LIDAR TECHNOLOGY BASED ON FIBER SYSTEM AND ITS APPLICATION

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ABSTRACT

The sodium atom existed in the metal layer of the earth's atmosphere has a high atomic number density and a large scattering cross section. Sodium layer can act as a good tracer for atmospheric detection in the middle and lower-thermosphere (MLT) region. The sodium fluorescence lidar uses ultrashort pulsed laser to excite sodium atoms, which enabling simultaneous detection of wind and temperature in the middle and upper atmosphere. This paper reports on the development of sodium fluorescence laser radar in recent years, especially the integration of fiber-coupled optical switches and fiber-coupled acousto-optic frequency modulation technologies, which greatly improved the stability and reliability of lidar system and reduced the maintenance of lidar operation, laying a good foundation for the application of lidar observations under harsh environments. This technology has been applied to the sodium wind /temperature lidar in Yangbajing, Tibet and has been running stably for a long time.

1. INTRODUCTION

A layer of metal atoms exists at a height of 80-120 km of the earth's atmosphere. The metal layer contains several kinds of metal atoms and ions, such as iron, sodium, potassium, calcium, and calcium ions [1]. Due to the high column density of sodium atoms and the relatively large scattering cross section, is the sodium layer is relatively easier to be detected [2,3]. Based on several decades of research and development, the lidar technique for sodium layer detection based on sodium fluorescence scattering mechanism became more and more mature. In 1990s, the simultaneous detection of wind and temperature of the sodium layer was carried out using narrow linewidth laser and multi-wavelength transmitter

[5]. In the late 1990s, ultra-narrow bandwidth optical filtering technology was applied to the sodium lidar receiver, which enabling the full diurnal observation capability of sodium lidar thus permitting sodium layer wind and temperature measurement under sunlit conditions [6]. However, in the early studies of sodium wind temperature lidar, in order to realize the three-wavelength laser emission for simultaneous wind and temperature measurement, a ring-cavity dye laser, a free-space acousto-optic frequency modulation unit are usually used in the laser transmitter, so the optical path of the laser system is complex, and the adjustment and maintenance are also difficult, greatly limiting the lidar application. In recent years, optical fiber technology has been developed rapidly. Fiber-coupled fast optical switching technology and fiber-coupled acousto-optic frequency modulation technology can improve the configuration of laser unit from free-space light transport to fiber-coupled mode, greatly simplifying the optical path adjustment and reducing the maintenance difficulty and providing a good means for mobile and field observations. This article reports the latest development of narrowband sodium lidar and its application.

2. METHODOLOGY

In the early laser radar emitting system, a ring cavity dye laser is usually used. Since the ring cavity laser has a long optical path, it is particularly sensitive to environmental factors such as vibration, pressure, temperature, etc., and frequency locking and adjusting are quite difficult. In addition, in the three-frequency switching unit, two free-space acousto-optic modulator (AOM) with very small aperture of about 0.3 mm are used. The frequency switching unit has an optical path of several meters, requiring a very high

adjustment accuracy, resulting in that the operation and maintenance are extremely difficult.

The lidar system introduced in this paper adopts a commercial solid-state diode laser (Toptica Company), which can output 1178 nm single-mode continuous-wave (CW) laser with power of more than 1W. After fiber splitting, its frequency is multiplied by a periodically poled lithium niobate (PPLN) waveguide and input into a sodium atom cell to obtain Doppler-free saturation absorption spectrum for laser frequency stabilization [7]. The other part of the laser light is input into the one-in-three-out fiber-coupled switcher for AOM+, AOM- and F0. The output of the optical switcher is then sent to a Raman fiber amplifier [8], and the amplified 1178nm CW laser light is multiplied by PPLN crystal to obtain laser at wavelength of 589 nm. Finally, the 589 nm CW laser is injected into a pulsed dye amplifier. This system replaced the conventional ring cavity laser and free-space AOM unit [9]. Since the entire optical path adopts the optical fiber mode, less optical path adjustment is required, and the conventional observation operation and daily maintenance became simpler, which can be used in unmanned lidar system.

Fig. 1 Principle of fiber-coupled laser system. OSW1-3: fiber-coupled optical switcher; SHG1-2: second harmonic generation; RFA: Raman fiber amplifier; AOM1-2: acousto-optic modulator.

3. RESULTS

The design of laser transmitter has been successfully applied to the Yangbajing sodium layer wind and temperature lidar system, and the lidar operation is simple and the working state is stable. Typical wind and temperature observational results in MLT region are shown in Figure 2.

Fig. 2 The observational results of sodium lidar on Oct 17th 2017. (a) meridional wind. (b) zonal wind. (c) temperature.

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