during this period. Including the verifying of overlap and the fine-tuning performance of FOV pointing to 46-60 km Rayleigh regions and 200-1000km metastable helium fluorescence regions. Because of the limit of the SNSPD photo surface's size, the fiber diameter is limited, resulting in limitation of FOV. So, the overlap of the lidar system must be considered and verified carefully. We are still performing experiments and data processing algorithm to verify the reliability of our signal and data.

Table 1. Instrument parameters

Sub system	Parameter	Value
Laser	Laser pulse energy	70-140mJ
	Wavelength	1083.034 nm
	Repetitional rate	50Hz
	Beam expansion factor	30
	Beam divergence	1mrad
Telescope	Telescope Aperture	1m
	Distance of telescopes	1.75m
Fiber	Receiving fiber core diameter	62.5um
	Fiber NA	0.27
SNSPD	Quantum efficiency	20%
	Dark counts	100 cps

4. Summary

In this paper we introduce a high-performance metastable helium lidar system in China. The key instrument parameters are shown. Observations are performed in case of clear night since November 2023 and more than 30 days of valid data was collected. More data processing and retrieval methods will be conducted in the future.

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6. References

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