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D4.6.2: Implementation of new Lidar acquisition channels at the Rome ACTRIS NF [B10]

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LIST OF ACRONYMS

ACTRIS: Aerosols, Clouds, and Trace gases Research InfraStructure

ACTRIS-IT: Italian component of the distributed research infrastructure ACTRIS

AERONET: Aerosol Robotic Network

AERONET OC: Aerosol Robotic Network Ocean Component

ARS: Aerosol Remote Sensing

ARTE: Atmospheric Rome joinT supersitE

CARS: Centre for Aerosol Remote Sensing

EarthCARE: Earth Cloud Aerosol and Radiation Explorer

ESFRI: European Strategy Forum on Research Infrastructures

FOV: Field Of view

LIDAR: LIght Detection And Ranging

NF: National Facility

OU: Operative Unit

PMT: PhotoMulTiplier

RMR: Rayleigh-Mie-Raman

RI: Research Infrastructure

UTLS: Upper Troposphere and Lower Stratosphere

WP: Work Package

1. INTRODUCTION

The aim of this deliverable, prepared in the context of the ITINERIS project within the Work Package 4, is to report the implementation of new acquisition channels at the multi-telescope lidar located at CNR-ISMAR-RM. Within the framework of the Aerosols, Clouds, and Trace gases Research InfraStructure (ACTRIS) labelling, the implementation of these channels is required to join the ACTRIS network. ACTRIS is a European research infrastructure producing and coordinating the provision of harmonized high-precision data and data products on short-lived atmospheric constituents and on the processes leading to the variation of these constituents. The multi-wavelength multi-telescope Rayleigh-Mie-Raman (RMR) system at CNR-ISMAR-RM is now included as a National Facilities (NF) of the Atmospheric Rome joinT supersitE (ARTE) for the Aerosol Remote Sensing (ARS) component. One of the main objectives of the Task 4.6 activity is strengthening the observational capacity of the CNR-ISMAR-RM to characterize atmospheric aerosols through maintaining and enhancing the Lidar measurement capabilities of the Rome ACTRIS ARS NF within the Italian Network of Environment RIs.

The document is structured in 8 different chapters. Annexes and references are reported at the end of the document.

2. THE ITALIAN ATMOSPHERIC ROME JOINT SUPERSITE (ARTE) NF

The Italian National Facilities ARTE comprises two experimental sites in Rome, Italy. The first site, CIRAS, is located in the semi-rural Tor Vergata hills (41.88°N, 12.68°E, 107 m a.s.l.) and is managed by the Institute of Atmospheric Sciences and Climate with the participation of the Institute of Marine Sciences. The second site, BAQUNIN, is an urban site at La Sapienza University in the city center (41.90°N, 12.51°E e 75 m a.s.l.) and is managed by the university. These sites are strategically placed for monitoring and characterizing air pollution, benefiting from sea breeze circulation, Saharan dust transport, and energetic weather events. The unique combination of these factors makes Rome a significant location for atmospheric research in Europe. The collaboration between the two sites provides access to advanced instrumentation for atmospheric remote sensing and satellite data validation. Current observations at these sites are focused on understanding and measuring atmospheric composition.
ARTE contributes to both national and international monitoring networks (e.g. NASA AERONET, E-Profile, Earlinet, NDACC, Skynet, Alice-net) and for the validation of satellite data (e.g. GPM, EarthCARE).

3. IDENTIFIED GAPS AND NEEDS FOR INTEGRATION

With regard to the technical infrastructure, the system parameters shall be as much as possible compliant with the latest mandatory ACTRIS requirements for an ARS NF operation as for the guidelines defined in the document 'Guidelines and recommendations for the candidate ACTRIS Aerosol Remote Sensing Observational Platforms' (Version 02, rev. 01, published 11 October 2022). Measurements of aerosol extinction, backscatter and depolarization-ratio profiles must be performed at either 355 nm or 532 nm, with at least one-wavelength Raman with polarization discrimination capability by means of the Δ90 technique (+/- 45°) through the use of a calibrator. The analysis and detection equipment must be capable of acquiring profiles throughout the troposphere up to the lower stratosphere with a height resolution equal to or lower than 15 m and a time resolution equal to or lower than 60 s.

The long-run sustainability of this activity within ITINERIS is directly associate not only with the acquisition of innovative state-of-the-art instruments and their installation, but also with their continuous maintenance and calibration by qualified and experienced personnel. The long-term growth of the technical research infrastructure (RI) can be achieved through the synergy between instrumental upgrade and human capital harmonization at the ISMAR facility in Rome. Thus, a lot of effort has been dedicated to the process of identifying and selecting qualified and motivated personnel to support the sustainability of an innovative harmonized RI with the aim of a permanent position of such personnel. These objectives are directly interconnected with the RI development.

4. RMR LIDAR SYSTEM UPGRADE

With the objective of implementing new lidar acquisition channels at the Rome ACTRIS and enabling the improvement of the observation capacity and potential in the analysis and processing of data from the RMR lidar system, the purchase of carefully selected equipment and devices was required. Specifically:

1. analysis and detection equipment to be installed within a modular structure based on an opto-mechanical standard that is already widespread in industry and commercially available so that new system configurations can be implemented with additional components, accessories, adapters and compatibility with the optical elements of the RMR lidar system where it will be integrated. The system is composed by:
    a. 3 transient recorders for the measurement and counting of photoelectric pulses to reconstruct the vertical profile of the atmospheric signal in certain vertical intervals;
    b. a spectrometer (focal length of 750 mm, f/9.7) with the possibility of installing up to 3 diffraction gratings along with a specific mechanical coupling system for the acquisition system;
    c. a single-photon counting system with 32-channel multi-anode PMT that allows counting of the signal from the spectrometer via a fibre-optic assembly compatible with the optical elements of the RMR lidar system;
2. No. 4 optical units for spectral selection of lidar signal. These units shall guarantee the reception of the lidar signals backscattered by the atmosphere through elastic scattering at 355 and 532 nm respectively, with the information on the polarization state of the signal at 532 nm, and through Raman scattering at 387, 407 and 607 nm respectively. This system is compatible with the optical elements of the RMR lidar system where it will be integrated;
3. No. 10 photomultipliers (PMT) for the detection of lidar signal radiation with their maximum responsivity at the wavelength of interest and with low dark count, which is specific for photon counting measurement. This system shall be compatible for the integration with the optical elements of the RMR lidar system;
4. No. 1 multi-axis electronic control system consisting of at least 3 control units (board) to control 3 or more axes for system automation.

An overview of the new configuration for the 150 and 300 mm telescopes and for one 500 mm telescope with the resulting upgrade in the number of acquisition channels is given in Table 1.

Table 1:Specifications for the upgraded acquisition channels at the Rome ACTRIS NF.

Current CH#	New CH#	Tele ⌀ (mm)	λ (nm)	Type
N/A	1	1 x 150	354,7	Elastic transmitted
N/A	2		354,7	Elastic reflected
N/A	3		386,7	N_2 Raman
N/A	4		407,5	H_20 Raman
1	5		532,1	Elastic

N/A	6		607,6	N_2 Raman
8	7	1 x 300	354,7	Elastic transmitted
N/A	8		354,7	Elastic reflected
4	9		386,7	N_2 Raman
5	10		407,5	H_20 Raman
2	11		532,1	Elastic
N/A	12		607,6	N_2 Raman
3	13	8 x 500	354,7	Elastic
6	14		386,7	N_2 Raman
7	15		407,5	H_20 Raman
N/A	16 - 47	1 x 500	350 – 650	Aerosol fluorescence

A detailed list of technical requirements for the hereby referred instrument is included in the ANNEX 1 of this document.

5. PROCEDURES FOR THE PERSONNEL

One position for personnel with the profile of Technologist (III level) has been published in the Italian "Gazzetta Ufficiale" and ad hoc CNR website on January 17th, 2023. Following the selective procedure and interview following the CNR rules, the winner of the selection started on July 17th, 2023. The Technologist has been working in strict collaboration with the 2 researchers (III level) and 1 PhD student.

6. EQUIPMENT PROCEDURES

The Operative Unit of Roma organized the purchase procedures at ISMAR level. The following Table 2 reports the organization into the four tender procedures which have been classified by their timing details. The procedures started according to the timeline foreseen in ITINERIS.

Table 2: Procedures for acquisition of equipment. The start and end dates are given in terms of bimesters starting from the beginning of the project.

Instrument description	**ISMAR unit**	**Procedure**	**Activity**	**Start of procedure**	**End of procedure**
Analysis and detection equipment	ROMA	Direct purchase	4.6	B4	To be defined
No. 4 optical units for spectral selection of lidar signal	ROMA	Direct purchase	4.6	B4	B5
No. 10 photomultipliers (PMT) for the detection of lidar signal	ROMA	Direct purchase	4.6	B4	B6
No. 1 multi-axis electronic control system	ROMA	Direct purchase	4.6	B4	To be defined

7. CONCLUSIONS

Thanks to the upgrade and enhancement of the system's instrumentation by adding new remote-sensing channels at different wavelengths of interest in the field of atmospheric lidar, multiple research and scientific applications are possible. For example: aerosol characterization through fluorescence measurements; the study of the impact of aerosol fluorescence in the troposphere and in the upper troposphere and lower stratosphere (UTLS) on the measurement of water vapor; estimation of the aerosol particles' shape; identification of the particle type with the polarization-lidar technique such as discrimination between ice crystals and cloud droplets and between dust and marine aerosols. Furthermore, the instruments will be employed in satellite Cal/Val activities for upcoming lidar satellite missions (e.g. EarthCARE, Earth Cloud, Aerosol and Radiation Explorer). Finally, in the future, the CNR-ISMAR-RM Rayleigh-Mie-Raman for its innovative instrumental configuration, unique in the international scene, could potentially be a reference system for the observation of the atmosphere using the lidar technique.

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Freudenthaler, V., Linné, H., Chaikovski, A., Rabus, D., and Groß, S.: EARLINET lidar quality assurance tools, Atmos. Meas. Tech. Discuss. [preprint], in review, 2018, https://doi.org/10.5194/amt-2017-395.

Guidelines and recommendations for the candidate ACTRIS Aerosol Remote Sensing Observational Platforms, available at https://www.actris.eu/topical-centre/cars/announcements-resources/documents.

ANNEX 1 – CNR-ISMAR-RM EQUIPMENT AND DEVICES REQUIREMENTS

The equipment and devices presented in Section 4 for CNR-ISMAR-RM must have the following characteristics.

Analysis and detection equipment

a) No. 3 transient recorders with 16-bit analogue/digital converter at 40 MHz, supporting simultaneous acquisition in photocount (greater than 300 MHz) and 16-bit analogue with high time response (up to the single laser pulse).
b) No. 1 spectrometer with a focal length of 750mm, focal aperture of f/9.7, No. 3 diffraction gratings, corresponding mechanical coupling system for the PMT and software for grating adjustment.
c) No. 1 single-photon counting system with 32-channel multi-anode PMT photomultiplier, fibre-optic bundle, high-voltage power supply, Ethernet interface, maximum counting frequency 1.6 GHz, capable of supporting simultaneous photocounting up to 240 MHz, 625 ps resolution Photocathode in 'multi-alkali' material with responsivity ranging from 300 nm to 650 nm.

No. 4 optical units for spectral selection of lidar signal

a) No. 2 wavelength separation units, one for a f/3 telescope with 150 mm diameter and one for a f/3 telescope with 300 mm diameter.
b) No. 1 wavelength separation unit for a f/3 telescope with 500 mm diameter.
c) No. 1 wavelength separation unit for fibre optics signal from a f/3 telescope with 150 mm diameter.
d) Accessories (spanner, retaining rings, adhesive for optical systems and digital depth gauge) for mounting and installing the optical units.

No. 10 radiation detection systems (photomultiplier tubes)

a) No. 2 PMT module optimized for photocounting with cable connection, active photocathode area made of 'super bialkali' material and protective borosilicate glass window.
b) No. 8 PMT module optimized for photocounting with cable connection, active photocathode area made of 'ultra-bialkali' material and protective borosilicate glass window.
c) No. 12 Mechanical adapter with C-mount thread connection.

General characteristics of PMTs

a) Cathode responsivity at wavelengths 355 nm and 532 nm (mA/W): equal to or greater than 50.
b) Cathode responsivity at wavelengths 387 nm and 407 nm (mA/W): equal to or greater than 100.
c) Cathode responsivity at 607 nm wavelength (mA/W): equal to or greater than 20.
d) Maximum dark current (nA): 10 or less.
e) Input voltage (V): equal to or less than 12.
f) Bandwidth -3 dB (MHz): equal to or better than 80 MHz.
g) BNC connector installed on output signal cable.
h) Arrangement of holes for integration with opto-mechanical systems by C-mount thread adapters.

No. 1 multi-axis electronic control system consisting of at least 3 control units (board) to control 3 or more axes

The 3 system's control units must be able to manage a servo motor with the following characteristics:

- Incremental microencoder.
- Speed equal to or greater than 0.1 mm/s.
- Acceleration equal to or greater than 0.1 mm/s^2.
- Resolution equal to or less than 2 µm
- Accuracy of ±4 µm or less.
- Working stroke of 15 mm or more on X and Y axes.
- Working stroke of 24 mm or more on Z axis.

General characteristics of each control unit:

- Ability to control 3 or more servo motors.
- USB and/or Ethernet ports for remote management via PC.
- Windows-based management software and/or LabVIEW drivers.
- Power supply included.