RECENT UPGRADES OF THE EOLE AND AIAS LIDAR SYSTEMS OF THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS OPERATING SINCE 2000 IN ATHENS, GREECE

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ABSTRACT

The technical specifications and advances/ upgrades of the stationary (EOLE) and mobile (AIAS) lidars located at the National Technical University of Athens (NTUA) are presented in this paper. EOLE is a multi-wavelength combined backscatter/Raman lidar system, which is part of the EARLINET lidar network since May 2000. AIAS is a mobile 532 nm elastic depolarization lidar system. Both instruments have been upgraded during 2019, in the frame of PANACEA to be part of the Greek National Research Infrastructure for aerosol research, under the umbrella of the European Strategy Forum on Research Infrastructures (ESFRI).

1. INTRODUCTION

Since 2000, the Laser Remote Sensing Unit (LRSU) of NTUA [37.96°N, 23.78°E, 212 m asl.] is operating the EOLE lidar system. Through these years, the system has been gradually upgraded regarding its operational wavelengths and configuration. Nowadays, EOLE is an advanced 6-wavelength elastic-Raman lidar system (Fig. 1), equipped with two depolarization channels (355 and 532 nm), able to perform independent and simultaneous measurements of the vertical profiles of the aerosol backscatter coefficient at 354.93, 532 and 1064.2 nm, aerosol extinction coefficient and linear particle depolarization ratio at 354.93 and 532 nm, water vapor mixing ratio (using the H_2O Raman channel at 407 nm) and ozone in the troposphere [1-3]. Here we will limit our presentation on the aerosol measurement profiling.

2. EXPERIMENTAL SET-UP

The advanced elastic-Raman lidar system (EOLE) of LRSU is based on a pulsed Nd:YAG laser system (Spectra Physics Lab-170-10) (Fig. 1) which emits, simultaneously, pulses at 354.93-532-1064.2 nm, with energies of 240-310-260 mJ, respectively, at 10 Hz repetition frequency. The laser beams are horizontally polarized (>90%) at 532-1064.2 nm and vertically polarized (>90%) at 354.93 nm. The laser beam containing all three wavelengths is expanded by an achromatic Galilean telescope (x3), before being emitted in the atmosphere, thus its divergence remains <0.17 mrad (FWHM). A 300 mm diameter Cassegrainian telescope (focal length f=600 mm, FOV=1.5 mrad) collects all elastically backscattered lidar signals (354.93-532-1064.2 nm), as well as those generated by the spontaneous Raman effect (by atmospheric N_2 at 386.6-607.4 nm and by H_2O at 407.5 nm).

Figure 1. The LRSU elastic-Raman lidar (EOLE).

A second laser is used to emit vertically polarized beam at 355 nm (>99%), while an additional telescope (200 mm diameter, Dall-Kirkham Cassegrainian) with focal length f=1000 mm, collects the elastically backscattered lidar signals at 355 and 532 nm (at 2 polarization planes:

parallel and vertical), which are optically separated by polarizing beam splitter cubes.

At the entrance of the 300 mm diameter telescope a high grade fused silica optical fiber (N.A. =0.22±0.02 and 1.5 mm core diameter) is used to transfer the lidar signals to the 6-wavelength spectrometer, which is equipped with achromatic collimating lenses, dichroic beam splitters, as well as doublets, eye pieces and interference filters (IFF) placed in front of the detectors (Photo-multiplier tubes-PMTs at 354.93-386.6-407.5-532-607.4 nm and Avalanche Photo Diode at 1064.2 nm). In Table 1 the technical characteristics of the receiving system of EOLE are summarized.

	354.9 nm	**386.6 nm**	**407.5 nm**	**532 nm**	**607.4 nm**	**1064.2 nm**
IFF bandwidth (nm, FWHM)	1.8	0.84	0.5	0.5	1.06	0.97
Transmission (%)	47.5	77.4	51	45	78.7	45.7
Out of band blocking (>OD)	6	8	10	4	6	4
Detector model-Hamamatsu	R7400P-03	R7400U-P06	R7400U-02	R7400-P02	R7400U-20	Si-APD-1.5
Eye-piece	YES	YES	YES	YES	YES	YES

Table 1. Technical characteristics of the optical components of the wavelength separation system of EOLE.

All optical components of the 6-wavelength spectrometer are mounted on micrometric positioners and rotators, fixed on an anti-vibrating optical table; therefore, they can be placed at an optimal position. The choice of the optical components, as well as their optimal position has been identified through advanced ray-tracing code (Zemax), by simulating the projection of the laser beam down to the PMTs' photocathodes. Narrowband IFFs are used to suppress the atmospheric background noise at the detected wavelengths (354.93-354.93-386.6-407.5-532-607.4-1064.2 nm) (cf. Table 1).

The PMTs (operating both in the analog and photon-counting mode) and APD (operating in the analog mode) output signals, are fed into fast transient recorders (Licel GmbH) working in both the analog (using 20 MHz Analog to Digital Converters-ADC at 12-bits resolution) and photon counting (maximum 250 MHz count rates) mode, at 8196 range bins. EOLE's overlap distance is of ~600 m, while the vertical raw resolution of the acquired lidar signals is 7.5 m.

3.1.2 Mobile two-wavelength depolarization elastic lidar system

Additionally, a Raymetrics S.A. (Greece) van-mounted 1064 nm (elastic) and 532 nm (elastic) depolarization lidar (AIAS) is available (Fig. 2), to provide the vertical aerosol linear depolarization ratio in the troposphere, thus evaluating the sphericity of the probed aerosols. AIAS is based on a pulsed Nd:YAG laser system (Litron Nano SG 150-10 Series) which emits pulses at 532 and 1064.2 nm, with energies of 95 and 55 mJ, respectively, at 10 Hz repetition frequency.

Figure 2. The 532 nm LRSU elastic depolarization lidar (AIAS lidar).

The laser beam at 532 nm is vertically polarized (>99%) using a λ-2 waveplate and is expanded by a Galilean telescope (x4), before being emitted in the atmosphere, thus its divergence remains <0.4 mrad.

A 200 mm diameter Dall-Kirkham Cassegrainian telescope (focal length f=1000 mm) collects the elastically backscattered lidar signals at 532 nm (at 2 polarization planes: parallel and vertical) and at 1064 nm. A secondary mirror is used to guide the backscattered light to wavelength separation unit (WSU), which is equipped with collimating lenses, dichroic beam splitters, polarizing cubes, as well as doublets and very narrow (0.6 nm

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FWHM) interference filters (IFF) placed in front of the detectors (Photo-multiplier tubes-PMTs at 532 nm). A dichroic mirror is used to separate the 532 nm from the 1064.2 nm signals, while a polarizing cube beam splitter mounted in a rotating base, is used to separate the co-polarized and de-polarized light at 532 nm, and to calibrate the signals.

	532 nm (p and s-polarization)	**1064 nm**
IFF bandwidth (nm, FWHM)	0.6	0.97
Transmission (%)	44.24	45.70
Out of band blocking (>OD)	6	4
Detector model-Hamamatsu	R7400U-P02	Si-APD-3.0
Eye-piece	YES	YES

Table 2. Technical characteristics of the optical components of the wavelength separation system of AIAS.

Both EOLE [2] and AIAS [3] lidars follow the quality assurance protocols of EARLINET and have been validated through direct intercomparisons, both at hardware and software level, in the frame of the EARLINET, ASOS and ACTRIS projects [4-7].

4. The PANACEA PROJECT

The PANhellenic infrastructure for Atmospheric Composition and climatE change (PANACEA) is a Research Infrastructure (RI) where specialized atmospheric observations (aiming to adequately monitor the atmospheric composition, radiation disturbances and essential climate variables) will be performed. Thus, PANACEA is envisioned to be a distributed European RI (adopting the ACTRIS/ESFRI structure according to the EU Regulation 651/26.6.2014) to provide specific services to stakeholders, as well as a network of excellence at national level.

The specific objectives of PANACEA are to:

- create a novel RI of excellence in atmospheric sciences that will catalyze collaboration at national and international level, minimizing costs and enhancing networking and mobility through intra- and trans-national access;

- promote development of new technologies for atmospheric observation of aerosols, clouds, radiation, greenhouse and trace gases, in close partnership with national and European Union SMEs;

- provide access to tools and data, allowing various beneficiaries (e.g. scientific community, institutions, Regions, local/national authorities, large companies/industries and SMEs, NGOs) to exploit and develop synergistic atmospheric characterization techniques;

- improve the efficiency of current facilities, through the application of tailored harmonization processes; promote QA/QC via creation of specialized calibration centers;

- provide access to high-quality information and services to end-users (research community, education, local/regional/national authorities, large companies/industries/SMEs, environmental and health protection agencies, energy, tourism and transport sectors, international organizations and networks, NGOs, etc.);

- provide state-of-the-science expertise, assisting policy making on issues such as climate change, natural hazards, air quality and long-range transport of pollutants;

- create and use educational and training platforms for students and young scientists in the fields of air quality and climate change.

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Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

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