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A 1083 nm Pulsed Laser Source for Helium Resonance Fluorescence Lidar

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Abstract: Metastable helium resonance fluorescence (1083.0nm) lidar has proven to be an effective technique for studying the 200-1000 km atmosphere which is important for enhancing the safety of low Earth orbit satellite and improving navigation accuracy. But the high energy pulsed laser required for this lidar system is a technical challenge. Here, a 1083 nm pulsed laser system for metastable helium lidar has been developed. The design consists of an optical parametric generation stage with single-frequency seed light injection, followed by high power optical parametric amplification to obtain a high pulse energy and narrow linewidth output（>100mJ,<100MHz）that meets helium lidar detection requirements. The laser source setup provides a basis for research related to metastable helium density measurements. Meanwhile, wavelength of the laser scanning can be achieved by tuning the current and temperature of the seed laser power source, which makes it possible to realize the measurements of the velocity and the temperature of thermosphere.

1. Introduction

For middle and upper atmosphere, space weather events can cause a significant influence on modern navigation and communication systems, increasing safety risks and economic loss, as well as threatening human life. Moreover, metastable He is an important atmospheric species in the thermosphere. Therefore, laser remote sensing can be employed to investigate metastable He as a probe to get the information of this height [1]. Simultaneously, for stronger backscattered signal, higher spatial resolution, and signals will not be contaminated by photon noise associated with random fluctuations in the laser frequency and linewidth, the high energy, narrow-linewidth, pulsed laser source (1083nm) is an essential part for the ground-based resonance helium lidar system.

In these years, Laser at 1083nm has developed rapidly with time, for instance, a single frequency 1083nm ytterbium fiber laser has been demonstrated, and the highest peak power of the output pulse reaching 6.93W(693 uJ/pulse) at the repetition rate of 10 kHz was obtained with a typical pulse duration of ~130ns [2,3]. Diode-pumped Nd: GdVO4 laser at 1083 nm was presented and combined with Q-switch could output pulsed laser at 1083nm reaching 111 uJ/pulse with a typical pulse duration of ~ 77ns [4,5]. A distributed Bragg reflector (DBR) laser output continuous wave laser at 43 1083nm with an output power of 5.3 W [6].

In this paper, we will introduce a High-energy, narrow-linewidth, pulsed laser. It is suitable for resonance fluorescence lidar of metastable helium that uses optical parametric generator (OPG) and optical parametric amplifier (OPA) with the advantages of no complex resonant cavity, solid-state, stable performance, ease of operation, and inexpensive.

2. Instrument

There are three parts make up of this laser source system, a 2nd SHG stage based on KTP(KTiOPO4) crystal pumped by 1064nm laser, an injection seeded OPG stage based on KTP crystals arrangement pumped by laser at 532nm, and both of OPA stages(A1 and A2) based on KTP crystals pumped by 532nm laser. The optical layout of the whole transmitter system is shown in Figure 1.

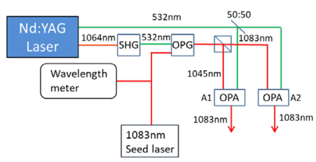

Figure 1. The pulsed 1083nm laser source system

3. Results

To weaken the influence of fluctuating energy for return signal, energy stability of the laser source of the lidar system is crucial. the energy of the pump lasers for the OPA stages was measured by a power meter (Ophir, Nova*II*) for about an hour, and the two output energies from OPA stages were simultaneously measured by an energy meter (Coherent, FieldMax*II*-TOP) for about an hour. those curves of energy are depicted in Figure 2. The analysis of all results is in Table 1. The standard deviation of the laser at 1083nm is smaller than that of the pump laser. It's noticeable that the jitter of the output laser at 1083nm from the laser source is less than that of the pump laser. The energy of the laser source is stable enough for the lidar system with an integration time of 10min.

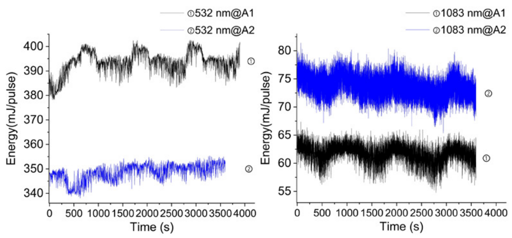

Figure 2. (a) The energy of pump laser at 532nm for 2nd OPA stage versus time. (b) The energy of output laser at 1083nm from 2nd OPA stage versus time.

Table 1. The analysis of the pump laser and signal laser curve.

	532nm		1083nm	
	A1	**A2**	**A1**	**A2**
Maximum energy(mJ/pulse)	402	355	67	81
Minimum energy(mJ/pulse)	378	338	55	65
Average value(mJ/pulse)	384	349	62	73
Standard deviation	4.5	3.3	1.4	1.7

By optical heterodyning, the pulsed laser of the OPA stages and the seed laser, the spectral linewidth of the laser source was measured. The seed laser's electric field is shifted by the carrier frequency, 400MHz, from an acoustic-optic modulator. The two linearly polarized plane waves from the seed and the pulsed laser are mixed by 1x2 single-mode fused fiber optic couplers(50:50 Coupling Ratio) on a fast photodetector. The spectral intensity profile, which is presented in Figure 3, was obtained by performing a Fast Fourier Transform (FFT) analysis on the beat waveform. It is immediately apparent that the linewidth of the laser source is less than 62MHz.

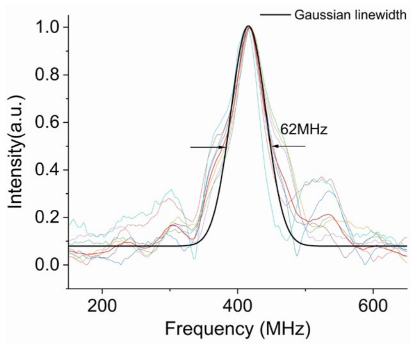

Figure 3. The spectral linewidth of the laser source.

4. Summary

In conclusion, we have demonstrated a high-energy, narrow-linewidth, pulsed 1083nm laser system. The energy and the spectral linewidth of the instrument are shown.

5. Acknowledgements

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6. Reference

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