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AN OZONE–AEROSOL LIDAR AND A THREE–WAVELENGTH INVERSION TECHNIQUE

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ABSTRACT

This paper describes a ozone–aerosol lidar developing at Institute of Atmospheric Physics of Chinese Academy of Sciences, a three–wavelength inversion technique and its simulation experiments for simulteneously determining ozone concentration profile and aerosol optical property (including backscattering coefficient profile and size distribution)。 The simulation operation is according to parameters of the lidar。 The lidar will be operational in Beijing by March 1995。

LIDAR SYSTEM

This lidar is designed to measure: (1) 10–50km ozone profile; (2) 6–35km aerosol profile (including the aerosol size distribution in the stratosphere) ; (3) cirrus; (4) 30–70km atmospheric temperature。

Fig.1 shows a block diagram of the lidar。 The transmitter consists of a XeCl excimer laser with output energy 140mJ at 308nm and a Nd–YAG laser with output energy 120mJ at 355nm, 240mJ at 532nm and 450mJ at 1060nm。 The receiving telescope has a diameter of 1m。 The received light beam through the pupil of the telescope is gated by a mechanic chopper。 Then, the beam is collimated by a collimating lens and by means of a dicroic beamsplitter the UV radiation is seperated from the rest。 The UV radiation is by means of another dicroic beamsplitter seperated into two parts at 308nm and 355nm with each sent to interference filter and then PMT。 The 1060nm radiation is seperated from the 532 radiation by a dicroic beamsplitter also, then sent to a filter and detected by a photodiode。 The 532nm radiation after a filter is divided into two parts, one of which is sent to a polarizer with the two polarizitions detected by PMT, and another is directly sent to PMT。 There are three analog–detection channels and three photon counting channels。 Two analog channels are used for polarizition detection of the 532nm radiation and another is for the 1060nm radiation。 Three photon counting channels are used for 308, 355 and 532nm radiation。

All lidar functions is controlled by a 80486 PC。

INVERSION TECHNIQUE AND SIMULATION OPERATION

It can be concluded according to Qiu's Paper (See: Science in China, 1994, Vol.36, 1381–1390) that there can be a large error in the stratospheric ozone concentration measured by DIAL, if the aerosol scattering is neglected, especially for the volcanic stratospheric aerosol, the error can be up to 100%。 Therefore, it is significant to develop a ozone–aerosol lidar and corresponding inversion technique。

Aerosol backscatter (extinction) coefficient are wavelength–dependent。 The 308nm backscatter coefficient can not be determined from the 308nm lidar return signals。 The coefficient can be determined according to Mie calculation from the measured aerosol backscatter coefficient at the 355nm or 532nm wavelength if aerosol size distribution and its refractive index are known。 Usually, the effect of refractive index is not important。 In this paper, a three–wavelength lidar inversion technique is proposed for a simulteneous determination of ozone concentration profile, aerosol backscattering coefficient profile and its size distribution in the stratosphere。 The inversion technique goes like this:

(1) Derive aerosol backscatter coefficients $\beta_a(\lambda_2,z)$ and $\beta_a(\lambda_0,z)$ at two wavelengths of 532nm and 355nm from lidar return signals。 Then the integrated backscatter depths between z_1 and z_2 can be derived as follows:

$$T_2 = \int_{z_1}^{z_2} \beta_a(\lambda_2,z)dz$$

$$T_0 = \int_{z_1}^{z_2} \beta_a(\lambda_0,z)dz$$

$z_1 = 15$km and $z_2 = 25$km would be suitable.

To assume the following power law form of the aerosol size distribution:

$$n(r) = cr^{-(v^* + 1)} \quad for \ r > 0.1\mu m$$

$$n(r) = c0.1^{-(v^* + 1)} \quad for \ r \leqslant 0.1\mu m$$

Under the assumption the ratio between two backscatter depths T_2 and T_0 is a function of the size distribution parameter v^*, marked as $R(v^*)$.

(2) Select diferent v^* and then derive the ratio $R(v^*)$ through Mie calculation with an assumed aerosol refractive index, and if the ratio is equal to the measured ratio, the corresponding v^* is taken as the solution of the size distribution. Then according to the size distribution and the refractive index determine aerosol backscatter coefficient at the 308 nm wavelength and the extinction coefficients at three wavelengths of 532nm, 355nm and 308nm;

(3) Derive the ozone profile by using above-determined aerosol scattering data。

In simulation operation, lidar return signals are simulated according to parameters of our lidar, where the laser shot number of the 308nm wavelength is 10^5, and then according to the repetion rate the laser shot number for both 355nm and 532nm is 10^4.

Next, this paper describes some numerical experiments with conclusions as follows:

(1) There can be a large error in the ozone concentration solution if aerosol scattering is neglected. Neglecting aerosol backscatter has much stronger effect on the ozone solution than neglecting aerosol extinction。

(2) A difficulty to consider aerosol scattering is that the aerosol backscatter coefficient at the 308nm wavelength can not be determined from lidar return signals at same wavelength。 The coefficient can be determined from the measured backscatter coefficient at the 355nm or 532nm wavelength if aerosol size distribution and its refractive index are known, and the ozone solution is sensitive to the error of aerosol size distribution, especially for heavy stratospheric volcanic cloud。

(3) A considerable improvment of the ozone concentration solution can be obtained by using the present three-wavelength inversion method, and the aerosol backscattering coefficient profole and its size distribution in the stratosphere can be simulteneously determined。 This point can be found from Figs.2 and 3, which show inversion results of ozone and aerosol profiles, respectively. As shown in Fig.2, compared with the exact ozone profile (solid-curve), there is a large error of the ozone solution (dots) without considering aerosol scattering with the standard deviation being 22.9%, but the solution (crosses) by the present three-wavelength inversion algorithm is much better than the former, its standard deviation is only 4.4%. In Fig.3 the exact 532nm aerosol backscatter coefficient profile (solid-curve) is derived with a assumption of Junge aerosol size distribution of $\nu^* = 3$ according to Lidar measurement data over Mauna Loa Observatory on December 28, 1982 (J. Deluisi et al., 1985, NOAA Data Report ERL ARL-5). The retrieved aerosol backscatter coefficient profile (crosses) is in very good agreement with the true one, its standard deviation being only 4.8% and and the integrated backscatter depths having a error of 0.5%. The solution of Junge distribution parameter ν^* derived from two-wavelength integrated backscatter depths is 2.84, being close to its exact value of 3. In this paper, some numerical experiments on no Junge aerosol size distribution will be given.

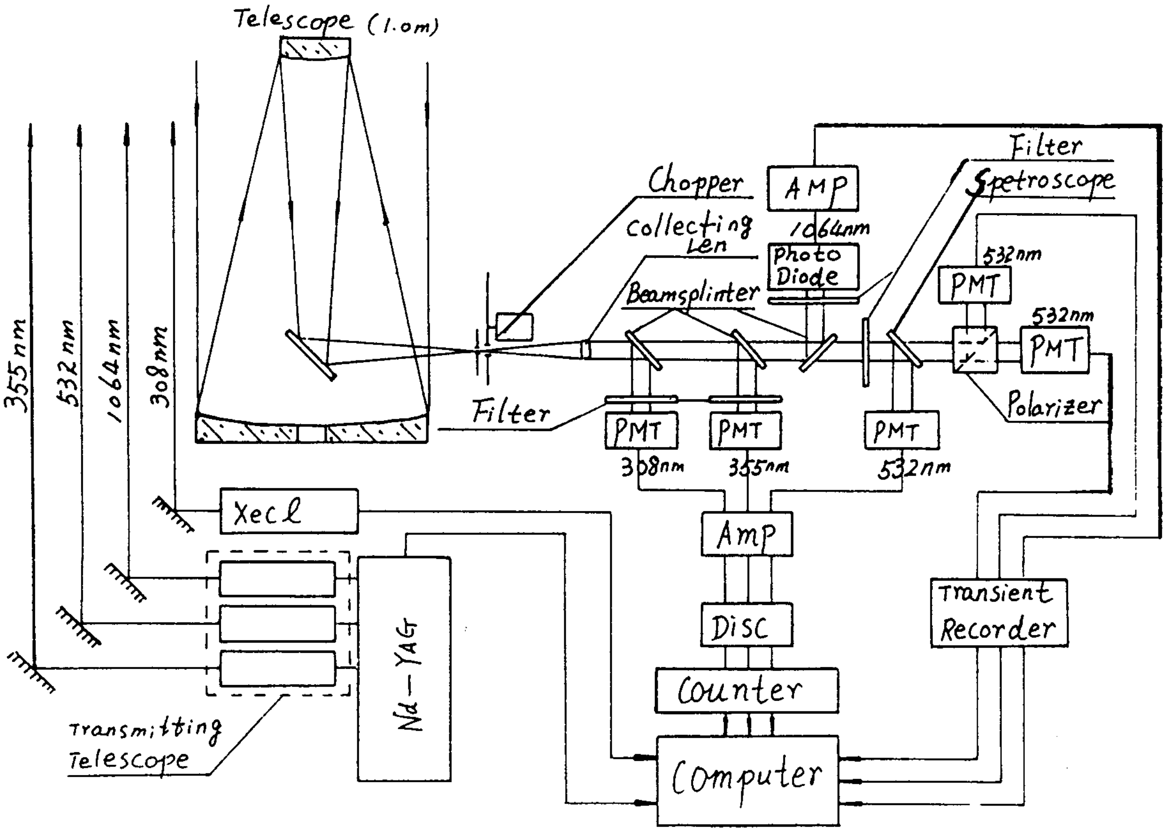

Fig.1 Block Diagram of the Lidar

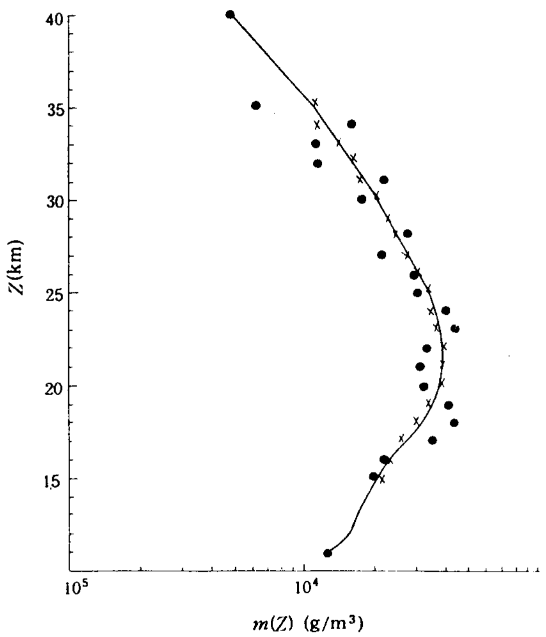

Fig.2 Ozone inversion result

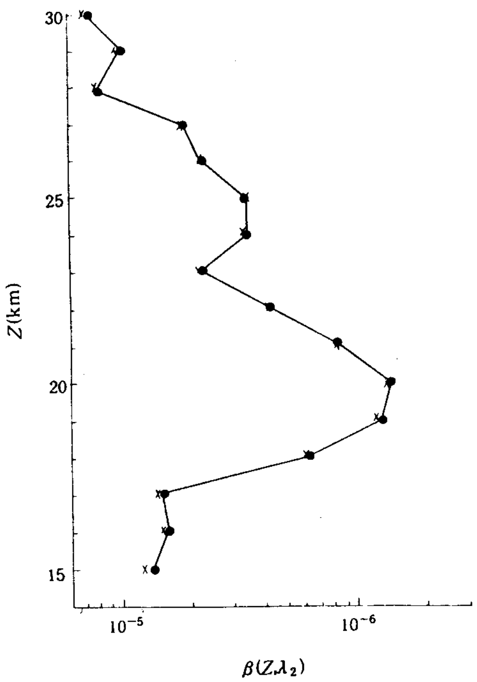

Fig.3 Aerosol inversion result