

## LEAF HEMISPHERICAL REFLECTANCE AND TRANSMITTANCE MEASUREMENT

Equipment needed:

- Integrating sphere
- Spectrometer
- Spectrometer Laptop

Installation of the instruments:

- Start the ASD instrument using the current adaptor as energy source.
- Start the integrating sphere lamp using the current adaptor as energy source.
- Mount the integrating sphere on the tripod and attach the spectrometer bare fibre through its top port (Port H in fig 1).
- Start RS3 software in the computer
- Get familiar with the elements you will use to cover the ports during the measurement procedure (Fig 2)

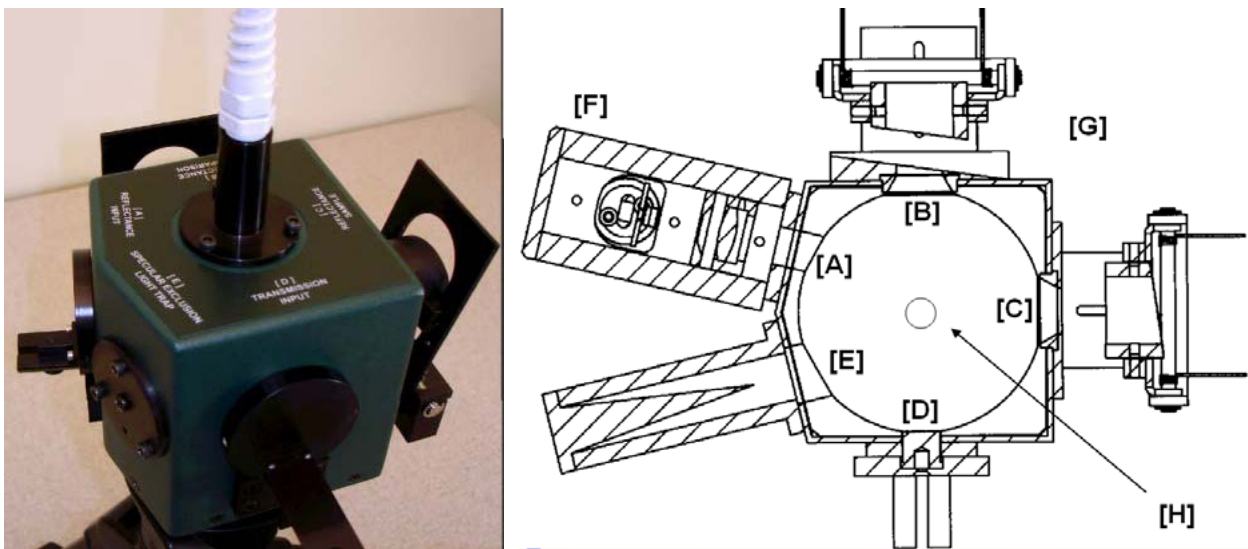


Fig 1. ASD Integrating sphere and scheme showing the position of the different ports



Fig 2. Elements used during reflectance and transmittance measurement procedures. (1) Lamp, (14) White calibrated reference, (3) Light trap, (10) and (11) white reference built-in ports.

### Measurement protocol:

- Warm the spectrometer and the integrating sphere lamp up for at least 30 minutes
- In the main menu of RS3 software click *Spectrum Save* under *Control*. Change the base name into the tree sample ID and the starting measure number into 1. Click OK.
- Click *Control – Adjust configuration* and set the *Spectrum average* to 15 in case it is needed.
- Check FOV setting, it must be *Bare Fiber* (any foreoptics attached). You can check all the configuration parameters in the main screen of RS3 software (Fig 3).

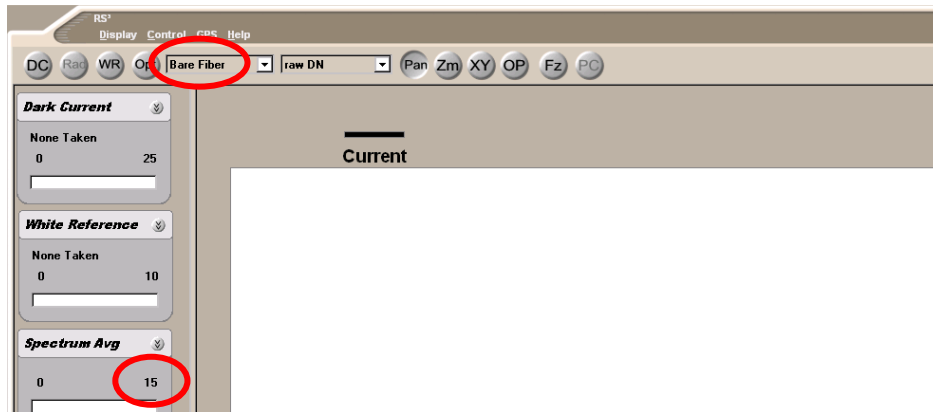


Fig 3. Measurement settings displayed in RS3 software window.

- Select three leaves from the sample bag. The integrating sphere port diameter are approx 1 cm, so try to find 3 leaves (if possible) where there is a circle of 1 cm diameter not covering the main leaf nerve.
- Repeat the steps below for each of the three leaves, at the end you'll have a total of 12 files per tree sample.
- Reflectance measurement (Fig 4a to 4d):
  - o Move the lamp to port A, cover port D with white reference cover built-in-port (element 11 in fig.2). Leave those elements fixed during the reflectance measurement.
  - o Stray light measurement: Place white reference cover in front of the lamp on port C (element 14, fig 2), cover remaining port B with the light trap (element 3, fig 2), click **Opt** bottom, and when optimisation is complete, click **WR** bottom. **Switch** ports B and C elements and click **Space** to save the measurement.
  - o Uncorrected reflectance measurement: Place white reference cover in front of the lamp on port C (element 14, fig 2), cover remaining port B with leaf and close the aperture with the black tap, click **Opt** bottom, and when optimisation is complete, click **WR** bottom. **Switch** ports B and C elements and click **Space** to save the measurement.
- Transmittance measurement (Fig 4e to 4h):
  - o Move the lamp to port D, cover port A with white reference cover built-in-port (element 11 in fig.2). Leave those elements fixed during the reflectance measurement.
  - o Stray light measurement: Place white reference cover in front of the lamp on port B (element 14, fig 2), cover remaining port C with the light trap (element 3, fig 2), click **Opt** bottom, and when optimisation is complete, click **WR** bottom. **Switch** ports B and C elements and click **Space** to save the measurement.
  - o Uncorrected transmittance measurement: Place white reference cover in front of the lamp on port B (element 14, fig 2), cover remaining port C with leaf and close the aperture with the black tap, click **Opt** bottom, and when optimisation is complete, click **WR** bottom. Place the leaf between the sphere and the lamp, and cover port C with the light trap, click **Space** to save the measurement.

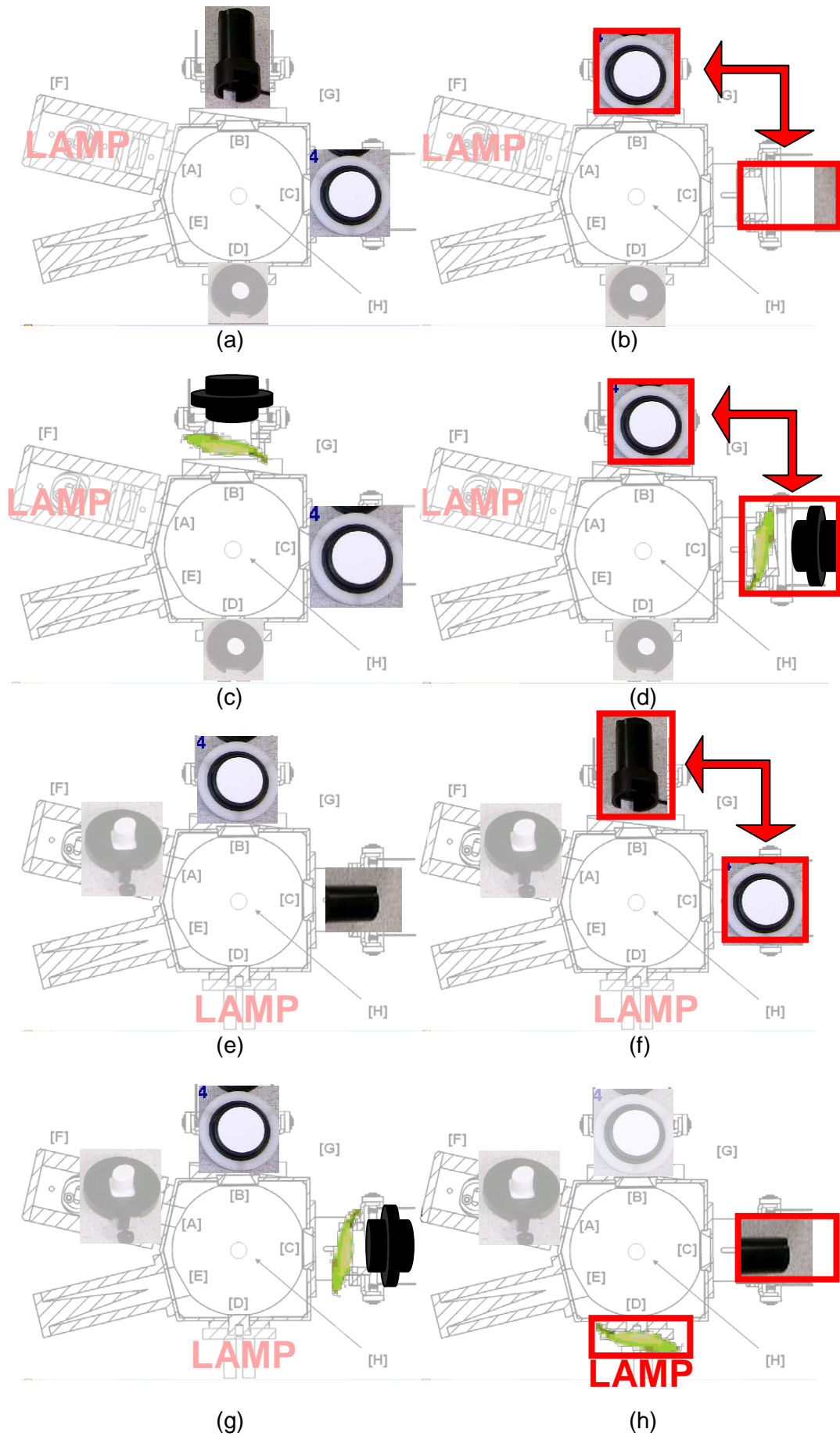


Figure 4. Scheme showing the eight integrating sphere positions for reflectance and transmittance measurement

## **ANNEX I. MATLAB CODE FOR AUTOMATIC PROCESSING**

The resulting 'rfl\_measurements.csv' and 'tns\_measurements.csv' are comma-separated files with the reflectance and transmittance spectra of all the leaves in the folder in alphabetical order

```
ASD_files = dir('<folder map>');
ASD=struct2cell(ASD_files);
[n m]=size(ASD);
num=(m/4);
ALL_RFL=zeros(2150,num+1);
ALL_TNS=zeros(2150,num+1);
for f=0:num-1;
stray_rfl=ASD_files(f*4+1).name;
meas_rfl=ASD_files(f*4+2).name;
stray_tns=ASD_files(f*4+3).name;
meas_tns=ASD_files(f*4+4).name;
str_rfl=csvread(stray_rfl,2);
file_rfl=csvread(meas_rfl,2);
str_tns=csvread(stray_tns,2);
file_tns=csvread(meas_tns,2);
ALL_RFL(:,1)=str_rfl(:,1);
ALL_TNS(:,1)=str_rfl(:,1);
wv=str_rfl(:,1);
RFL_C=(file_rfl(:,2)-str_rfl(:,2))*0.99./(1-str_rfl(:,2));
TNS_C=(file_tns(:,2)-str_tns(:,2))*0.99./(1-str_tns(:,2));
ALL_RFL(:,f+1)=RFL_C;
ALL_TNS(:,f+1)=TNS_C;
end;
csvwrite('rfl_measurements.csv',ALL_RFL);
csvwrite('tns_measurements.csv',ALL_TNS);
```

## **ANNEX II. TO TAKE INTO ACCOUNT**

1. Every time we optimise or get a reference, the port in front of the light is covered by spectralon
2. The lamp output light must be collimated. Sometimes the lamp behind the collimator moves and the output light is not diffuse. We would see non-homogeneous light footprint when illuminating a surface with the lamp. When this happens, we have to move the lamp back to its position.
3. Every time you take a measurement, be sure the spectrum you are recording looks like a typical reflectance or transmittance spectrum. In the case of taking the stray light, it must be a spectrum close to 0.

## **ANNEX III. TYPICAL PROBLEM SOLVING**

1. If after optimising the integration time is very high or the signal noisy:
  - a. The bare fiber is not fully inserted in the upper port
  - b. The lamp intensity is too low
    - i. Check the power supply (flat battery?)
    - ii. Lamp may need to be changed
  - c. The port in front of the lamp is not covered by spectralon (remember in every optimising/reference step we are illuminating the spectralon panel)
2. If we missed one step measuring a leaf (remember we end up having 4 readings per leaf). We can restart from the measurement missed clicking *Control-Spectrum Save* then changing the file number to the one we missed. When we tell the software to save the reading, it will double-check if you want to overwrite the file.