Application Note

Monitoring ecosystem optical properties with the UniSpec-SC

Understanding patterns of ecosystem properties is important if we are to effectively monitor ecosystem change due to a variety of reasons (e.g. global changes, human management). Remote sensing provides a great tool for monitoring the earth's surface at different temporal and spatial scales. Patterns of vegetation and biodiversity dynamics are important ecosystem properties, with strong links to important ecosystem functions. Species distribution and vegetation change pattern at different temporal (e.g. seasonal) and spatial scales offer an ecological basis for land use and conservation plans. Ground base ecosystem monitoring can be accomplished using the PP Systems' **UniSpec-SC** (single channel) spectral analysis system (this can also be achieved using the **UniSpec-DC**). This application note mainly targets the use of the **UniSpec-SC** for ecosystem monitoring.

The **UniSpec-SC** has widely been used for leaf level reflectance measurement with a built-in halogen lamp, bifurcated fiber optic cable (UNI400-Standard/UNI410-Mini) and a leaf clip (UNI500-Standard/UNI501-Mini). The **UniSpec-SC** can be easily used for canopy and ecosystem reflectance measurements so that the measurements can be used for multi-scale analyses (Cheng et. al., in press). For measurements of canopy reflectance, the internal halogen lamp is not required and can be disabled. At present, PP Systems offers two options for measurement of canopy and ecosystem reflectance based on a "defined" and "manual" field of view (FOV):

Option 1 –Defined FOV

If the exact FOV is required, PP Systems can supply FOV lens with a defined FOV. Most customers will require a straight fiberoptic (generally 2m in length) and a specific FOV for the downward looking foreoptic. At present, we offer three different FOV lens accessories (3°, 6° or 12°) along with associated fiberoptics to choose from.

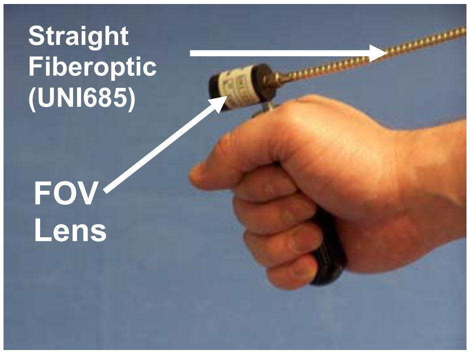

Figure 1. Straight Fiberoptic (SMA-SMA) and FOV lens.

Other FOV lens and straight fiberoptics are available and made to order. If a different FOV or straight fiberoptic is needed, please contact PP Systems and let us know the requirements. The FOV lens has a standard tripod thread built into it to allow it to be used with camera tripods (for stationary use) or it can be used for hand-held applications with a simple hand grip supplied as standard. It is very common for customers to request a 2m length fiberoptic along with one or more FOV lens.

PP SYSTEMS

For **UniSpec-SC** customers that want to measure canopy/ecosystem reflectance using a defined FOV lens, we recommend the following system configuration:

Qty	Cat. No.	Description
1	UNI007	UniSpec-SC Spectral Analysis System (310-1100nm, VIS/NIR) Including: System console, user interface, basic spares, software and operation manual.
1	UNI685	Straight Fiberoptic, 2M, SMA-SMA
1	UNI700	3° FOV Lens
1	UNI420	Uncalibrated Reference Standard

If a customer requires a 6° or 12° FOV, then recommend the following in addtion to or instead of the Part No. UNI700:

Qty	Cat. No.	Description
1	UNI705	6° FOV Lens
1	UNI710	12° FOV Lens

Option 2 – Manual FOV

For the downward looking foreoptic, PP Systems can supply a straight fiberoptic (Part No. UNI684) with a standard SMA type connector (for connection to the UniSpec-DC detector and a custom ferrule on the other end). The custom ferrule has a 100mm tip constructed out of stainless steel. The ferrule provides a FOV determined by the acceptance angle of the fiberoptic (approximately 25° full angle). A simple way to manually reduce the FOV is to slip over the ferrule a piece of "Hypo Tube" that is slightly longer than the ferrule itself. For example, a piece of "Hypo-tube" that is approximately 10mm longer than the 100mm ferrule will provide a FOV (full angle) of approximately 20°.

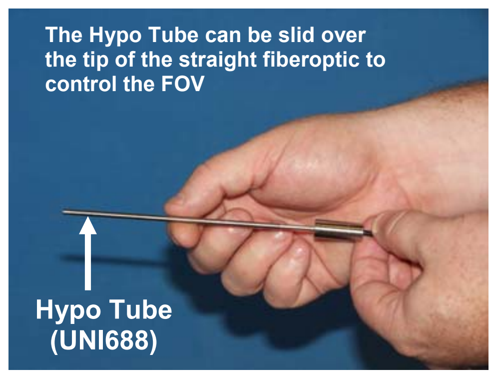

Figure 2. Straight fiberoptic (SMA-custom ferrule) and hypo tube.

For **UniSpec-SC** customers that want to measure canopy/ecosystem reflectance using a manual FOV, we recommend the following system configuration:

Qty	Cat. No.	Description
1	UNI007	UniSpec-SC Spectral Analysis System (310-1100nm, VIS/NIR) Including: System console, user interface, basic spares, software and operation manual.
1	UNI684	Straight Fiberoptic, 2M (for use with the Hypo Tube)
1	UNI688	Hypo Tubing (1/8" Diameter)
1	UNI420	Uncalibrated Reference Standard

If a different length straight fiberoptic is required, please contact PP Systems and let us know the requirements.

The **UniSpec-SC** detects radiance from 310 to 1100 nm with an average nominal bandwidth of approximately 3 nm and a full-width-half-maximum of approximately 10 nm. To get high resolution of the measurement, it is important to adjust the integration time to make the radiance measurement at about 90 to 95 percent of the full scale (e.g. ~60K A/D counts). To sample canopy/plot radiance, the end of the fiberoptic is placed over a canopy or plot. The viewed footprint can be easily calculated using field of view angle and the distance between canopy/plot surface and fiberoptic. The reference is very critical and should be taken seriously. Since the **UniSpec-SC** is a single channel instrument, it is important to perform the reference measurement (against a reference standard/target) frequently, especially when the ambient light is changing (cloudy/partly cloudy/sunny, etc.). Therefore, before performing scans on the sample, ensure that you have a good reference scan for best results. Reflectance is determined from canopy radiance divided by radiance of a 99%-reflective white standard panel (equation 1):

$$R_{target} = \frac{I_{target}}{I_{99\%\,panel}} \qquad (1)$$

Figure 3. Using **UniSpec-SC** in the field to measure ecosystem optical properties. Reference measurement (left) and target measurement (right) are required in order to calculate the reflectance. (Photo courtesy of Dr. John A. Gamon at California State University, Los Angeles)

where R_{target} is the percent reflectance of the target, $I_{99\%panel}$ is the response of the **UniSpec-SC** sensor when the straight fiberoptic is over the 99% reflectance panel (Figure 3 left), I_{target} is the response of the **UniSpec-SC** sensor when the fiberoptic scans the target (Figure 3, right). Several vegetation indices can be calculated using different combination of the reflectance at a certain wavelength based on the research interests. The normalized difference vegetation index (NDVI) is generally used to estimate fraction of PAR absorbed by the canopy/ecosystem (fPAR). Photochemical reflectance index (PRI) is generally used to estimate light use efficiency and water band index (WBI) is mainly used to estimate surface wetness and water vapor fluxes. NDVI, fPAR, PRI and WBI can be easily calculated using equation 2~5:

$$NDVI = \frac{(R_{800} - R_{680})}{(R_{800} + R_{680})} \qquad (2)$$

$$fPAR = 1.24 \times NDVI - 0.168 \qquad (3)$$

$$PRI = \frac{R_{531} - R_{570}}{R_{531} + R_{570}} \qquad (4)$$

$$WBI = \frac{R_{900}}{R_{970}} \qquad (5)$$

The fPAR equation (Equation 3) was a relationship derived empirically by comparing NDVI values to field measured fPAR values for a large range of southwestern vegetation (r^2 = 0.95, Sims et al., in press). In this relationship, a correction was applied for the green part of the vegetation, eliminating any confounding contribution of non-photosynthetic vegetation components (e.g. stems or dead leaves) to the fPAR. NDVI and PRI are two useful vegetation indicies for estimating the carbon sequestration function of the ecosystem (Fuentes et. al., in press; Sims et. al., in press). WBI is a very important index showing plant and water relation (Claudio et. al., in press). These indices can also be used for species land cover analysis and comparing for the seasonal effects on the ecosystems (Figure 4) (Claudio et. al., in press).

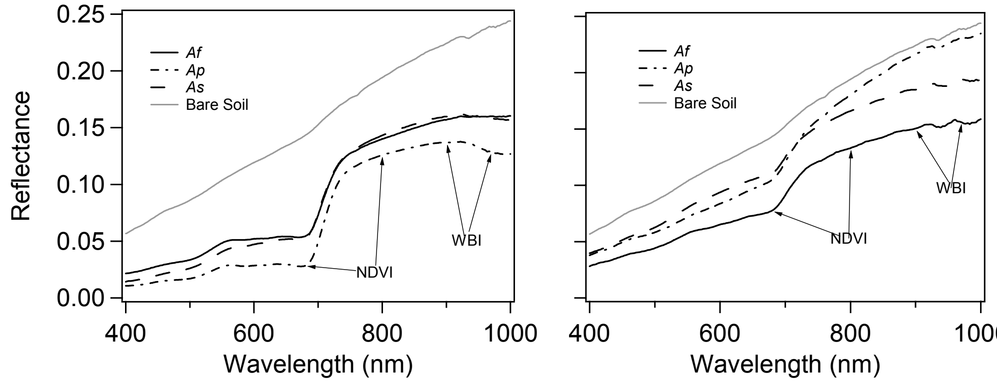

Figure 4. Different species have very different spectral pattern at different seasons. This indicates that we can use **UniSpec-SC** to monitor species distribution and stress level. (*Af = Adenostema fasciculatum* (chamise); *Ap = Arctostaphylos pungens* (manzanita); *As = Adenostema sparsifolium* (redshank))

References:

Cheng Y, Gamon JA, Fuentes DA, Mao Z, Sims D, Qiu HL, and Claudio HC (in press), A multi-scale analysis of dynamic optical signals in a Southern California chaparral ecosystem: a comparison of field, AVIRIS and MODIS data. *Remote Sensing of Environment*.

Fuentes DA, Gamon JA, Cheng Y, Qiu HL, Mao Z, Sims DA, Rahman AF, Oechel WC, Luo H (in press), Mapping carbon and water vapor fluxes in a chaparral ecosystem using vegetation indices derived from AVIRIS. *Remote Sensing of Environment*.

Claudio HC, Cheng Y, Fuentes D, Gamon JA, Rahman AF, Qiu H, Sims DA, Luo H, and Oechel WC (in press). Monitoring drought effects on vegetation water content and fluxes in chaparral with the 970nm water band index. *Remote Sensing of Environment*.

Sims, DA, Luo, H, Hastings, S, Oechel, WC, Rahman, A, and Gamon, JA (in press), Parallel adjustments in vegetation greenness and ecosystem CO_2 exchange in response to drought in a Southern California chaparral ecosystem. *Remote Sensing of Environment*.

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