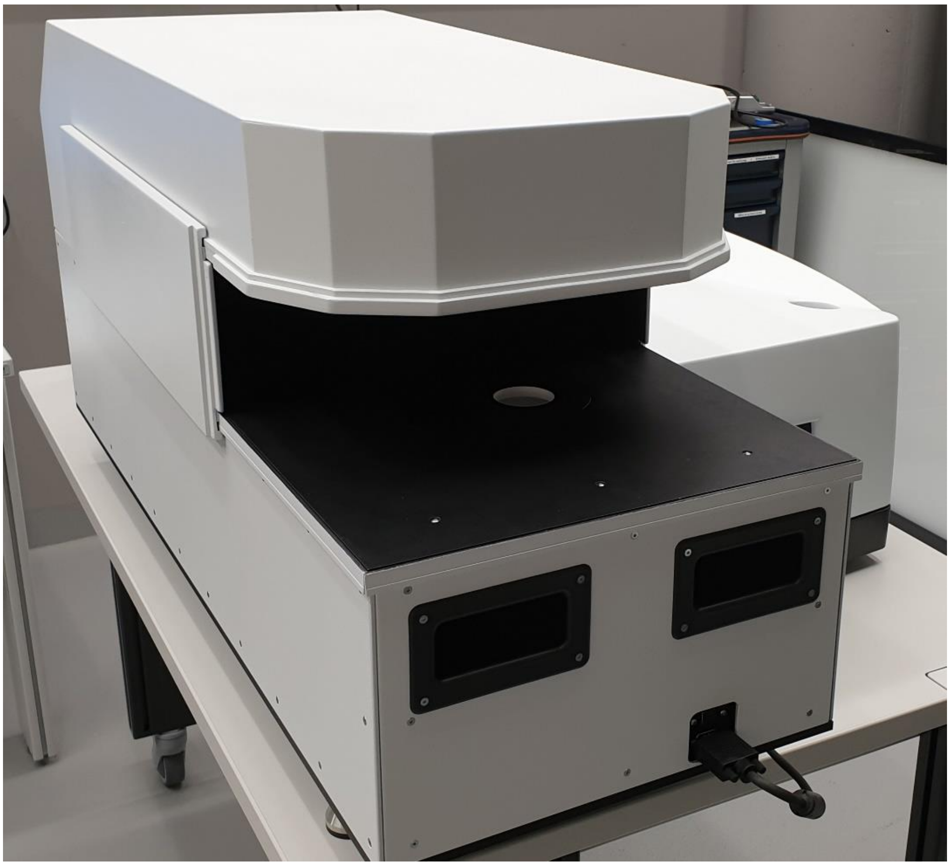
UL150

Upward looking 150 mm Integrating Sphere Accessory

User Manual



Versopm 20 September 2019
www.omtsolutions.com

UL150 Integrating Sphere Accessory

User manual

Table of Contents

UL150 Integrating Sphere Accessory

User manual

Introduction

The UL150 Integrating sphere accessory

The UL150 is a unique accessory available only for PerkinElmer LAMBDA 950 and LAMBDA 1050 series.

The use of light-diffusing materials such as patterned cover glasses used in solar cells and textured/coated glasses used in buildings and greenhouses is increasing. In solar cell applications, patterned glass captures and traps the light better within the structure ensuring maximum cell efficiency. In greenhouses, the use of diffuse glass optimizes distribution of light for improved plant growth. The ability to measure the transmission and reflection properties of these materials accurately is a key requirement in the development and manufacture of high efficiency solar cells and light-diffusing glazing.

The UL150 Integrating sphere accessory has been delivered together with the following items:

1. ∅50 mm Port insert
2. ∅25 mm Port insert
3. Calibrated Second Surface Reference Mirror
4. Black pad (for 0% baseline calibration)
5. This manual
6. USB stick with electronic copies of this manual and applicable software

The accessory is pre-aligned and fully tested at the OMT Solutions laboratory using a PerkinElmer Lambda 1050.

Main features UL150 sphere accessory

- Minimum wavelength range 250 – 2,450 nm.
- Angle of incidence 8 degrees in both transmission and reflection;
- Measurement accuracy < 0.2T% and < 0.5R% for a specular sample;
- Sample size up to at least 350 mm x 650 mm;
- Sample orientation: horizontal;
- Sphere diameter 150 mm inner diameter;
- Sphere material: pressed PTFE;
- Sphere entrance port diameter 25 mm or 50 mm (both with help of an insert);
- Beam diameter at sample position 10 mm circular;
- Detector UV/Vis: photomultiplier tube (PMT);
- Detector NIR: Broadband InGaAs with triple stage Peltier cooling;

Principle of operation

The optical path of the spectrophotometer's sample beam through the accessory is shown in the figures 1a and 1b below.

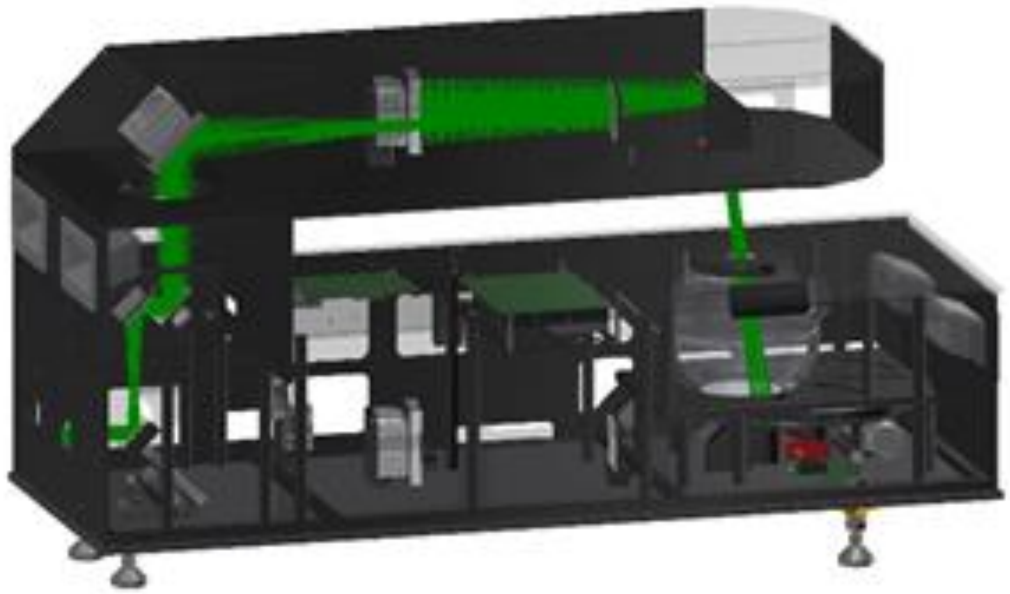


Fig. 1a. Sample beam in Transmittance mode

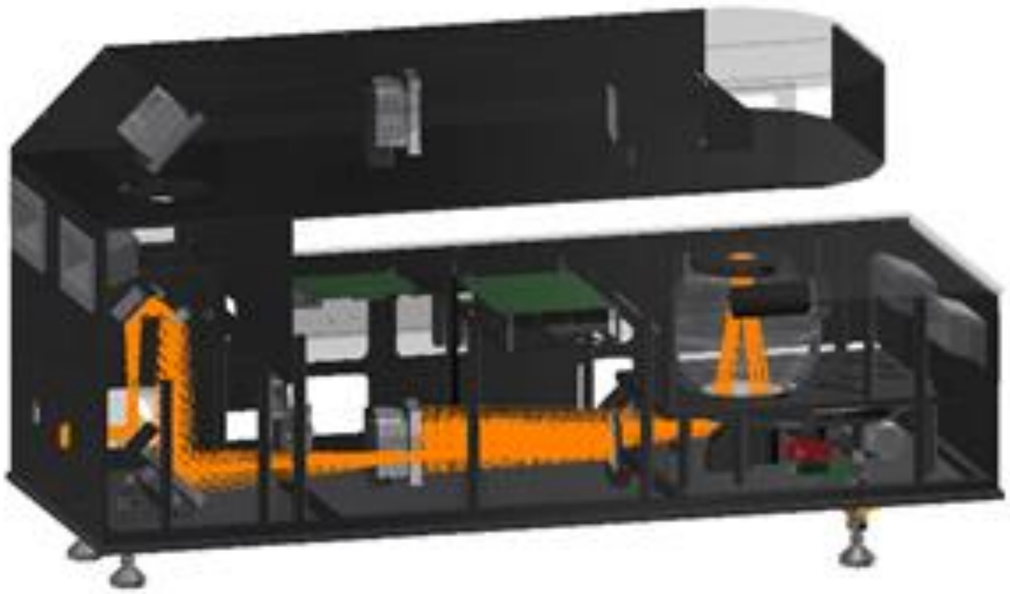


Fig. 1b. Sample beam in Reflectance mode

Applications

Flat specular samples

To measure flat specular glass samples, the ∅25mm Port insert is recommended to get the best signal to noise ratio.

Patterned substrates

To measure patterned glass samples and other patterned substrates, the ∅50mm Port insert is recommended to get the best signal to noise ratio. In case of samples with two different surfaces (e.g. flat/patterned) it is recommended to measure both sides in transmittance and reflectance.

Diffuse samples

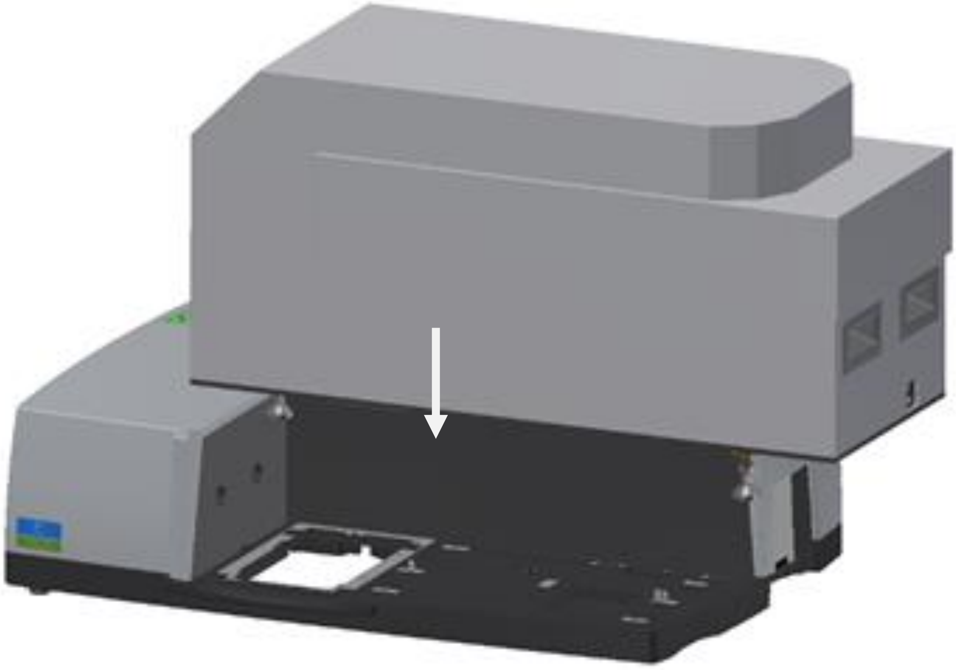
To measure diffuse samples, the ∅50mm Port insert is recommended to collect the total transmitted/reflected sample beam.

Getting Started

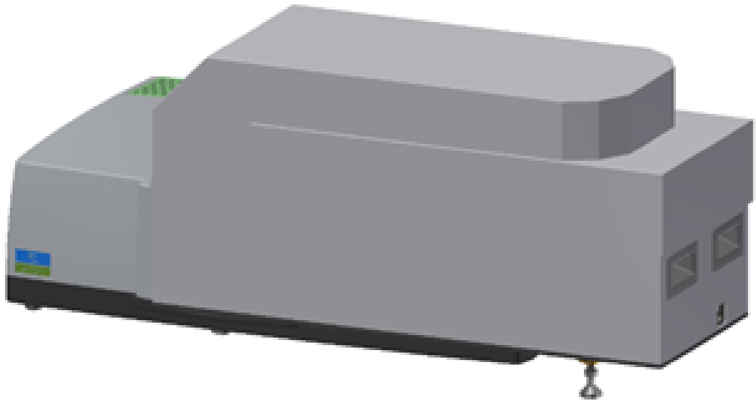
Installation of the accessory

1. Close the UVWinlab software and switch of the instrument.
2. Remove the sample compartment, the sample compartment lid and the detector unit from the spectrophotometer, see picture below.

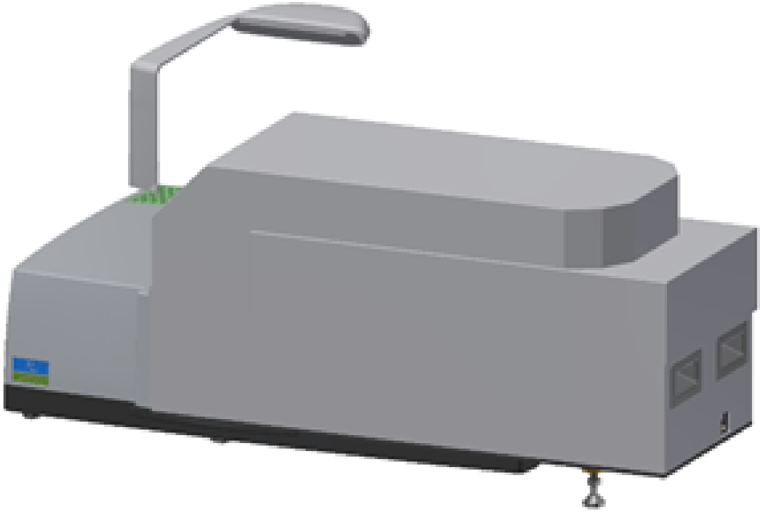
3. Install the accessory



4. Check the feet below the UL150 and adjust them to make sure the UL150 is placed stable

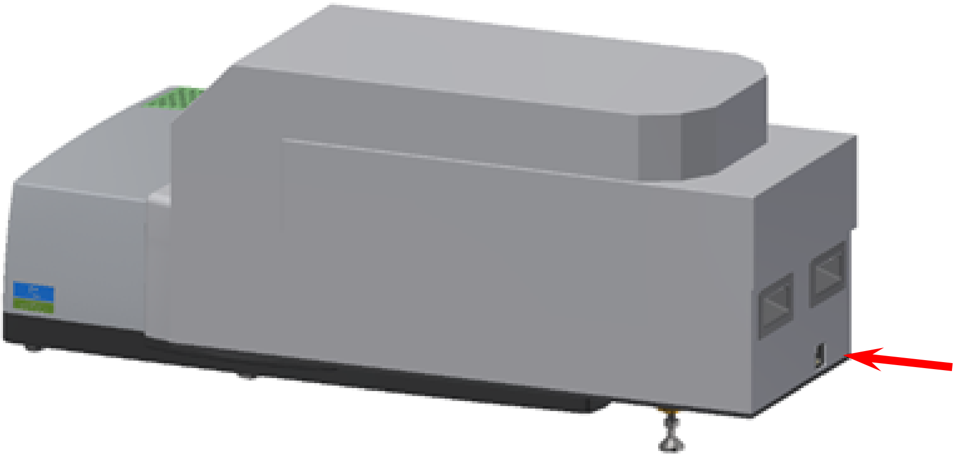


5. Place the sample compartment lid of the UL270 accessory from above onto the instrument.



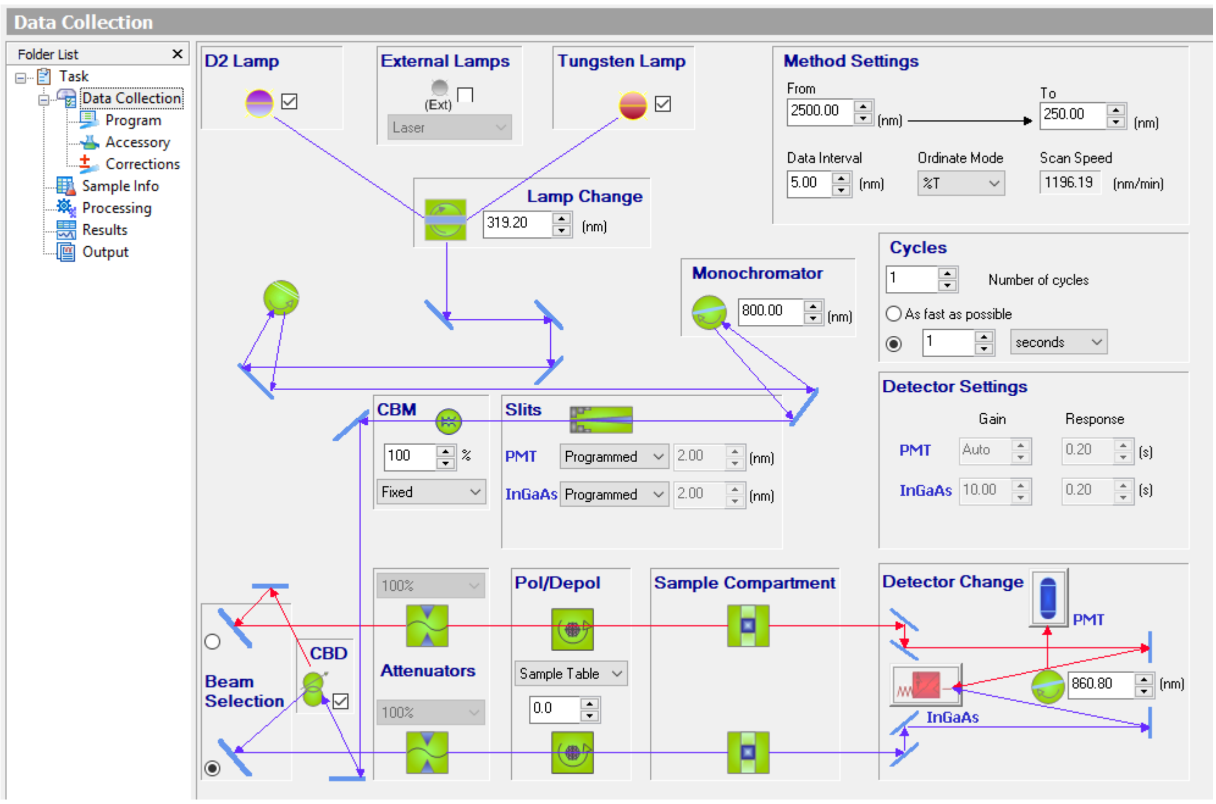
6. Open the UL270 accessory sample compartment and install the appropriate port insert (here the 50 mm port insert is shown):

7. Connect the UL150 with one of the 15 pins D-sub accessory connectors on the instrument:



UVWinLab instrument settings

For preparing a UVWinLab method, typical instrument settings for the UL150 in the Data Collection page are shown here:



The UL150 has 4 measurement modes; Total Reflectance, Diffuse Reflectance, Total Transmittance and Diffuse Transmittance.

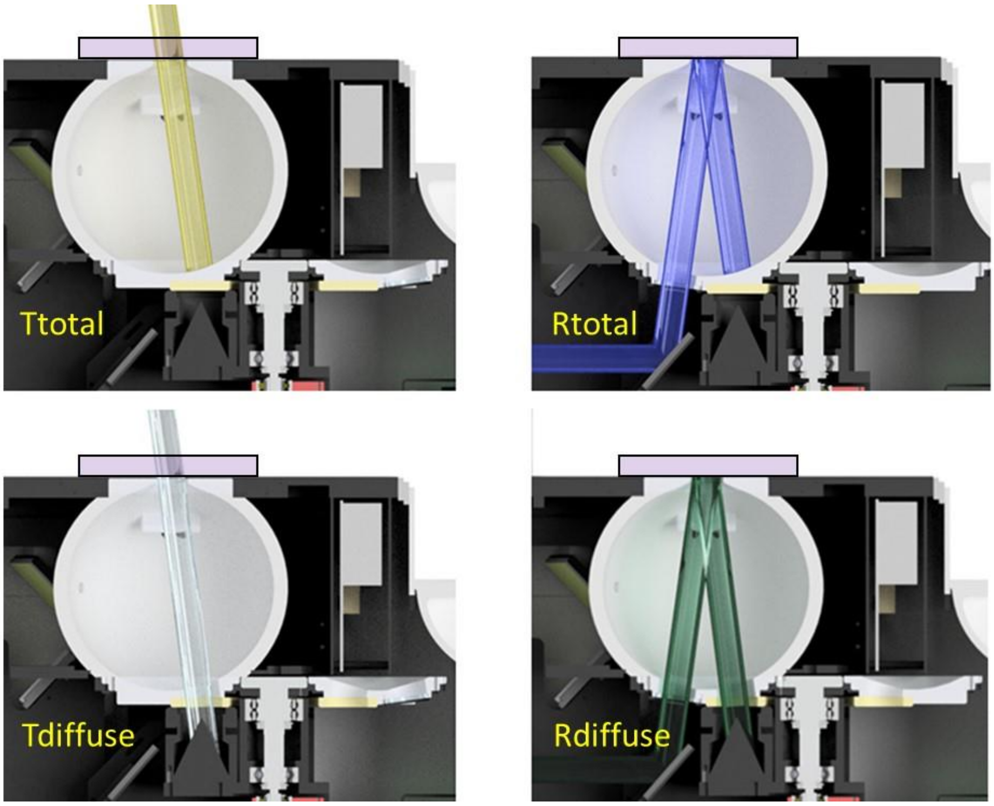
To switch between these modes the UL150 uses a stepper motor drive that UVWinlab recognizes as a polarizer drive (although the UL150 does not contain a polarizer).

In the screen print above, the Pol/Depol setting (polarizer drive angle) is set to 0, which corresponds with Total Transmittance mode.

To select one of the UL150 measurement modes in UVWinLab the polarizer angle must be set to the value indicated in the following table:

Measurement mode	Polariser angle setting
Ttot = Total Transmittance (direct + diffuse)	0
Tdif = Diffuse Transmittance (direct component excluded)	88
Rtot = Total Reflectance (specular + diffuse)	176
Rdif = Diffuse Reflectance (specular component excluded)	264

These angles determine the position of a revolving disk that changes the bottom part of the sphere to enable to pass the beam where necessary. In case of the Diffuse Reflectance and Diffuse Transmittance the direct beam is dumped into a light trap (see picture below)

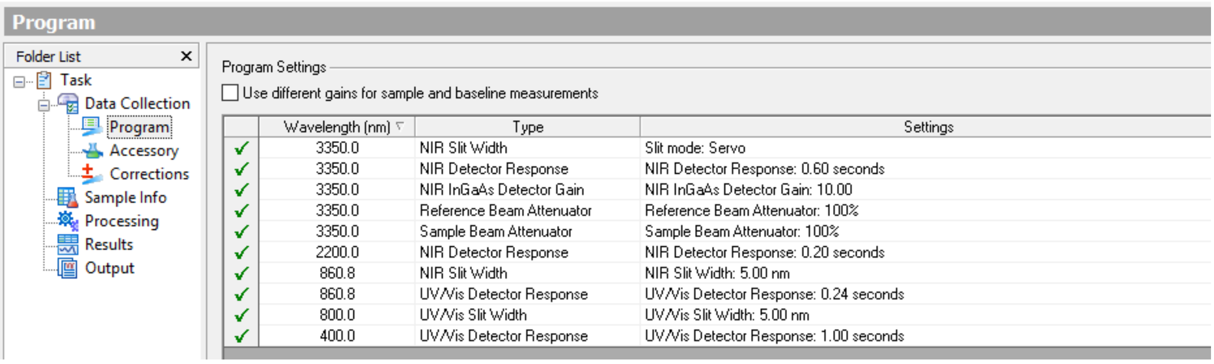


To raise the energy level for wavelengths between 860.8 nm and 800 nm the grating change point is set at 800 nm while keeping the detector change point at 860.8 nm.

With these settings Programmed mode has to be used for the slit/gain/integration time settings because of the 3 separate wavelength ranges. The following settings are typical for this accessory:

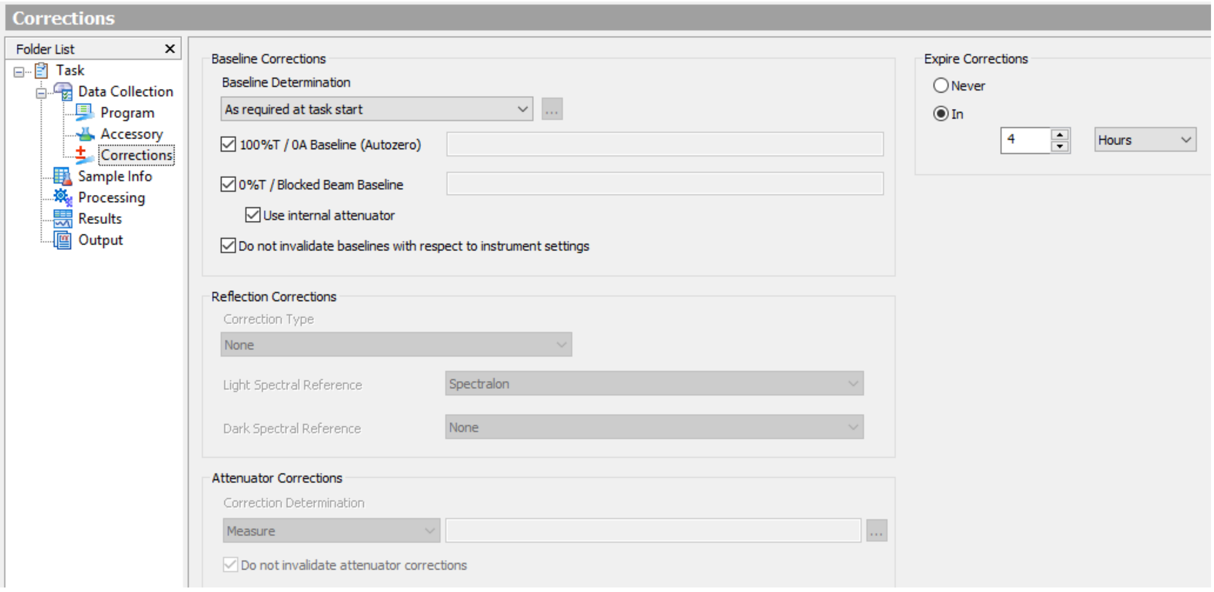
Slit settings / Width [nm]		InGaAs (NIR) and PMT Gain settings		Integration Time [sec]	
wavelength	setting	wavelength	setting	wavelength	setting
2500 nm – 860.8 nm	Servo	2500 nm – 860.8 nm	10	2500 nm – 2200 nm	InGaAs 0.6s
				2200 nm – 860.8 nm	InGaAs 0.2s
860.8 nm – 800 nm	5 nm	860.8 nm – 800 nm	Auto	860.8 nm – 800 nm	PMT 0.24s
800 nm – 400 nm	5 nm	800 nm – 400 nm	Auto	800 nm – 400 nm	PMT 0.24s
400 nm – 250 nm	5 nm	400 nm – 250 nm	Auto	400 nm – 250 nm	PMT 1s

In the Program Settings page of UVWinLab this is implemented as follows:



UVWinLab correction settings

On the Correction page, the following settings are recommended:

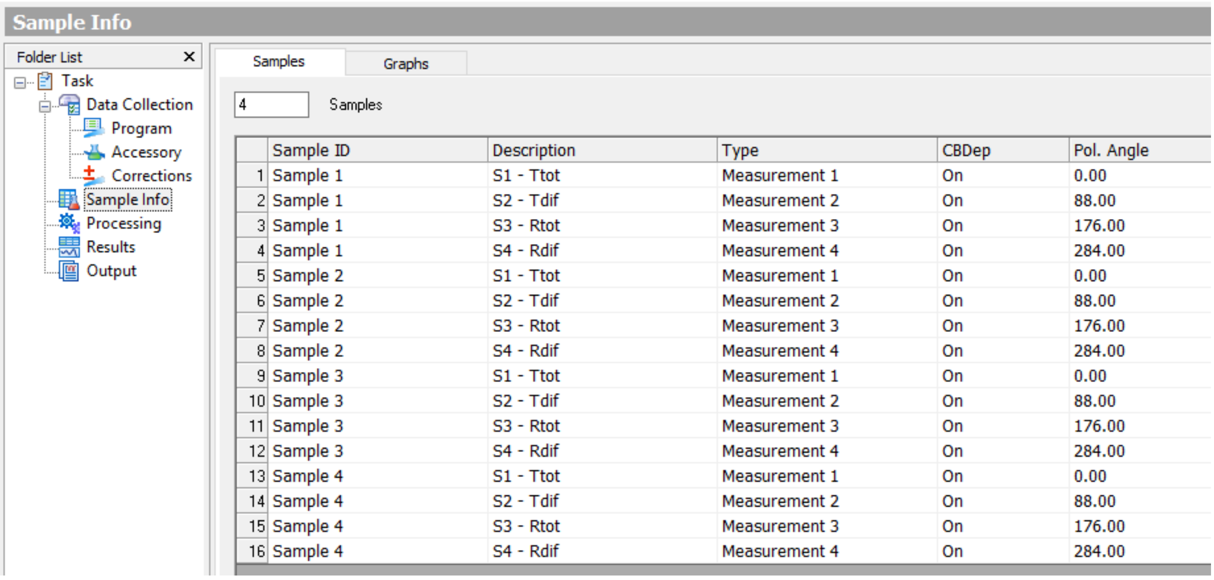


Measurements and calculations

Sample measurements

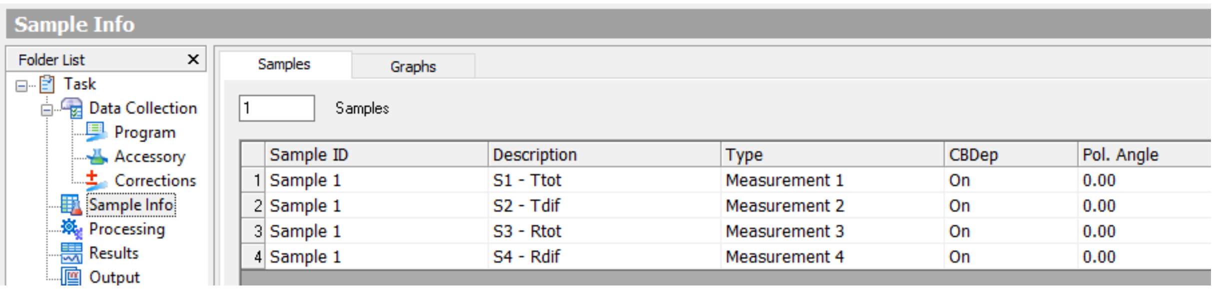
In this chapter, we give an example of a method that performs all 4 types of measurements on each sample.

The Sample list for these measurements is prepared as follows (example for 4 samples):



	Sample ID	Description	Type	CBDep	Pol. Angle
1	Sample 1	S1 - Ttot	Measurement 1	On	0.00
2	Sample 1	S2 - Tdif	Measurement 2	On	88.00
3	Sample 1	S3 - Rtot	Measurement 3	On	176.00
4	Sample 1	S4 - Rdif	Measurement 4	On	284.00
5	Sample 2	S1 - Ttot	Measurement 1	On	0.00
6	Sample 2	S2 - Tdif	Measurement 2	On	88.00
7	Sample 2	S3 - Rtot	Measurement 3	On	176.00
8	Sample 2	S4 - Rdif	Measurement 4	On	284.00
9	Sample 3	S1 - Ttot	Measurement 1	On	0.00
10	Sample 3	S2 - Tdif	Measurement 2	On	88.00
11	Sample 3	S3 - Rtot	Measurement 3	On	176.00
12	Sample 3	S4 - Rdif	Measurement 4	On	284.00
13	Sample 4	S1 - Ttot	Measurement 1	On	0.00
14	Sample 4	S2 - Tdif	Measurement 2	On	88.00
15	Sample 4	S3 - Rtot	Measurement 3	On	176.00
16	Sample 4	S4 - Rdif	Measurement 4	On	284.00

During the autozero it can be easier to start with a single sample entry. All “polarizer angles” should be set to zero to allow the autozero to be performed in the Ttot mode only, which then forms the baseline for all modes of operation:

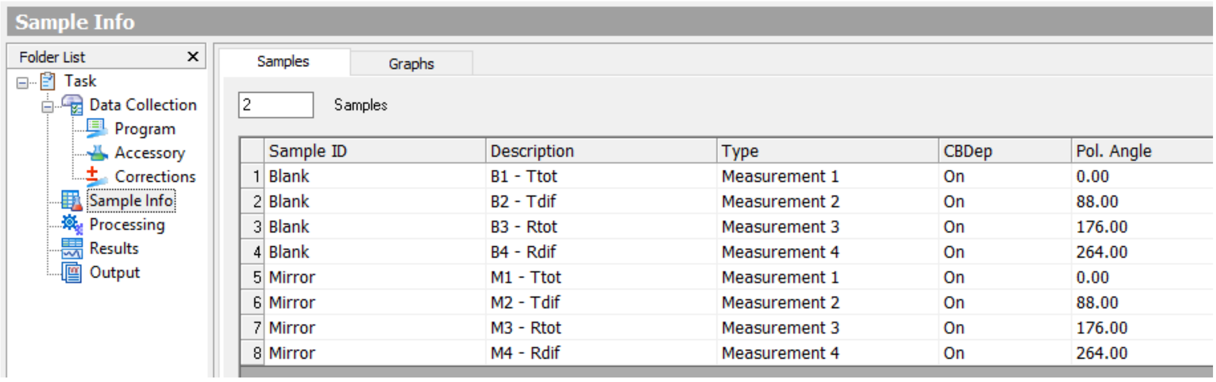


	Sample ID	Description	Type	CBDep	Pol. Angle
1	Sample 1	S1 - Ttot	Measurement 1	On	0.00
2	Sample 1	S2 - Tdif	Measurement 2	On	0.00
3	Sample 1	S3 - Rtot	Measurement 3	On	0.00
4	Sample 1	S4 - Rdif	Measurement 4	On	0.00

Reference measurements

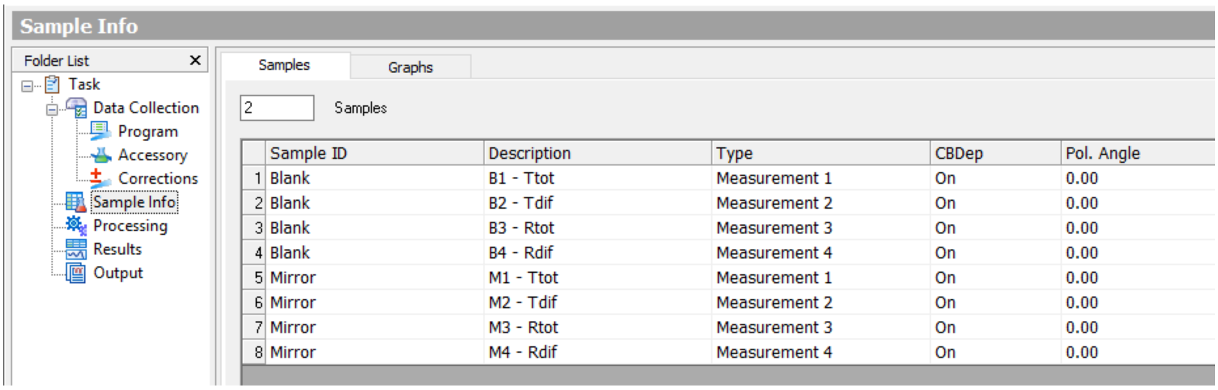
In order to obtain data for calibrating the scale of the measurements and perform the proper corrections for the various forms of straylight, we need to perform the same measurements as on the sample, for a calibrated reference mirror and a blank (=no sample present) .

The Sample list for these measurements is prepared as follows (example for 4 samples):



	Sample ID	Description	Type	CBDep	Pol. Angle
1	Blank	B1 - Ttot	Measurement 1	On	0.00
2	Blank	B2 - Tdif	Measurement 2	On	88.00
3	Blank	B3 - Rtot	Measurement 3	On	176.00
4	Blank	B4 - Rdif	Measurement 4	On	264.00
5	Mirror	M1 - Ttot	Measurement 1	On	0.00
6	Mirror	M2 - Tdif	Measurement 2	On	88.00
7	Mirror	M3 - Rtot	Measurement 3	On	176.00
8	Mirror	M4 - Rdif	Measurement 4	On	264.00

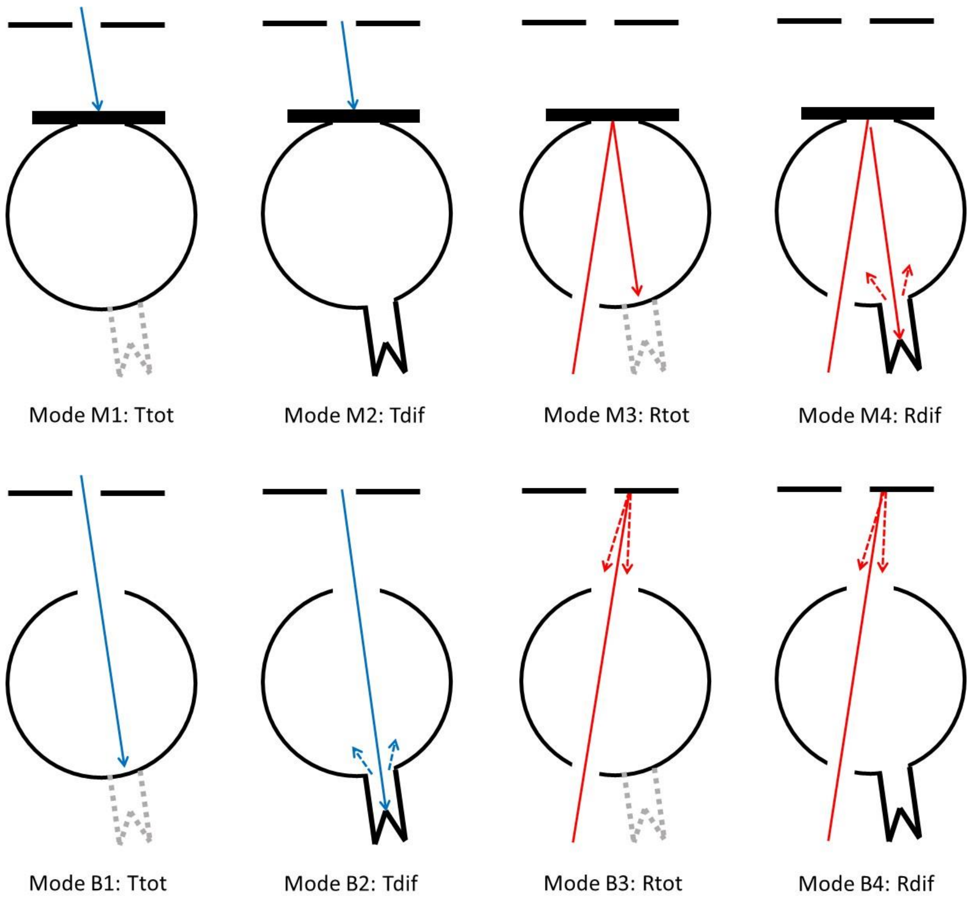
During the autozero, all “polarizer angles” should be set to zero to allow the autozero to be performed in the Ttot mode only (similar to the sample measurements:



	Sample ID	Description	Type	CBDep	Pol. Angle
1	Blank	B1 - Ttot	Measurement 1	On	0.00
2	Blank	B2 - Tdif	Measurement 2	On	0.00
3	Blank	B3 - Rtot	Measurement 3	On	0.00
4	Blank	B4 - Rdif	Measurement 4	On	0.00
5	Mirror	M1 - Ttot	Measurement 1	On	0.00
6	Mirror	M2 - Tdif	Measurement 2	On	0.00
7	Mirror	M3 - Rtot	Measurement 3	On	0.00
8	Mirror	M4 - Rdif	Measurement 4	On	0.00

Calibration and straylight corrections

The reference measurements with the calibrated reference mirror and the blank (without sample) provide us with reference spectra according to 8 different measurement geometries, schematically shown in the following pictures:



The 8 reference spectra are:

M1 = 0% reference spectrum for total transmittance and reflectance (beam blocked)

M2 = 0% reference spectrum for diffuse transmittance and reflectance (beam blocked)

M3 = 100% reference spectrum for total and diffuse reflectance (before correction with the mirror calibration data))

M4 = measurement of the Light Trap reflection component of the diffuse reflectance straylight spectrum

B1 = 100% reference spectrum for total and diffuse transmittance

B2 = measurement of the Light Trap reflection component of the diffuse transmittance straylight spectrum)

B3 = measurement of the straylight component originating from the reflection of the upper part of the sample compartment

B4 = measurement of the straylight component originating from the reflection of the upper part of the sample compartment, including possible interaction with the lower light trap

The reflection of the light trap during diffuse transmittance measurements is given by:

$$R_{LT} = \frac{M_{B2} - M_{M2}}{M_{B1} - M_{M2}} \quad . \tag{1}$$

The reflection of the light trap during diffuse reflectance measurements is given by:

$$R_{LR} = \frac{M_{M4} - M_{M2}}{M_{M3} - M_{M2}} R_M \quad , \tag{2}$$

in which R_M is the calibrated reflectance of the reference mirror.

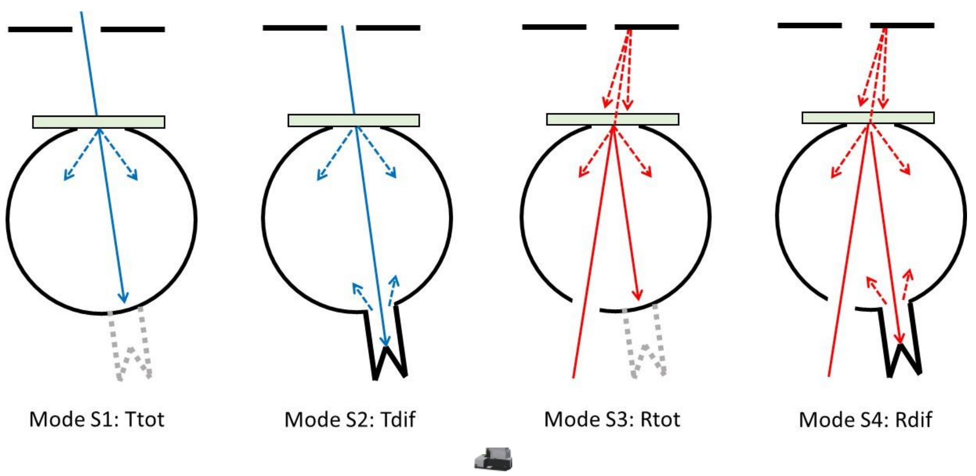
The apparent reflectance of the part of the sample compartment ceiling that contributes to the measured total reflectance of transparent samples is given by

$$R_{U3} = \frac{M_{B3} - M_{M1}}{M_{M3} - M_{M1}} R_M \tag{3}$$

The apparent reflectance of the part of the sample compartment ceiling that contributes to the measured diffuse reflectance of transparent samples is given by

$$R_{U4} = \frac{M_{B4} - M_{M1}}{M_{M3} - M_{M1}} R_M \tag{4}$$

In order to see how these reflections influence the sample measurements we have to look at the schematics of the measurements as shown in the following picture:



Total transmittance Ttot

The total transmittance is determined by correcting the sample measurement M_{S1} with the reference measurements according to

$$T_{tot} = \frac{M_{S1} - M_{M1}}{M_{B1} - M_{M1}} \qquad (5)$$

Diffuse transmittance Tdif

The total transmittance is determined by correcting the sample measurement M_{S2} with the reference measurements, yielding

$$T'_{dif} = \frac{M_{S2} - M_{M1}}{M_{B1} - M_{M1}} . \qquad (6)$$

This needs to be corrected for the reflection contribution of the light trap:

$$T'_{dif} = T_{dif} + T_{dir}\, R_{LT} = T_{dif} + (T_{tot} - T_{dif})\, R_{LT} \qquad (7)$$

By rearranging terms we obtain:

$$T_{dif} = (T'_{dif} + T_{tot}\, R_{LT})/(1 - R_{LT}) \qquad (8)$$

Total reflectance Rtot

The total reflectance is determined by correcting the sample measurement M_{S3} with the reference measurements according to

$$R'_{tot} = \frac{M_{S3} - M_{M1}}{M_{M3} - M_{M1}}\, R_M \qquad (9)$$

This needs to be corrected for the reflection contribution from the sample compartment ceiling:

$$R'_{tot} = R_{tot} + T_{dir}\, R_{U3} T_{dif} \qquad (10)$$

By rearranging terms we obtain:

$$R_{tot} = R'_{tot} - R_{U3} T_{dif} (T_{tot} - T_{dif}) \qquad (11)$$

Diffuse Reflectance Rdif

The total reflectance is determined by correcting the sample measurement M_{S3} with the reference measurements according to

$$R'_{dif} = \frac{M_{S4} - M_{M1}}{M_{M3} - M_{M1}} R_M \quad (12)$$

This needs to be corrected for the reflection contributions from the light trap and from the sample compartment ceiling:

$$\begin{aligned} R'_{dif} &= R_{dif} + R_{dir} R_{LR} + T_{dir} R_{U4} T_{dif} \\ &= R_{dif} + (R_{tot} - R_{dif}) R_{LR} + T_{dir} R_{U4} T_{dif} \end{aligned} \quad (13)$$

By rearranging terms we obtain:

$$R_{dif} = (R'_{dif} - R_{U4} T_{dif} (T_{tot} - T_{dif}) - R_{tot} R_{LR}) / (1 - R_{LR}) \quad (14)$$