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SPECTRA OF THE MONTH

NON-DESTRUCTIVE PILL SORTING USING NIR SPECTROSCOPY

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INTRO

BACKGROUND OF APPLICATION

Pill sorting is a critical step in pharmaceutical manufacturing, ensuring that each medication meets strict requirements for composition and dosage. While sorting is often associated with weight-based verification at the pharmacy level, manufacturers must also verify pill identity and formulation during production, where even minor compositional differences can impact quality and safety.

Conventional methods for confirming pill composition typically involve dissolving or grinding tablets prior to analysis. Although effective, these techniques are destructive and render the medication unusable. To avoid this, many facilities are turning to non-destructive analytical approaches. Spectroscopy provides a fast, contact-free method for evaluating pill composition, making it well suited for high-throughput sorting applications.

The spectral regions used for pill identification can span from the UV to the mid-infrared, depending on the formulation. For nonsteroidal anti-inflammatory drugs (NSAIDs) such as aspirin and ibuprofen, multiple distinctive absorption features appear in the near-infrared (NIR) range. In addition to reliable differentiation, practical pill sorting requires rapid measurements, precise timing, and repeatability. This study demonstrates that all of these requirements can be met using our NIR spectrometers.

In this experiment, NIR absorbance spectra were collected from multiple aspirin pills and a single ibuprofen pill. A measurement setup representative of industrial pill-sorting systems was implemented and will be featured at our Photonics West 2026 booth. Although the pills share a similar appearance, their NIR spectra reveal clear differences, allowing the ibuprofen tablet to be identified as an intentional outlier among the aspirin samples.

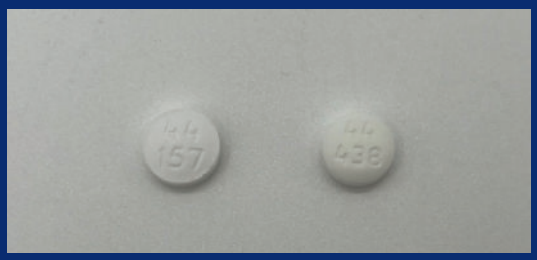

FIGURE #1 NSAID pills used for this experiment, including aspirin (left) and ibuprofen (right).

DESCRIPTION OF SPECTROSCOPY SETUP

The setup for this experiment (Figure 2) utilized our AvaSpec-NIR256-1.7-HSC-EVO spectrometer. Specifically for measurements in the NIR range up to 1.7 µm, this model pairs our high-sensitivity optical bench with next generation electronics for exceptional performance, including 0.4 ms/scan sample speed and integration times as fast as 20 µs. The AvaSpec-NIR256-1.7-HSC-EVO is equipped with our trusted InGaAs (Indium-Gallium-Arsenide) array detector, a thermally electric-cooled optical bench, and our ultra-low-noise electronics board with both USB3.0 and Giga-Ethernet connection ports onboard. Additional features include multiple grating and replaceable slit options, as well as digital and analog I/O ports, which can be used to control the shutter or pulse of connected light sources and the gain setting of the spectrometer, with either High Sensitivity or Low Noise. The instrument used in this experiment had a wavelength range of 900-1700 nm and a 50-micron slit installed.

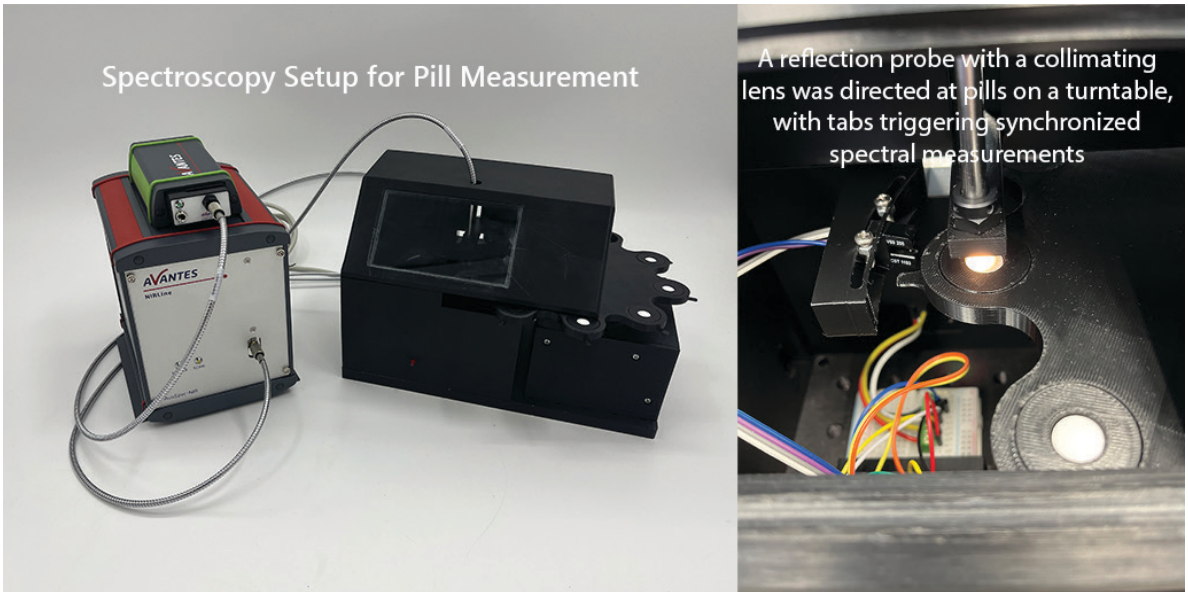

FIGURE #2 Experimental setup for pill measurements. The pills were placed in a turntable that had tabs on the end to activate an optical trigger connected to the spectrometer. This allowed precise measurements of each pill to best determine where the outlier pill was located. When the outlier pill was detected, a red LED mounted on the front of the housing was illuminated.

The light source used for this experiment was the AvaLight-Hal-S-Mini, a compact, stabilized halogen light source. Designed to work from visible light to near-infrared, the AvaLight-Hal-S-Mini is equipped with an adjustable focusing on the fiber connection to maximize output power at desired wavelengths. Other features of the AvaLight-Hal-S-Mini include an internal TTL shutter that is controllable from an AvaSpec spectrometer, and the ability to directly attach a cuvette holder, attenuator, or a combined cuvette holder and attenuator.

Other accessories used for this experiment included an FCR-7UVIR400-2-ME reflection probe, a collimating lens, a WS-2 white reference tile, and a custom-designed, 3D-printed system to simulate a real pill sorting application. This system included a turntable controlled by an Arduino Uno, an optical trigger activated by tabs on the ends of the turntable wheel that externally triggered the spectrometer, an arm to hold the collimating lens in place, an LED that lit up when the outlier pill was detected, and an enclosure to isolate the measurement and reduce the effects of ambient light.

DESCRIPTION OF METHODOLOGY

Aspirin and ibuprofen pills were purchased from a local pharmacy and chosen for their similar round, white appearance, making them difficult to distinguish visually. Nine aspirin pills and a single ibuprofen pill were placed on a turntable, with the ibuprofen randomly selected as the outlier; the experiment would have worked similarly if the positions were swapped. The turntable rotated at approximately 1.4 rev/s and included tabs at each sample position to activate an optical trigger, which was slightly offset to compensate for trigger delays. Additionally, an LED was connected to the spectrometer and programmed to illuminate via a TTL signal whenever a significant difference in a spectral peak was detected.

For data analysis, we used Absorbance mode and the TimeSeries module in AvaSoft, our exclusive custom software package. Absorbance mode, as the name suggests, is designed for absorbance applications, where the reference measurement will report 0 A.U. (absorbance units) and higher A.U. values for the dark measurement. In this experiment, the WS-2 white reference tile with the light source engaged was used as the reference. The same tile with the light source disengaged was used as the dark. These measurements were taken with the turntable off for ease of acquisition. We used an integration time of 5ms, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. While a large number of averaging would typically be used with such a short integration time to provide more consistent spectra results, for this application, averaging was set to 1 to ensure a single measurement was associated with each pill. The TimeSeries module was used to record the magnitude of an observed absorbance peak for each pill sample over the whole duration of measurements. This module can also track the peak wavelength in a certain range or the integral of a wavelength range over time, among other functions. This mode was also used to send a TTL signal out from the spectrometer when the absorbance peak intensity fell outside a defined range, determined from previous measurements of the pills. This TTL signal was sent to a red LED mounted on the front of the enclosure to provide an additional visual indication when the ibuprofen pill was measured.

TEST DATA AND RESULTS

Displayed below are the absorbance measurements of both pills, along with the TimeSeries of absorbance peak intensity between 1645-1665 nm:

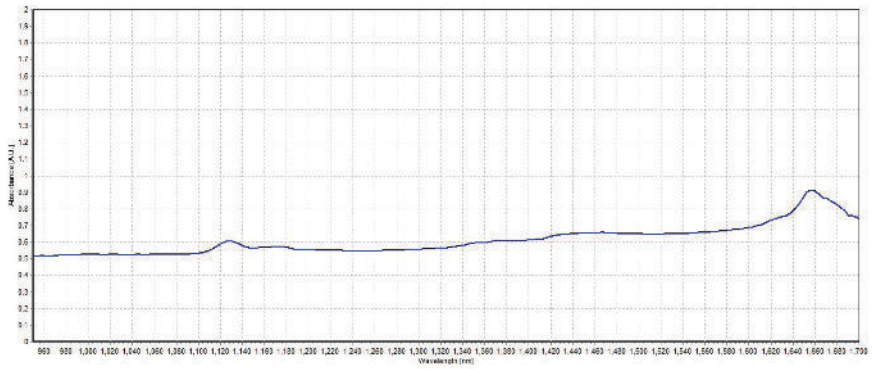

FIGURE #3: Absorbance spectrum of aspirin pill.

TEST DATA AND RESULTS

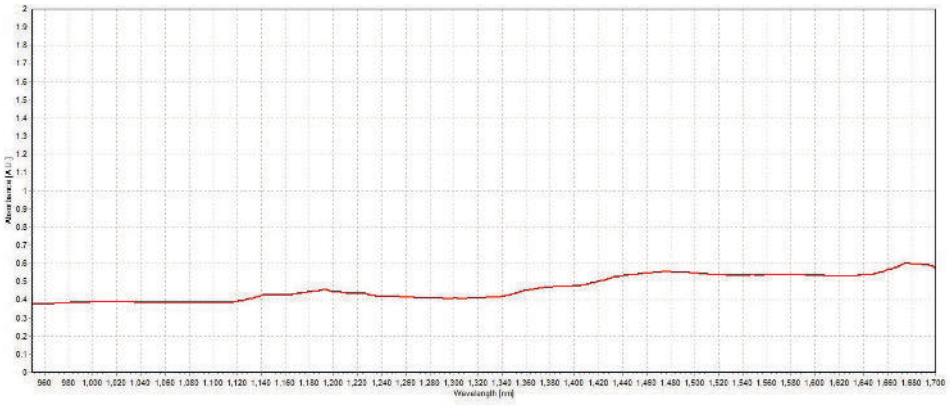

FIGURE #4: Absorbance spectrum of ibuprofen pill

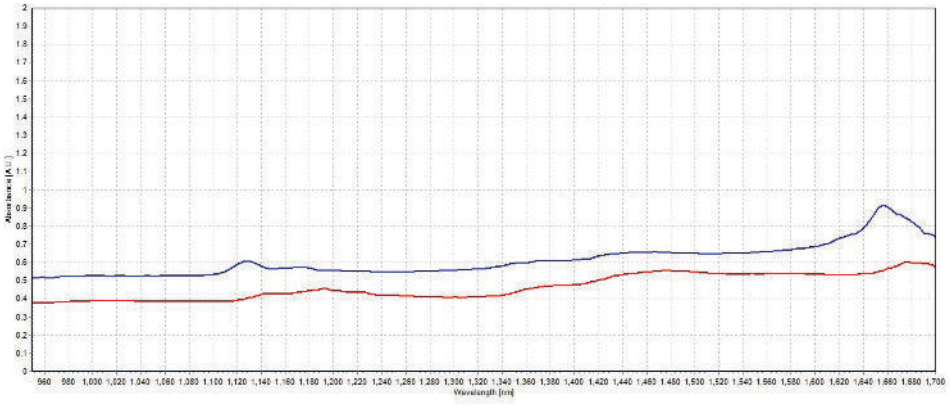

FIGURE #5: Absorbance spectra of aspirin pill (blue) and ibuprofen pill (red), shown together for comparison.

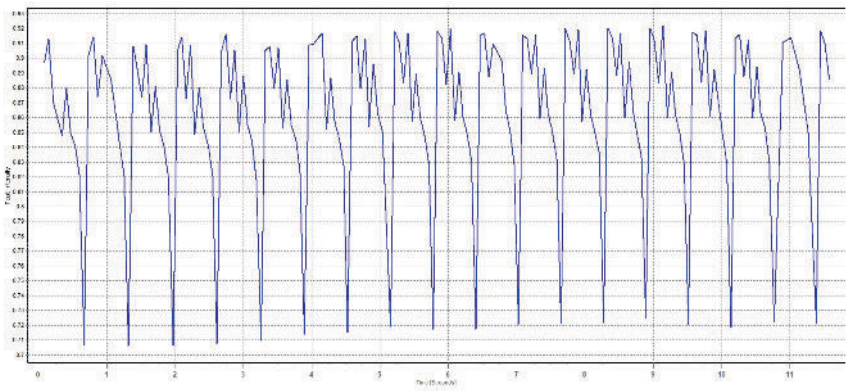

FIGURE #6: TimeSeries measurement of absorbance peak intensity between 1645-1665 nm.

ANALYSIS

The pill measurements in showed a mostly flat absorbance spectrum across the measured range, with a few notable differences. The aspirin pill showed absorbance peaks around 1130 nm and 1655 nm (Figure 3). These peaks were not seen in the ibuprofen pill measurement (Figure 4). Of these two peaks, the difference at 1655 nm was more pronounced, as seen when comparing the two spectra (Figure 5). With this, the 1655 nm peak was tracked in the TimeSeries module to demonstrate differences in the peak intensity during the experiment duration. At this point, the turntable was engaged to see how well the setup could accurately and consistently measure the pills. This resulted in an evident cycle, where the aspirin absorbance peak was reported between 0.84-0.92 A.U., while the ibuprofen absorbance peak was much lower at around 0.70-0.72 A.U. (Figure 6). The TimeSeries function was defined such that any A.U. below 0.75 resulted in a TTL output from the spectrometer to the mounted LED.

While this setup clearly identifies an ibuprofen pill among aspirin pills, more nuanced and complex analysis must be done when identifying between the same kinds of pills but determining if any are outside any regulatory requirements. This kind of in-depth assessment can be done through more involved chemometric models that analyze first and second derivatives of the spectra, among other factors. These algorithms can also monitor multiple peaks or other data points to better characterize differences across the entire spectral range. For our purposes though, the present experiment provides a clear metric for pill sorting that can be built upon for real-world pharmaceutical applications.

CONCLUSION

In conclusion, the present experiment highlights the use of our spectrometers to detect spectral differences between pharmaceutical pills of similar composition. The difference in one absorbance peak intensity was monitored and used to track when the outlier pill was measured. While this technique can be used for clear differences in pills, more complex analysis must be implemented to apply this principle to similar pills in a batch to determine if any are outside a defined specification. The AvaSpec-NIR256-1.7-HSC-EVO is a highly versatile NIR spectrometer with plenty of available options to match the bandwidth and requirements fitting your application. The AvaLight-Hal-S-Mini is an equally versatile light source that provides broad spectral coverage from the lower end of the visible range up through the NIR region thanks to a tungsten-halogen bulb. Lastly, with the success of this pill sorting setup, we are excited to fully demonstrate it in action at Photonics West 2026! Please contact Avantes for more information on the configuration that is best suited for your data collection.

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CONTACT

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