Light Source Compensation in Absorption and Transmission Spectral Measurements

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The simplest type of absorption spectrometer is based upon a single beam configuration. As shown in Figure 1, the incident light at each wavelength (λ) passes through the sample and the transmitted light is then detected. The amount of light absorbed by the sample is determined from the incident light intensity ($I_{0\lambda}$) and the transmitted light intensity (I_λ). The absorbance at any given wavelength is defined as:

$$A_\lambda = \log \frac{I_{o\lambda}}{I_\lambda}$$

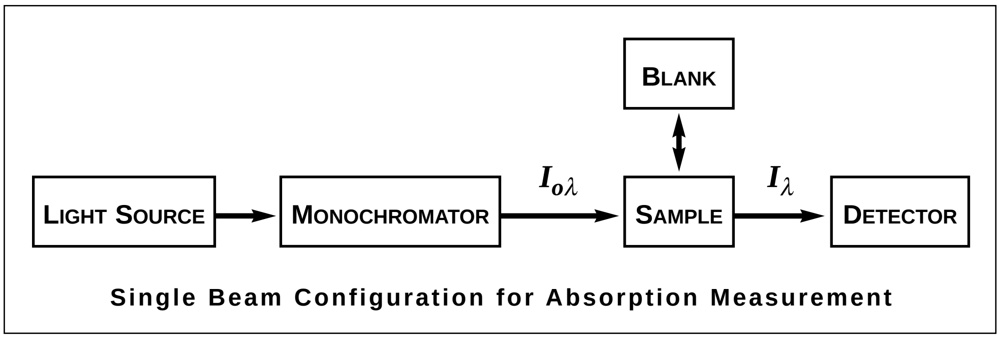

FIGURE 1

To get an absorbance spectrum, a blank or reference spectrum must first be taken in order to have the $I_{0\lambda}$ for each measurement point. After the $I_{0\lambda}$ spectrum is recorded, the spectrum of the sample can be taken and can then be divided by the reference spectrum. The log of the resultant spectrum will produce the absorbance spectrum.

The accuracy, and more importantly, the reproducibility of the calculated absorbance at each point in the spectrum is primarily limited to the stability of the illumination source over the time that the measurement is made. Accurate measurements of multiple samples, especially in a manufacturing environment, could be compromised by short term and long term source variability.

In order to eliminate unwanted effects due to source fluctuations, a dual beam configuration can be employed wherein at each measurement point the source is simultaneously monitored and the measurement is compensated for any variation in its output. Figure 2 shows a typical source compensating dual beam configuration.

In this configuration a beam splitter is used to send a small percentage of the incident light ($I_{0\lambda}$) directly to a second detector, D2. The signal from this detector ($I_{\lambda 2}$) is measured simultaneously with the signal from the primary detector, D1, which is monitoring the light intensity (I_λ) after passage through the sample.

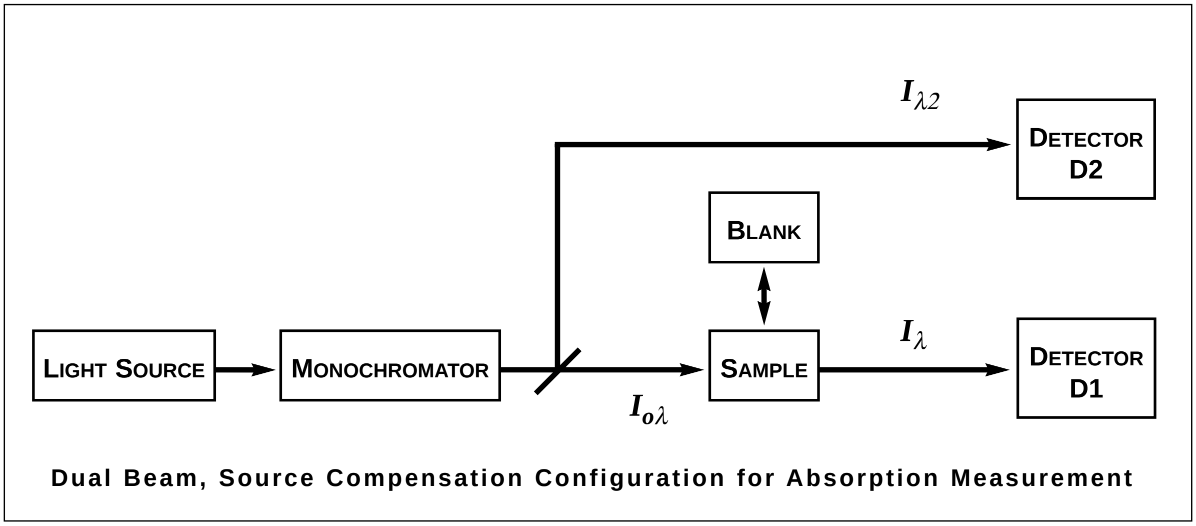

FIGURE 2

We can compensate for differences due to the wavelength dependent reflectivity variations of the beam splitter and response differences between the detectors, by creating a calibration or correction file which is the ratioed output, D1/D2, with no sample in place. When the data from D2 is multiplied by this calibration, the resultant intensity value would be the same as that which would be measured by D1 with no sample in place, i.e., $I_{0\lambda}$. It would then be possible to take real time absorbance measurements which are independent of the absolute intensity of the source or changes in its long term spectral output.

$$A = \log \left(\frac{\text{correction file x D2}}{\text{D1}} \right) \rightarrow \frac{\{I_{o\lambda}\}}{\{I_{\lambda}\}}$$

In as much as detector and grating responses do not change significantly over very long periods of time, this configuration is extremely stable, reproducible and independent of the source. Therefore, if multiple measurements are to be made at different spectral bandwidths, or there is variability in the reproducibility of the monochromator slits, it would not be necessary to take new blank spectra for each bandpass selection or slit readjustment, as would be the case in a single beam design.

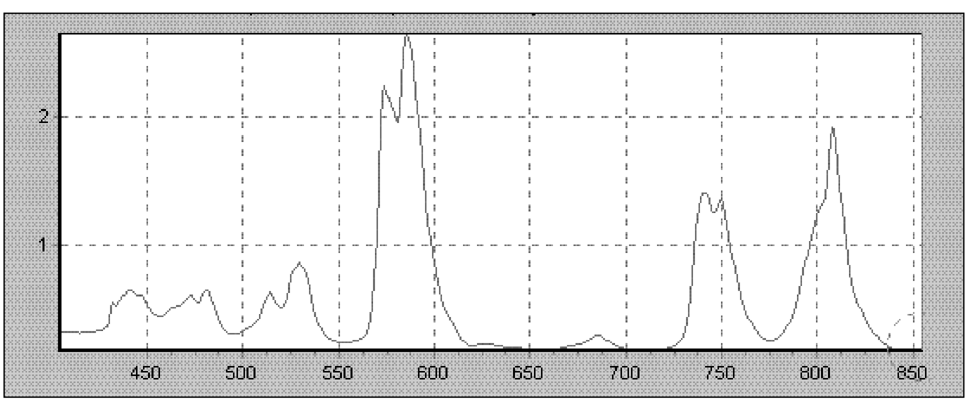

FIGURE 3

Figure 3 is an absorption spectrum of didymium. Figure 4 is an expanded view of the 744nm peak, showing the change in the absorbance values when the lamp output is varied over a 15% range. In Figure 5 the same spectra were acquired with the source compensation channel being read and the calculation performed in real time. It is evident that the dual beam configuration leads to extremely reproducible results over a wide operating range.

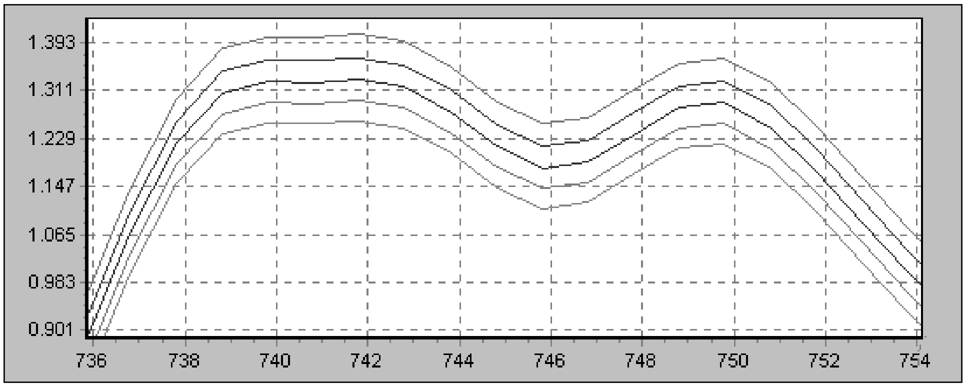

FIGURE 4

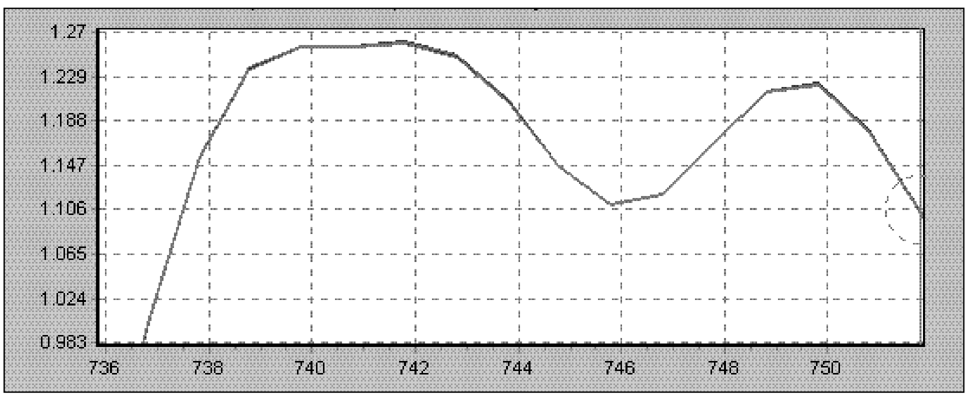

FIGURE 5

Is source compensation always necessary? For one-shot survey analysis, where the accuracy of the measurement can be to within a few percent, source compensation does not offer a significant advantage. However, if measurements are to be made continuously or the reproducibility of the measurement must be better than 1%, then the dual beam configuration is warranted.

Acton Research offers a source compensation accessory that can be used over the 200 - 2000nm range and mounts directly to any of its monochromator exit slits. This design permits source compensation to be added to any ARC sample chamber or client-designed sampling system. The compensation accessory has also been designed to be used with fiber optic cables and probes. It is also appropriate for reflectance and fluorescence measurements. The NCL data acquisition system and SpectraSense™ software incorporate all the automated functionality required for on-the-fly compensation and real time measurements in absorbance, % Transmission and % Reflectance units.

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