DEPOLARIZATION CHANNEL FOR BARCELONA LIDAR. IMPLEMENTATION AND PRELIMINARY MEASUREMENTS.

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ABSTRACT

A new depolarization channel has been implemented in the BarcelonaTech University (UPC) multi-wavelength lidar system. The optical and mechanical designs are presented. The special configuration of the total power channel is also detailed, with the relevant aspects in measurement inversion. Some preliminary measurements are presented for Saharan dust intrusion events.

1 INTRODUCTION

The capability of measuring depolarization of the backscattered light, together with multi-wavelength detection, improves the ability of a lidar system to identify the aerosols present in the atmosphere, as it has been pointed out by different authors [1]–[4].

The BarcelonaTech University (UPC) Remote Sensing Lab (RSLab) has implemented a new depolarization channel for its lidar system. The depolarization channel has been tested with measurements during Saharan dust intrusion events taking place on May and June 2016.

2 THE UPC LIDAR MAIN RECEIVER CONFIGURATION

The lidar system at UPC [5] presents a non-common receiver configuration that is sketched in Figure 1. A 14-inch telescope collects the backscattered light, which is delivered to the poly-chromator unit by means of a 3-m long multi-mode fiber bundle of 3 mm diameter. The poly-chromator delivers light to the 6 photo-receivers tuned at 1064, 532 and 355 nm (elastic backscattering) and 607, 407 and 387 nm (Raman channels).

According to fiber optics theory [6], a multi-mode fiber will not preserve the polarization of the guided light.
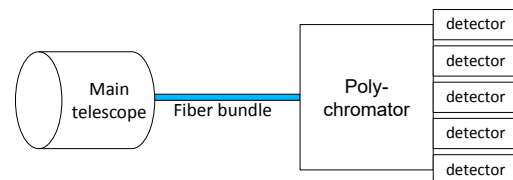

Figure 1 UPC lidar receiver configuration, including a depolarizing multi-mode fiber bundle.

This fact makes that the overall behavior of the receiver is non-sensitive to the polarization of the incoming light. So the main receiver becomes total-power collecting.

To check this feature, we measured the depolarization introduced by the fiber bundle, with a simple test set, presented in Figure 2. The laser beam passes through a linear polarizer before being fed to the fiber bundle.
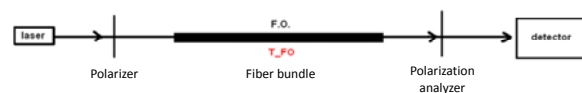

Figure 2 Test set for checking the polarization behavior of the fiber bundle

The polarization state of the output light was measured in two different situations: with the fiber bundle cable placed straight and rolled up. The results are plotted in Figure 3. The measured circularities are 0.96 for the cable straight and 0.93 for the cable rolled up.

This depolarization capability is also useful to make our system insensitive to the di-attenuation of the different beam-splitters used in the poly-chromator unit.
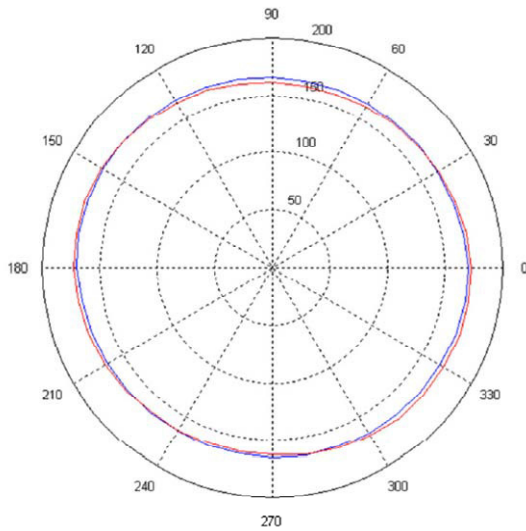
Figure 3 Polarization state measurement at the output of the fiber bundle cable for two situations: straight (blue line) and rolled up (red line) cable.[7]

3 NEW DEPOLARIZATION CHANNEL

The depolarization channel has been built by means of an auxiliary telescope attached to the lidar mechanical setup. The auxiliary telescope is, in fact, a 300-mm focal distance, 70-mm aperture diameter, TAIR-3S telephoto lens.

The optical setup, sketched in Figure 4, includes an eye-piece lens that produces an image of the telescope aperture onto the photo-receiver (a Licel R9880U PMT module) sensitive area. This arrangement allows distributing the collected light over the PMT sensitive surface, while a 1-mm field-stop iris limits the field of view to approx. 3.3 mrad.
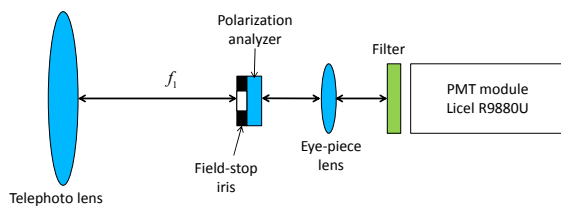

Figure 4 Optical setup of the depolarization channel

A polarization analyzer located at the focal plane of the telephoto lens selects the desired polarization of the collected light. When performing measurements, the position of the analyzer is oriented to collect the cross-polar component; when performing the needed calibration of the channel [4] the analyzer is oriented alternatively at +45 and -45 degrees from the nominal position.

Finally, an interference filter at 532 nm is located near the photo-receiver surface. According to this arrangement, the collected light rays are not parallel when passing through the filter. This fact implies that the filter effective spectral width is greater than the specified value (0.5 nm). This has implications especially in the molecular contribution to the depolarized backscattered light [8] and must be taken into account when processing the measurement results.

4 PRINCIPLE OF OPERATION [4]

The primary depolarization measurement is done by comparing the signals detected by the depolarization and total power channels

$$S_{Dep}\left(90^{\text{o}}, R\right) = V_{Dep}\left(R\right) \cdot P_{\perp}\left(R\right)$$
$$S_{Tot}\left(R\right) = V_{Tot}\left(R\right) \cdot P_{Tot}\left(R\right) \tag{1}$$

where $P_{\perp}\left(R\right)$ and $P_{Tot}\left(R\right)$ are the cross-polar and total powers collected while $V_{Dep}\left(R\right)$ and $V_{Tot}\left(R\right)$ are the depolarization and total power channels responsivities, as a function of height over the lidar R. The primary observable is

$$\delta^{*}\left(90^{\text{o}}, R\right) = \frac{S_{Dep}\left(90^{\text{o}}, R\right)}{S_{TOT}\left(R\right)} \tag{2}$$

In parallel to the measurement process, a channel calibration (with respect to the total power channel) must be performed to obtain the system channel ratio

$$V^{*}\left(R\right) = \frac{V_{Dep}\left(R\right)}{V_{Tot}\left(R\right)} \tag{3}$$

The calibration is done by performing two short measurements with the polarization analyzer rotated +45 and -45 degrees from the nominal position, $S_{Dep}\left(90^{\text{o}}+45^{\text{o}}, R\right)$ and $S_{Dep}\left(90^{\text{o}}-45^{\text{o}}, R\right)$. The system calibration profile is then computed by comparing with the signal obtained simultaneously from the total power channel, $S_{Tot}\left(R\right)$:

$$V^{*}(R) = 2\sqrt{\frac{S_{Dep1}(90°-45°,R)}{S_{Tot1}(R)} \cdot \frac{S_{Dep2}(90°+45°,R)}{S_{Tot2}(R)}} \tag{4}$$

Figure 5 shows the result of a calibration performed on December 2nd 2016. As it can be noted, a spatial average is performed
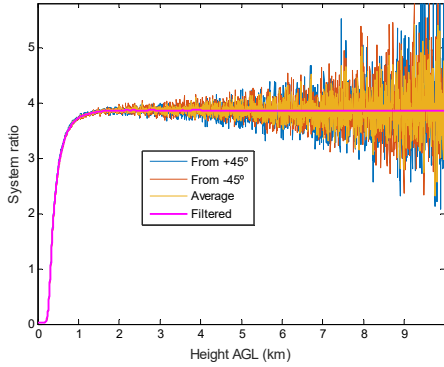

Figure 5 System channel-ratio calibration performed on December 2nd 2016.

The volume depolarization ratio is then computed

$$\delta^{V}(R) = \frac{\delta^{*}(90°,R)}{V^{*}(R) - \delta^{*}(90°,R)} \tag{5}$$

Finally, the particle depolarization ratio is computed by using concurrently the results of the molecular $\beta^{m}(R)$ and particle $\beta^{p}(R)$ backscattering coefficients of the atmosphere under measure, via an elastic or Raman inversion of the total power 532-nm channel:

$$\delta^{p}(R) = \frac{\left[1+\delta^{m}(R)\right] \cdot \delta^{V}(R) \cdot \rho(R) - \left[1+\delta^{V}(R)\right]\delta^{m}(R)}{\left[1+\delta^{m}(R)\right] \cdot \rho(R) - \left[1+\delta^{V}(R)\right]} \tag{6}$$

where:

$$\rho(R) = \frac{\beta^{m}(R) + \beta^{p}(R)}{\beta^{m}(R)} \tag{7}$$

and $\delta^{m}(R)$, the molecular volume depolarization ratio is usually considered a constant, which depends on the temperature and the spectral width of the photo-receiver [8].

5   RESULTS

Two Saharan dust intrusion events took place around Barcelona area in late May and early June 2016. Measurements were performed with the UPC lidar and simultaneously with a co-located Micro Pulse Lidar, associated to MPLnet [9]. This Micro Pulse Lidar provides the range-corrected total power and depolarization signals and calculates the volume depolarization in real time.

Figure 6 and Figure 7 show two consecutive measurements during May 26th. They show a Saharan dust layer around 3.7 km altitude, with particle depolarization ratio exceeding 20% (more than 15% is characteristic of this kind of aerosol). Both measurements show good agreement between the UPC lidar and the MPL.
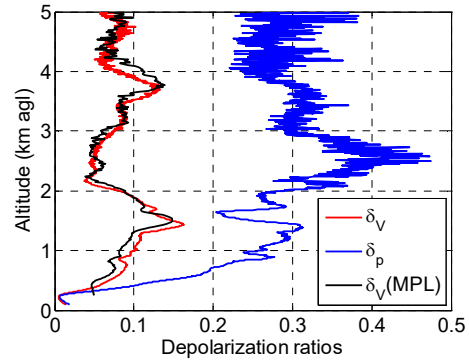

Figure 6 Measurement performed on May 26th 2016, 14:24 UTC
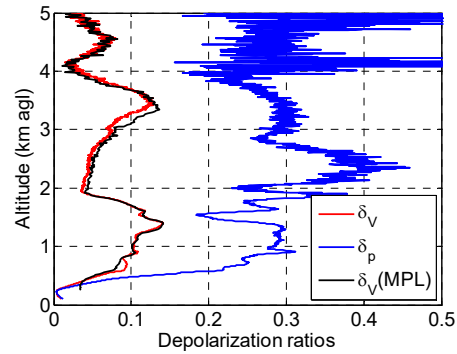

Figure 7 Measurement performed on May 26th 2016, 15:40 UTC.

Figure 8 and Figure 9 show measurements taken, respectively, in the beginning and in the maximum of an intrusion event in June 2016. Figure 8 shows a small value of volume depolarization up to 5 km, while Figure 9 shows a great mass of aerosol between 3 and 4 km height,

also with particle depolarization over 20%. In this latest measurement, there is a noticeable difference with the MPL measurement, very likely due to some mechanical tolerance in the telescope pointing not considered because of the absence of a calibration on the day of the measurement.
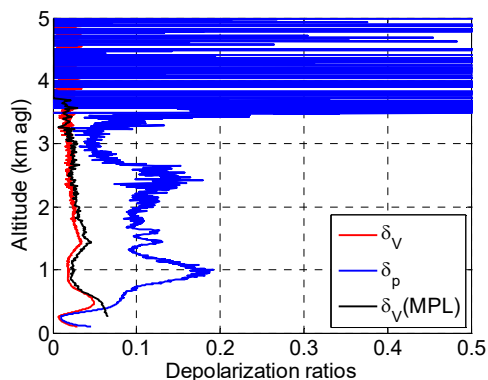

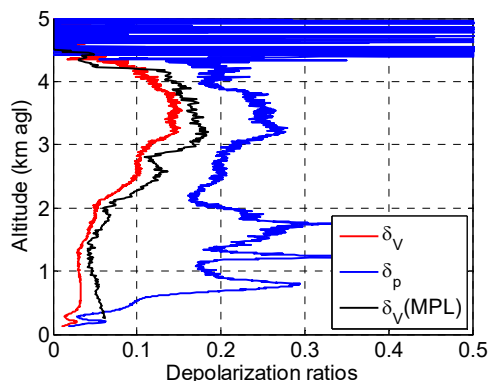*Figure 8 Measurement performed on June 7th 2016, 8:37 UTC.*

Figure 9 Measurement performed on June 10th 2016, 13:17 UTC

6   CONCLUSIONS

The new depolarization channel of the UPC lidar has been introduced with details of architecture and principle of operation. Measurements performed during two Saharan dust intrusion events are used to test the new channel. Particle depolarization ratios varying between 10 and 40 % are found in the dust layers. Comparisons of the volume depolarization with an MPL system show a good agreement between both systems and demonstrate the reliability of the new depolarization channel of the UPC multi-wavelength lidar.

References

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