ACTRiS
Centre for Aerosol Remote Sensing

High Power Lidar: Standard Operation Procedures for NF operation

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Table of Contents

1. Applicability of the document 3
2. Acronyms 3
3. Reference documents 3
4. Introduction 3
5. Installation 4
   5.1. Preparation of the AHL environment 4
      Instrument location 4
      Environmental temperature and humidity considerations 4
      Outgoing window 5
      Connection with a power supply 5
      Diffuse reflections 5
      Interference with and from nearby instruments 5
   5.2. Preliminary set up of the instrument 5
   5.3. On-site installation tests 6
   5.4. Preparation of the operation and maintenance logbook 6
6. Operation 7
   6.1. Check up of the AHL environment 7
   6.2. Check up of the lidar 7
      Laser 7
   6.3. Switching on the lidar 7
      Laser 8
      Polarization calibrator 8
      Electronics 8
      Checking the alignment 8
   6.4. Performing the measurements 9
      Dark measurement 9
      Normal measurement 9
      Polarization measurement 9
   6.5. Finalizing the measurements 9
      Submission of the raw data 9
      Filling the operation logbook 9
7. Maintenance 10
   7.1. Laser 10
   7.2. Emission optics 10
   7.3. Receiving optics 10
   7.4. Filling the maintenance logbook 10
8. References 11

1. APPLICABILITY OF THE DOCUMENT

These guidelines apply to the National Facilities within ACTRIS operating High Power Lidar instruments.

2. ACRONYMS

ACTRIS - Aerosol, Clouds and Trace gases Research InfraStructure

NF - National Facility

CARS - Centre for Aerosol Remote Sensing

AHL – Aerosol High Power Lidars

PMT – Photo Multiplyer

APD – Avalanche Photo Doide

SCC – Single Calculus Chain

ND – Neutral Density

EM – Electro Magnetic

3. REFERENCE DOCUMENTS

High Power Lidar: QA operation procedures

4. INTRODUCTION

The current document will act as a guideline and does not replace the user manuals and the operator's personal experience. In case any information does not apply to your lidar instrument, please contact the appropriate representative within CARS for further support:

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All safety procedures that apply within your research institution must be applied and should not be in contradiction with the guidelines found in this document.

Before using this document, please read carefully all user manuals from all components and modules that are part or are connected to each lidar instrument.

5. INSTALLATION

5.1. Preparation of the AHL environment

Instrument location

- The AHL instruments are designed for indoor or outdoor use. Based on the technical specifications of each instrument, the operation could be performed in outdoor or indoor conditions.
    - **For outdoor** AHL instruments, the installation could be made either outdoor or indoor;
    - **For indoor** instruments, the installation should be made in a controlled environment, safe of outdoor environmental factors;
- The ALH should be installed in a **secured location** with limited access for unauthorized persons.
- The ALH should be operated only by **trained operators.**
- The installation site should be equipped with a **sufficiently large hatch** or window for accessing the atmosphere.
    - the layout of the ALH could be setup for **vertical measurements** (5° zenith measurements are indicated to avoid specular reflections from cirrus clouds) or could measure **under higher zenith angles** taking into consideration all eye safety measures that apply for the specific site and location;
- The ALH should be installed in a **clean environment**, safe from dust or other sources of contamination (like reactive gases).
- Direct **sunlight illumination** of the AHL should be **avoided**.
    - direct sunlight must never be focused by the telescope, even partially, because this can easily destroy parts of the telescope, the detection box, and the receivers;
    - direct sun exposure on the telescope tube and surfaces above the telescope (e.g. windows and chimneys) can also be detrimental for the measurements because it can increase the collected solar background;
    - direct sun exposure applied on parts of the instrument could cause temperature gradients which can affect the alignment;
- To reduce the risk of rain contamination during operation, an **exterior rain sensor** should be installed to monitor the presence of rain drops and humidity. Automatic safety measures are suggested (proximity detectors, laser shutdown during rain episodes, hatch close during rain).

Environmental temperature and humidity considerations

- The **operating temperature** should be kept stable (±2-3°C) to reduce the effects of thermal effects on the frame and opto-mechanics.
- The storage and operating relative humidity (**RH)** should be kept in the range of 30-50% if not otherwise mentioned by the manufacturer of the instrument.

https://www.researchgate.net/publication/266475572_The_effect_of_moisture_and_temperature_on_optical_coatings_used_in_eye-safer_lasers#fullTextFileContent

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3864060/#:~:text=Keep%20optical%20components%20in%20a,with%20plenty%20of%20air%20circulation.

https://www.laboratory-supply.net/blog/humidity-control-necessity/

Outgoing window

- The **outgoing window** should be wide enough to accommodate both the telescope dimensions and the outgoing beam.
- The walls of the location should be **painted black** to reduce the diffuse reflection effects (or at least the walls next to the outgoing window).

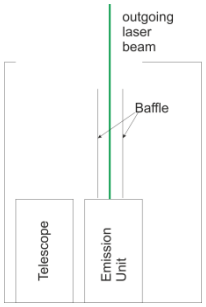
Connection with a power supply

- The laser power supply should be connected to a **different power source** from the detection power supply.
    - for three phase power supply, we recommend using each phase for
        - laser power
        - detection
        - AC unit
    - it is advised to move the laser power supply as far as possible from the detection unit;
- **Ground loops** could affect the signal quality and should be avoided. Authorized personnel should check the electrical setup of the site.

  https://www.bapihvac.com/application_note/understanding-ground-loops-application-note/#:~:text=What%20is%20a%20Ground%20Loop,picks%20up%20interference%20currents%20easily.

Diffuse reflections

- For indoor AHL, the outgoing lidar beam should be **enclosed** to reduce the diffuse reflection effects in the vicinity of the ALH unit.
    - a laser baffle could be installed to reduce the diffuse reflections inside the lidar location;



Interference with and from nearby instruments

- Additional instrument that are installed close to the AHL could be a source of EM-interference. We recommend **reducing** the number of **high power instruments** installed in the vicinity of the AHL unit.

5.2. Preliminary set up of the instrument

- The initial installation of the AHL instrument should be performed with **authorized personnel** only.
- If the AHL instrument is a commercial version, the supplier of the instrument should include a **full training course** (on site or at the supplier's location) before the final delivery.

- The supplier of the instrument should provide a **full set of manuals** that includes all the aspects and units of the AHL. The operator should study all documentation before operating the AHL.
- Once the instrument is installed, several aspects related to the **layout** of the instrument should be considered .
    - all signal cables should be isolated from all power cables (the signal cables should not touch any other cable to reduce the risk of interference);
    - in case of Licel detection (many lidar units are equipped with Licel detection modules) the signal detection range should be set to 0-100 mV;
        - The maximum signal level (near range peak) of the analogue channels should be adjusted by means of neutral density filters to about 50 mV in order to avoid excessive signal induced distortions.
        - The signal intensity should be set to the desired levels by using ND filters (not the high voltage of the detection).

5.3. On-site installation tests

- Once the AHL is set-up, a **full set of QA** tests should be performed.
- The QA tests should **include**:
    - Telecover
    - Rayleigh Fit
    - Polarization calibration
    - Zero Bin
    - Dark signal measurement

*note: The **procedure** on how to perform the QA measurements can be found in the "High Power Lidar: QA operation procedures" document.*

5.4. Preparation of the operation and maintenance logbook

- All lidar related activities should be **logged** in a centralized logbook.
- The logbook should include: **maintenance work, lidar upgrades, measurement log** (including calibration logs), **ND filter** replacement, etc.
- A logbook **template** can be found by using the following link.

6. OPERATION

6.1. Check up of the AHL environment

- Before switching on the AHL instrument, it is important to check the **integrity of the exit windows** (if any).
- Check the **integrity of all the emission optics** that are exposed to dust, humidity or other external factors.
- Check all environmental parameters like **temperature and humidity** (around the AHL premises) to be in the predefined parameters.
- Check the atmospheric conditions for **low clouds (below 5 km) and rain/snow/fog**
- Check the **weather forecast** for the duration of the measurement set (in case of scheduled measurements).
    - for **unattended continuous measurements**, the AHL instrument should be equipped with failsafe systems able to properly react to external factors:
        - switch off the AHL in case of **fog**
        - switch off the AHL and close any protective windows in case of **rain/snow**
        - switch off the AHL in case of **unauthorized movement** close to the laser emission
        - switch off the instrument during the presence of **aerial vehicles**
        - **automatically switch on** the instrument after the factors described above are no longer present
        - switch off the instrument in case of **technical failure** (malfunction of the AHL or supporting equipment like heating or cooling)
        - switch off the instrument in case of **smoke**
        - **safely switch off** the instrument and close the protective windows during **power failures**
        - remotely **monitor** the status of operation for the AHL

6.2. Check up of the lidar

Prior to powering on the AHL instrument, it is essential for the operator to conduct a thorough assessment of each individual module. This includes checking the status of the laser, ensuring proper functioning of the detection system, verifying the integrity of the optics, and evaluating the instrument's resilience against potential power failures.

Laser

- Check the replacement interval for the laser lamps, filters, water replacement (based on the information provided by the laser manufacturer).
- Check the water level and the temperature values of the laser (e.g. harmonic generators, cooling unit) and any other parameters provided by each laser unit (e.g. laser power, humidity inside the laser cavity, coolant flow) and any other parameter indicated by the laser manufacturer in the user manual.

6.3. Switching on the lidar

- **Remove any covers** or shutters from the Emission/Reception unit.

- Make sure the laser radiation is **not obstructed**.
- **Power on all modules** that are used for the measurement (Laser, electronics, detectors, other controllers) according to the specific procedure used for each module.

Laser

- Turn on the **flashlamp** of the laser.
- Wait until the **cooling agent temperature** is stabilised (if not otherwise specified by the manufacturer).
- Turn on the **Q-switch** of the laser.
- For some laser models, the harmonic generators must be adjusted or checked before each measurement.

note: This is a general procedure of turning on a laser unit. Please check the user manual to make sure the procedure applies to your specified laser model.

Polarization calibrator

- Make sure the polarization calibrator is set to the zero position (normal measurement) for each polarization channel.

Electronics

For Licel based detection modules:

- Set the detector **HV levels** according to the values provided in the user manual or by the instrument supplier.
- Check that the maximum **analogue signal level** is less than half of the detection range and not less than 10% of the detection range (for all channels used during the measurement).
    - In case the signal is out of the suggested range, use ND filters to adjust the signal levels (remove or add according to each case);
    - Do not change the laser power (since the divergence of the laser could be affected);
    - Do not change the detector HV to adjust the signal levels (since the operation of each detector could be affected: quantum efficiency, discriminator level, dead time);

For Polly-XT based detection modules:

- Check the saturation level of the signal.

Checking the alignment

- Turn on the CCD camera and check the alignment of the laser beam relative to the receiving unit (please see the “High Power Lidar: QA operation procedures” document for more information).

note: After each alignment, please check the signal levels and adjust using ND filters.

- In case of additional shutters installed in the receiving unit (Raman channel shutters):
    - For daytime measurements: make sure the Raman channels shutters are closed;
    - For nighttime measurements: make sure that the Raman channels shutters are opened;

6.4. Performing the measurements

Dark measurement

The Dark measurement should be performed for all analogue channels of the lidar instrument.

- Close the main telescope shutter (in case the instrument has multiple telescopes close all telescope shutters).
- Perform a Dark measurement.
    - Same setup as the normal measurement;
    - Average over an increased time period (e.g. 10 minutes or more);
    - Record the profiles;
- Open the main telescope shutter (in case the instrument has multiple telescopes open all telescope shutters).

Normal measurement

note: Keep the same setup as used for the Dark measurement.

- Set the acquisition software to store the averaged profiles between 10-60 s. (it is suggested to use a shorter time interval to reduce the risk of cloud contamination: e.g. 10 s).

Polarization measurement

- Perform an interleaved Δ90° polarization calibration measurement according to the "High Power Lidar: QA operation procedures" document.

6.5. Finalizing the measurements

Once all measurements are completed:

- Turn off the laser emission (according to the user manual);
- Turn off the detectors HV;
- Close the shutters (or cover the telescope);
- Close any protective window used during the measurements;

Submission of the raw data

- Check the measurement and polarization calibration data using the ATLAS software;
- Convert the measurement and polarization calibration data into the SCC format;
- Send the data to the SCC;
- Check the lidar products returned by the SCC;
- For the selected products, submit the corresponding *.nc files to the SCC;

Filling the operation logbook

- Fill in the measurement information in the operation logbook;
- Fill in the polarization calibration information in the operation logbook;
- Fill in any information on the hardware updates (e.g. updating the ND filters for some channels) in the operation logbook;

7. MAINTENANCE

7.1. Laser

- The operator should check the replacement interval for the laser lamps, filters, water replacement (based on the information provided by the laser manufacturer).
- The operator should check the laser power at a predefined interval according to the user manual (e.g. 6 months) or every time the signal intensity indicates a signal decrease. If the signal intensity is decreased check the user manual or contact the laser supplier to find how to adjust the energy to the initial output power.
- The operator should check the laser output window for damage at a predefined interval (at least 6 months).
- The laser unit should be sent for maintenance according to the user manual

7.2. Emission optics

The emission optics is prone to damage due to dust or water droplets condensing on the coatings.

- The operator should check all emission optics (in contact with the high energy laser radiation) at a predefined interval (at least 3 months).
- The operator should remove dust with a low pressure air from all emission optics before turning on the laser (avoid sandblasting).

7.3. Receiving optics

- Clean the optics only if the signal is too attenuated. Use dedicated tools and trained personnel.
  https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=9025
  https://www.edmundoptics.com/knowledge-center/application-notes/optics/cleaning-optics/

7.4. Filling the maintenance logbook

- All maintenance activities performed on the AHL instrument should be recorded in a dedicated maintenance logbook

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