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HIGH SPECTRAL RESOLUTION LIDAR USING CESIUM VAPOR BLOCKING FILTER: MEASUREMENT OF THE MIE/RAYLEIGH SCATTERING RATIO

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High spectral resolution lidar(HSRL) is an effective method for measuring visibility, aerosol density, and temperature. The HSRL using the atomic vapor blocking filter was proposed and evaluated by Shimizu et al.(1-2), and the merit of the use of the atomic filter was shown. The atomic filter has very large rejection ratio, and its band width can be changed by varying the operational temperature. Futhermore, the atomic filter is easy to use as a high resolution optical component because the spectral character does not depends on the incident beam angle.

Figure 1 shows the absorption lines of the cesium vapor at 388.865 nm measured by a narrow band dye laser pumped by a XeCl excimer laser. The structure seen in Fig.1 is due to the spin splitting in the ground state. The spectral bandwidth of the laser was 1.5 GHz, and the wavelength was scanned by the pressure tuning. The dependence of the transmission on the operational temperature is shown in Fig.1.

We develope a method to obtain the Mie/Rayleigh scattering ratio and the atomospheric temperature using a laser with a intermediate bandwidth($\sim$1.5GHz) and a cesium vapor filter. Figure 2 shows the block diagram of the HSRL system. A small portion of the transmitted laser beam is taken as the reference light. The receiving optics consists of a single cesium vapor cell and a photomultiplier tube. The scattered light and the reference light are detected after transmitting through the cesium vapor cell. The measured spectrum of the scattered light is analyzed by the deconvolution method, as described below, using the reference spectrum.

Let the normalized spectrum of the laser be $L(\nu)$, the spectrum of the light scatterd by aerosols and molecules can be written as

$$M'(\nu)=\int M(\nu')L(\nu'-\nu)d\nu', \qquad (1)$$

$$R'(\nu)=\int R(\nu')L(\nu'-\nu)d\nu'.$$

Meanwhile, the transmission spectrum of the cesium filter measured by the laser can be written as

$$T'(\nu)=\int T(\nu')L(\nu'-\nu)d\nu . \qquad (2)$$

Where $T(\nu)$ is the real transmission spectrum of the cell. Therefore, the recorded spectrum of the scattered light, $I(\nu)$, observed through the filter by scanning the laser can be expressed by the following equation.

$$\begin{aligned} I(\nu) &= \int T(\nu')[C_m M'(\nu'-\nu) + C_r R'(\nu'-\nu)]d\nu' \qquad (3) \\ &= \int\int T(\nu')[C_m M(\nu'')L(\nu''-\nu'+\nu) \\ &\qquad + C_r R(\nu'')L(\nu''-\nu'+\nu)]d\nu' d\nu'' \\ &= \int T'(\nu')[C_m M(\nu'-\nu) + C_r R(\nu'-\nu)]d\nu' \end{aligned}$$

Where C_m and C_r represent the coefficients for Mie and Rayleigh scattering. It can be seen from Eq.(3) that we can obtain the spectrum of the scattered light from $I(\nu)$ if only we know the spectrum of the filter measured by the same laser, $T'(\nu)$, which is identical with the reference spectrum.

Figure 3 shows the recorded spectra of the reference light and the signal light scattered at the height of 180m. The operational temperature of the cesium filter is 460K. The abcissa of Fig.3 is the laser frequency measured from the line center of the cesium vapor filter. The Mie/Rayleigh scattering ratio, 1.57 was obtained from the data shown in Fig.3 by the least square method using the theoretical spectra of the Mie and Rayleigh scattering and assuming the atmospheric temperature. If the spetrum is recorded with the higher signal-to-noise ratio, the temperature also can be determined from the least square fitting.

References

(1) H.Shimizu, S.A.Lee and C.Y.She, Applied Optics 22 (1983) 1373-1381.
(2) H.Shimizu, K.Noguchi and C.Y.She, Appl. Opt. 25 (1986) 1460-1466.

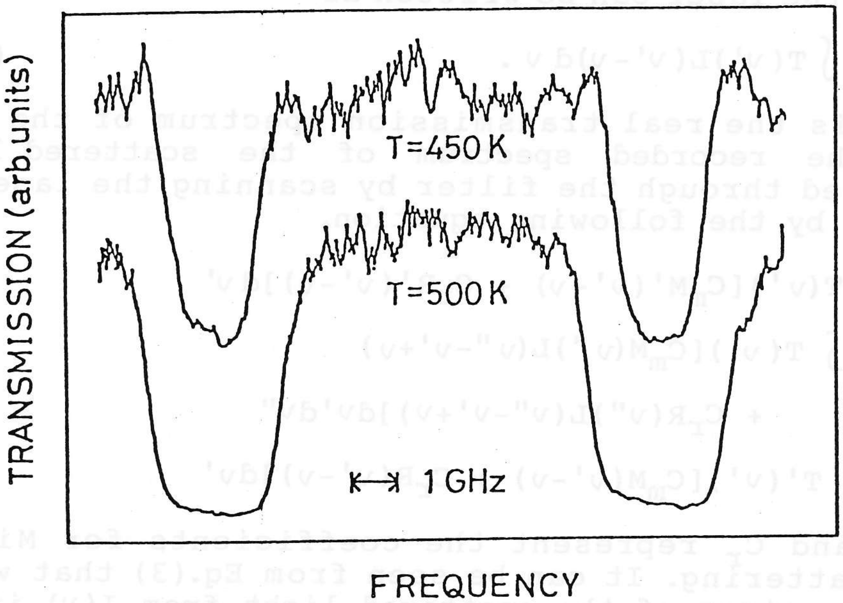

Fig.1 Transmission spectrum of the cesium vapor blocking filter.

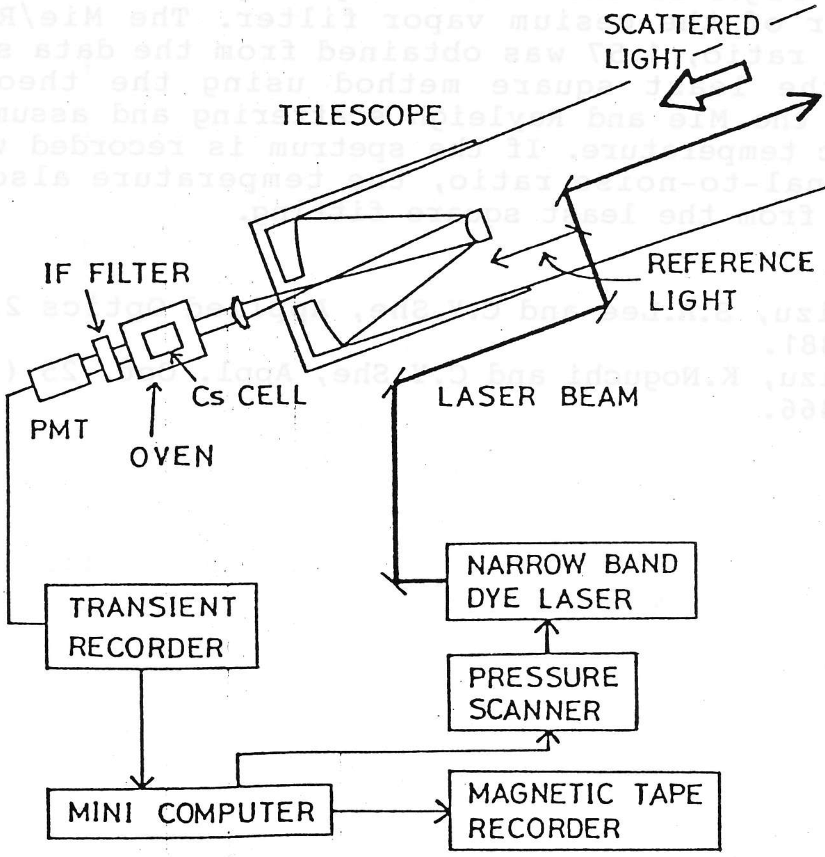

Fig.2 Block diagram of the HSRL.

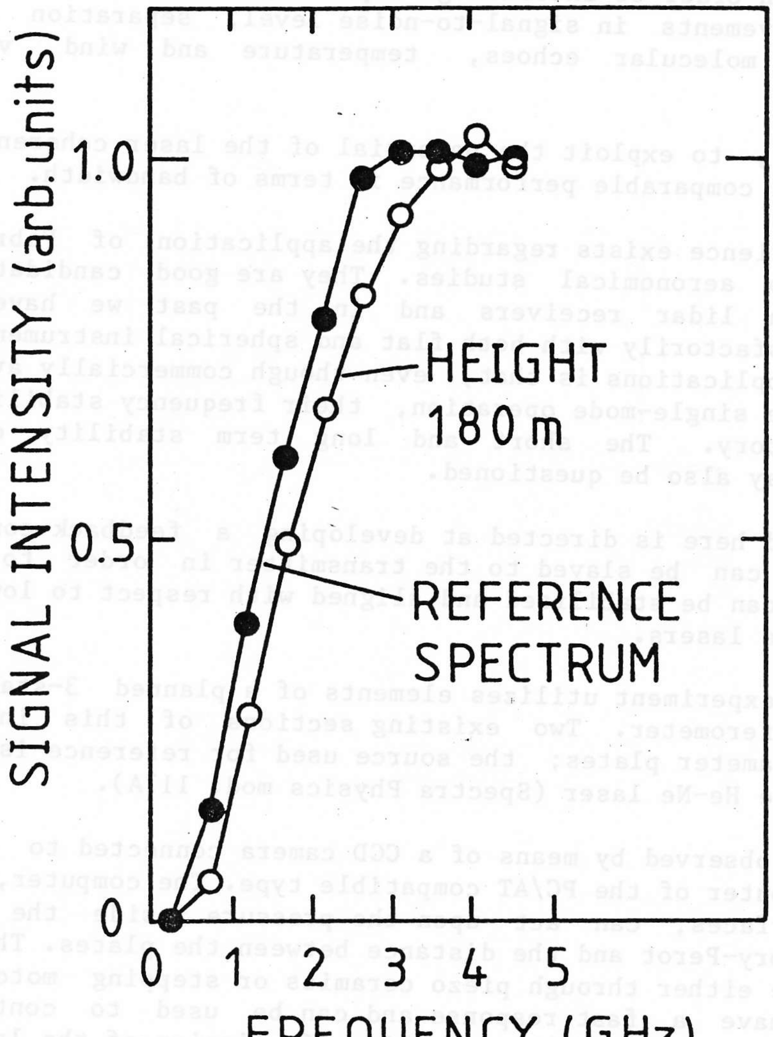

Fig.3 Recorded signal intensity as a function of the laser frquency.