CURRENT AND FUTURE LIDAR MEASUREMENTS AT NY ÅLESUND, SPITSBERGEN

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ABSTRACT

The Koldewey Aerosol Raman Lidar (KARL), located in Ny Ålesund, Spitsbergen at 78.9N, 11.9E was operated since summer 2001 as a "3+2" Raman lidar designed to measure tropospheric aerosol and water vapour. This system was significantly upgraded end 2008 and shall serve as a common lidar system which, with only one collection mirror, probes the tropos- and the stratosphere. The technical details of this new lidar are introduced, first preliminary data are given and its purpose is discussed.

INTRODUCTION

While the inner Arctic is generally a remote and pristine site with aerosol optical depths (AOD) frequently around 0.05 at 550nm (Herber et al. [1]), significant aerosol occurrences due to Arctic Haze (Ritter et al. [2]) in spring and forest fire (Fromm et al. [3]) during summer regularly occur. Recently Hoffmann et al. [4] described aerosol layers from the Kasatochi volcano at the tropopause and lower stratosphere over Spitsbergen, observed in Aug/Sep. 2008. Apart from aerosol in this climatologically sensitive region liquid water at low temperatures is still a source of major insecurities in recent climate models – an overview of models employed for the IPCC 2007 is discussed in Gorodetskaya [5]. Recent experiments were published by Verlinde [6]. These facts underline the need to have a multi-purpose lidar system at Spitsbergen which is capable to measure aerosol from the PBL to approx. 20km height as well as subvisible, thin and mixed-phase clouds. Due to the polar day conditions from mid March till end Sep. the Raman channels should be analyzable in daylight conditions as well.

In this article some optical and technical properties of the improved lidar system at our Arctic site are introduced. In Sec. 3 some preliminary data are presented and a short outlook for future work is given.

2. DESCRIPTION OF THE INSTRUMENT

The KARL is a Nd:YAG based “3+2” Raman Lidar. The extinction is measured by the N_2 shifted lines from the 2nd and 3rd harmonic and, additionally, a water vapour channel at 407nm as well as depolarisation at 355nm and 532nm are recorded. Already in November 2006 a new laser (Spectra Pro 290-50) was successfully installed in the lidar, which works at 50Hz and yields more than 10W at 355nm and 532nm and 20W at 1064nm. After beam widening the laser now has an effective divergence of 0.5mrad in the sky. For detection one 70cm F2.5 mirror is used which is aligned coaxial to the laser beam. The technical details of the system are summarized in Tab. 1. Prior to this one-detection mirror solution two different mirrors for the near and far field have been employed. This two-mirror design always had some characteristic disadvantages: Apart from the need to have the detection optics with IF and transient recorders double (which we only had for the "green branch" of 533nm, 607nm and 660nm), the field of view (fov) of the small near field mirror was larger than that for the bigger far-field mirror. Hence, both data sets showed different amounts of multiple scattering and it was sometimes difficult to compare them.

For the beam widening telescope (BWT) simply a commercial schiefspiegler (Kutter 110/2720) from AOK Swiss could be employed. Only the tube was shortened and snapped off perpendicularly, as depicted in Fig.1. As an entrance lens a single CaF_2 biconcave lens is sufficient, thanks to the long focal lengths of the BWT. The laser beam is expanded by a factor of 11 and directed by the flat mirror in the upper right from the heated laser room into the open telescope hall.

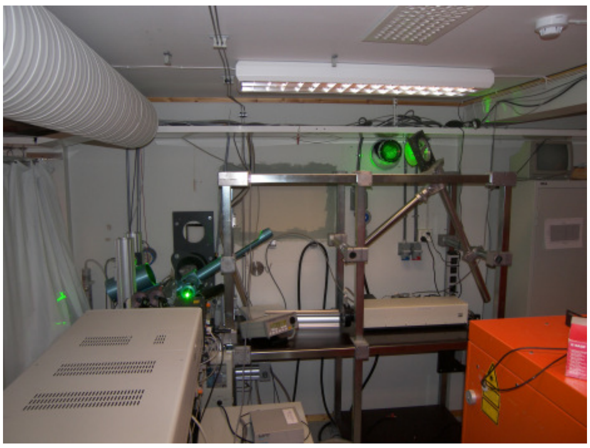

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Fig.1: The laser and the BWT (light blue)

Unfortunately, due to a bad energy distribution within the laser beam the true divergence in the sky is still 0.5mrad, larger than originally expected. This is lamentable because a small fov is important to achieve a high signal to noise ratio ("distinguish correct from wrong photons").

Laser wavelengths	**355nm, 532nm, 1064nm**
Laser pulse energy	**200mJ (@355),** **300mJ (@532),** **500mJ (@1064)**
Laser pulse rep. rate	**50 Hz**
Laser beam divergence	**0.5mrad after expansion (laser has egg-shaped profile)**
Recording telescope	**70cm (f=1.75m)**
Telescope FoV	**0.57mrad – 2.85mrad variable**
Detection channels **(elastic)**	**355nm: both parallel and perpendicular** **532nm: both parallel and perpendicular** **1064nm: unpolarized**
Detection channels **(inelastic)**	**N_2 Raman: 387nm, 607nm** **H_2O Raman: 407nm**
Range + Resolution	**Max. 7.5m / 10 sec typical: 60m / 100 sec** **Raman: 100m / 30 min: 8km**
Detection	**H5773 -03/04 from Hamamatsu, for 1064: APD**

Tab.1: Some basic properties of KARL

A schematic view of the focal detection unit with the movable iris is given in Fig.2. Some care was taken to use seperate fiber optics for the elastic (espec. UV) and Raman-shifted lines to minimize fluorescence effects within the glass.

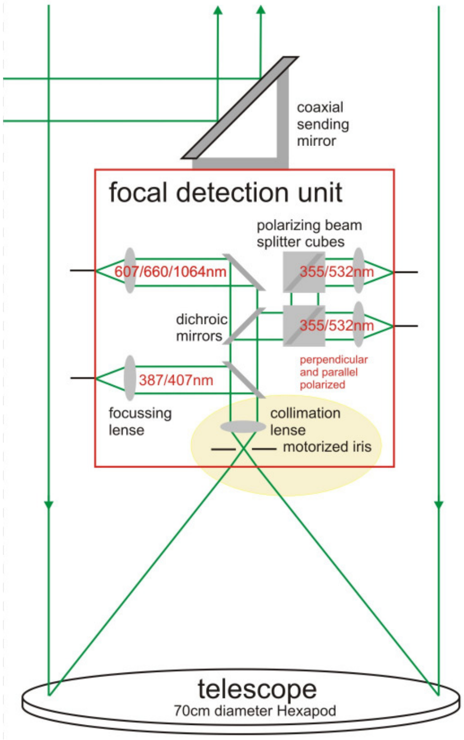

Fig.2: The focal detection unit

The diameter of the focal detection unit is about 18cm in diameter, the width of the outgoing widened laser beam is about 12cm.

The ability of the system to measure different height layers from the low tropo- up to the stratosphere is mainly achieved by a movable aperture stop, which can be positioned from 1mm "before" (nearer to the collection mirror) the infinity focus to 11mm behind the infinity focus, which corresponds to a focus for objects in 280m distance. Of course, by switching from near to far measurements the different signal intensity due to the large signal dynamics must be considered, which results basically from the $1/z^2$ dependence of the return lidar signal. As even modern photomultipliers only have a linear range of less than 5 orders of magnitude (information from Hamamatsu), care must be taken to adapt the signal intensity accordingly. In our case we chose a reduction of the photomultipliers (PMT) high voltage for near-range measurements. In tests of the system we found a stable, linear response of the PMT above 650V. The same fortunate behaviour was found for the IR channel, as seen in Fig.3: Here the backscatter ratio at 1064nm is plotted for the infinity configuration and during a second and third data set the voltage for the APD was increased by more than 40V, which corresponds to an increase in sensitivity by a factor of 8. The derived backscatter ratio does not depend on the High Voltage.

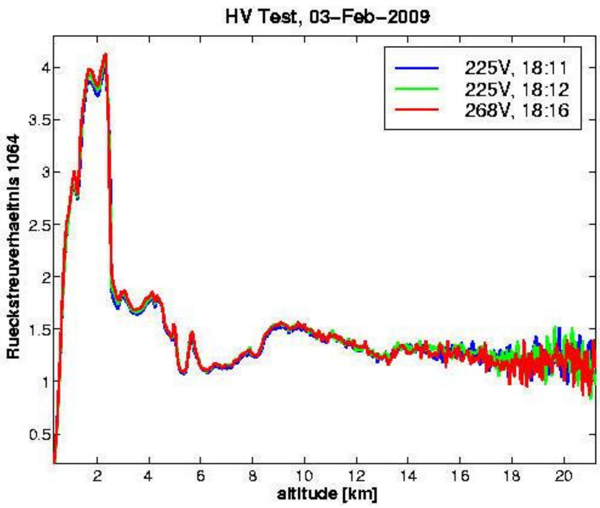

Fig.3: The backscatter in IR does not depend on the APD volatage

Apart from the aperture position, also its diameter can be varied from 1mm to 5mm as well. This feature allows multiple field of view (MFOV) measurements, as described in Bissonnette [7]. The idea behind this concept is that a bigger fov collects more light from different multiple scattering events in and directly behind a cloud. As the multiple scattering is mainly caused by large and non-spherical particles, whose microphysical properties are most difficult to derive by an inversion of the extinction and backscatter coefficients (Böckmann [8] and Veselovskii et al [9]. (These codes are generally based on Mie theory, so they cannot be applied to ice crystals. Moreover, the Mie extinction and backscatter efficiencies become smooth for large size parameters x:

$$x \equiv \frac{2\pi r}{\lambda} > 40$$

so that principally no information of particles which are large compared to the laser's wavelengths can be retrieved.) Hence, a MFOV measurement should be the natural expansion to a Raman lidar to constrain the microphysical properties of the scatterers. A first example of a thin tropospheric cloud is presented in Fig.4. It shows the difficulty, caused by a very high temporal variability of the cloud properties. Unfortunately in the current set up the aperture stop can only be moved by an explicit command via a control PC. Hence, recording 500 laser shots, storing and switching the diameter takes about 19 seconds in the current configuration. This time seems to be still too long to "freeze in" the microphysical conditions within clouds. Hence, we will deploy a strategy in the future where averages over a series of quick diameter changes will be analysed.

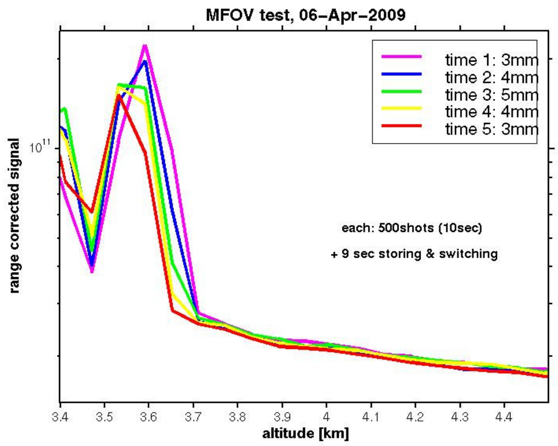

Fig.4: Example of MFOV measurement

In Fig.4 only around 3.7km altitude in the slightly decreasing count rate from time 3 to 5 may show an influence of the aperture diameter.

In Fig.5 an example of a measurement with different iris position is given. The 2 positions employed refer to the focal plane at infinity (FPInv) and 5mm, corresponding to 615m object distance. The (little) boundary layer aerosol, which is visible even in Arctic winter (prior to the Haze season), cannot be recorded with the FPInv position. However, the 5mm position of the iris still shows complete overlapp at large distances. This result shows that an optimal fixed aperture position might be somewhat behind the FPInf.

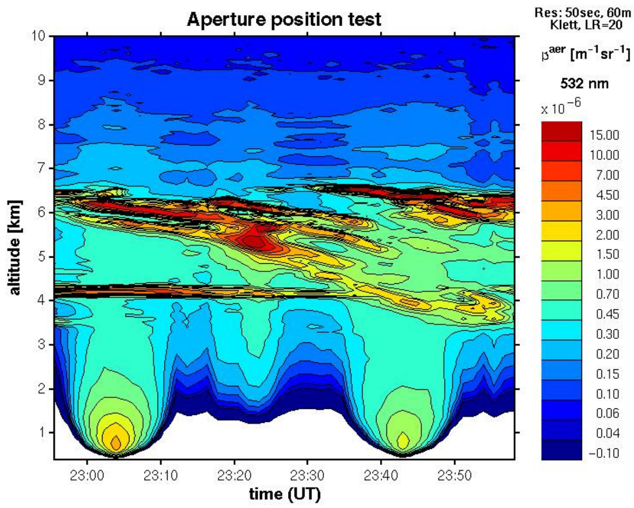

Fig.5: Tests with moving aperture from 1mm (infinity focus) to 5mm (focus at 615m).

3. OBSERVATIONS

The first measurements with the rebuild KARL were performed in spring this year during the international PAMARCMIP campaign. Interestingly, even this summer increased stratospheric aerosol layers were observed. An example is given in Fig.6. Trajectory calculations indicate that these aerosol layers, some of them distinct, others smoothed out, are very likely due to the mount Sarychey eruption. So far, these stratospheric aerosol layers were recorded on several days in July and August and show an optical depth of 0.05 at 532nm (hence doubling the total AOD). A more detailed analysis is under way. Especially we are interested to compare the lidar with meteorological data to see possible effects of the aerosol with temperature or ozone anomalies. It should be noted that in volcanic quiescent times the Junge layer over Spitsbergen is hardly visible.

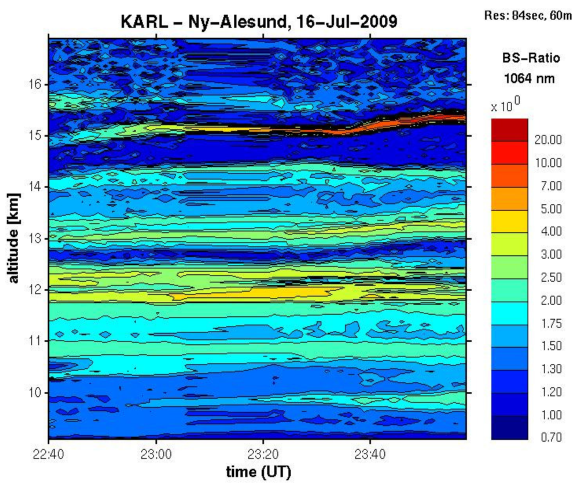

Fig.6 Backscatter of aerosol from Sarychev volcano

Apart from these measurements of clouds and sporadic aerosol events we will continue to monitor Arctic Haze regularly. The possibility to measure the polarisation in 2 different colours allows to estimate an aspect ratio of aerosol (Duncan, Thomas, [10]). Hence an inversion of lidar data with T-Matrix theory (instead of Mie) becomes possible in the future. As Arctic Haze over Ny Ålesund always showed a small depolarisation (2% to 4% at 532nm) this will hopefully further improve the possibility to derive microphysical aerosol properties from remote sensing data.

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