

Installation of an automatic spectrometer at Mauritius and preliminary results of NO₂ over Mauritius

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An automatic spectrometer developed at Indian Institute of Tropical Meteorology Pune is installed at the University of Mauritius, Reduit, Mauritius for monitoring total column density of NO₂ and O₃. The spectrometer is programmed for observations between 80° and 90° solar zenith angles in the spectral region 410–450 nm. The observations collected for few days during September and October 1998 are analysed, and total column densities of NO₂ found to be of the order of 4×10^{15} molecules per cm². This preliminary result compares with similar southern latitude stations.

THE molecular absorption bands in the UV and visible regions tend to be rather broad because simultaneous electronic, vibrational, and rotational transitions are evolved. Fortunately, some key species in atmospheric chemistry have sufficiently structured electronic absorption spectra in UV/visible spectral region¹.

One can measure the transmitted intensity at an absorption peak (I) and the intensity on either side of the absorption peak (I_0) and apply Lambert–Beer's law to obtain the concentrations of the species under study. However, the wide range of both gases and particulates in ambient air leads to a complex mixture of light scattering and absorption when a beam is propagated through air. Hence, the modification known as differential optical absorption spectroscopy (DOAS) eliminates the source, instrumental and scattering functions. Different UV-visible spectrometers^{2–4} monitor the important atmospheric species like O₃, NO₂, SO₂, OClO, BrO, CH₂O, etc. Generally, for atmospheric studies the spectrometer is used in either the scanning mode or stationary mode; in the scanning mode the grating is rotated or the spectrum is scanned by a rotating device and a photomultiplier tube is used as detector, while in the stationary mode the array or matrix type of detectors like diode array detector or charge couple detectors CCD are used.

Experimental arrangement

The experimental arrangement is shown in Figure 1. The zenith sky radiations are collected by a quartz lens mounted on a tube which focuses the radiation on the liquid light guide. This in turn transmits the radiation towards the entrance slit of the spectrometer installed in the room. A home-made Czerny–Turner spectrometer has mirrors with 30 cm focal length 15 cm diameter and 10 cm × 10 cm grating with 2400 grooves per mm blazed at 500 nm. At the exit plane of the spectrometer, a rotating disk with a 30 cm diameter on which slits of width 0.5 mm and height 1 cm are made at the peripheral region, is placed at 5 cm interslit distance. This disk is rotated with a speed to scan 75 slits per second and dispersed region of 45 mm. The 5 mm scan region without any signal is used for dark current recording. The output of the 45 mm × 10 mm spectral region of 40 nm is collected on a photomultiplier tube of 25 mm diameter by light cone, which collects the output cone of the radiation beam. The output of the photomultiplier is amplified by a fast amplifier and then interfaced to a personal computer (PC). The photomultiplier supply voltage is generated through a D.C. to D.C. converter which is controlled by the PC using control voltage of the order of 0 to 5 V with multiplication factor of 200, i.e. 0 to 5 V control voltage can give 0 to 1000 V D.C. supply voltage to the photomultiplier tube.

The selection of the spectral region is achieved by rotating the grating using a geared stepper motor. The stepper motor is controlled by the PC through an interfacing cord to isolate the direct interaction of the stepper motor back pulses and the PC. The grating is selected so that the overlapping of orders and the response function of the detector do not require order sorting filters.

Observational procedure

The measurable amount of percentage absorption of the species under study is observed during high solar zenith

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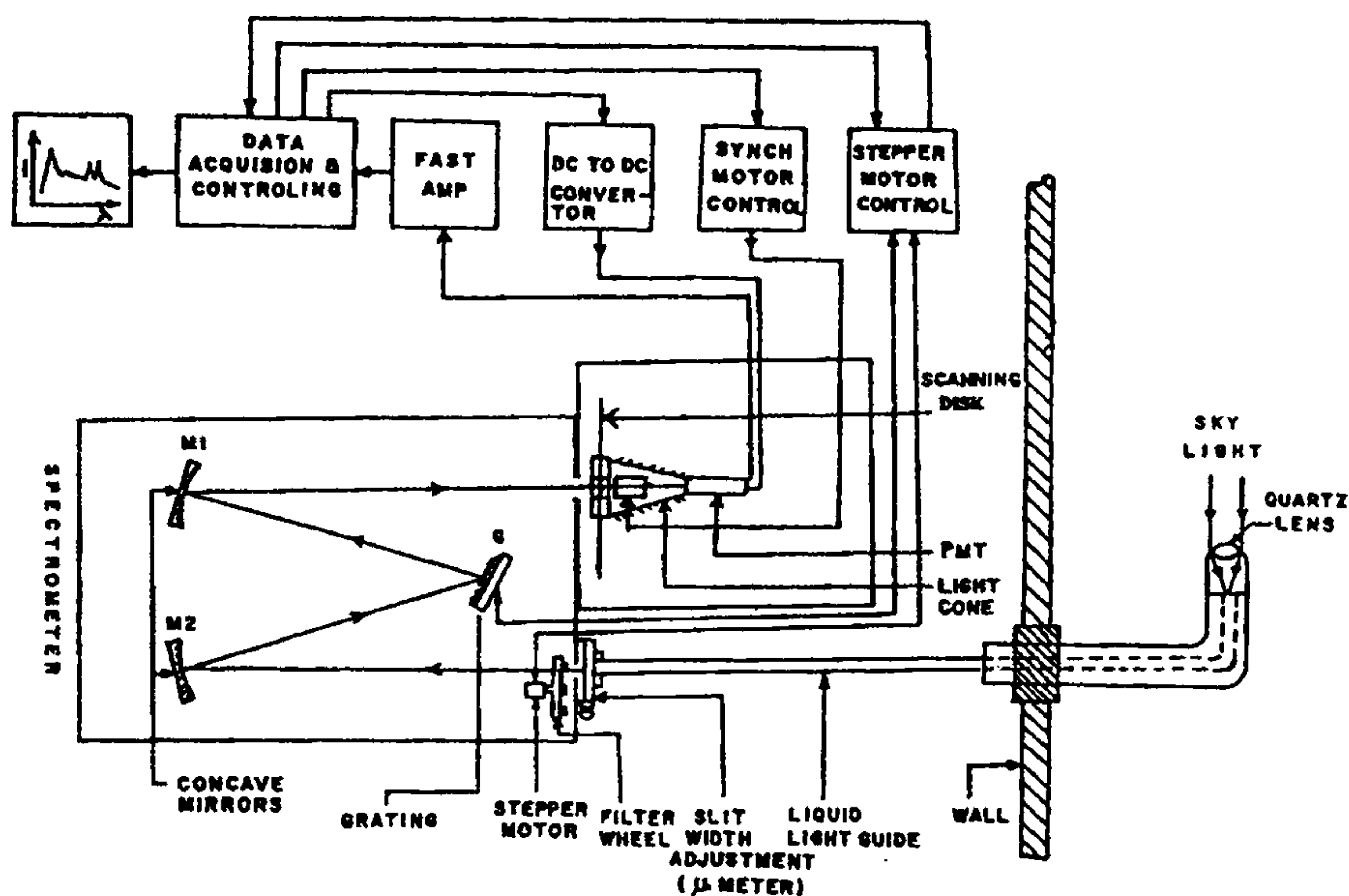


Figure 1. Rotating slit scanning UV-visible spectrometer.

angles. Hence, the zenith sky observations are carried out during 85° to 90° solar zenith angles only. The reference spectrum is recorded during 45 to 55 solar zenith angles with the spectrometer programmed for the zenith angle setting of the observational schedule. Parameters such as solar zenith angle interval for observations, signal level expected, latitude/longitude of stations, integration time, and the number of output samples to be collected, etc. are set before the observation. Once the observation schedule is set, the spectrometer will automatically take observations.

In the beginning, the photomultiplier tube (PMT) supply voltage increases. For each set of increase in the PMT voltage, the amplifier output is compared with the expected output (O/P) signal. If the O/P is less than expected O/P, the PMT supply voltage then increases. When the O/P from amplifier is just above the expected O/P signal, the increase in PMT voltage stops. A time interval of 10 s is used to stabilize the whole system before starting each observation; also during this time the PMT voltage setting secures the PMT supply voltage. In addition, in the beginning of each slit motion, the reference signal is generated by an opto-interrupter pair. The reference signal is used to trigger A/D conversion of the O/P signal. The O/P signal recorded during various zenith angles is shown in Figure 2. The portion of the spectra in the scale 411 to 417 nm shows dark current level for each spectra. The observed spectra is wavelength calibrated using a mercury vapour lamp and solar spectra.

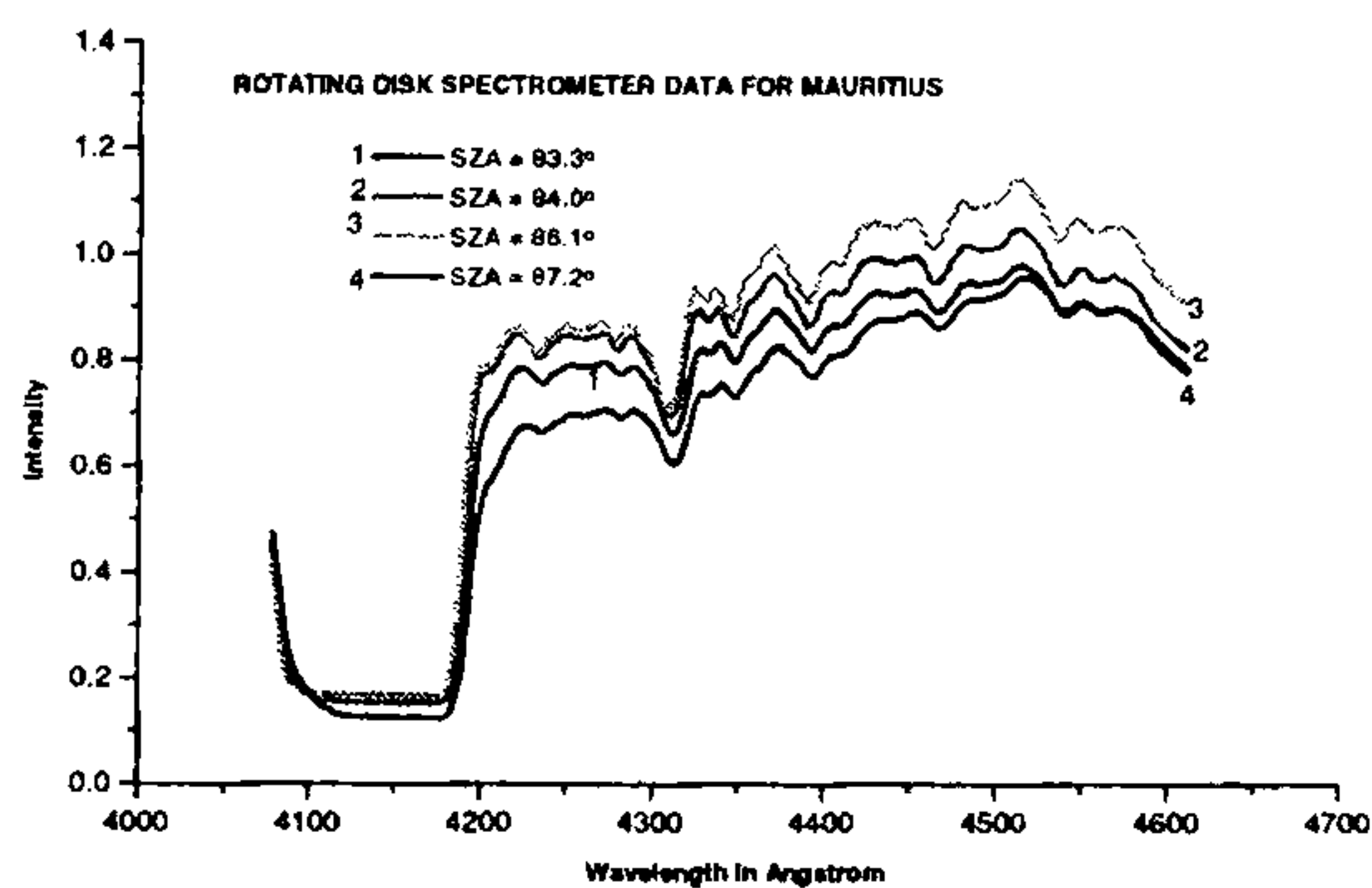


Figure 2. Observed zenith sky spectra for various solar zenith angles.

Data reduction procedure

The observed zenith sky spectrum during high solar zenith angles is divided by the reference spectrum, and this ratio spectrum is used for further analysis. In this procedure, the absorption structure reflected in the solar spectra due to Fraunhofer lines is eliminated and other functions like the differential effect of atmospheric species between noon and evening is retained. The ratio spectra in the spectral region 420 to 460 nm contains the structure due to atmospheric absorption species, Fraunhofer filling in, Rayleigh scattering, etc. The contribution due to various absorption species and Fraunhofer filling is a structural

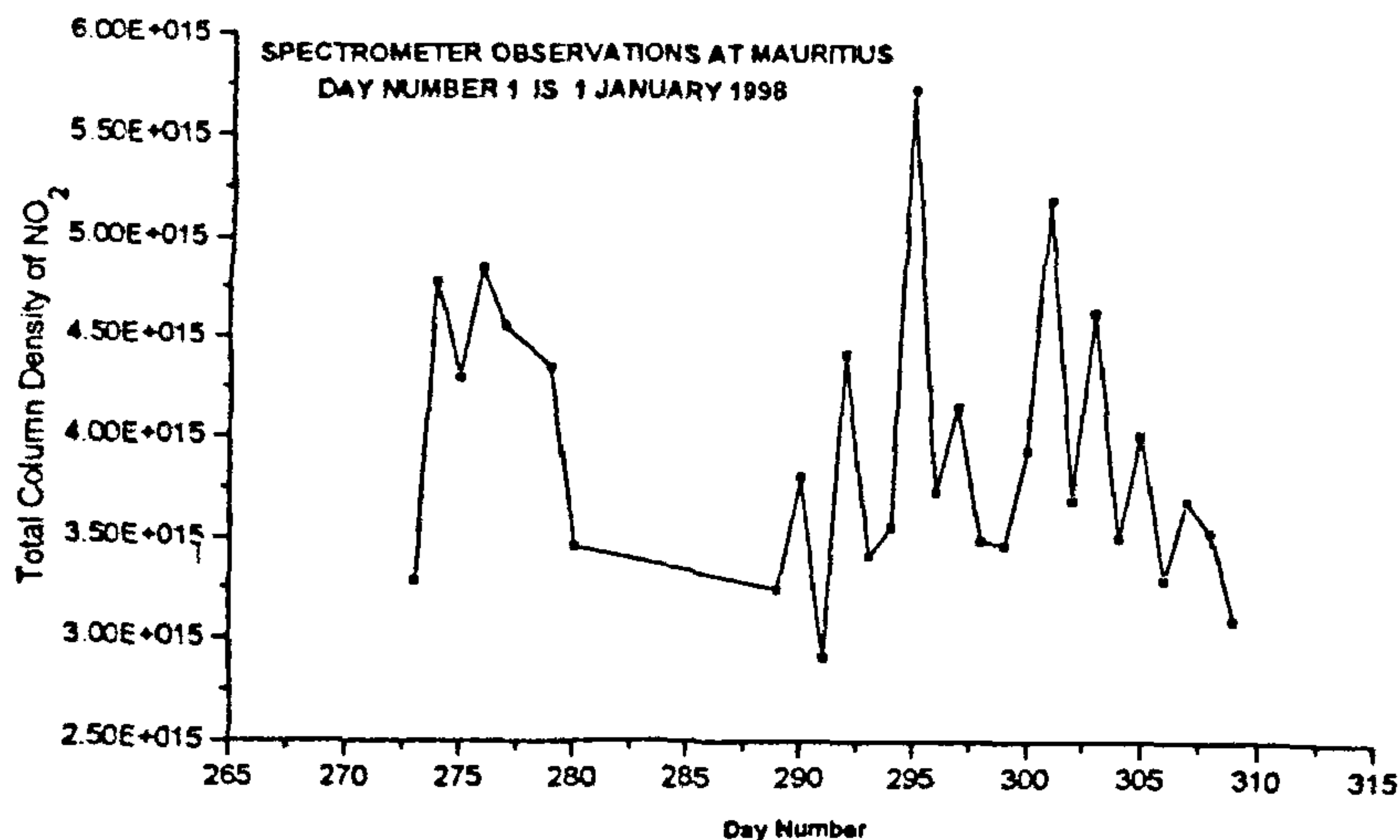


Figure 3. NO₂ total column density at Mauritius.

one. However, the Rayleigh-scattering and Mie-scattering contributions are slowly varying. The least square fitting method by matrix inversion technique is used to derive the differential molecular densities. These are differential slant column densities. The enhancement factors for species are calculated by assuming a standard vertical profile of the species under study. The differential slant column densities are divided by differential air-mass factors which gives the total column density for the species under study. The slant column density of NO₂ for day 273 to 309 is plotted in Figure 3. The total column density of the NO₂ is of the order of 4×10^{15} and is comparable with other southern latitude stations during September–October period.

Results and discussion

We have indigenously developed an automatic spectrometer and installed it at the University of Mauritius for

continuous observation of the total column density of NO₂ and O₃. The improved scanning system for the spectrometer will give better signal to noise ratio for monitoring other atmospheric species like NO₂, O₃, OClO, BrO, CH₂O, etc.

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