Measuring spectral reflectance and transmittance (350-2500 nm) of small and/or narrow leaves using the Spectra Vista Corporation (SVC) DC-R/T Integrating Sphere

Version 2

Etienne Laliberté,Raymond Soffer

Abstract

Here we describe the standardised protocol used by the Canadian Airborne Biodiversity Observatory (CABO) to measure leaf spectral reflectance and transmittance, using an integrating sphere fitted to a portable full-range field spectroradiometer, for the special case where an individual **leaf is too small and/or too narrow** to entirely cover the reflectance or transmission port of the integrating sphere. Briefly, three arrays of mature, healthy and sunlit leaves from a canopy plant are arranged on a custom sample mount, and are then used for measurements of adaxial reflectance and transmittance. Reflectance measurements are referenced to a calibrated Spectralon® disk and corrected for stray light. Our leaf spectroscopy protocol is an adaptation of that of Noda et al. (2013) to the SVC DC-R/T sphere, and also builds from protocols by the Carnegie Airborne Observatory and the SVC integrating sphere user manual.

Citation: Etienne Laliberté,Raymond Soffer Measuring spectral reflectance and transmittance (350-2500 nm) of small and/or narrow leaves using the Spectra Vista Corporation (SVC) DC-R/T Integrating Sphere. **protocols.io**
dx.doi.org/10.17504/protocols.io.qp7dvrn
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Guidelines

Handling Spectralon®

- **Do not touch Spectralon®** (e.g. sphere interior, reference disks, plugs) with your fingers.
- **Do not use canned air** to remove dust on the Spectralon® disk; canned air contains chemicals that can alter Spectralon®'s optical properties.
- **Do not attempt to clean Spectralon®** in the field, other than **blowing surface dust only on the Spectralon® reference disk or sphere plugs** using the Canless Air Duster System; cleaning Spectralon® requires a special procedure that should only done in the lab.

Equipment

- Spectra Vista Corporation HR-1024i full-range (350-2500 nm) field spectroradiometer
- Spectra Vista Corporation 3-inch Spectralon® DC-R/T Sphere
- Semi-rugged laptop or PDA running the SVC Scan software

- Canless Air Duster System O_2 Hurricane (**never use canned air**) to remove dust from the

surface of the Spectralon® reference disk

- Plastic containers with lids to temporarily store leaf arrays during measurements (optional)

Consumables

- Nitrile gloves for handling leaves
- Whatman No. 2 filter paper (110 mm diameter)
- Acetate sheets (to make thin plastic sample mounts)
- Manila file folders (to make thin cardbboard sample platforms)
- Scotch™ Magic Tape

Before start

1. Consult the user manual of the spectroradiometer and the integrating sphere to set up the instrument.
2. The instrument should be set up in the shade, sheltered as much as possible from the elements.
3. All canopy plants selected for measurements should have already been tagged, identified, and georeferenced before spectroscopy measurements start.
4. The spectroscopist should be positionned as close as possible to the sampled plants to minimise time from collection to measurement.
5. The spectroscopist should be in a confortable position and have enough room around the instrument to spread leaf samples around without the risk of mixing up individual leaves during handling.
6. **Mature, fully-developped, healthy-looking leaves from the sunlit (>3 h per day of direct sunlight) portion of the canopy are selected** for spectral measurements from the bulk leaf sample (often one of a few branches). Leaves should be collected from the uppermost surface of the branch (i.e. receiving the most direct sunlight).

Materials

Manila File Folders 116723 by Staples

Write-On Transparency Film 954144 by Staples

Whatman™ Qualitative Filter Paper: Grade 2 Circles (110 mm diameter) 09-810E by Fisher Scientific

Scotch™ Magic Tape 14172 by Staples

Protocol

Instrument Set-Up

Step 1.

Install the integrating sphere onto the spectroradiometer.

NOTES

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Follow the SVC integrating sphere manual p. 6-16.

Instrument Set-Up

Step 2.

Position the lamp over the sphere **primary light entrance port**.

SAFETY INFORMATION

The lamp can get very hot. Grab it by the slotted heat shield.

NOTES

Etienne Laliberté 24 Apr 2018

Make sure lamp is secured in locked position.

Instrument Set-Up

Step 3.

Power the spectroradiometer on and **warm up for >15 min**.

Instrument Set-Up

Step 4.

Power the integrating sphere lamp and **warm up for >5 min**.

Instrument Set-Up

Step 5.

Screw the tethered light trap on the **transmission port** sample holder.

NOTES

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The light trap can stay on the sample holder for the entire measurement session.

Instrument Set-Up

Step 6.

Check lamp alignment.

NOTES

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Use a thin piece of paper at the exit of the reflectance sample port (empty port) the to ensure the light beam under-fills and is centered in the reflectance port. **If it is not, then proceed to lamp**

alignment as described in the SVC integrating sphere user manual, p. 29-32.

Software Set-Up

Step 7.

Ensure that the spectroradiometer is connected to the computer via Bluetooth.

NOTES

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The default Bluetooth password for SVC HR-1024i spectroradiometers is **hr1024i**.

Software Set-Up

Step 8.

Launch SVC Scan.

Software Set-Up

Step 9.

Select **auto-save mode** using *File > Data Options > Auto Save.*

Software Set-Up

Step 10.

Select *File > New* to create a new working folder in your shared '**spectra**' Google Drive CABO folder.

NOTES

Etienne Laliberté 04 Jun 2018

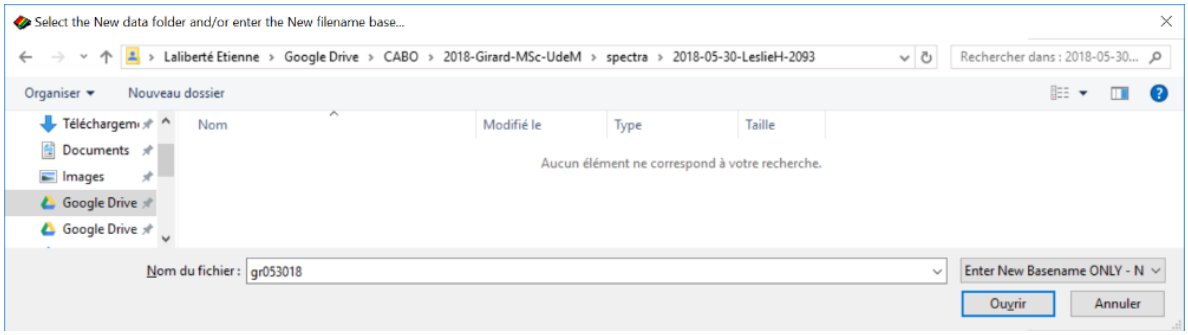
If you do not yet have a shared Google Drive folder for your project, contact the CABO data manager to create one (etienne.laliberte@umontreal.ca or jeremy.goimard@umontreal.ca).

Your shared CABO Google Drive folder should be named *YYYYstarted-YourLastName-Degree-University*, e.g. 2018-Girard-MSc-UdeM.

Software Set-Up

Step 11.

Create a new folder named *YYYY-MM-DD-SiteID-SpectroradiometerSerialNumber* (without spaces) within that '**spectra**' folder, and keep the default file base name (= *grMMDDYY*).



NOTES

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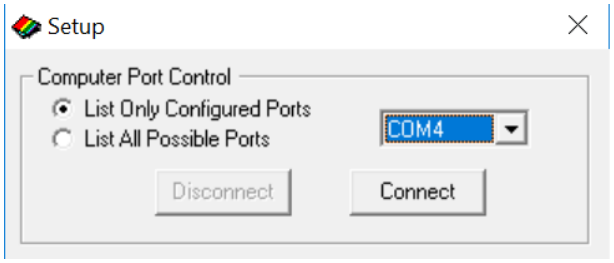
The base file name is the prefix for all files that will be saved within that folder. In auto-save mode, each file will be added an incremental step, e.g., *gr053018_0000.sig*, *gr053018_0001.sig*, etc.

Software Set-Up

Step 12.

Go to *Control* > *Setup Instrument...* to connect the spectroradiometer.



NOTES

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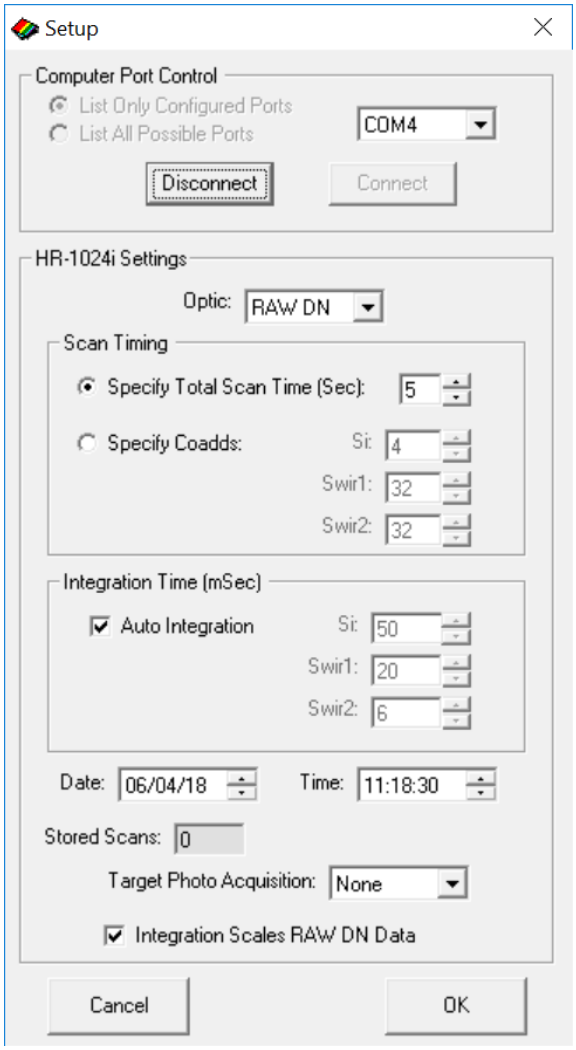
Different instruments may be configured under different virtual COM ports.

Software Set-Up

Step 13.

1. Choose the *RAW DN* optic
2. Select 5 sec scan time
3. Select *Auto Integration*
4. Ensure the date and time are correct

5. Check *Integration Scales Raw DN Data*

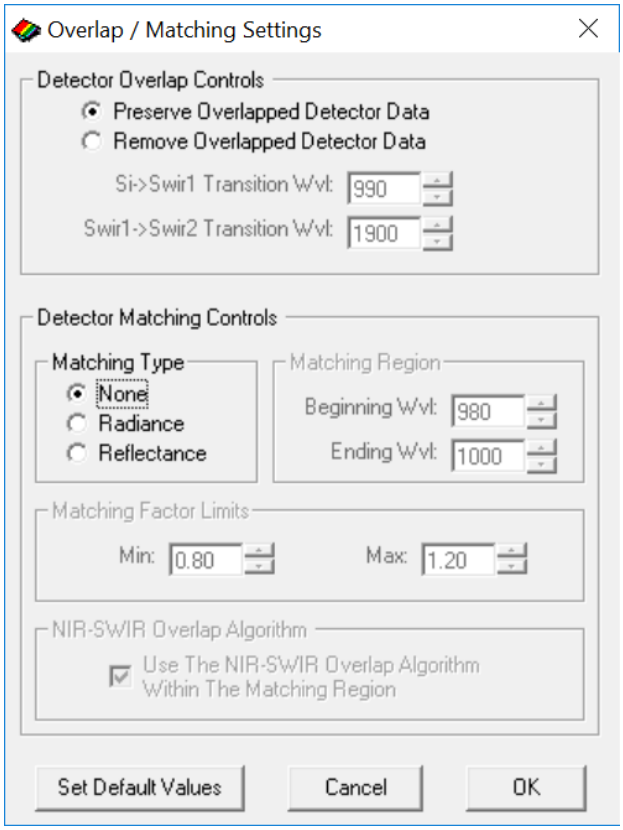


Software Set-Up

Step 14.

In *Control* > Overlap / *Matching Settings:*

1. Select *Preserve Overlapped Detector Data*
2. Select *Matching Type > None*



Review Protocol Summary Diagram

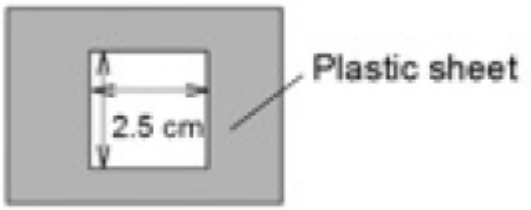
Step 15.

Review the document summarising the different sphere configurations (A–I), and the scans that need to be recorded in each configuration.

Prepare Sample Mounts and Holders

Step 16.

Build a few sample mounts from thin plastic (e.g. acetate sheets).



NOTES

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The sample mount is made of a thin plastic sheet with a square window that is larger than the edge of the sample port lip (e.g. 2.5 cm × 2.5 cm).

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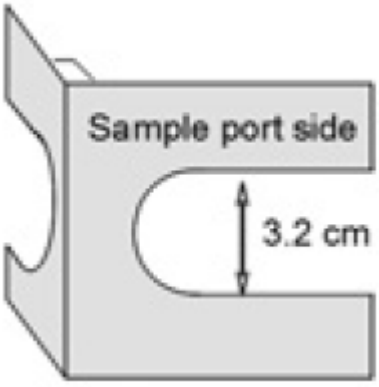
Fig. 3a from Noda et al. (2013). https://doi.org/10.1111/pce.12100

Prepare Sample Mounts and Holders

Step 17.

Build a few sample platforms from thin cardboard (e.g. file folders).



NOTES

Etienne Laliberté 25 Apr 2018

The sample platform is made of cardboard and will eventually attach to the integrating sphere to create a flat surface.

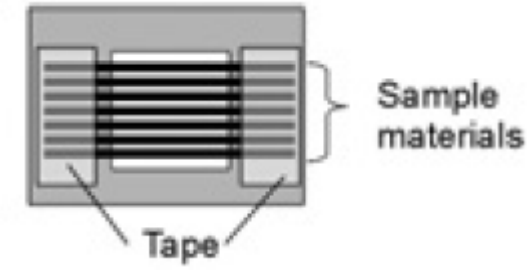
Etienne Laliberté 25 Apr 2018

Fig. 3c from Noda et al. (2013). https://doi.org/10.1111/pce.12100

Prepare Leaf Arrays

Step 18.

Fix leaves onto the sample mount with tape to make leaf array #1.



NOTES

Etienne Laliberté 25 Apr 2018

Fig. 3b from Noda et al. (2013). https://doi.org/10.1111/pce.12100

Etienne Laliberté 04 Jun 2018

Try to position as much leaf material as possible in the center of the port where the intensity of the light beam will be highest.

Leaves should be separated by about 1 mm to avoid multiple scattering among them.

If leaves are shorter than the sample mount hole (i.e. <2.5 cm long), fix leaves by their petiole with tape in one (or two) rows.

Prepare Leaf Arrays

Step 19.

Fix leaves onto the sample mount with tape to make leaf array #2.

NOTES

Etienne Laliberté 04 Jun 2018

Try to position as much leaf material as possible in the center of the port where the intensity of the light beam will be highest.

Leaves should be separated by about 1 mm to avoid multiple scattering among them.

If leaves are shorter than the sample mount hole (i.e. <2.5 cm long), fix leaves by their petiole with tape in one (or two) rows.

Prepare Leaf Arrays

Step 20.

Fix leaves onto the sample mount with tape to make leaf array #3.

NOTES

Etienne Laliberté 04 Jun 2018

Try to position as much leaf material as possible in the center of the port where the intensity of the light beam will be highest.

Leaves should be separated by about 1 mm to avoid multiple scattering among them.

If leaves are shorter than the sample mount hole (i.e. <2.5 cm long), fix leaves by their petiole

with tape in one (or two) rows.

Prepare Leaf Arrays

Step 21.

Fix sample mount holding leaf array #1 onto the sample platform with tape.

NOTES

Etienne Laliberté 25 Apr 2018

The sample mount holding the leaf array should be sandwiched between the two sides of the cardboard sample platform.

Prepare Leaf Arrays

Step 22.

Fix sample mount holding leaf array #2 onto the sample platform with tape.

NOTES

Etienne Laliberté 25 Apr 2018

The sample mount holding the leaf array should be sandwiched between the two sides of the cardboard sample platform.

Prepare Leaf Arrays

Step 23.

Fix sample mount holding leaf array #3 onto the sample platform with tape.

NOTES

Etienne Laliberté 25 Apr 2018

The sample mount holding the leaf array should be sandwiched between the two sides of the cardboard sample platform.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 24.

Screw the tethered light trap on the **reflectance port** sample holder.

NOTES

Etienne Laliberté 24 Apr 2018

The light trap can stay on the sample holder for the entire measurement session.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 25.

Place the tethered calibrated Spectralon® reflectance standard over the **reflectance port**.

NOTES

Etienne Laliberté 24 Apr 2018

Place the standard over the reflectance port so that the light beam shines directly on its reflective surface (= facing inside of the sphere).

Configuration A: Reflectance Mode, Leaf Array, Reference

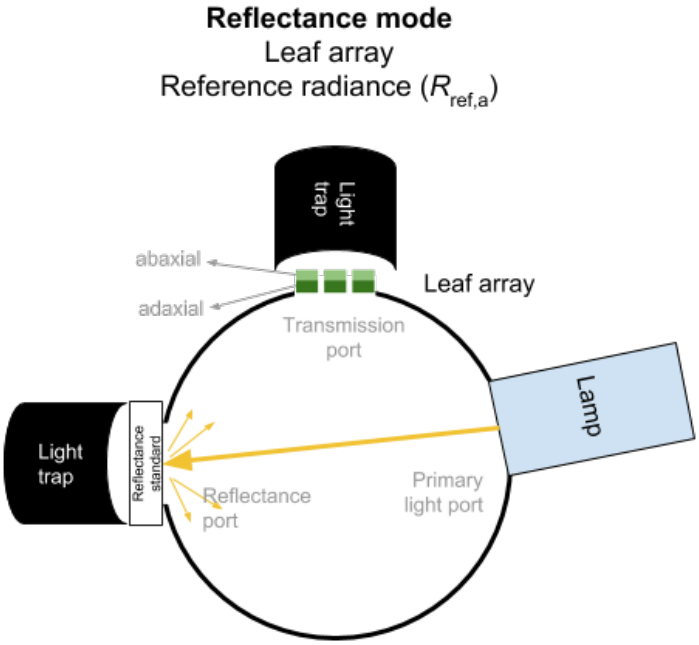
Step 26.

Position leaf array #1 over the **transmission port** so that the **adaxial** (upper) surfaces of the leaves face into the sphere.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 27.

Collect a '**Reference Scan**' in this configuration.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **reference radiance** in reflectance mode for the **leaf array** ($R_{ref,a}$). The reference data will be automatically saved in all successive target scan files until a new 'Reference Scan' is made.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 28.

Collect a '**Target Scan**' in the same configuration and **save the file**.

Configuration B: Reflectance Mode, Leaf Array + Paper, Reference

Step 29.

Place a filter paper directly behind the sample platform holding leaf array #1.

NOTES

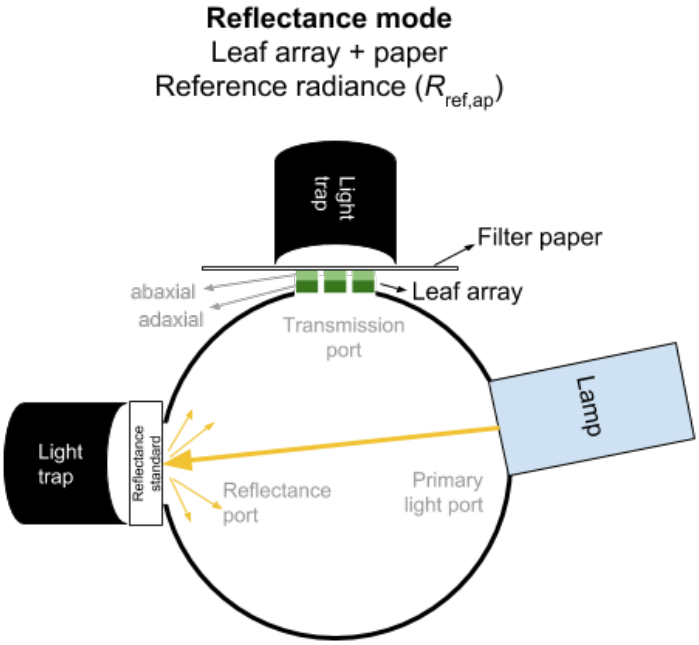
Etienne Laliberté 25 Apr 2018

The leaf array #1 should remain in the same position.

Configuration B: Reflectance Mode, Leaf Array + Paper, Reference

Step 30.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **reference radiance** for the **leaf array + paper** in reflectance mode ($R_{ref,ap}$).

Configuration C: Reflectance Mode, Paper, Reference

Step 31.

Carefully remove the sample platform holding leaf array #1 from the transmission port.

NOTES

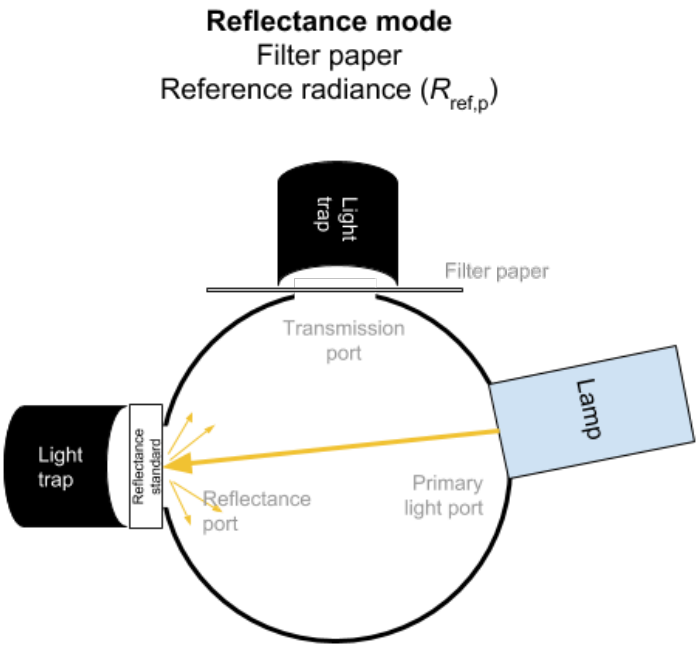
Etienne Laliberté 25 Apr 2018

The filter paper should remain in the same position.

Configuration C: Reflectance Mode, Paper, Reference

Step 32.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 25 Apr 2018

This corresponds to the **reference radiance** for the **filter paper** in reflectance mode ($R_{ref,p}$).

Configuration D: Reflectance Mode, Stray light

Step 33.

Remove the filter paper from the transmission port sample holder.

Configuration D: Reflectance Mode, Stray light

Step 34.

Remove the tethered calibrated Spectralon® reflectance standard from the reflectance port.

Configuration D: Reflectance Mode, Stray light

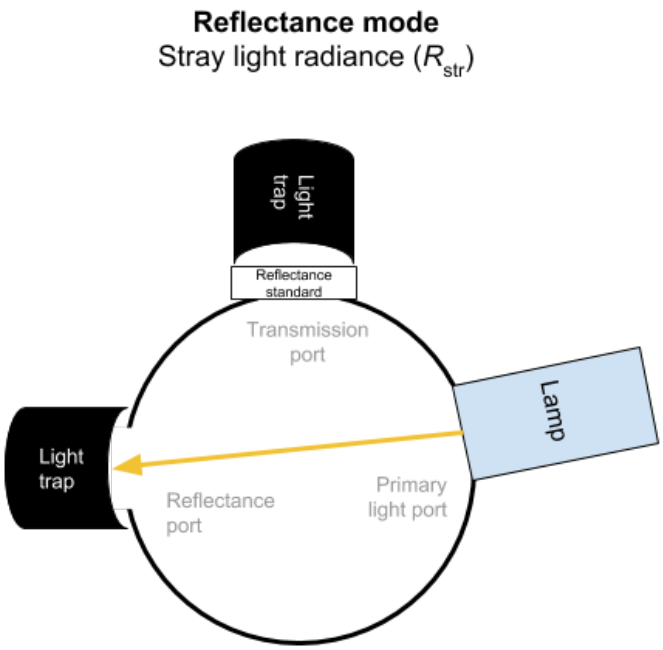
Step 35.

Place the tethered calibrated Spectralon® reflectance standard over the **transmission port**.

Configuration D: Reflectance Mode, Stray light

Step 36.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 25 Apr 2018

This corresponds to the **stray light radiance** in reflectance mode (R_{str}).

Configuration E: Reflectance Mode, Paper, Target

Step 37.

Place the filter paper over the **reflectance port**.

NOTES

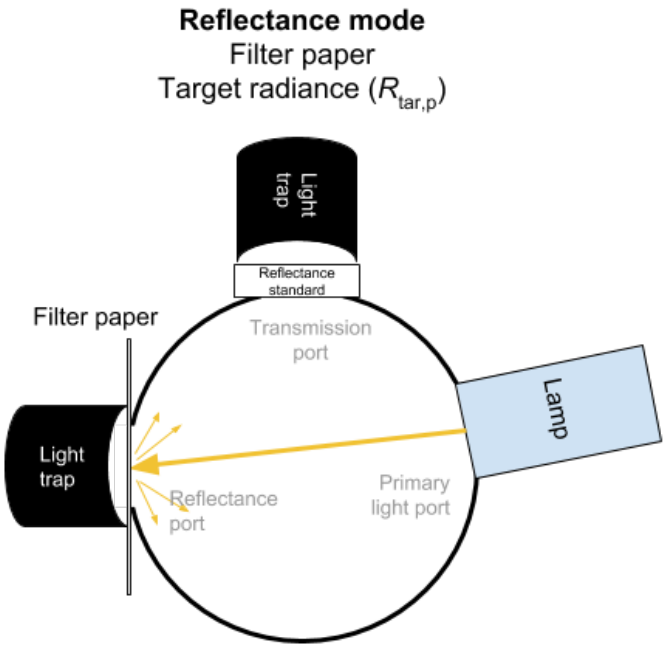
Etienne Laliberté 25 Apr 2018

Focus the measurements on the same area of the paper used in previous measurements.

Configuration E: Reflectance Mode, Paper, Target

Step 38.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of the **filter paper** in reflectance mode ($R_{tar,p}$).

Configuration F: Reflectance Mode, Leaf Array #1 + Paper, Target

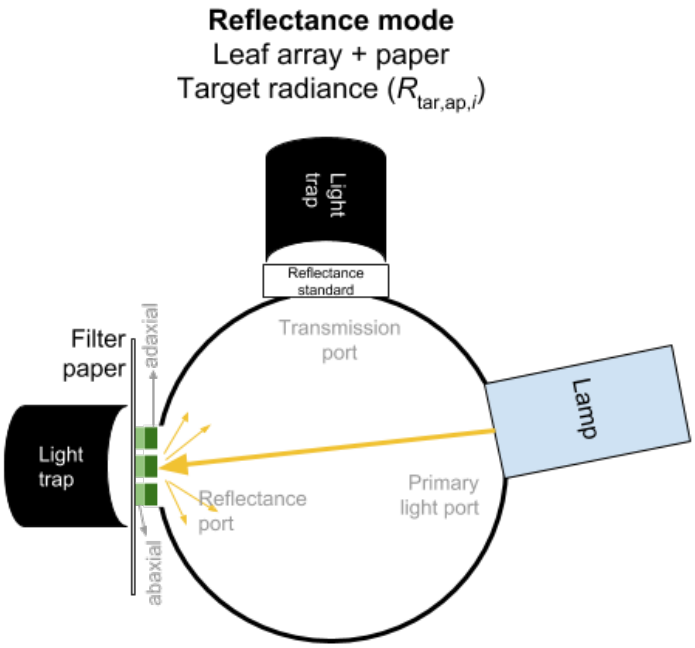
Step 39.

Position the sample platform containing leaf array #1 in front the filter paper over the **reflectance port** with the **adaxial** (upper) surfaces of the leaves face into the sphere.

Configuration F: Reflectance Mode, Leaf Array #1 + Paper, Target

Step 40.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #1 + paper** in reflectance mode ($R_{tar,ap,1}$).

Configuration G: Reflectance Mode, Leaf Array #1, Target

Step 41.

Remove the filter paper from the reflectance port.

NOTES

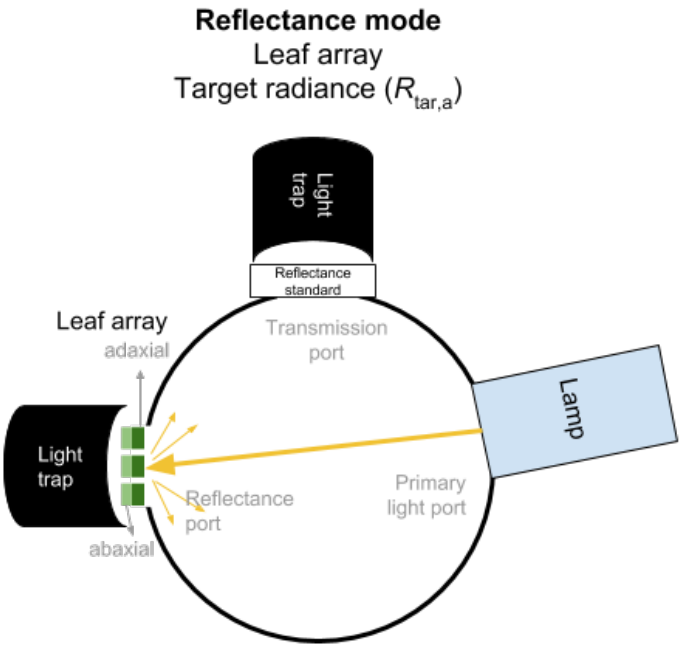
Etienne Laliberté 04 Jun 2018

The sample platform holding leaf array #1 should remain in the same position.

Configuration G: Reflectance Mode, Leaf Array #1, Target

Step 42.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #1** in reflectance mode ($R_{tar,a,1}$).

Configuration F: Reflectance Mode, Leaf Array #2 + Paper, Target

Step 43.

Carefully replace leaf array #1 by leaf array #2.

Configuration F: Reflectance Mode, Leaf Array #2 + Paper, Target

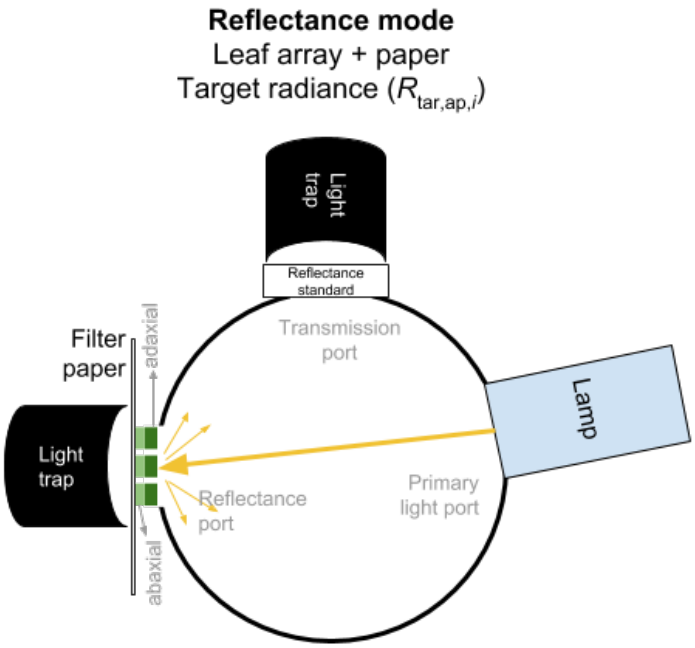
Step 44.

Place the filter paper directly behind leaf array #2 over the **reflectance port**.

Configuration F: Reflectance Mode, Leaf Array #2 + Paper, Target

Step 45.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #2 + paper** in reflectance mode ($R_{tar,ap,2}$).

Configuration G: Reflectance Mode, Leaf Array #2, Target

Step 46.

Remove the filter paper from the reflectance port.

NOTES

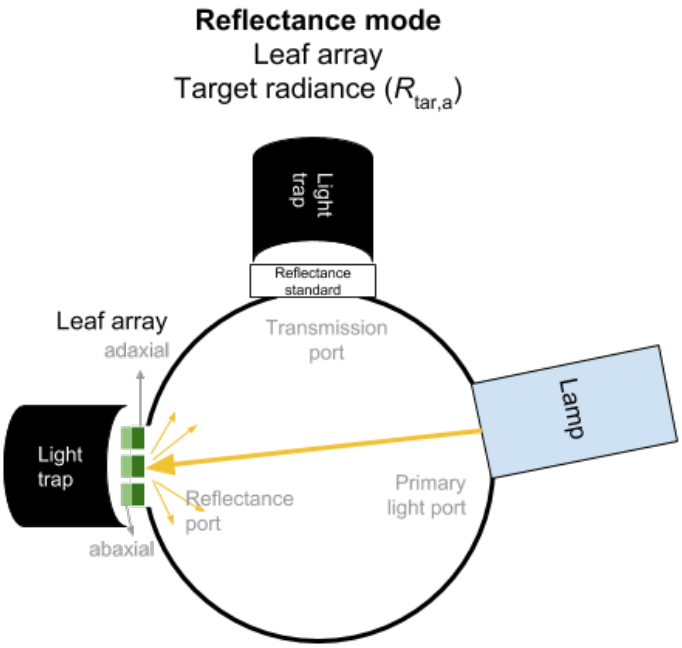
Etienne Laliberté 04 Jun 2018

The sample platform holding leaf array #2 should remain in the same position.

Configuration G: Reflectance Mode, Leaf Array #2, Target

Step 47.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #2** in reflectance mode ($R_{tar,a,2}$).

Configuration F: Reflectance Mode, Leaf Array #3 + Paper, Target

Step 48.

Carefully replace leaf array #2 by leaf array #3.

Configuration F: Reflectance Mode, Leaf Array #3 + Paper, Target

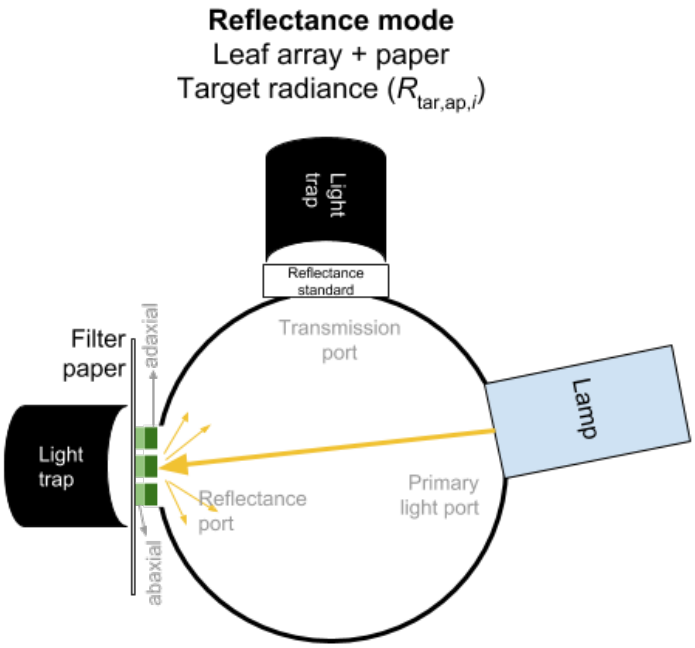
Step 49.

Place the filter paper directly behind leaf array #3 over the **reflectance port**.

Configuration F: Reflectance Mode, Leaf Array #3 + Paper, Target

Step 50.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #3 + paper** in reflectance mode ($R_{tar,ap,3}$).

Configuration G: Reflectance Mode, Leaf Array #3, Target

Step 51.

Remove the filter paper from the reflectance port.

NOTES

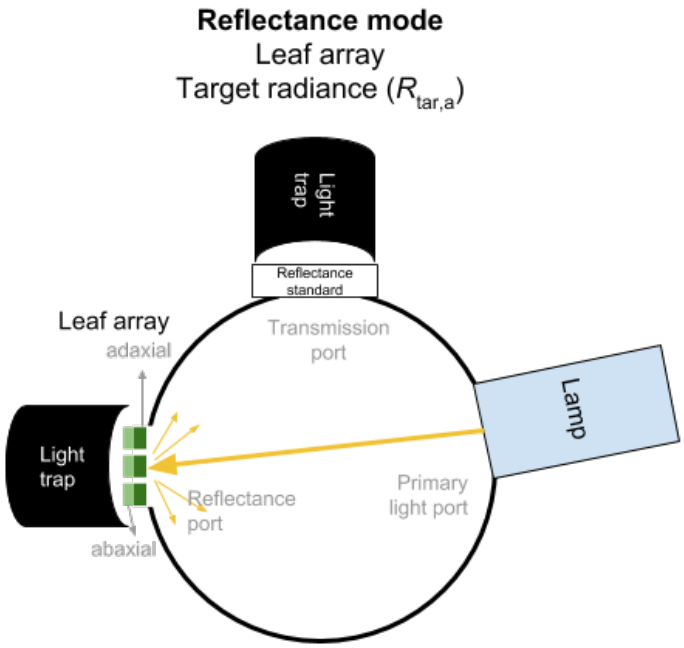
Etienne Laliberté 04 Jun 2018

The sample platform holding leaf array #3 should remain in the same position.

Configuration G: Reflectance Mode, Leaf Array #3, Target

Step 52.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** of **leaf array #3** in reflectance mode ($R_{tar,a,3}$).

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 53.

Remove leaf array #3 from the reflectance port.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 54.

Place the tethered calibrated Spectralon® reflectance standard over the **reflectance port**.

NOTES

Etienne Laliberté 24 Apr 2018

Place the standard over the reflectance port so that the light beam shines directly on its reflective surface (= facing inside of the sphere).

Configuration A: Reflectance Mode, Leaf Array, Reference

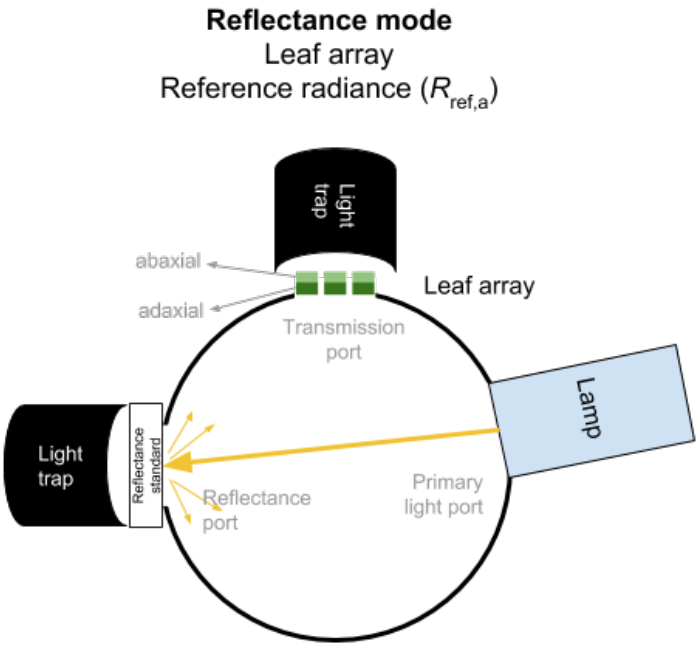
Step 55.

Position leaf array #1 over the **transmission port** so that the **adaxial** (upper) surfaces of the leaves face into the sphere.

Configuration A: Reflectance Mode, Leaf Array, Reference

Step 56.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

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This second reference radiance measurement is only used to assess system stability in reflectance mode.

Configuration H: Transmittance Mode, Reference

Step 57.

Remove leaf array #1 from the **transmission port**.

Configuration H: Transmittance Mode, Reference

Step 58.

Position the sample platform containing leaf array #1 over the **reflectance port** with the **abaxial** (lower) surface of the leaves facing into the sphere.

Configuration H: Transmittance Mode, Reference

Step 59.

Remove the tethered calibrated Spectralon® reflectance standard from the sphere **transmission port**.

Configuration H: Transmittance Mode, Reference

Step 60.

Remove the light trap from the transmission port sample holder.

Configuration H: Transmittance Mode, Reference

Step 61.

Position the lamp over the sphere **transmission port**.

SAFETY INFORMATION

The lamp can get very hot. Grab it by the slotted heat shield.

NOTES

Etienne Laliberté 24 Apr 2018

Make sure lamp is secured in locked position.

Configuration H: Transmittance Mode, Reference

Step 62.

Install the Spectralon® plug over the **primary light port**.

NOTES

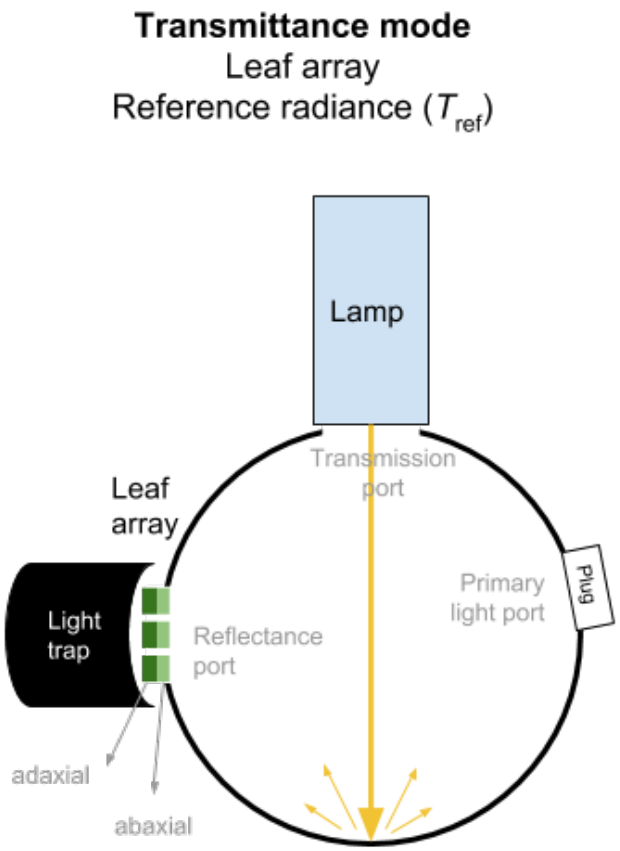
Etienne Laliberté 24 Apr 2018

Ensure that the curved plug is placed the correct way to match the curvature of the sphere.

Configuration H: Transmittance Mode, Reference

Step 63.

Collect a '**Reference Scan**' in this configuration.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **reference radiance** in transmittance mode for the **leaf array** (T_{ref}). The reference data will be automatically saved in all successive target scan files until a new 'Reference Scan' is made.

Configuration H: Transmittance Mode, Reference

Step 64.

Collect a '**Target Scan**' in this configuration and **save the file**.

Configuration I: Transmittance Mode, Target

Step 65.

Carefully remove leaf array #1 from the **reflectance port**.

Configuration I: Transmittance Mode, Target

Step 66.

Gently pull lamp and transmission port sample holder away from the sphere.

SAFETY INFORMATION

The lamp can get very hot. Grab it by the slotted heat shield.

Configuration I: Transmittance Mode, Target

Step 67.

Place the sample platform holding leaf array #1 over the **transmission port** with the abaxial (lower) surfaces of the leaves facing into the sphere.

Configuration I: Transmittance Mode, Target

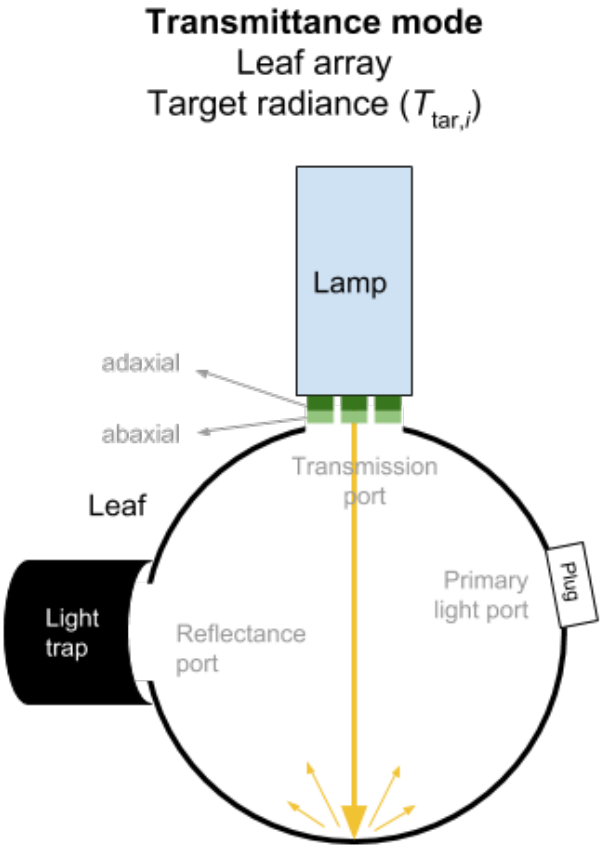
Step 68.

Release the transmission sample holder and move lamp back to its locked position.

Configuration I: Transmittance Mode, Target

Step 69.

Collect a '**Target Scan**' under this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** in **transmittance** mode for leaf array #1 ($T_{tar,1}$).

Configuration I: Transmittance Mode, Target

Step 70.

Carefully replace leaf array #1 by leaf array #2.

Configuration I: Transmittance Mode, Target

Step 71.

Collect a '**Target Scan**' under this configuration and **save the file**.

NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** in **transmittance** mode for leaf array #2 ($T_{tar,2}$).

Configuration I: Transmittance Mode, Target

Step 72.

Carefully replace leaf array #2 by leaf array #3.

Configuration I: Transmittance Mode, Target

Step 73.

Collect a '**Target Scan**' for leaf array #3 in this configuration and **save the file**.

NOTES

Etienne Laliberté 04 Jun 2018

This corresponds to the **target radiance** in **transmittance** mode for leaf array #3 ($T_{tar,3}$).

Configuration H: Transmittance Mode, Reference

Step 74.

Remove leaf array #3 from the transmission sample port holder.

Configuration H: Transmittance Mode, Reference

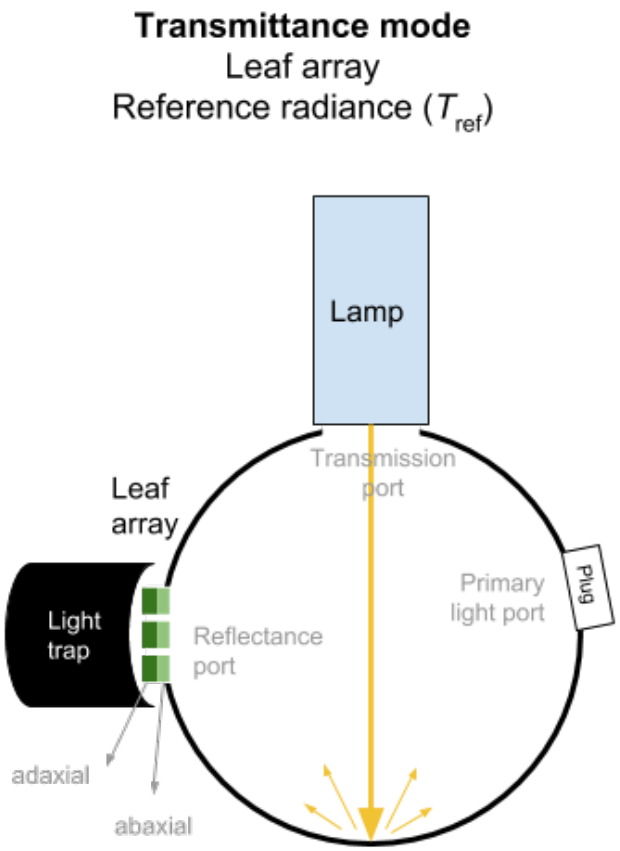
Step 75.

Position the sample platform containing leaf array #1 over the **reflectance port** with the **abaxial** (lower) surface of the leaves facing into the sphere.

Configuration H: Transmittance Mode, Reference

Step 76.

Collect a '**Target Scan**' in this configuration and **save the file**.



NOTES

Etienne Laliberté 04 Jun 2018

This second reference radiance is only used to assess system stability in transmittance mode.

Calculating Absolute Adaxial Reflectance of Leaf Array

Step 77.

The equation (Noda et al. 2013; eqn. 9) for **adaxial reflectance** of leaf array i, $\rho_{a,i}$ is

$$\rho_{a,i} = [(R_{tar,a,i} - R_{str}) \div (R_{ref,a} - R_{str})] \times \rho_{ref} \times [1 \div (1 - G_{r,i})]$$

where

$R_{tar,a,i}$ is the target radiance of leaf array i (adaxial side) in reflectance mode,

$R_{ref,a}$ is the reference radiance used for all leaf arrays in reflectance mode,

R_{str} is the stray light radiance in reflectance mode,

ρ_{ref} is the absolute reflectance of the calibrated Spectralon® reflectance standard, and

$G_{r,i}$ is the gap fraction in reflectance mode for leaf array i, which is calculated **at 400 nm** (Noda et al. 2013; eqn. 13) by

$$G_{r,i} = [\ (\ (R_{tar,ap,i} - R_{str}) \div (R_{ref,ap} - R_{str})\ ) - (\ (R_{tar,a,i} - R_{str}) \div (R_{ref,a} - R_{str})\ )\ ] \times (\ \rho_{ref} \div \rho_{p})$$

where

$R_{tar,ap,i}$ is the target radiance of leaf array i + filter paper in reflectance mode,

$R_{ref,ap}$ is the reference radiance used for all leaf arrays + filter paper in reflectance mode, and

ρ_{p} is the absolute reflectance of the filter paper, which is calculated (Noda et al. 2013; eqn. 3) by

$$\rho_{p} = [(R_{tar,p} - R_{str}) \div (R_{ref,p} - R_{str})] \times \rho_{ref}$$

where

$R_{tar,p}$ is the target radiance of the filter paper in reflectance mode, and

$R_{ref,p}$ is the reference radiance of the filter paper in reflectance mode.

Calculating Absolute Adaxial Transmittance of Leaf Array

Step 78.

The equation for **adaxial transmittance** of leaf array i, $\tau_{a,i}$ is

(modified from eqn. 15 of Noda et al. 2013 for the SVC sphere)

$\tau_{a,i} = [\ (T_{tar,i}\ \div T_{ref}) - G_{t,i}\ ] \times [\ 1 \div (1 - G_{t,i})\ ]$

where

$T_{tar,i}$ is the target radiance of leaf array i in transmittance mode,

T_{ref} is the reference radiance used for all leaf arrays in transmittance mode,

$G_{t,i}$ is the gap fraction in transmittance mode for leaf array i, which is calculated **at 400 nm** (since $\tau_{a,i} = 0$ at that wavelength) by

$G_{t,i} = T_{tar,i} \div T_{ref}$

Warnings

The lamp of the integrating sphere can get **very hot** and should handled from its slotted base to avoid burns.