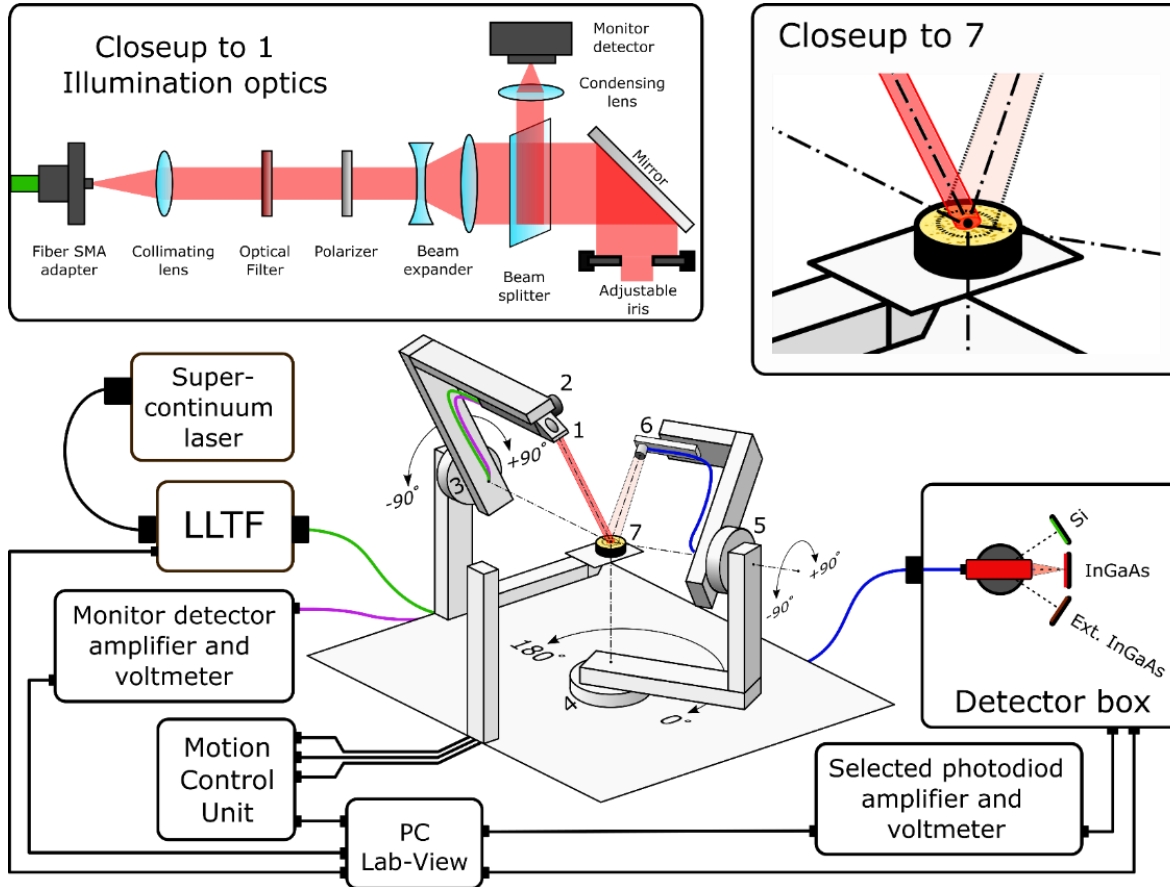


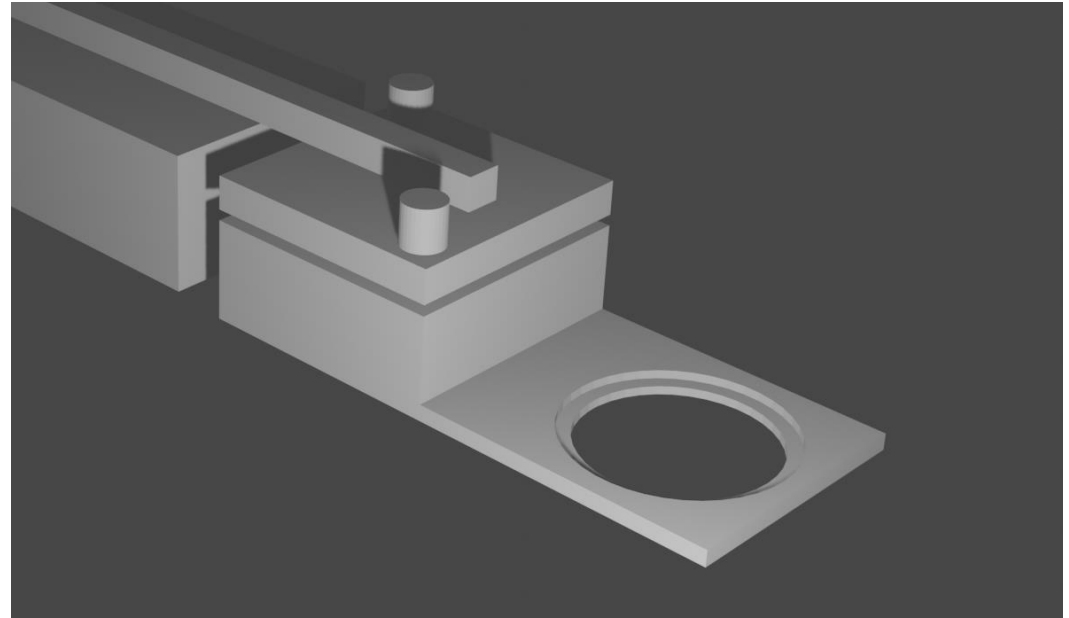
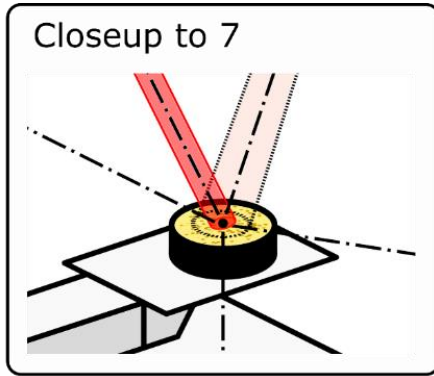
BTDF primary facility for the measurement of horizontal samples

*Robin Aschan
Farshid Manoocheri
Dmitri Lanevski*

3D goniometer setup



Conversion to transmittance config.

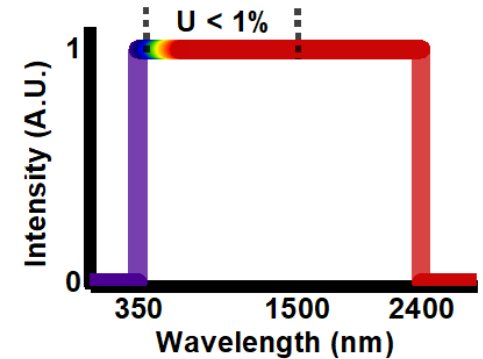
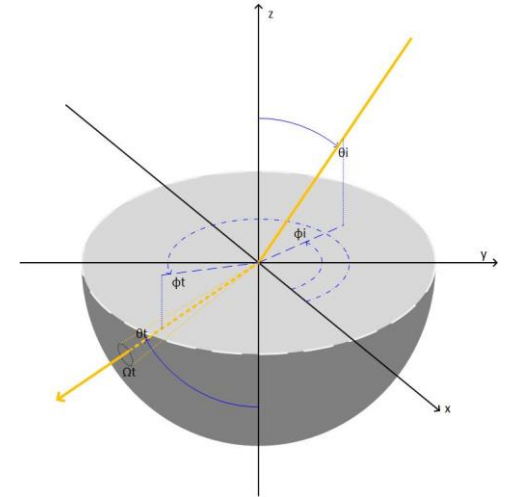




Aalto University

3D goniometer setup properties

Type	BTDF
Wavelength range	400 to 1650 nm (2100 nm)
Incident angles	$\theta_i = 0^\circ$ to $\pm 60^\circ$
Viewing angles	$\theta_t = 0^\circ$ to $\pm 70^\circ$ $\varphi_t = 0^\circ$ to 180°
Angular accuracy	$< 0.1^\circ$
Repeatability	$< 1\%$
Beam diameter	Variable: $\varnothing = 4$ to 20 mm
Sample-to-aperture distance	200 mm
Viewing area	Depends on θ_t , At $\theta_t = 0^\circ$ we have $\varnothing = 20$ mm
Viewing solid angle	Nominal value, $\Omega = 0.002$ sr



A! 3D goniometer uncertainty budget

Aalto University

Source of uncertainty	Standard uncertainty	Uncertainty in radiance signal of reference sample / %	Uncertainty in radiance signal of test sample / %	Uncertainty in sBRDF of test sample / %
Measurement noise*	0.30% - 0.40%	0.30 - 0.40	0.30 - 0.40	0.42 - 0.57
Non-linearity of the detectors*	0.05% - 0.09%	0.07 - 0.13	0.07 - 0.13	0.10 - 0.18
Stray light	<0.01%	<0.01	<0.01	0.01
Beam and sample nonuniformity**	0.14%	<0.01	0.14	0.14
Wavelength**	0.15 nm	0.015	0.015 - 0.15	0.02 - 0.15
Illumination and viewing angle**				
illumination zenith angle	0.09°	0.04	0.08	0.09
viewing azimuthal angle	0.09°	<0.01	0.06	0.06
viewing zenith angle***	0.09°	0.02	0.02 - 0.9	0.03 - 0.9
Polarization**	0.10%	<0.01	0.1	0.1
Instrument stability	0.1%	0.1	0.1	0.14
Sample surface level	0.1 mm	-	-	0.14
Reference sBRDF data	0.20%	-	-	0.20
Combined standard uncertainty of $q_m(\lambda, \theta'_i, \varphi'_i, \theta'_r, \varphi'_r)$				0.56 - 1.14

* These uncertainties depend on detector type at different wavelength ranges of measurements

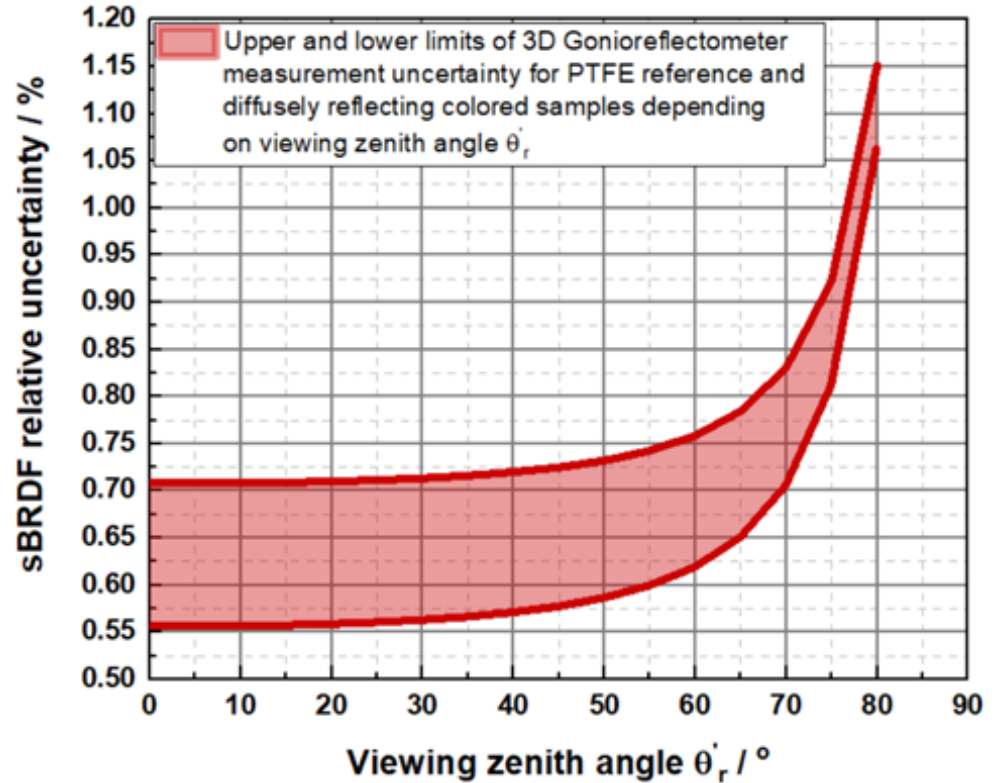
** These uncertainties depend on measurement sample

*** This uncertainty depends on viewing zenith angle



Aalto University

3D goniometer measurement uncertainty



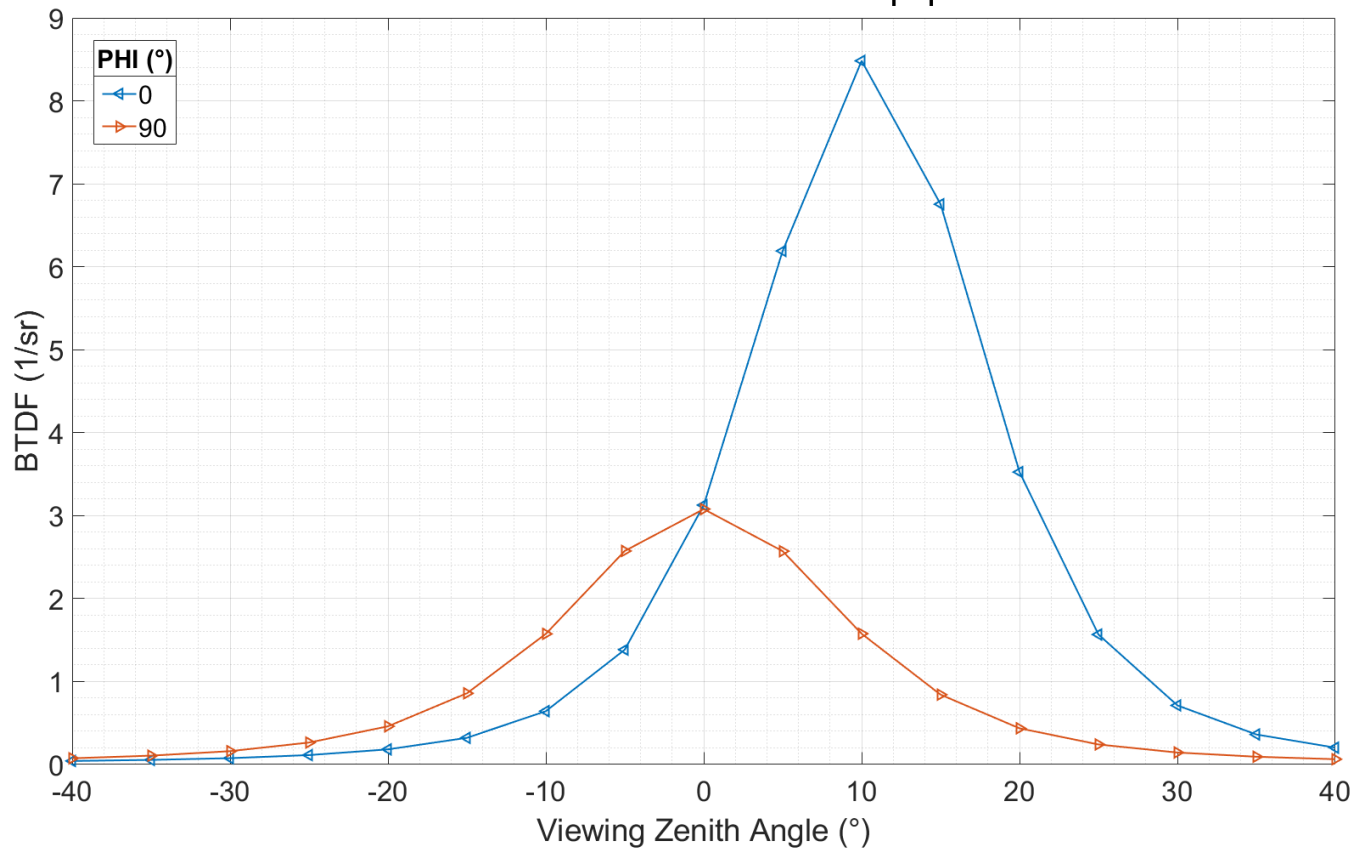
BxDiff – Set 13

Name	Thorlabs DG20-220
Type	NBK7, active surface sandblasted
Scattering description	Gaussian, FWHM 16°
Dimensions (mm x mm x mm)	Ø 50.8 x 2

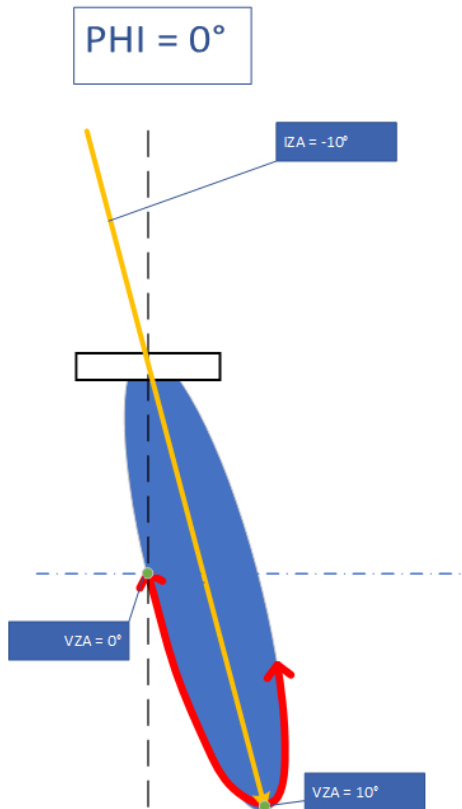
BxDiff – Set 13 – DG20

in- and out-of-plane, a-pol.

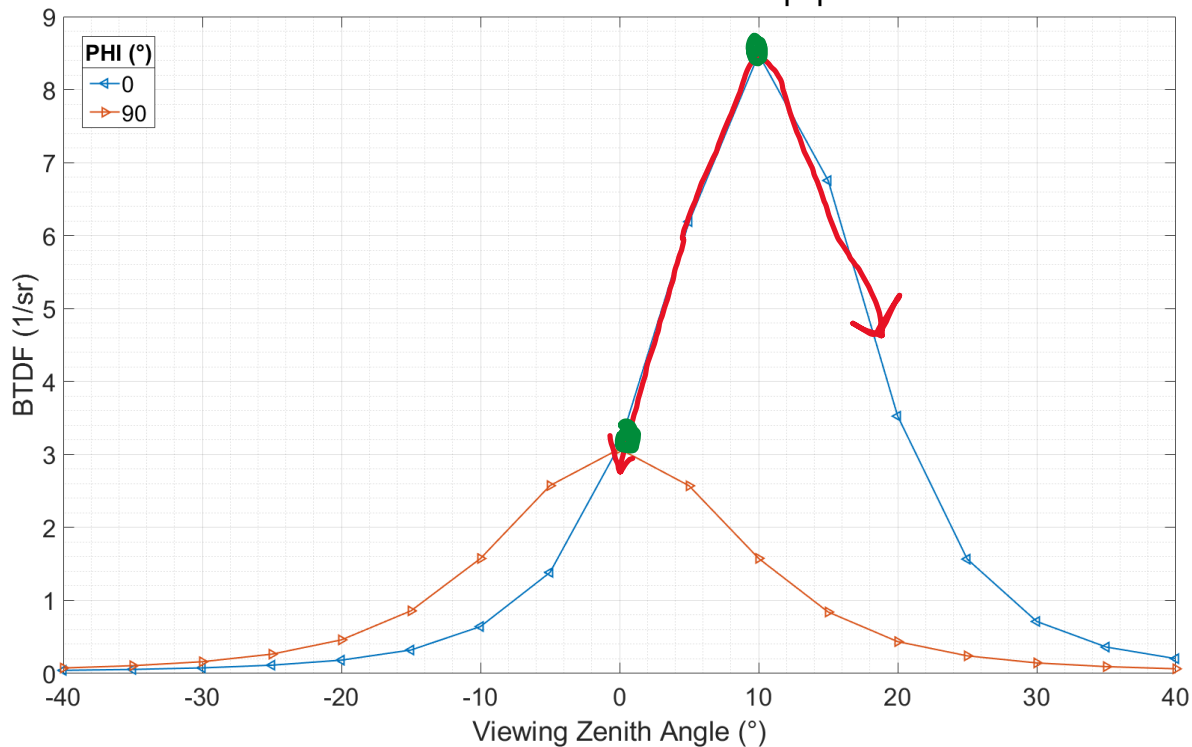
Wavelength = 550 nm, Incident angles $(\theta_i, \phi_i) = (170^\circ, 0^\circ)$



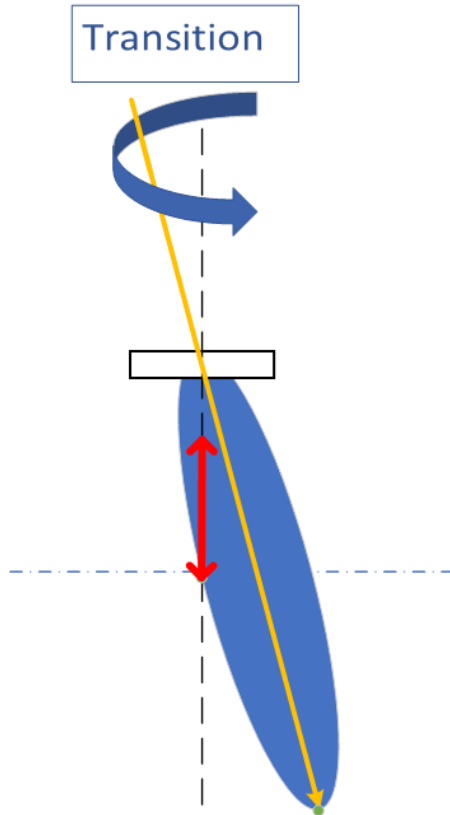
In- and out-of-plane visualization



Wavelength = 550 nm, Incident angles $(\theta_i, \phi_i) = (170^\circ, 0^\circ)$



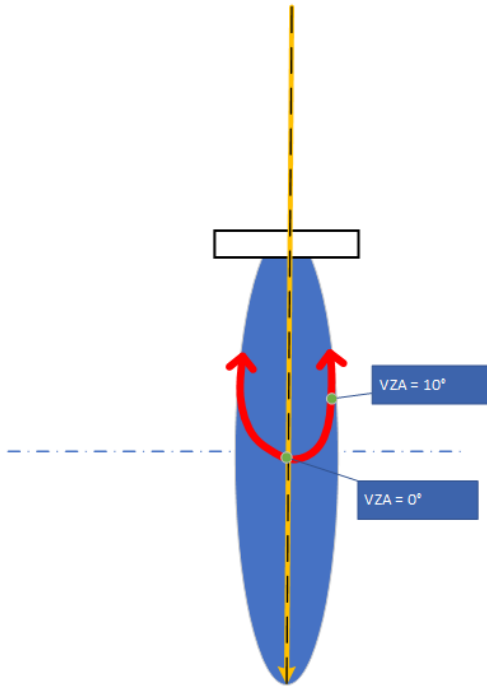
In- and out-of-plane visualization



- **Transition to $\text{PHI} = 90^\circ$**
- **Detector move perpendicular to the slide**
- **We should measure the same value at $\text{VZA} = 0^\circ$**

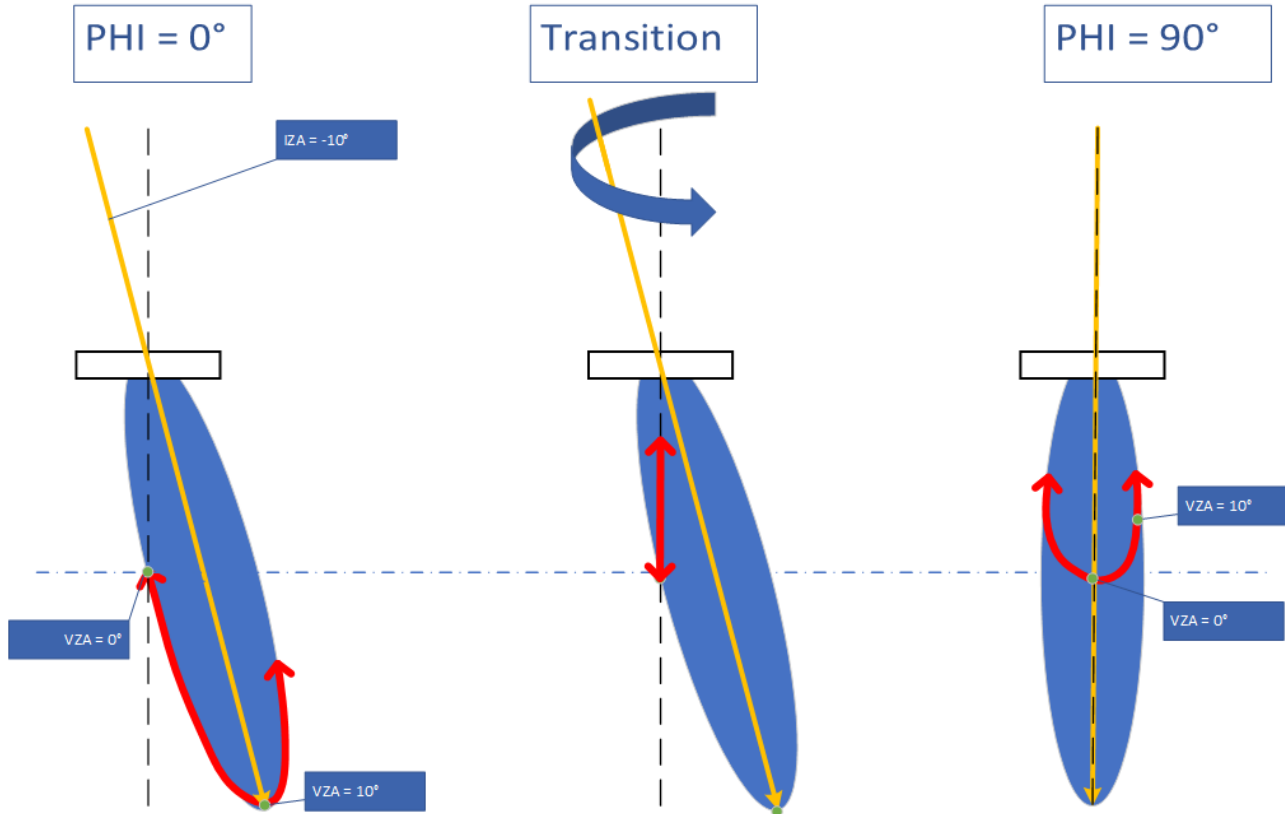
In- and out-of-plane visualization

PHI = 90°



- Starting point VZA = 0°
- Detector moves parallel to the slide from this perspective
- We miss the specular peak

In- and out-of-plane visualization



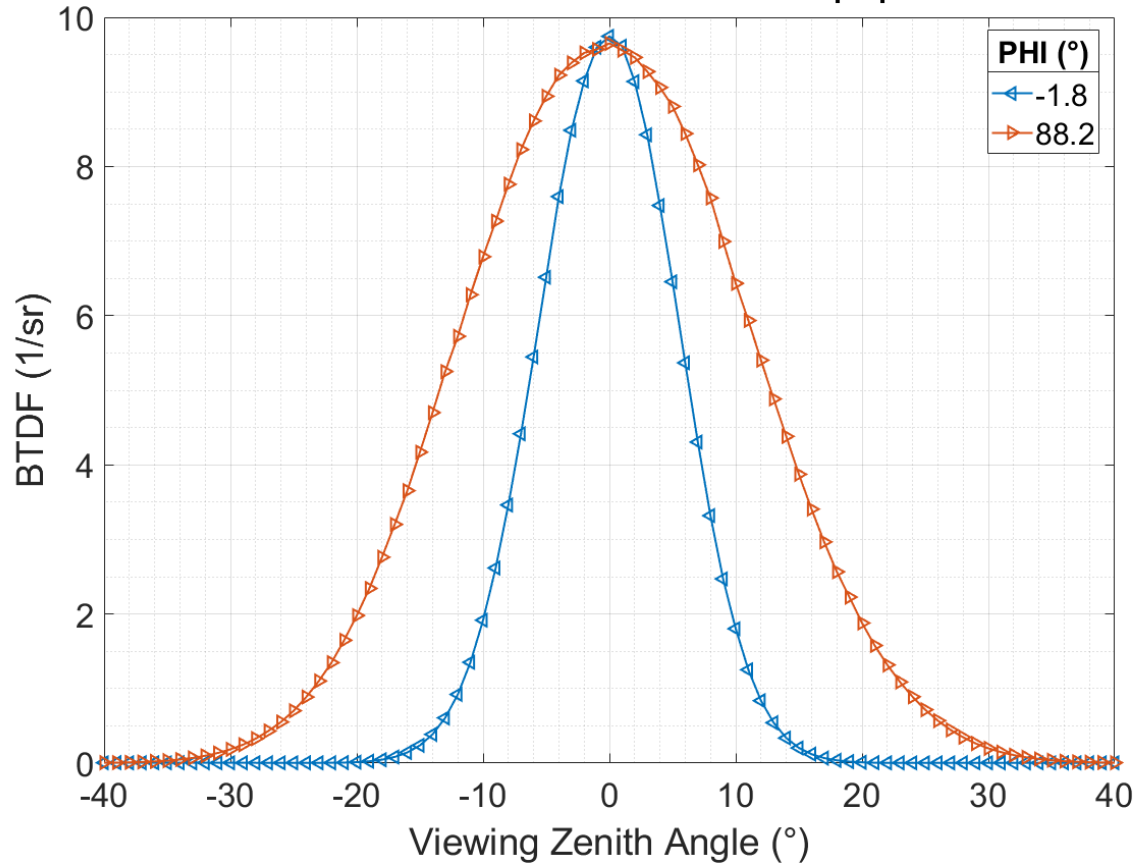
BxDiff – Set 13

Name	Temicon PAN001008
Type	Holographic on standard-glass
Scattering description	Gaussian elliptical, FWHM 24° x 12°
Dimensions (mm x mm x mm)	50 x 50 x 2

BxDiff – Set 13 - Temicon

in-plane, a-pol.

Wavelength = 550 nm, Incident angles(θ_i, ϕ_i) = (180°, 0°)



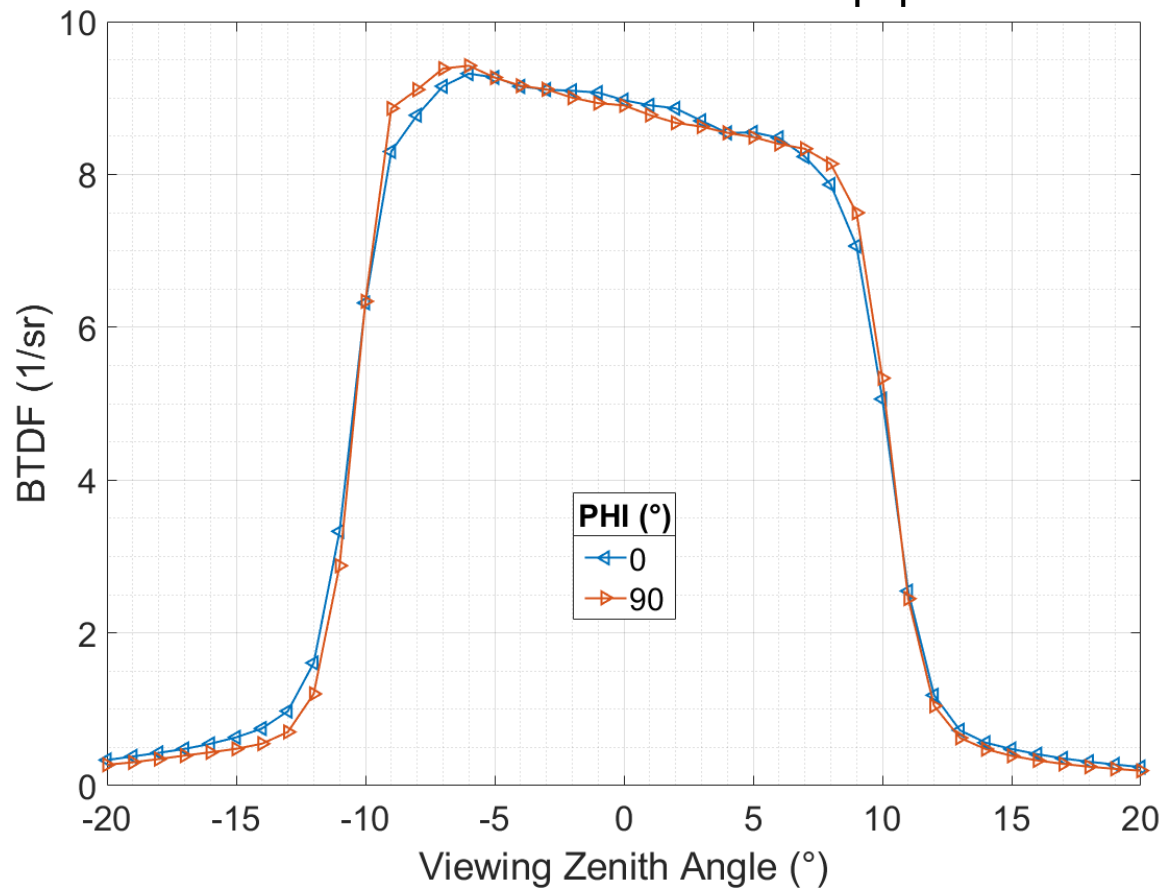
BxDiff – Set 10

Name	Thorlabs ED1-S20
Type	Injected molded Zeonor on N-BK7
Scattering description	Rectangular, FWHM ~ 20°/20°
Dimensions (mm x mm x mm)	Ø 25.4 x 1.5

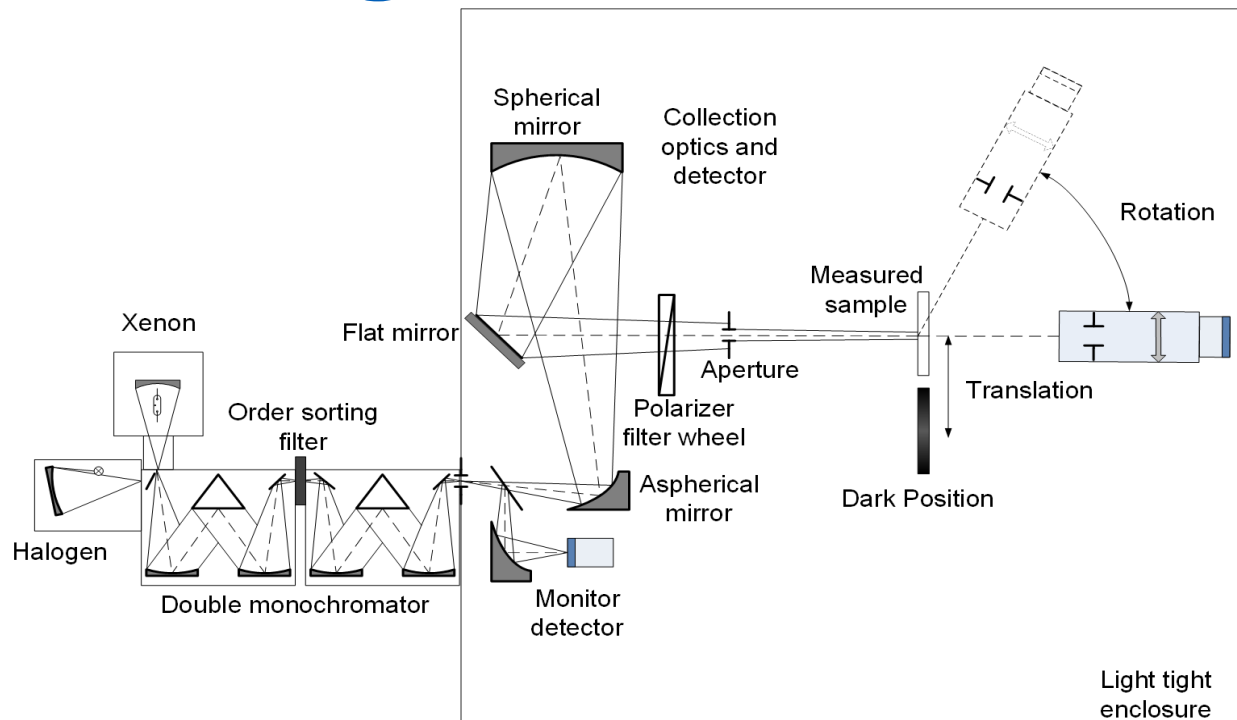
BxDiff – Set 10 – ED1

in-plane, a-pol.

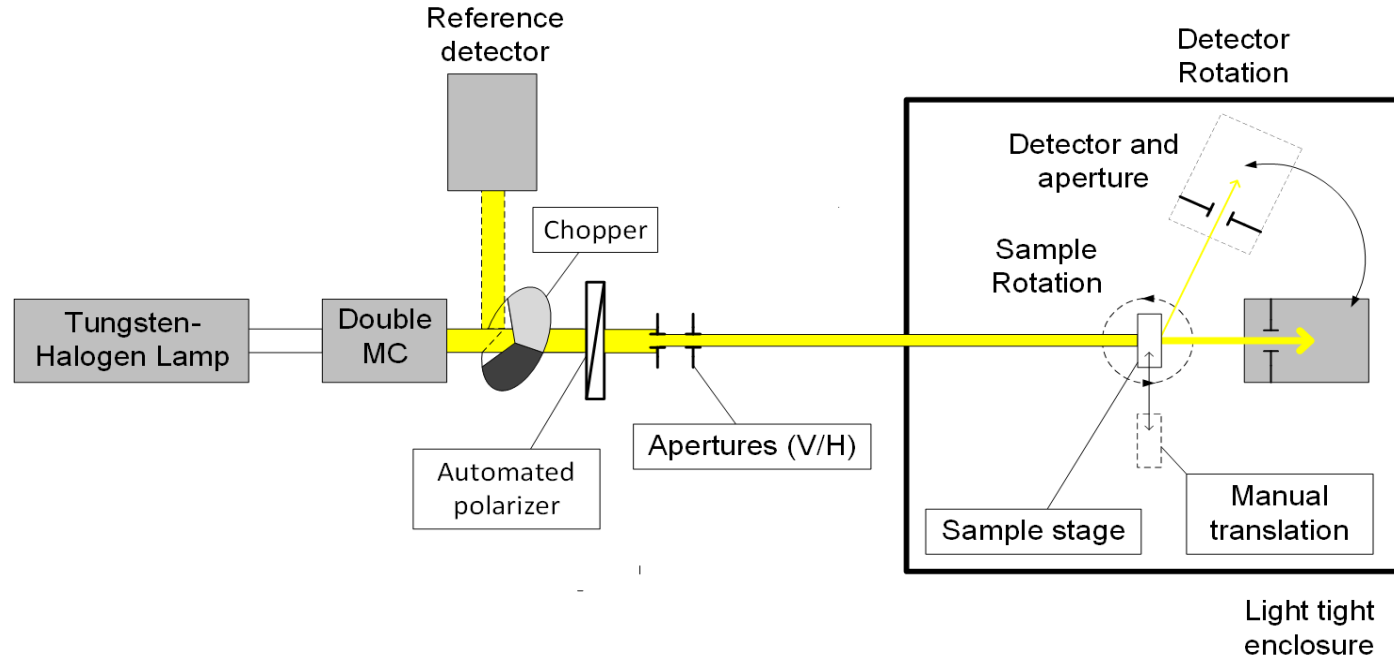
Wavelength = 550 nm, Incident angles $(\theta_i, \phi_i) = (180^\circ, 0^\circ)$

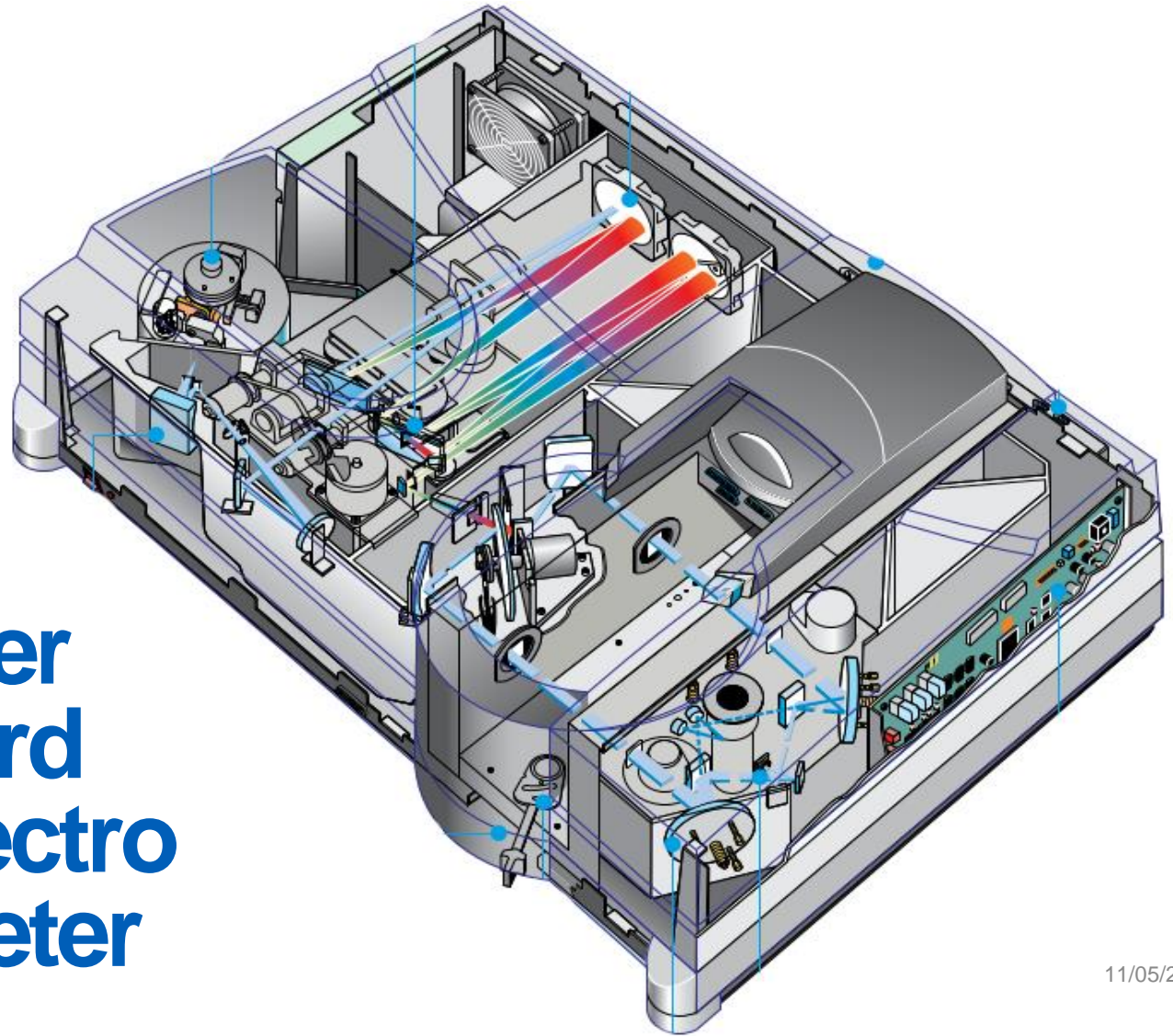


Absolute reference standard gonioscatterometer



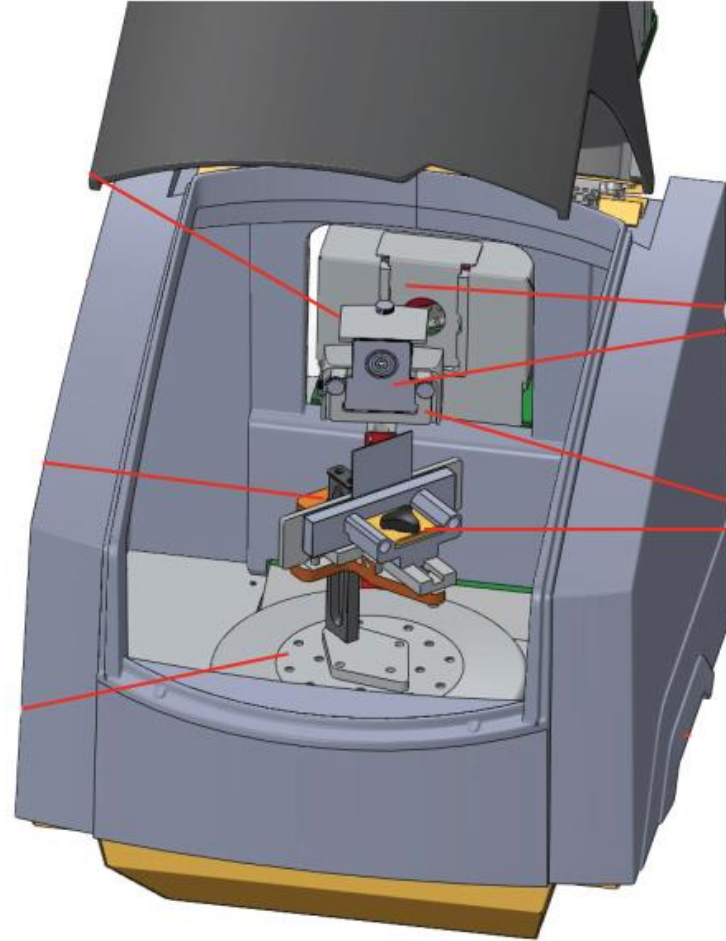
Transfer standard goniospectrophotometer





Transfer standard goniospectro photometer

Transfer standard goniospectro photometer



Measurement geometry & Instrument parameters

Type	BTDF
Wavelength range	250 to 2500 nm
Incident angles	$\theta_i = 0^\circ$
Viewing angles	$\theta_t = 0^\circ$ to $\pm 170^\circ$ $\varphi_t =$ Manual rotation
Angular accuracy	$< 0.2^\circ$
Repeatability	$< 1 \%$
Beam diameter	10x5 mm
Sample-to-aperture distance	130 mm
Viewing angle	Nominal value, $\Omega = 0.015$ sr

Measurements

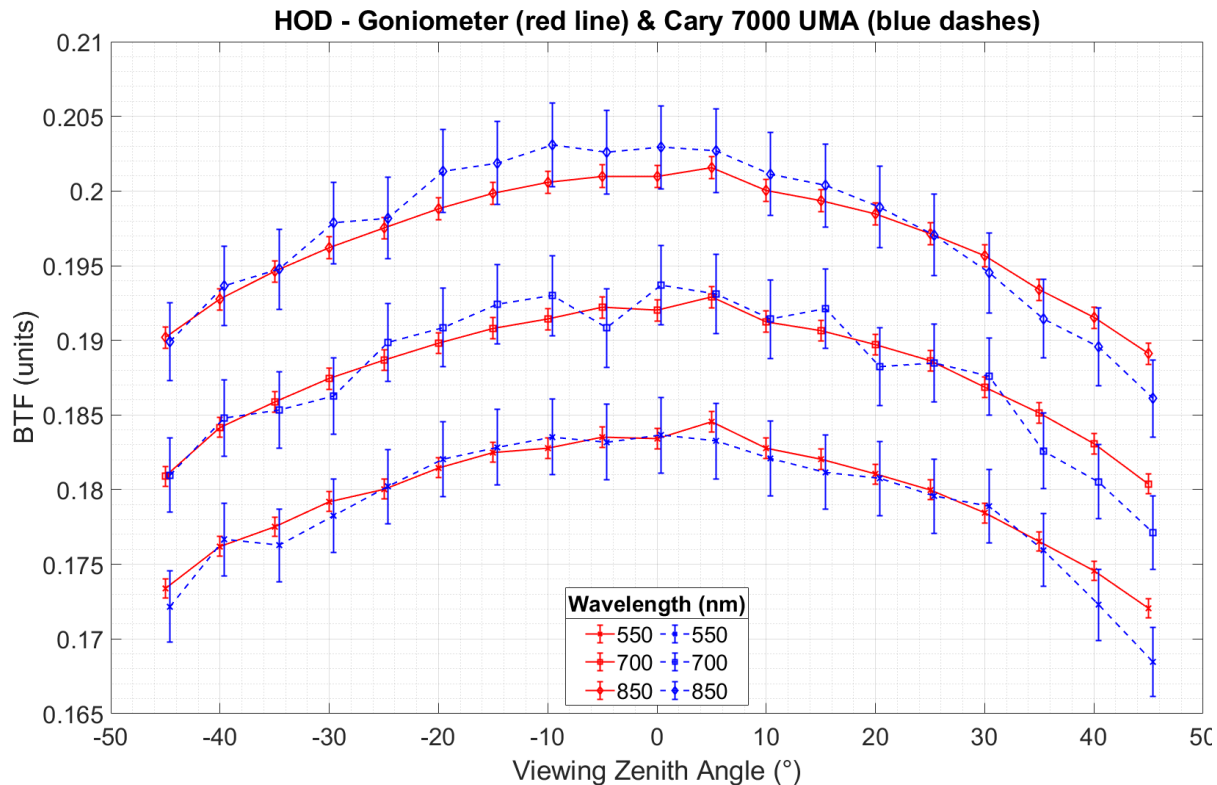
- In-plane
- Average Polarization
- Not reference corrected

BxDiff – Set 14

Name	Heraeus HOD-500
Type	Fused synthetic SiO ₂ with uniform bubbles
Scattering description	Lambertian
Dimensions (mm x mm x mm)	Ø 50 x .2

BxDiff - Set 14 – HOD 500

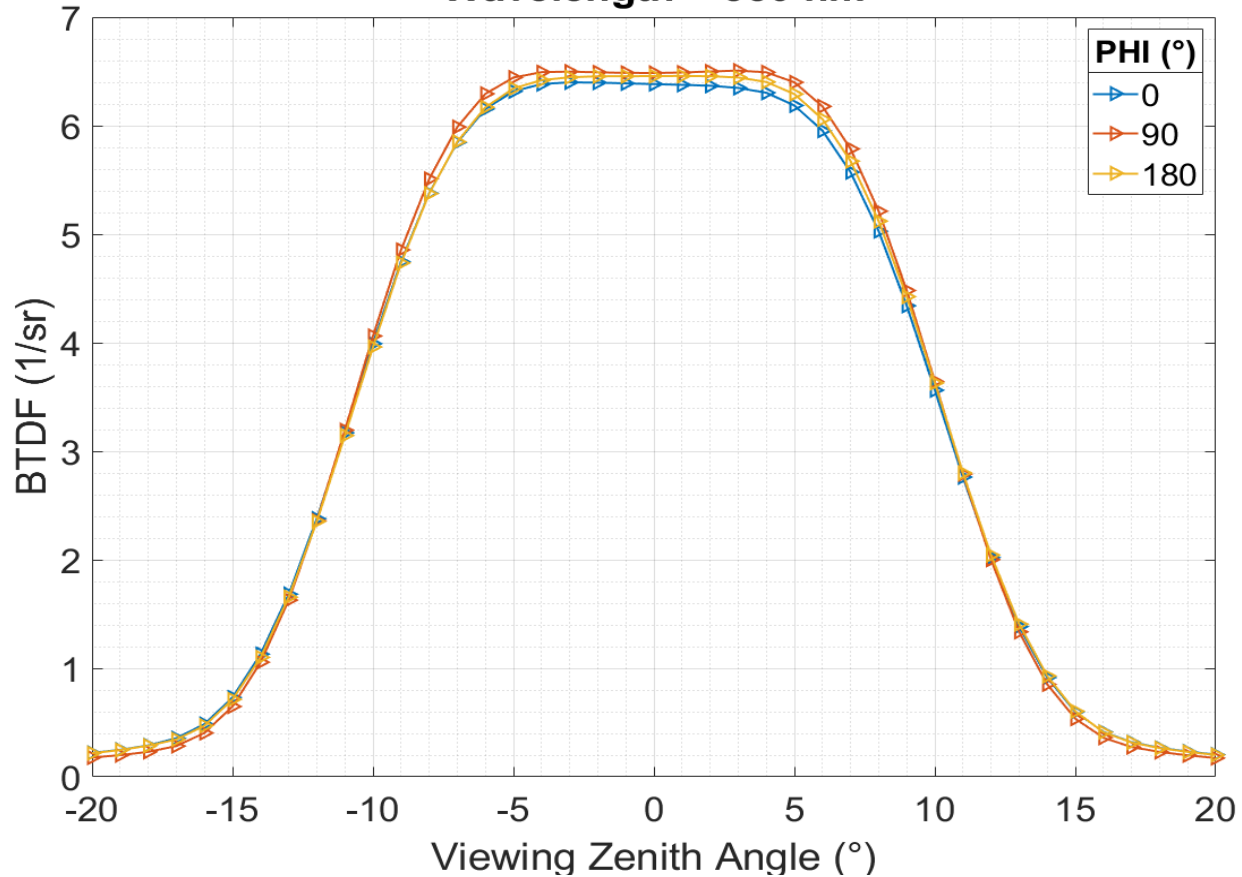
in-plane, a-pol.



BxDiff - Set 10 – ED1

Transfer Instrument

Wavelength = 550 nm



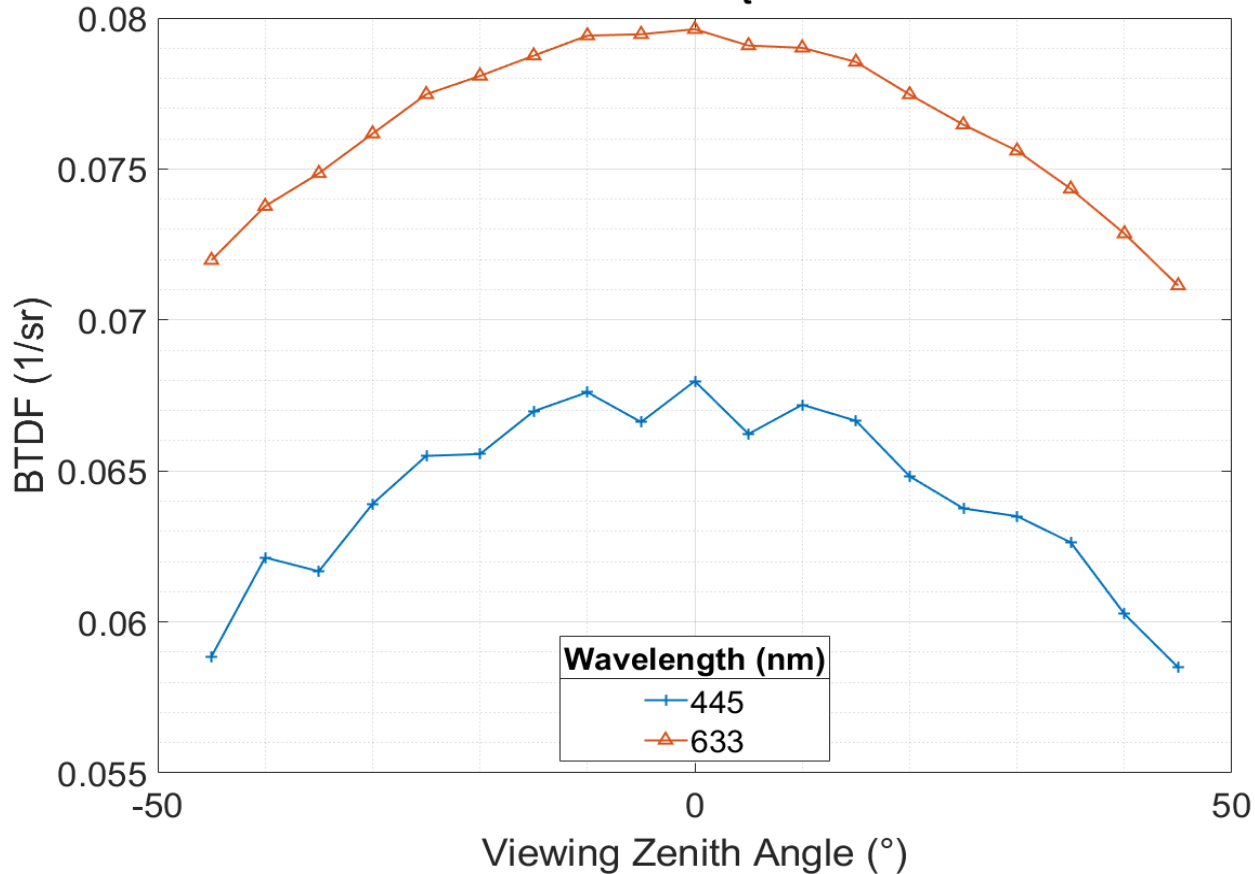
BxDiff – Set 10

Name	Sphere Optics
Type	Zenith Polymer; PTFE foil, between two 90 mm x 110 mm plates
Scattering description	Lambertian
Dimensions (mm x mm x mm)	Ø 45 x (3/0,25/3), 3 by plate

BxDiff - Set 10 – PTFE

Transfer Instrument

Viewing $\phi_t = 0^\circ$



End of presentation