NOTES AND CORRESPONDENCE

**Simultaneous Multiple Wavelength Laser Radar
Measurement of the Stratospheric
Aerosol Layer****By Yasunobu Iwasaka***Water Research Institute, Nagoya University, Chikusa-ku, Nagoya 464, Japan***Hiroshi Fukunishi, Takeo Hirasawa, Ryoichi Fujii****and****Hiroshi Miyaoka***National Institute of Polar Research, Itabashi-ku, Tokyo 173, Japan**(Manuscript received 5 October 1982, in revised form 19 February 1983)***Abstract**

Preliminary measurement of the stratospheric aerosol layer using multiwavelength laser radar ($\lambda=0.6943\mu\text{m}$ and $0.3471\mu\text{m}$) are presented. This result suggested that there was noticeable change on the vertical distribution of size distribution and/or chemical composition of the aerosol particles. The contribution of Mie scattering component at $\lambda=0.3471\mu\text{m}$ to the total scattered light becomes apparently smaller than that at $\lambda=0.6943\mu\text{m}$ owing to the so-called "dependence of λ^{-4} in Rayleigh scattering", and this enables us to search out easily the fitting point which is used to distinguish the Mie scattering component from the measured total scattering power intensity.

Laser radar has been used to remotely study various phenomena in the atmosphere since the 1960's. Especially for the monitoring of the stratospheric aerosols, laser radar is very useful and many interesting results have been reported on the basis of the laser radar measurements; for example 1) the enhancement of the stratospheric aerosol layer by the strong volcanic eruptions (e.g., Hirono *et al.*, 1981; Iwasaka and Hayashida, 1981; Meixner *et al.*, 1981; D'Altorio *et al.*, 1981; Reiter *et al.*, 1982), 2) the decay process of enhanced aerosol layer (e.g., Russell and Hake, 1977; McCormick *et al.*, 1978; Hirono *et al.*, 1977; Iwasaka, 1981a), 3) the seasonal change of the stratospheric aerosol content (e.g., Reiter *et al.*, 1979; Iwasaka, 1981b), 4) the vertical change of the stratospheric aerosol size (Iwasaka and Isono, 1977; Iwasaka, 1982), 5) the horizontal transport of the aerosol particles (e.g., Kent and Philip, 1980), and the eddy diffusion of the aerosol particles (Remsberg, 1980;

Hirono *et al.*, 1981).

Most of these researches have been performed using single wavelength laser radar, normally the Ruby laser radar with wavelength $\lambda=0.6943\mu\text{m}$ or Nd YAG laser radar of $\lambda=1.06\mu\text{m}$. As described by Iwasaka and Isono (1977) the simultaneous multiple wavelength laser radar measurement is very powerful to gain information on the size distributions of the stratospheric aerosol particles which is useful to study the aerosol formation processes and the optical properties of the aerosol layer, even if it is impossible to know fully exact size distribution functions.

The measurements of the stratospheric aerosol layer have been made at Tokyo since June 1982 using the laser radar which can emit simultaneously laser pulse of Ruby fundamental ($\lambda=0.6943\mu\text{m}$) and its second harmonic ($\lambda=0.3471\mu\text{m}$). Until now the simultaneous laser radar measurements of the stratospheric aerosol layer at different wavelengths, $\lambda=0.6943\mu\text{m}$ and

Table 1 Main characteristics of laser radar system

Transmitter	
Laser wavelength	0.6943 μm (Ruby, Fundamental) 0.3471 μm (Ruby, Second harmonic)
Laser power	1.0 J/pulse (Max. 0.6943 μm) 0.25 J/pulse (Max. 0.3471 μm)
Pulse repetition rate	1.0 Hz
Pulse duration	40 nsec
Receiver	
Telescope	50 cm ϕ (Cassegrain)
Photomultiplier	R 1333 (0.6943 μm , DC signal) 943-03 (0.6943 μm , Photon counting) 943-03 (0.3471 μm , Photon counting)
A/D converter	8 bit/word, 960 words
Photon counter	100 channels, 2 series
Data processor	Mini computer (Melcom 70/10)

0.3471 μm have not been reported. The present result, then, must be interesting for the research on the stratospheric aerosols.

The main characteristics of laser radar system used here are listed in Table 1.

Curve in Fig. 1 is the profile of range corrected value of backscattering power for $\lambda=0.6943\mu\text{m}$ constructed by integrating the 0.5 km range resolution data from 200 laser soundings taken on July 18, 1982. Similar structure is shown in Fig. 2 which is the integration of 200 laser shots also. As expected from Fig. 2, the aerosol particles produce less of an enhancement of backscattered light at 0.3471 μm and agrees well with the model calculations by Iwasaka *et al.* (1981) which suggested the contribution of the backscattered light of particulate matter to the total scattered light at $\lambda=0.3471\mu\text{m}$ is not so large in comparison with that at $\lambda=0.6943\mu\text{m}$

since the wavelength dependence of Rayleigh scattering (λ^{-4}) causes that the contribution from Rayleigh scattering to the total scattered light becomes larger, the shorter the wavelength becomes.

The scattering ratios of particulate matter deduced from the measurements of backscattered light are shown in Fig. 3 and Fig. 4. It is assumed here that the matching height is 12.5 km in measurements of both $\lambda=0.6943\mu\text{m}$ and $\lambda=0.3471\mu\text{m}$. The effect of atmospheric ozone on the transmittance of $\lambda=0.3471\mu\text{m}$ is not so serious problem for the analysis of backscatter light measured at $\lambda=0.3471\mu\text{m}$ since the absorption cross section of ozone rapidly decreases according to the increase of wavelength in the range from $\lambda \approx 0.3\mu\text{m}$ to $\lambda \approx 0.35\mu\text{m}$. The profile of backscattering ratio for $\lambda=0.6943\mu\text{m}$ shows noticeable peak which is certainly due to the volcanic eruption of Mt. El Chichon (May–April

Fig. 1 Range corrected value of received power at wavelength $\lambda=0.6943\mu\text{m}$, July 18, 1982 (unit is arbitrary) (curve F). Reference curve A is the estimation for the dust free atmosphere (U.S. Standard Atmosphere, 1972).

Fig. 2 Range corrected value of received power at $\lambda=0.3471\mu\text{m}$, July 18, 1982 (unit is arbitrary) (curve S). Reference curve A is the estimation for the dust free atmosphere (U.S. Standard Atmosphere, 1972).

Fig. 3 Scattering ratio of particulate matter measured at $\lambda=0.6943\mu\text{m}$, July 18, 1982.

Fig. 4 Scattering ratio of particulate matter measured at $\lambda=0.3471\mu\text{m}$, July 18, 1982.

1982, Mexico) at 22–24 km. Similar peak is found also in Fig. 4, but not so large as the peak in Fig. 3.

The ratio of $\beta(z, 0.6943\mu\text{m})/\beta(z, 0.3471\mu\text{m})$, $\beta(z, 0.6943\mu\text{m})$ and $\beta(z, 0.3471\mu\text{m})$ are back-scattering coefficient at altitude z measured at $\lambda=0.6943\mu\text{m}$ and $0.3471\mu\text{m}$ respectively, is approximately 1/2 for the Junge type or Zold type size distribution function of aerosol particles (Iwasaka *et al.*, 1981). Therefore the ratio $[R(z, 0.6943\mu\text{m})-1]/[R(z, 0.3471\mu\text{m})-1]$, where $R(z, 0.6943\mu\text{m})$ and $R(z, 0.3471\mu\text{m})$ are scattering ratio at z measured at $\lambda=0.6943\mu\text{m}$ and

$0.3471\mu\text{m}$ respectively, is expected to be about 8 also under the condition of usual type size distribution function of aerosols. Roughly speaking the measured $[R(z, 0.6943\mu\text{m})-1]/[R(z, 0.3471\mu\text{m})-1]$ is in reasonable range for the main peak of aerosol layer (22 km–24 km) but apparently smaller than the estimation for the region from 14 km to 20 km.

Below 14 km scattering ratio of $\lambda=0.3471\mu\text{m}$ is larger than the value of $\lambda=0.6943\mu\text{m}$, but this does not show actual atmospheric condition. We think that this is caused by the receiving of too many backscattered photon at $\lambda=0.6943\mu\text{m}$ which results in so-called multiphoton event in the detector.

The noticeable change of $[R(z, 0.6943\mu\text{m})-1]/[R(z, 0.3471\mu\text{m})-1]$ suggests that the chemical composition and/or size distribution of aerosols are not homogeneous in the present stratospheric aerosol layer. As described before, present stratospheric aerosol layer is highly disturbed by the volcanic eruption of Mt. El Chichon, and therefore the above mentioned feature in measurements is possibly due to the after effect of this eruption. It is very interesting for the study on new particle formation in the enhanced aerosol layer through volcanic eruptions that the value of $[R(z, 0.6943\mu\text{m})-1]/[R(z, 0.3471\mu\text{m})-1]$ was smaller in the region from 14 km to 20 km than the estimation which was deduced under the condition of typical aerosol size distribution function. One possible interpretation is that new particle formation through gas-to-particle conversion is very active owing to the large amount of SO_2 gas loading, and therefore very fine size particles is rich in this region.

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成層圏エアロゾル層の多波・同時レーザレーダ観測

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波長 $\lambda=0.6943\mu\text{m}$ 及び $0.3471\mu\text{m}$ で成層圏エアロゾル層の同時レーザレーダ観測を行った。この結果は、エアロゾル層内で、粒径あるいは化学組成に著しい空間変化があることを示している。波長が短くなるにつれ Rayleigh 散乱係数が急増し（いわゆる λ^{-4} 則）相対的に波長 $0.3471\mu\text{m}$ での Mie 散乱成分が全散乱光強度に占める割合が小さくなるため、データ解析の上で“fitting point”をさがすのに大いに参考になる。