P1-5 Sodium Temperature Lidar System for Measuring Mesopause Region at Syowa Station, Antarctica

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1. Introduction

Recently, researches in the field of geophysics have paid attention to the upper measosphere and the lower thermosphere near the mesopause (height range from 80 km to 110 km), because it is an important coupling region between the middle and upper atmosphere, where the atmospheric waves propagating from the lower atmosphere or disturbance from the thermospheric events plays important roles in the energy budget through the mesopause region.

Among the various observational techniques, there is a lidar for measuring the mesospheric sodium layer, which is one of powerful tools for remotely probing the mesopause region. The mesopause region has been actively studied with lidars by some research groups in the world.

Recently, besides a sodium lidar, some effective remote sensing techniques have been developed by use of microwave radars and optical imagers. Then, we are planning to study the Antarctic mesopause region with a sodium temperature lidar cooperatively with MF radar, Fabry-Perot Doppler imager and auroral observing equipments at Syowa station for three years, 1999-2001. The objective of these cooperative observations is to make clear the mechanism of energetic interaction between the lower thermosphere and the upper mesosphere through the mesopause region over Antarctica.

Sodium temperature lidar provides the vertical structure of temperature and sodium density in the altitude region between 80 and 110 km. It is expected that energetic interaction between the lower thermosphere and the upper mesosphere through the mesopause region over Antarctica may be clarified from these cooperative observations.

In this paper, we describe the sodium temperature lidar system.

2. Sodium temperature lidar technique and System

The sodium temperature lidar consists of two injection seeded Nd:YAG lasers, a Dall-Kirkham Cassegrain type telescope and three channel photocounting processing units, as shown in Fig. 1. Specifications of this system are summarized in Table 1. The transmitter system is capable of emitting three laser beams with wavelengths of 532, 589 and 1064 nm with each line width below 100 MHz. A wavelength of 589 nm tuned accurately to the sodium D_2 resonance line is used for measuring sodium density and temperature profiles in the altitude range from 80 to 110 km near the mesopause.

We can determine the vertically resolved temperature structure throughout the sodium layer region by probing the thermally broadened sodium D_2 resonance structure with an extremely narrowband lidar. In measurement, temperature profile can be derived from the ratio of the sodium density profile obtained by tuning the laser wavelength at the minimum position between both peaks, f_a and f_b, to that at the peak of f_a, as shown in Fig. 2. This technique basically originates in the method given by the lidar group of the University of Illinois and Colorado State University.[1] In practice, both sodium density profiles can be obtained by changing a laser wavelength alternatively at each position in a short period and by accumulating each returned signal. This method can give the more accurate temperature profile by eliminating the error induced by the time variation of sodium density.

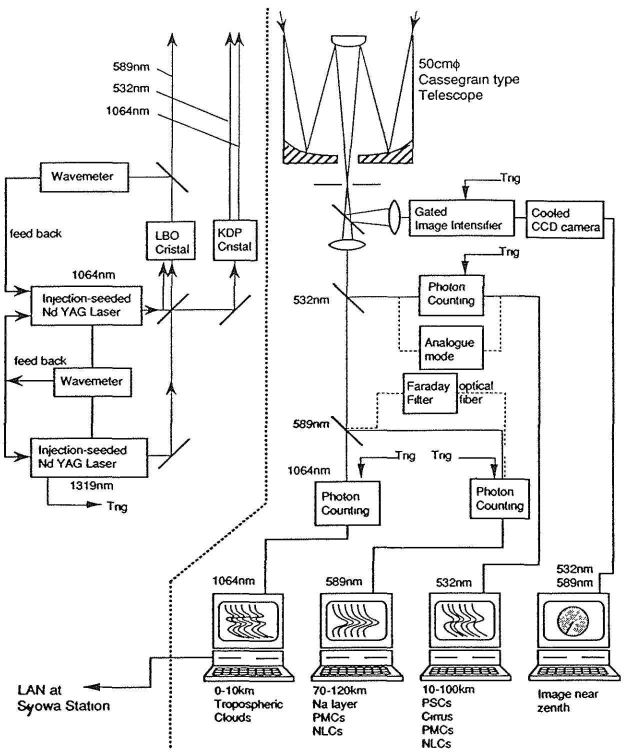

Figure 1. Block diagram of the sodium temperature lidar system

Table 1. Specifications of the sodium temperature lidar

Transmitter			
Wavelength	589 nm	532 nm	1064 nm
Energy	40 mJ/pulse	50 mJ/pulse	50 mJ/pulse
Line width	<100 MHz	<100 MHz	<100 MHz
Tuning width	80 pm		
Pulse width	30 ns	30 ns	30 ns
Repetition rate	10 Hz	10 Hz	10 Hz
Divergence	<0.2 mrad	<0.2 mrad	<0.2 mrad

Receiver	
Telescope type	Dall-Kirkham Cassegrain
Telescope diameter	0.5 m
Telescope area	0.20m^2
Field of view	1.0 – 3.0 mrad
Filter bandwidth	1.0 nm
Faraday filter bandwidth	2.0 pm
Detection	3 ch. for photon count
Range resolution	96 m (640 ns)
Time resolution	3 min

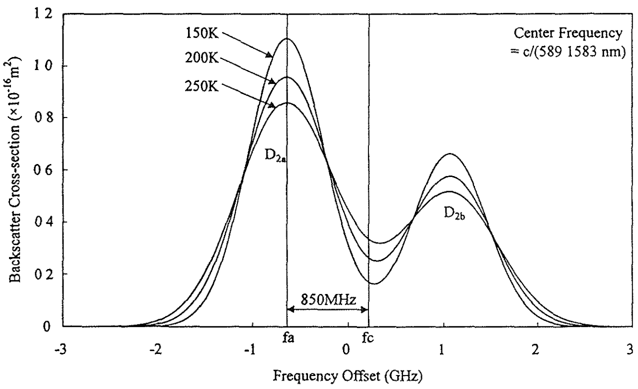

Figure 2. Sodium Doppler-broadened absorption spectrum

In order to satisfy the requirements described above, we have developed the transmitting system consisted of two injection seeded Nd:YAG lasers (1064 nm, 1319 nm), an AO frequency shifter of 425 MHz and nonlinear crystal of Barium Borate (BBO) for summing two wavelengths from lasers. One YAG laser at a wavelength of 1319 nm consists of two YAG rods in the cavity and one amplifier, which is seeded by a temperature controlled seeder laser. Another one at a wavelength of 1064 nm consists of only one YAG rod in the cavity, where a seeder light enters the YAG laser cavity through an AO frequency shifter. By returning a seeder light of 1064 nm passing through an AO device of frequency shift of 425 MHz with a mirror, the frequency of diffraction component can be shifted by +850 MHz. Alternating a normal component and a diffraction one with a shutter set up in front of a mirror, we can obtain alternatively two laser beams accurately tuned at the peak of f_a and at the minimum between both peaks, f_a and f_b from the sum frequency generation of two YAG laser outputs. Characteristics of emitted laser light is always monitored by measuring a wavelength of each seeder laser output by a wavemeter with an absolute accuracy of 0.1 pm and by detecting a Doppler-free spectrum from a sodium vapor cell. Performances of the transmitting system are summarized in Table 1.

As for the receiving system, a block diagram is shown on the right side of Fig. 1. Scattered photons are collected by telescope and collimated. The photons are divided into three detection units using two dichroic mirrors. Each photon passing through an interference filter, a polarizer and optical attenuators is detected with a cooled photomultiplier tube (PMT) which have an electric blanking gate switch to prevent the PMT from saturation by strong scattered photons from the lower atmosphere below 15 km. In daytime measurement especially during summer season without nighttime, only one channel for a wavelength of 589 nm is operated using an extremely narrowband Faraday filter.[2-3] The PMT output pulses are transferred to a multichannel scaler (MCS) which integrates the photocounts over many laser shots. The integrated signals are sent to each personal computer where real time data can be displayed and further processings can be made.

The lidar system was taken to Syowa station, Antarctica with the icebreaker ship 'Shirase' at the end of December, 1998. The system has been setting up since March this year. The test measurement will start at the beginning of July.

3. Summary

We introduced cooperative observation plan with a sodium temperature lidar, a MF radar and Fabry-Perot Doppler imager in Antarctica and the sodium temperature lidar system was described in detail for measuring the vertical structure of temperature and sodium density. In the symposium, we will show some preliminary data obtained in Antarctica.

References

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2. H. Chen et al., *Opt. Lett.* **18**, pp. 1019-1021, (1993).
3. H. Chen et al., *Opt. Lett.* **21**, pp. 1093-1095,(1996).