TECHNICAL NOTE TN2022_8 – WHITE REFERENCE TILE AND SAMPLE LEVEL

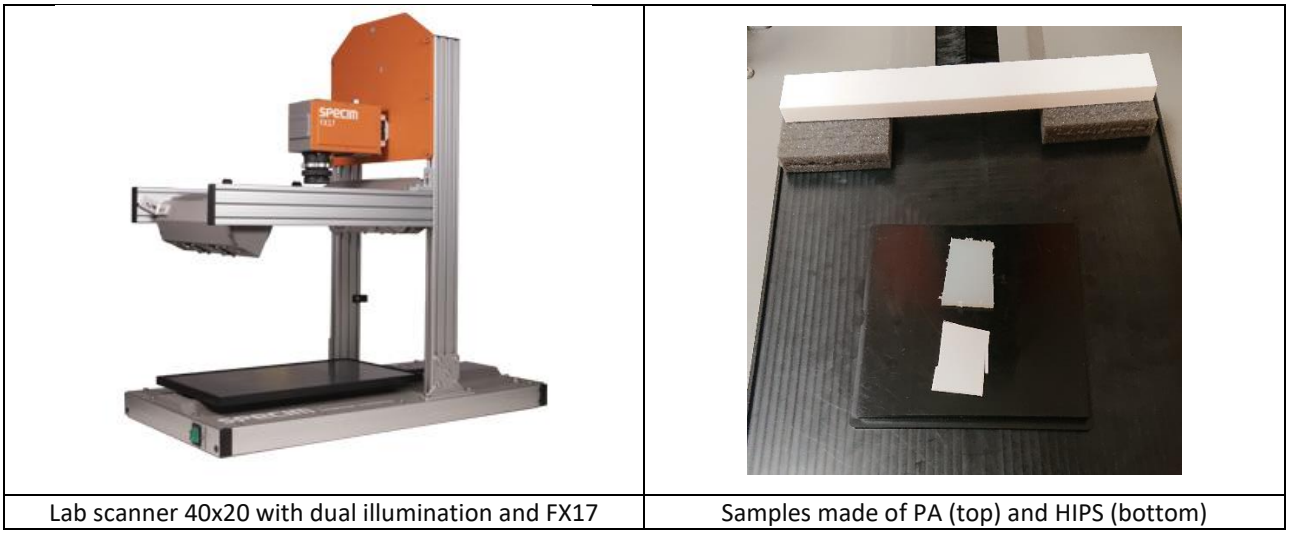
Introduction

When converting hyperspectral data into reflectance, the white reference is needed. It measured the incoming light, seen by the camera, taking into account the transmission of the optics and the Quantum Efficiency of the detector. Its role is therefore crucial in the obtention of good reflectance data. This article highlights why it is important to adjust the height of the white reference tile when making measurements.

Article

When proceeding with measurements, it is recommended to have the top surface of the white reference tile placed at the same level as the top surface of the sample. If the sample is not flat, the top surface of the sample is not the most relevant position for the white reference, but the middle "height" of the sample (of what can be seen). In order to assess how the level of the white reference tile may affect measurements, the following experiment has been carried out:

- A FX17 was mounted on a lab scanner with dual illumination (see Fig. 1)
- The white reference tile was placed so that its top surface was at 20 mm above the black sample tray. The illumination of the scanner was adjusted so that it maximized at this white reference level.
- Two flat samples of PA and HIPS (plastics) were measured 13 times, with every time a different level in respect to the white reference: -20 mm, -15 mm, -10 mm, -5 mm, same level, +5 mm, +10 mm, +15 mm, +20 mm, +25 mm, +30mm, +35mm and +40 mm.
- The illumination was not adjusted for each measurement but was kept constant so that the white refence signal was maximized. This approach was chosen as it is the most realistic one when users use the system.



Lab scanner 40x20 with dual illumination and FX17	Samples made of PA (top) and HIPS (bottom)

Figure 1: SPECIM lab scanner and samples used in this TN.

For easier reading of this TN, the analysis was divided not two parts: i) when the samples were first located lower than the white reference tile, and then ii), when those were located higher.

1. **Samples are placed at a lower position than the white reference tile**:

   Spectra of the samples were scrutinized and compared as in Fig.2:

   - The relative position of the samples with the white reference tile does not significantly affect the shape of the spectra. The change is mostly on their level.
   - Regarding the calculated reflectance level changes in respect to sample and white reference tile positions, it decreases while the sample gets deeper. The drop is in fact rather significant as for some wavelength is can be up to few %.

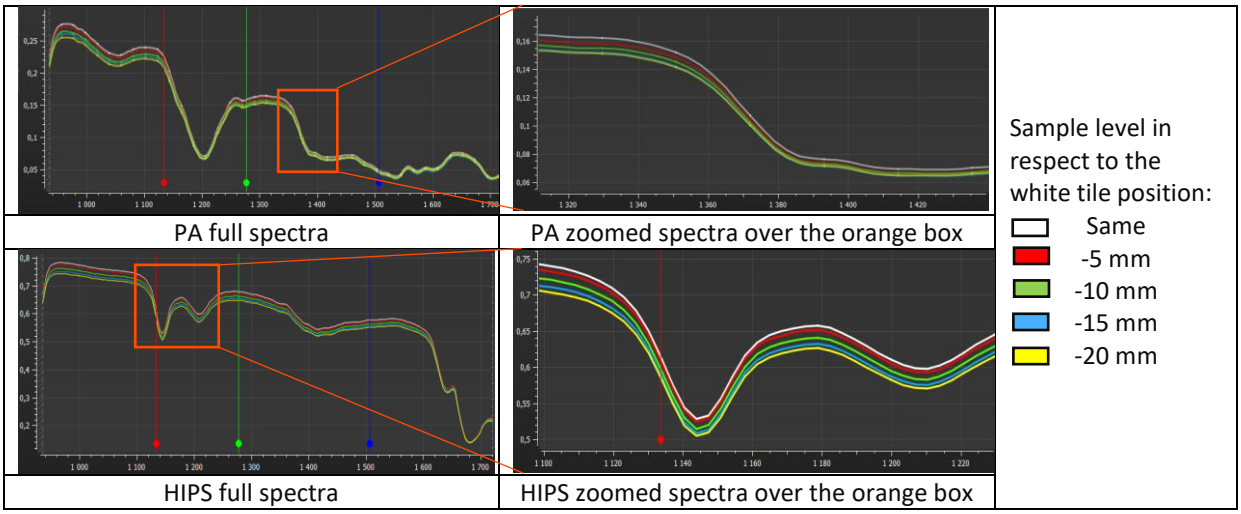
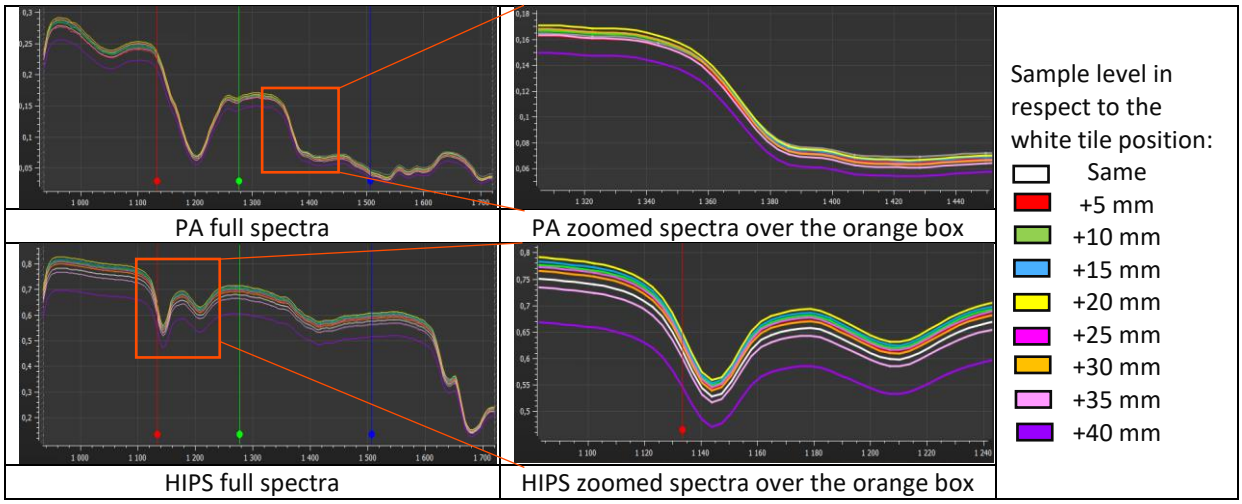


Figure 2: spectra of PA and HIPS acquired with FX17 at different negative levels in respect to the white reference position.

2. **Samples are placed at a higher position than the white reference tile**:

   Results are illustrated in Fig.3:

   - As observed in the previous section, the shape of the spectra is not affected, but only its level.
   - Here again, the calculated reflectance values vary with the level of the sample. This time there is not clear trend as observed previously, but the values increased or decreased with the increasing height difference. The variation can be larger than 10% (in absolute scale) which is very significant.

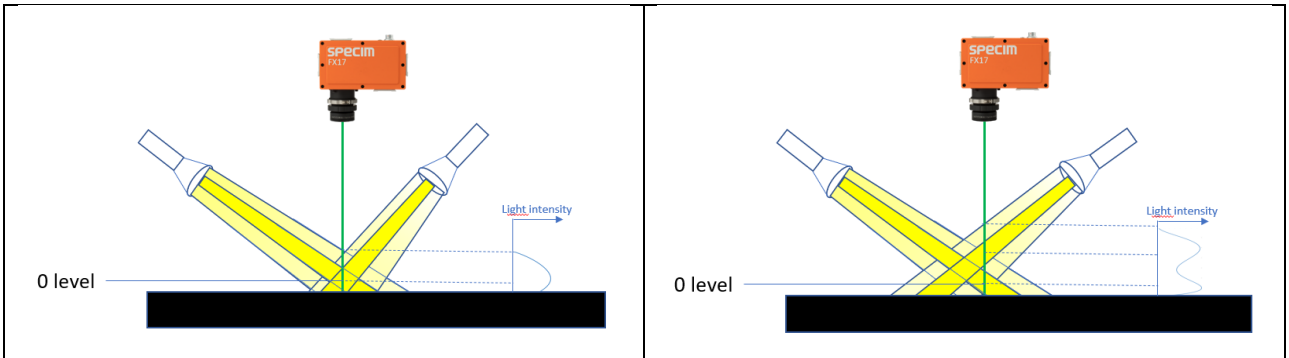


PA full spectra | PA zoomed spectra over the orange box

HIPS full spectra | HIPS zoomed spectra over the orange box

Figure 3: spectra of PA and HIPS acquired with FX17 at different positive levels in respect to the white reference position.

For both cases, the shape of the spectra is not affected by the difference of samples heigth with the white reference tile, but the spectrum level is. This is due to the variation of illumination irradiance along the pass-line of the camera. In Fig.4, two situations are illustrated: i) when the light is rather well adjusted to a single area and ii) when it is not. In the first case, the light irradiance will decrease when moving away from the 0 position, whereas in the second geometry, variations are not only in one direction.



The illumination is adjusted on a single area | The illumination is not adjusted on a single area

Figure 4: Illustration of light intensity variation along the pass-line of the camera depending on the illumination adjustment.

For some applications, the absolute signal level of the spectrum is crucial. For quantitative applications, this needs to be carefully considered, as a bias in observed reflectance would yield to major misinterpretation of data. There are in fact pre-processing tools which can correct drift or offsets in spectra (see TN2022_5 about Insight pre-processors). However, there are still applications which required a precise adjustment of the white reference tile level with the sample height. Colour measurement is one of those. The samples and the white reference tile should be placed at the same level, as precisely as possible.

For applications, which rely more on the shape of the spectra rather than on the level, this is not that critical, and there is some flexibility. For instance, for sorting, there could be a heights difference, which then allows the sorting of samples with a certain profile (like wastes). In the above example, HIPS and PA could still be sorted, even though they would not be placed at the same level as the one of the white reference tile. Samples could also have a different height, this would not affect their separation.

Also, the Depth of Field (DOF, see TN2022_1) should also be addressed here. Sample which are not flat may be imaged blurry. This is not directly linked with the difference of height with the white reference tile. However, the focus is typically adjusted at the same level of the white reference. Hence this final remark.

From an optical perspective, since the distances camera – samples and camera – white reference tile would not remain constant, this may be intuitive and straight forward to consider it as a reason for the spectral intensity variations. However this is not correct. Even though it is true that the energy of a light ray decreased with the square of its length, it is compensated by the increased of the pixel size on the sample (which by consequence also increased by an equal square factor the area of which the light is collected).

Nevertheless, when the sample height varies, the geometry camera – sample – illumination varies as well, and this combined with reflective properties of the sample surface may also explain the results of this study. If a sample has a perfect diffuse surface (Lambertian), then the reflected radiance measured by the camera is not affected by the change in the measurement geometry. But if there is any specular component in the reflectance of the sample, this may contribute in the measured variations. And in this study, samples are not Lambertian.

Version history

Version	Date	Author	Comments
1.0	Nov. 7th 2022	MMA, IKO, KKA, HHO	