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URBAN AEROSOL OPTICAL PROPERTIES MEASUREMENT BY ELASTIC COUNTER-LOOK LIDAR

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ABSTRACT

The new developed elastic lidar system utilizes two identical elastic lidars, in counter-look configuration, to measure aerosol backscattering and extinction coefficients without any hypotheses. Compared to elastic-Raman lidar and high spectral resolution lidar, the proposed counter-look elastic lidar can use low power eye-safe laser and all available wavelengths. With this prototype lidar system, urban aerosol optical properties and their spatial distribution have been directly measured, including backscatter coefficient, extinction coefficient and lidar ratio. The preliminary results show that the low cost and eye-safe counter-look configured elastic lidar system can be used to measure the aerosol optical properties distribution and give the hint of aerosol type.

1. INTRODUCTION

Lidar systems are widely employed to characterize atmospheric aerosol optical properties. From Lidar signals, it is possible to determine the particles optical and microphysical parameters through the application of inversion algorithms when measurements of both aerosol extinction and backscattering coefficients are available at different wavelengths [1, 2]. Aerosol extinction and backscattering coefficients can be independently measured by Raman lidar or high spectral resolution lidar system [3]. Nevertheless, the Raman and high spectral resolution lidar technique are hardly to apply to the near infrared, due to the dependence from λ^{-4} of the cross section of the process. Furthermore, the low absolute value of the Raman cross section involves the use of high power laser beams, with resulting economical, technical and safety problems, which add up a not negligible complexity of data processing. Therefore, it is difficult to apply conventional lidars to routine measurements in the control of fine particles in urban areas, to the control of emissions of industrial plants, energy production plants, incinerators etc., so that their usage is general limited to scientific research purpose.

With the aim to characterize the fine particles in the low part of atmospheric, an innovative instrument, patent of CNR (National Council of the Research) and CNISM (National Interuniversity Consortium for the Physical Sciences of Matter), has been proposed [4]. This application can be realized with the simultaneous employment of different wavelengths (from the ultraviolet to the infrared) and the use of low power and cheap laser sources.

2. METHODOLOGY

The principle of counter-look lidar system has been descripted in references [5]. The briefly discussion of the method is as follows.

Two identical elastic lidars locate in two separation positions, usually apart in several kilometers. The orientation of lidars are counter look each other. In this way, two laser beams pass the same atmosphere area.

The two range corrected signals (RCS) of lidar A and lidar B can be written as

$$RCS_A(z) = K_A \cdot \beta(z) \cdot \exp(-2\tau_{0z})$$

$$RCS_B(z) = K_B \cdot \beta(z) \cdot \exp(-2\tau_{zd})$$

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Where $\tau_{0z} = \int_{o}^{z} \alpha(\zeta) d\zeta$ and $\tau_{zd} = \int_{z}^{d} \alpha(\zeta) d\zeta$ are the optical depths from lidar A to z and from z to lidar B. K_A and K_B are two instrument constants. d is the distance from lidar A to lidar B.

From RCS_A and RCS_B, we can get backscattering and extinction coefficients, respectively.

$$\beta(z) = \sqrt{K \cdot RCS_A(z) \cdot RCS_B(z)}$$

$$\alpha(z) = \frac{1}{4} \frac{d}{dz} \ln\left(\frac{RCS_B(z)}{RCS_A(z)}\right)$$

Where K is a system constant. We can get it from the system calibration.

The aerosol backscattering and extinction can be calculated from total backscattering, $\beta(z)$, and extinction, $\alpha(z)$, subtracting the molecular contribution.

3. RESULTS

The first prototype of counter-look lidar system was implemented only for single wavelength elastic backscattering lidar. The main parameters of two elastic lidars are report in table 1.

Table 1. The main parameters of counter-look lidar system prototype

Laser		Telescope	
Energy per pulse (μJ)	5	Radius (cm)	10
Repetition frequency (Hz)	2000	Focal length (m)	0.5
Divergence (mrad) (with Beam Expander)	<0.2	Diaphragm opening (mm)	0.5
Wavelength (nm)	532	Angular opening (mrad)	1
Pulse duration (ns)	< 20		

The two lidar were located in two different places to across an urban area of Naples, Italy, shown in Figure 1.

Figure 1. The location (40.838099°, 14.183132°) of counter-look lidar system prototype.

Before the real measurement, the counter-look lidar system prototype has been calibrated with our Raman lidar, which is one of the EARLINET station [6], as shown in Figure 2. From the calibration, the system constant has been evaluated, in order to perform the backscattering coefficient calculation.

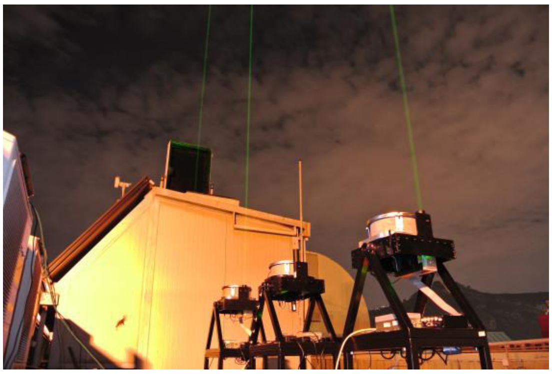

Figure 2. System calibration with the Raman Lidar of the Earlinet Naples station.

Lidar return signal has been acquired in both day and night time. 10 minutes integrated range corrected signals from lidar A and B are shown in Figure 3, as example.

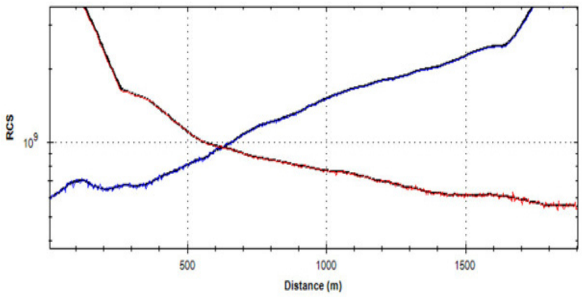

Figure 3. The 10 minutes integrated range corrected signals from two lidars measured on Dec 15, 2014

From above mentioned formula, aerosol backscattering and extinction coefficients have been retrieved without any Lidar Ratio hypothesis. Retrieved profiles are shown in Figure 4.

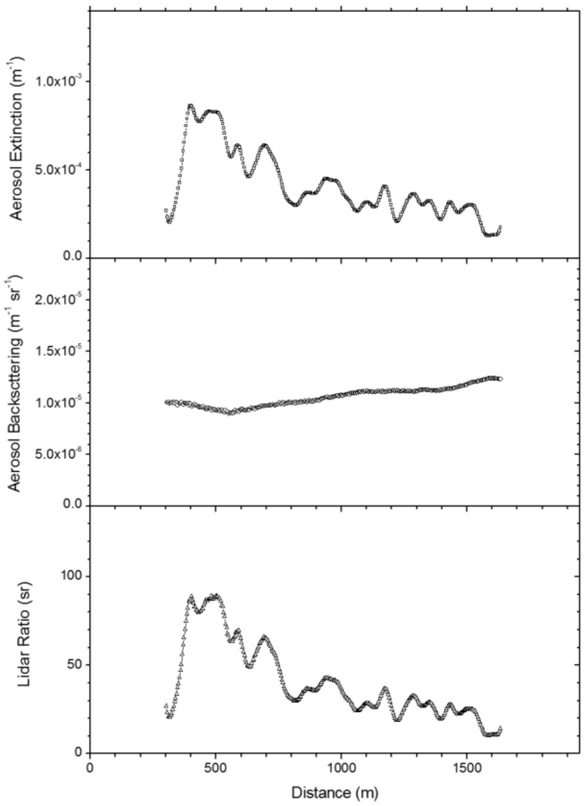

Figure 4. Retrieved aerosol backscattering and extinction coefficients distribution, measured in Dec 15, 2014.

There are not data in the first and the last 300 m. This is because in these range the lidar beam and the field of view are not total overlapped. The further evaluation of overlap function work should be done in future.

From the results in Figure 4, we can see that along the lidar path, even the aerosol backscattering coefficient dose not change very much, about 20%, the aerosol extinction coefficient vary a lot. The aerosol lidar ratio values show that there are two different aerosol types along the lidar path. The high lidar ratio, about 90 sr, around 500 m from lidar A, corresponds a high polluted urban aerosol. While beyond the 1000 m, the aerosol lidar ratio value is 20-30 sr. This is a typical natural aerosol. In fact, from the map, we can see that in that area there is little human activity.

4. CONCLUSIONS

The counter-look elastic lidar system is low cost and eye safe. It can be used in both day time and night time. With a simple lidar configuration and simple algorithm, we can independently retrieve aerosol backscattering and extinction coefficients. The preliminary result show that from the high precise lidar ratio, we can estimate the aerosol nature.

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