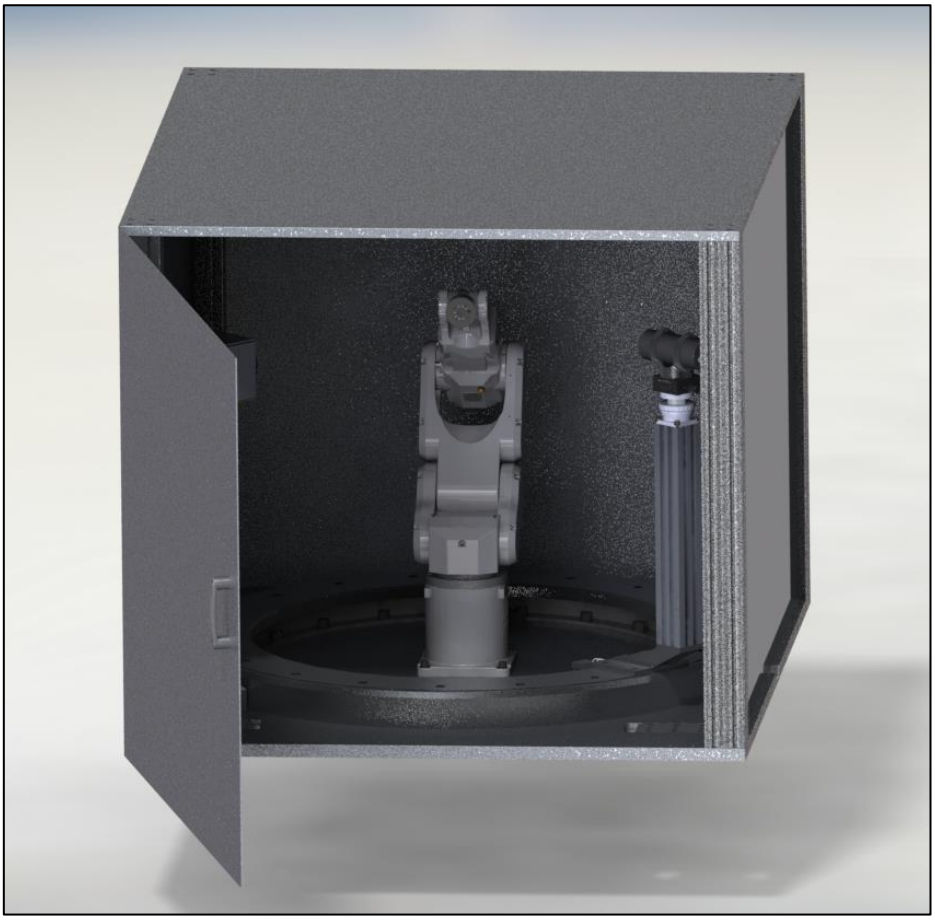

BiRT-2.0

Bi-directional Reflectance and Transmittance Distribution Function Measurement System

Photometric Solutions International Pty Ltd
Factory Two, 21-29 Railway Ave, Huntingdale, Vic, 3166, Australia
Tel: +61 3 9568 1879 Fax: +61 3 9568 4667
ABN 34 106 665 141
Email: sales@photometricsolutions.com
www.photometricsolutions.com

Part 1. BiRT-2.0 Bi-directional Reflectance and Transmittance Distribution Function Measurement System

The BiRT-2.0 is an advanced entry-level robot-based BRDF/BDTF measurement system. The system features:

- Light-tight enclosure with operator safety lockout;
- Collimated input beam with adjustable beam size;
- 6-axis robot for sample positioning and rotation in 3 axes;
- Precision slew ring for detector motion;
- Simultaneous multi-ranging photometer as well as spectroradiometer;
- Adjustable input aperture for detection optics;
- 2x reference standard reflectance tiles with ISO 17025 calibration certificate;
- Software control and coordination of all measurement functions.

The BiRT-2.0 is a scaled down version of an advanced research-grade BRDF/BTDF system developed by PSI and installed at the Measurement Standards Laboratory of New Zealand, which is the primary laboratory of New Zealand.

Theory of Operation

Measurements of BRDT/BTDF are used for characterisation of the appearance of surfaces. This involves illuminating the sample in multiple directions often over the full hemisphere of angles over the surface and then measuring the reflected light over the full hemisphere of angles from the surface; either in the same hemisphere as the incident beam in the case of BRDF or the opposite hemisphere in the case of BTDF.

Configurational views of the BiRT-2.0 without the light-tight enclosure are given in Figure 1 to Figure 3 below. Note that these images are a guide only, since the BiRT-2.0 will be housed in an enclosure that includes an operator safety lockout so the guards shown around the slew ring will not be required.

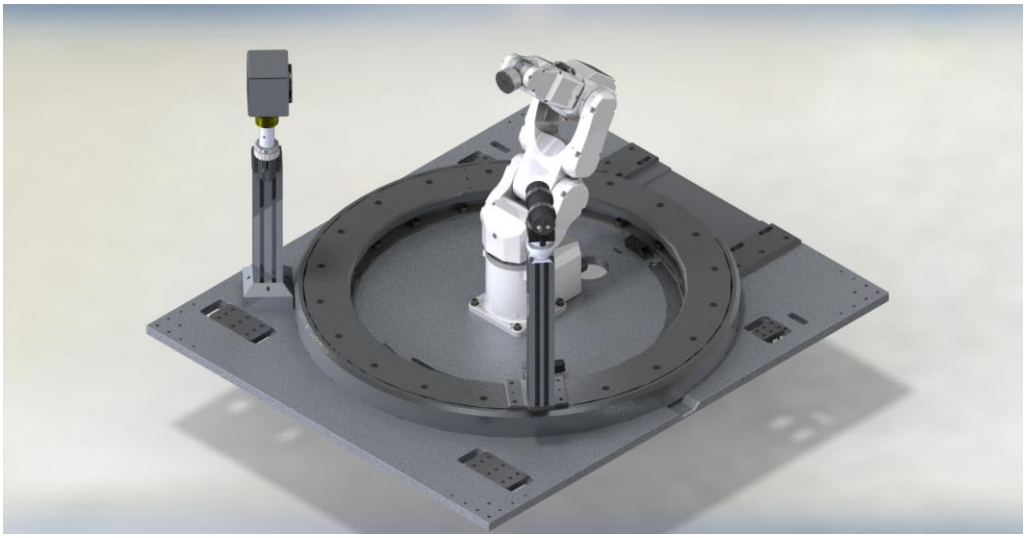

Figure 1: Isometric view 1

Figure 2: Isometric view 2

Figure 3: Isometric view 3

Robot & Slew Ring

The slew ring has a diameter of approximately 1 metre and has a carriage which houses the detector. The sample is positioned at the reference point of the system (above the centre of the slew ring) using a six-axis robot. The light source is placed in a fixed position and aimed also towards the reference point of the system. The combination of the three axes of rotation of the robot plus the single axis of rotation of the slew ring enables the system to set the required incident (θ_i, ϕ_i) angle and detected (θ_d, ϕ_d) angle. This is shown schematically in Figure 4 below.

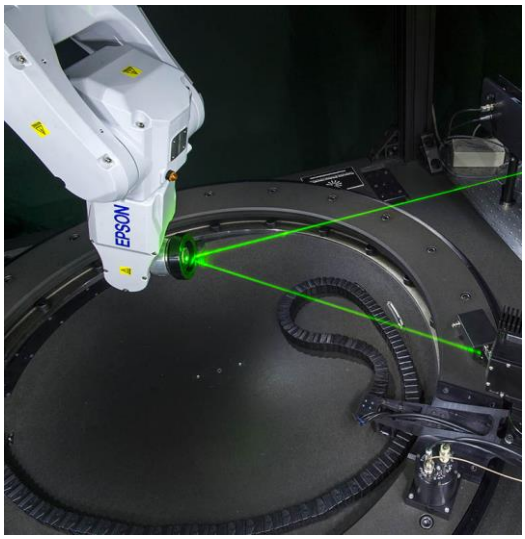

Figure 4: Image of the PSI BRDF/BDTF measurement system at the Measurement Standards Laboratory of New Zealand

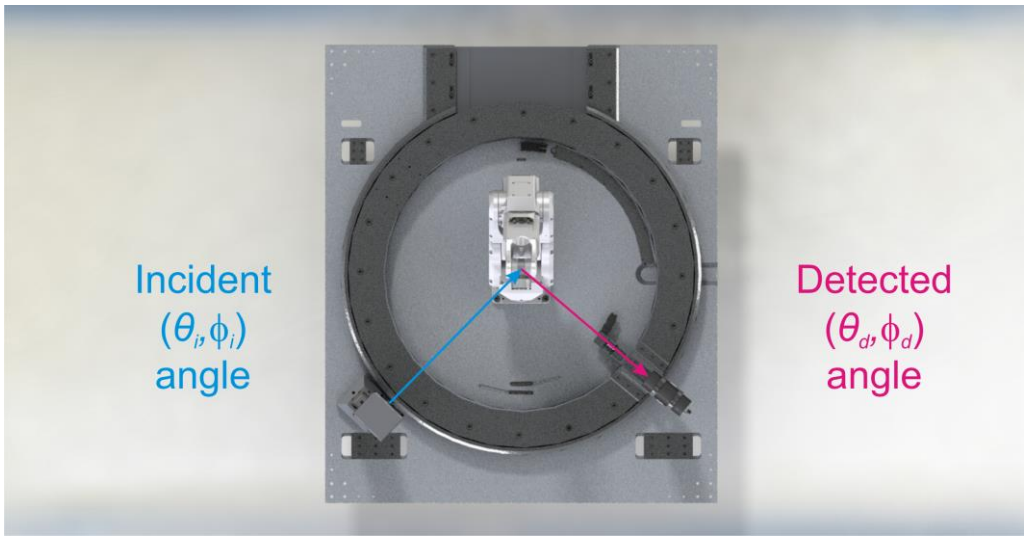

Figure 5: Schematic of incident and detected angles

Key specifications include:

Robot position repeatability:	± 20 μm
Robot angular repeatability:	approx. 0.1°
Robot angular resolution:	0.01°
Slew ring angular repeatability:	approx. 0.2°
Slew ring angular resolution:	0.01°

Light Source

The default light source is a collimated QH lamp. This is a broadband source covering the entire visible range and NIR which is run at a high correlated colour temperature in order to maximise the amount of signal in the blue end of the spectrum.

Other light sources are available on request or can be retro-fitted to the system in future.

Key specifications include:

Warm-up time:	Approx. 5 minutes
Correlated colour temperature:	Approx. 3,200 K
Drift:	< 0.25 % / hour
Measurement size:	1 mm, 3 mm or 10 mm interchangeable

Collection Optics

The collection optics for the detectors is f-matched to an optical fibre to transfer the received light from the detector head to the detector housing. Additionally, a high quality zero-aperture iris diaphragm is included on the front of the collection optics so that the operator can adjust the collection angle between wide angle (high signal) and low angle (high angular resolution). An aperture of 0.9 mm diameter will give an angular resolution of approximately 0.1° (for glossy samples), while the maximum aperture of 20 mm will give an angular resolution of approximately 2.3° but will receive around 500 times more signal (for diffuse samples).

Detectors

For the first detector, we will provide a simultaneous multi-ranging radiometer which will simultaneously read the broadband signal on four different amplification ranges. The software then chooses the measurement with the optimum amplification for each reading. With this system we have a dynamic range of 10^{10} (1 mA peak and 100 fA resolution). The amplifiers have built-in data acquisition and RS-485 comms with the PC. They have adjustable integration time (software-selectable) from 10 ms to 400 ms for trade-off between speed and accuracy.

The second detector is a 2048 pixel CCD array spectrometer with built-in shutter for automated dark measurements. Key specifications include:

Spectral range:	300 nm to 1000 nm
Optical bandwidth:	approx. 4 nm
Angular acceptance:	approx. ± 1°
Wavelength resolution:	1 nm
Wavelength accuracy:	0.25 nm
Digital electronic resolution:	16 bit ADC
Integration time:	0.01 to 65,535 ms
Dynamic range:	Approx. 10^7
Power supply:	Through USB or LAN, external option

The two detector systems, radiometer and spectroradiometer, are contained in the one housing. There will be one optical fibre input and the beam is split between the radiometer and the spectroradiometer so that the software can automatically combine measurements of the broadband signal and the spectrally-resolved signal without operator intervention.

Calibration

The system is self-calibrating by positioning the detector opposite the light source and measuring the light source directly.

Each measurement of a sample is then a ratio of the incident light source itself and is effectively a measurement of the spectral reflectance. Thus no calibrating sources such as reference tiles are necessary for calibration, although these are useful for verification.

Additionally, we will provide two reference reflectance tiles for relative calibration of the system. The tiles will be diffuse (near-Lambertian); one with high reflectance and one with low reflectance. They will be provided with calibration certificates from an ISO 17025 accredited laboratory.

Dead Angle

Because the light source is in the same hemisphere as the detector when measuring in reflectance mode, there will always be some part of the measurement field when the detector blocks the light source. The advantage of using a robot compared with traditional goniometers is that this is limited to within a field of only approximately 5° of the source.

In transmittance mode, the dead angle is limited by the depth of the sample holder and the size of the measurement area.

Software

The BiRT-2.0 comes with software that coordinates the measurement. Features include:

- A “manual mode” to perform arbitrary movements of the robot and slew ring for alignment purposes;
- Full measurement control including allowing the user to programme in their own angle ranges and intervals;
- In “high-speed” mode, the system moves continuously while taking measurements on the fly;
- In “high-accuracy” mode, the system stops at each measurement point to optimise the measurement signal-to-noise ratio.

The duration of a full test depends on the mode of measurement, the angular range and angular interval selected. In “high-speed” mode, the speed depends on the angular interval of measurement and angular precision set by the operator. For a given illumination direction, a complete hemispherical measurement with intervals of 5° in both θ and ϕ angles could be achieved in less than 15 minutes. In the case of high accuracy measurements, the measurement at each point will typically take between 0.3 and 3 seconds, depending on the strength of the signal.

PC

The client is to provide a PC based on PSI’s recommendations. We generally find that most problems encountered are PC-related so we prefer that this is supplied locally for local servicing.

Installation Requirements

The BiRT-2.0 comes with a light-tight enclosure so that it can be used in a room with normal lighting. Although the image shown on the front page of the quote shows the system “floating”, it is provided on a structure with braked wheels for manoeuvrability. The total size is approx. 1.4 metres wide x 1.4 metres deep x 1.6 metres high.

Shipping Terms

The equipment will be professionally packed in export-quality wooden cases but freight is not included (FCA Melbourne, Incoterms 2012).

Documentation

The equipment and software provided comes with a User Manual (in English) which details the procedures for measuring in easy to follow instructions. The manual also contains connection diagrams and troubleshooting guides to the various components of the system.

Installation and Training

Installation and training is not included but can be provided by special arrangement.

Warranty

PSI provides an unconditional warranty on all of the photometric equipment supplied for 12 months from the date of final acceptance, or according to the limitations of the warranty of the manufacturer of any individual component. During the warranty period, PSI will repair or replace any faulty equipment at no charge to the client. The client is responsible for fixing hardware failures in the PC system, however PSI will actively assist the client in determining the nature of and resolving any such problem that may occur.

This warranty does not cover misuse, abuse or accidental damage to the equipment. In such a case, all repairs and travel and accommodation expenses will be borne by the Client.