

InnoSpectra NIRScan

Spectrometer & Module

User Manual

Ver. 1.3

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www.inno-spectra.com



Thank you for choosing InnoSpectra! Please read this manual carefully and follow the operating instructions and application guidelines.

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Chapter 1 Introduction

1.1 Near-infrared Spectroscopy

Near-infrared spectroscopy (NIRS) is a spectroscopic method based on the absorption of electromagnetic radiation at wavelengths from 700 to 2500nm. NIRS is a form of molecular spectroscopy. NIR radiation is absorbed by molecules through a mechanism involving molecular vibration. Not all bonds in a molecule are capable of absorbing infrared radiation. Only those bonds that have a dipole moment that changes as a function of time are capable of absorbing infrared radiation. For example, O–H, N–H, C–H, S–H bonds are strong NIR absorbers. The most prominent absorption bands occurring in the NIR region are related to overtones and combinations of fundamental vibration. In vibrational spectroscopy, an overtone band is the spectral band that occurs in a vibrational spectrum of a molecule when the molecule makes a transition from the ground state ($v=0$) to the second excited state ($v=2$), which is called the first overtone, or from the ground state ($v=0$) to the third excited state ($v=3$), which is called the second overtone.

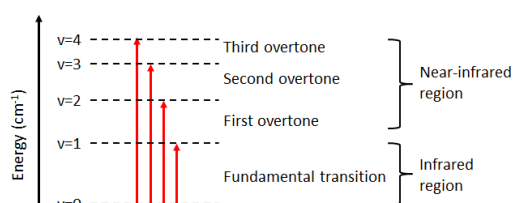


Figure 1.1 Vibrational Transitions

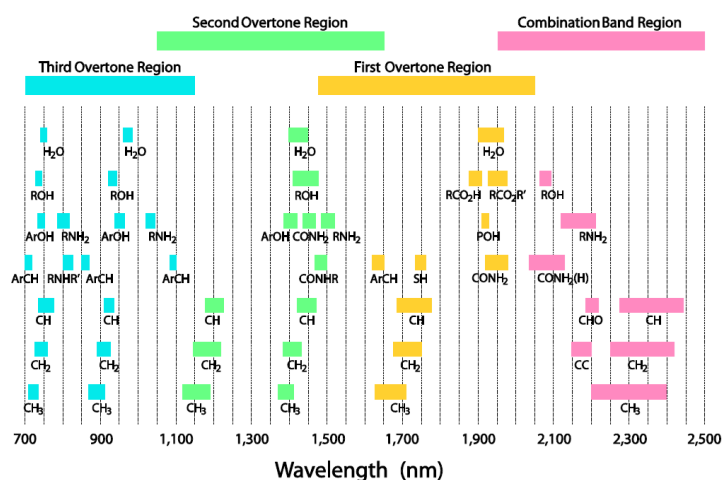


Figure 1.2 NIR Absorption Bands

1.2 NIR Measurement

Karl Norris, the Father of Near-Infrared Spectroscopy, discovered that the NIR region has a convenient combination of many practical properties, making it particularly suitable for a variety of chemical analysis applications. The advantages of the use of NIR are speed, cost, range of applicability, non-destructive, environmental benefits due to non-use of chemicals, and simultaneously multi-component analysis. NIRS has unique properties which makes it very useful for the analysis of most solid, slurry and liquid samples. There are four standard measurement modes for the acquisition of NIR spectra from a sample: transmission, reflectance, transreflectance, and interaction. NIRS in conjunction with chemometrics has revolutionized much of the general area of analyses. NIR analysis has been rapidly and widely applied in agriculture, petroleum, pharmaceuticals, biometrics, soil analysis, and so on.

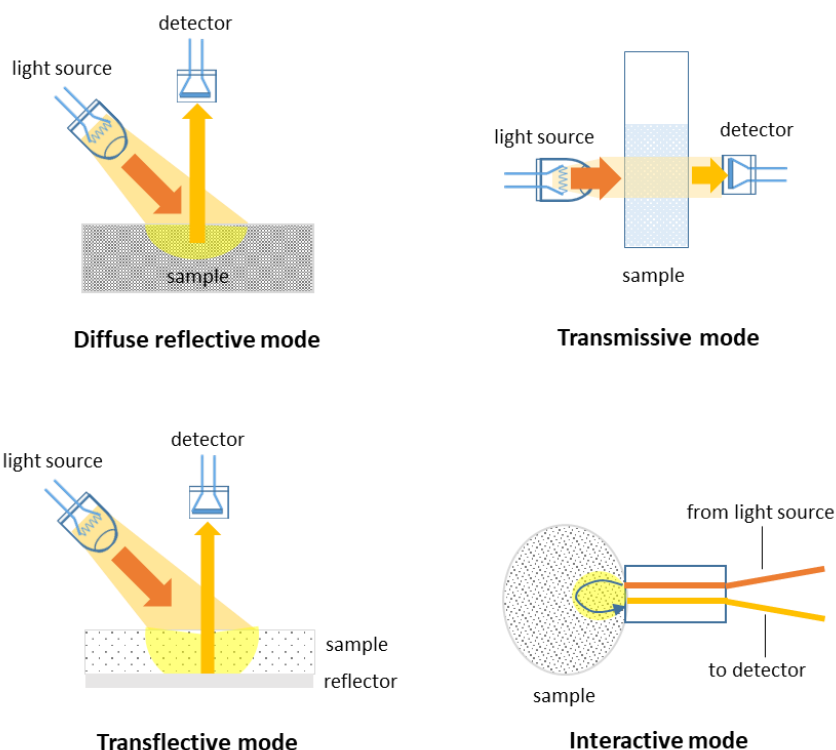


Figure 1.3 Measurement Modes for NIR Spectroscopy

1.3 DLP-based NIRScan Solutions

InnoSpectra Corporation (ISC) is dedicated to the development of NIRScan solutions. ISC offers a series of compact and cost-effective DLP-based NIR spectrometers including fiber input modules, diffuse reflective modules and transmissive modules in various wavelength range to support all sorts of applications. The optical engine of the DLP-based NIR spectrometer adopts a post-dispersive architecture, which is composed of an entrance slit, a set of collimating lenses, a bandpass filter, a diffraction grating, a set of focusing lenses, a DMD (digital micromirror device) as a programmable wavelength selector, a set of light receiving lenses and a single-element InGaAs detector. Compared to traditional spectrometers, DLP-based spectrometer use DMD and single-element InGaAs detector to replace expensive InGaAs linear array detector.

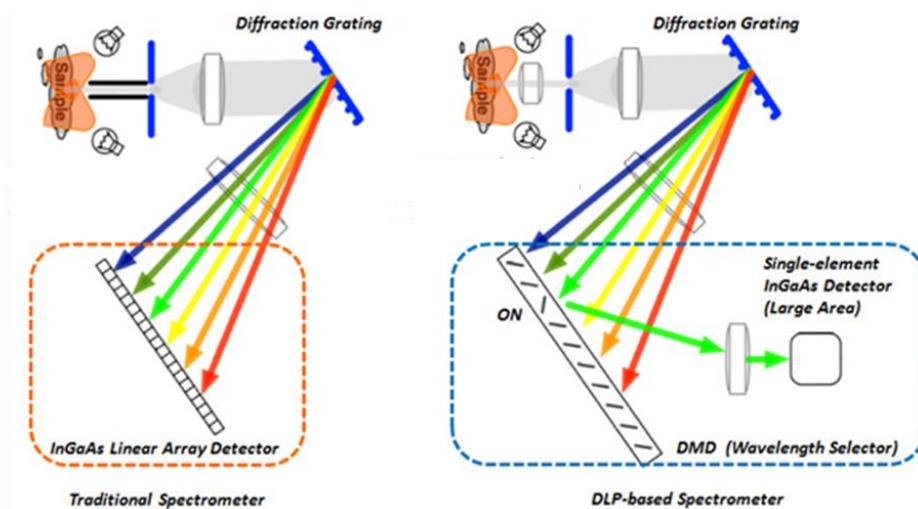


Figure1.4 Traditional vs. DLP-based Spectrometer

DLP technology in NIR spectroscopy provides the following advantages:

1. Higher performance through the use of a larger single-element detector ($\varphi=1\text{mm}$) in comparison to a linear array with very small pixels (e.g., $50\mu\text{m}$).
2. The high resolution DMD (e.g., $854*480$ pixels) allows custom patterns to optimize the optical performance of each individual system.
3. With programmable patterns, a DLP spectrometer can use Hadamard patterns to improve SNR. In Hadamard mode, a wide DMD pattern is displayed, so higher optical energy will be captured by the InGaAs detector.

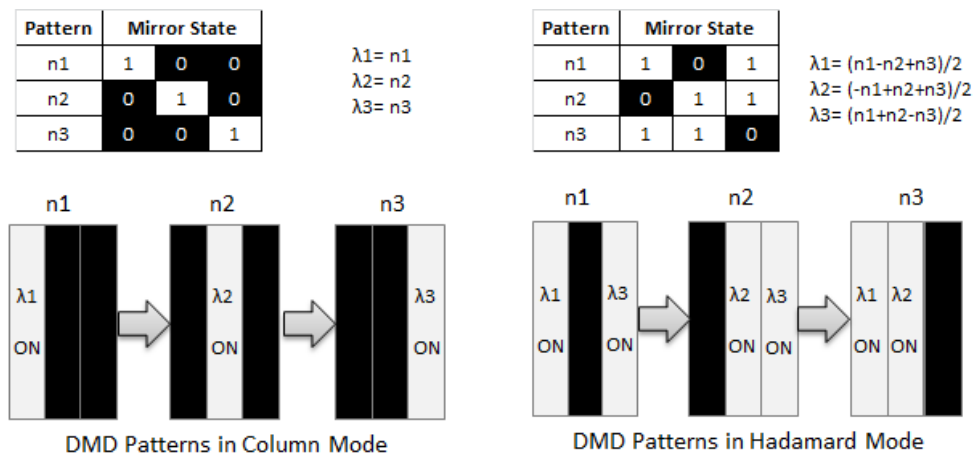


Figure1.5 Column Mode vs. Hadamard Mode

1.3.1 Selection Guide

ISC offers high performance and cost-effective DLP-based NIR spectrometers in various wavelength ranges:

- Standard 900-1700 nm
- Extended 1350-2150 nm
- Extended Plus 1600-2400nm
- Full Range 900-2400nm

You can refer to the following selection guide to find the model that suits your application scenario. Please contact ISC sales for more detailed product information and quick start guides for each model.

Module Selection Guide	Solid / Powder	Liquid / Slurry
Diffuse reflective modules / spectrometers: 900-1700nm: G1 / R2 / R3 / RT1 1350-2150nm: R11 / R12 1600-2400nm: R13 / R14 900-2400nm: R15 / R16	Diffuse reflective mode: Opaque solids and powders (e.g., grains, flour)	Transflective mode (requires a reflector): Transparent liquid (e.g., wine, oil)
	Transflective mode (requires a reflector): Transparent solids (e.g., transparent plastic sheet)	Diffuse reflective mode: Slurry, emulsion, or suspension (e.g., milk)
Transmissive modules / spectrometers: 900-1700nm: T1 / T2 1350-2150nm: T11 / T12 1600-2400nm: T13 / T14	Transmissive mode: Transparent solid (e.g., transparent plastic sheet)	Transmissive mode: Transparent liquid (e.g., wine, oil)
		Transmissive mode (in short optical path): Slurry, emulsion, or suspension (e.g., milk)
Fiber input modules / spectrometers: 900-1700nm: F1 / F2 1350-2150nm: F11 / F12 1600-2400nm: F13 / F14	Fiber input modules/spectrometers + accessories for a variety of applications including diffuse reflectance,transmission, transflectance and interactance measurements.	

1.3.2 Standard 900-1700nm

1. NIR-M-R2 (Diffuse Reflective Module)



Wavelength Range:	900 to 1700nm	Scan Window:	Protect and seal with sapphire glass
Signal-to-Noise Ratio (SNR):	5,000:1	Measurement Mode:	Diffuse reflective mode
Optical Resolution:	Typ. 10nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy(optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with SRM2036)	Sensors:	Humidity and temperature sensor
Detector:	1mm standard InGaAs (Uncooled)	Power:	Micro USB / UART / Li-ion battery(optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	76mm * 57.6mm * 26.8mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 80 g
Illumination Source:	two 0.7W tungsten filament lamps	Operating Temperature:	0~40°C, RH Max.85%

2. NIR-S-G1 (Diffuse Reflective Spectrometer)



Wavelength Range:	900 to 1700nm	Scan Window:	Protect and seal with sapphire glass
Signal-to-Noise Ratio (SNR):	5,000:1	Measurement Mode:	Diffuse reflective mode
Optical Resolution:	Typ. 10nm	Communication Interface:	Micro USB / Bluetooth Low Energy
Wavelength Accuracy:	Typ. ± 1 nm (verified with SRM2036)	Sensors:	Humidity and temperature sensor
Detector:	1mm standard InGaAs (Uncooled)	Power:	Micro USB / Li-ion battery (1000mAh@3.7V)
Slit Size:	1.8mm * 0.025mm	Dimensions:	82.2mm * 66mm * 43.5mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 150 g
Illumination Source:	two 0.7W tungsten filament lamps	Operating Temperature:	0~40°C, RH Max.85%

3. NIR-M-R3 (Diffuse Reflective Module)



Wavelength Range:	900 to 1700nm	Measurement Mode:	Diffuse reflective mode
Signal-to-Noise Ratio (SNR):	5,000:1	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 10nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with SRM2036)	Power Supply for Spectrometer :	5V 500mA for USB interface
Detector:	1mm standard InGaAs (Uncooled)	Power Supply for Illumination Source :	AC 100-240V~50-60Hz 0.4A / DC 5V 2A USB Adapter
Slit Size:	1.8mm * 0.025mm	Dimensions:	75.5mm*71.7mm*53.5mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 150g
Illumination Source:	one 5W tungsten filament lamp with reflector and lamp driver board	Operating Temperature:	0~40°C, RH Max.85%
Non-contact Diffuse Reflective Sampling Module:	Collection Region: Typ. 16mm in diameter Working Distance: Typ. 8mm from the sample surface to the sampling module	Accessory:	DC 5V 2A USB Adapter, USB Standard-A to Micro-B cable (1m), spacer for contact measurement (optional).

4. NIR-S-RT1 (Diffuse Reflective / Transflective Spectrometer)



Wavelength Range:	900 to 1700nm	Measurement Mode:	Diffuse reflective mode / Transflective mode
Signal-to-Noise Ratio (SNR):	5,000:1	Cuvette Holder:	Path length=1mm, Z-dimension=15mm
Optical Resolution:	Typ.10nm	Communication Interface:	Micro USB / Bluetooth Low Energy
Wavelength Accuracy:	Typ. ± 1 nm (verified with SRM2036)	Sensors:	Humidity and temperature sensor
Detector:	1mm standard InGaAs (Uncooled)	Power:	Micro USB / Li-ion battery (1000mAh@3.7V)
Slit Size:	1.8mm * 0.025mm	Dimensions:	93.5mm * 76mm * 73mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	<225g
Illumination Source:	two 0.7W tungsten filament lamps	Operating Temperature:	0~40°C, RH Max.85%
Scan Window:	Protect and seal with sapphire glass	Accessory:	white reference material (NIR-RM-1), USB Standard-A to Micro-B cable (1m)

5. NIR-M-T1 (Transmissive Module)



Wavelength Range:	900 to 1700nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	5,000:1	Cuvette Holder:	Path length=10mm, Z-dimension=4.75mm
Optical Resolution:	Typ.10nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm standard InGaAs (Uncooled)	Power:	Micro USB / UART / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	76mm * 91.8mm * 41.2mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	<106 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0~40°C, RH Max.85%

6. NIR-S-T2 (Transmissive Spectrometer)



Wavelength Range:	900 to 1700nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	5,000:1	Cuvette Holder:	Path length=10mm, Z-dimension=4.75mm
Optical Resolution:	Typ. 10nm	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm standard InGaAs (Uncooled)	Power:	Micro USB / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	109.8mm * 88.5mm * 51mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 250 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0~40°C, RH Max.85%

7. NIR-M-F1 (Fiber Input Module)



Wavelength Range:	900 to 1700nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	5,000:1	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ.10nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / UART / Li-ion battery (optional)
Detector:	1mm standard InGaAs (Uncooled)	Dimensions:	76mm * 54.5mm * 26.8mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 65 g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0~40°C, RH Max.85%

8. NIR-S-F2 (Fiber Input Spectrometer)



Wavelength Range:	900 to 1700nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	5,000:1	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 10nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / Li-ion battery (optional)
Detector:	1mm standard InGaAs (Uncooled)	Dimensions:	83.78mm * 64mm * 40.7mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 155 g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0~40°C, RH Max.85%

1.3.3 Extended 1350-2150nm

1. NIR-M-R11 (Diffuse Reflective Module)



Wavelength Range:	1350~2150nm	Measurement Mode:	Diffuse reflective mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power Requirement:	Min. 1.2 A (DC 5 V), high-power USB hub is preferred
Detector:	1mm extended InGaAs (Uncooled)	Fan :	40x40x10mm; 5V /6000RPM / 0.15m ³ /min.
Slit Size:	1.8mm * 0.025mm	Dimensions:	69.5mm * 48mm * 47.5mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 120g
Illumination Source:	three 0.7W tungsten filament lamps	Accessory:	USB Standard-A to Micro-B cable (1m)
Scan Window:	Ø6mm with square cover glass		

2. NIR-S-R12 (Diffuse Reflective Spectrometer)



Wavelength Range:	1350~2150nm	Measurement Mode:	Diffuse reflective mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power Requirement:	Min. 1.2 A (DC 5 V), high-power USB hub is preferred
Detector:	1mm extended InGaAs (Uncooled)	Fan :	40x40x10mm; 5V /6000RPM / 0.15m ³ /min.
Slit Size:	1.8mm * 0.025mm	Dimensions:	88mm *101.5mm * 50.9mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 340g
Illumination Source:	three 0.7W tungsten filament lamps	Accessory:	USB Standard-A to Micro-B cable (1m)
Scan Window:	Ø6mm with square cover glass		

3. NIR-M-T11 (Transmissive Module)



Wavelength Range:	1350~2150nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Cuvette Holder:	Path length=10mm, Z-dimension=15mm
Optical Resolution:	Typ. 12nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm extended InGaAs (Uncooled)	Power:	Micro USB / UART / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	96mm * 48mm * 38.2mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 100 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0~40°C, RH Max.85%

4. NIR-S-T12 (Transmissive Spectrometer)



Wavelength Range:	1350~2150nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Cuvette Holder:	Path length=10mm, Z-dimension=15mm
Optical Resolution:	Typ. 12nm	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm extended InGaAs (Uncooled)	Power:	Micro USB / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	138.4mm * 85mm * 58mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 305 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0~40°C, RH Max.85%

5. NIR-M-F11 (Fiber Input Module)



Wavelength Range:	1350~2150nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / UART / Li-ion battery (optional)
Detector:	1mm extended InGaAs (Uncooled)	Dimensions:	48mm * 59.5mm * 24.6mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 65 g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0~40°C, RH Max.85%

6. NIR-S-F12 (Fiber Input Spectrometer)



Wavelength Range:	1350~2150nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	3,000:1 @2000nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / UART / Li-ion battery (optional)
Detector:	1mm extended InGaAs (Uncooled)	Dimensions:	71.2mm * 56mm * 31mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 110 g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0~40°C, RH Max.85%

1.3.4 Extended Plus 1600-2400nm

1. NIR-M-R13 (Diffuse Reflective Module)



Wavelength Range:	1600~2400nm	Measurement Mode:	Diffuse reflective mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm(verified with RM-NIR)	Power Requirement:	Min. 1.2 A (DC 5 V), high-power USB hub is preferred
Detector:	1mm extended InGaAs (Uncooled)	Fan :	40x40x10mm; 5V /6000RPM / 0.15m ³ /min.
Slit Size:	1.8mm * 0.025mm	Dimensions:	75.8mm * 48mm * 48mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 150g
Illumination Source:	three 0.7W tungsten filament lamps	Accessory:	USB Standard-A to Micro-B cable (1m)
Scan Window:	Ø6mm with square cover glass		

2. NIR-S-R14 (Diffuse Reflective Spectrometer)



Wavelength Range:	1600~2400nm	Measurement Mode:	Diffuse reflective mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm(verified with RM-NIR)	Power Requirement:	Min. 1.2 A (DC 5 V), high-power USB hub is preferred
Detector:	1mm extended InGaAs (Uncooled)	Fan :	40x40x10mm; 5V /6000RPM / 0.15m ³ /min.
Slit Size:	1.8mm * 0.025mm	Dimensions:	88mm *101.5mm * 50.9mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 370 g
Illumination Source:	three 0.7W tungsten filament lamps	Battery Type:	One rechargeable 18650 battery can be installed (not included)
Scan Window:	Ø6mm with square cover glass	Accessory:	USB Standard-A to Micro-B cable (1m)

3. NIR-M-T13 (Transmissive Module)



Wavelength Range:	1600~2400nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Cuvette Holder:	Path length=10mm, Z-dimension=15mm
Optical Resolution:	Typ. 12nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm extended InGaAs (Uncooled)	Power:	Micro USB / UART / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	105mm * 48mm * 38.2mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 150 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0~40°C, RH Max.85%

4. NIR-S-T14 (Transmissive Spectrometer)



Wavelength Range:	1600~2400nm	Measurement Mode:	Transmissive mode
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Cuvette Holder:	Path length=10mm, Z-dimension=15mm
Optical Resolution:	Typ. 12nm	Communication Interface:	Micro USB / Bluetooth Low Energy (optional)
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Sensors:	Humidity and temperature sensor
Detector:	1mm extended InGaAs (Uncooled)	Power:	Micro USB / Li-ion battery (optional)
Slit Size:	1.8mm * 0.025mm	Dimensions:	138.4mm * 85mm * 58mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 355 g
Illumination Source:	one 0.7W tungsten filament lamp	Operating Temperature:	0 ~ 40°C, RH Max. 85%

5. NIR-M-F13 (Fiber Input Module)



Wavelength Range:	1600~2400nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / UART / Li-ion battery (optional)
Detector:	1mm extended InGaAs (Uncooled)	Dimensions:	68.8mm * 48mm * 27.3mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 110g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0~40°C, RHMax.85%

6. NIR-S-F14 (Fiber Input Spectrometer)



Wavelength Range:	1600~2400nm	Fiber Optic Connector:	SMA905 with key slot
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	Micro USB / UART / Bluetooth Low Energy (optional)
Optical Resolution:	Typ. 12nm	Sensors:	Humidity and temperature sensor
Wavelength Accuracy:	Typ. ± 1 nm (verified with RM-NIR)	Power:	Micro USB / UART / Li-ion battery (optional)
Detector:	1mm extended InGaAs (Uncooled)	Dimensions:	80mm * 65mm * 33mm
Slit Size:	1.8mm * 0.025mm	Weight:	< 195 g
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Operating Temperature:	0 ~ 40°C, RH Max. 85%

1.3.5 Full Range 900-2400nm

1. NIR-M-R15 (Diffuse Reflective Module)



Wavelength Range:	900~2400nm	Scan Window:	Sapphire glass
Wavelength Accuracy:	Typ. ± 1 nm	Collection Region:	Typ. 16mm in diameter
Optical Resolution:	10nm~12nm	Working Distance:	From the bottom of the sample to the surface of the scanning window, including the container thickness. The sensitivity is better when the distance is within 5mm, and 2mm is the best.
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	USB-C
Detector:	InGaAs (Uncooled)	Power Supply for Spectrometer:	5V / 3A (AC Adapter included)
Slit Size:	1.8mm * 0.025mm	Dimensions:	195.5mm * 114.5mm * 45mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 0.8 kg
Illumination Module:	One 5W tungsten filament lamp with reflector	Operating Temperature:	0 ~ 40 °C, RH Max.85%
Lamp life:	10,000 hours		

2. NIR-S-R16 (Diffuse Reflective Spectrometer)



Wavelength Range:	900~2400nm	Scan Window:	Sapphire glass
Wavelength Accuracy:	Typ. ± 1 nm	Collection Region:	Typ. 16mm in diameter
Optical Resolution:	10nm~12nm	Working Distance:	From the bottom of the sample to the surface of the scanning window, including the container thickness. The sensitivity is better when the distance is within 5mm, and 2mm is the best.
Signal-to-Noise Ratio (SNR):	3,000:1 @2200nm	Communication Interface:	USB-C
Detector:	InGaAs (Uncooled)	Power Supply for Spectrometer:	5V / 3A (AC Adapter included)
Slit Size:	1.8mm * 0.025mm	Dimensions:	208mm * 126mm * 70mm
Scan Capability:	Linear (Column) / Hadamard / Slew Scan	Weight:	< 1.5 kg
Illumination Module:	One 5W tungsten filament lamp with reflector	Operating Temperature:	0 ~ 40 °C, RH Max. 85%
Lamp life:	10,000 hours		

Chapter 2 Getting Started and Software Operation

2.1 Getting Started

2.1.1 System Requirement

Please check the following system requirements.

- ◆ OS: Windows 7/10 64bit and Windows 11.
- ◆ Display resolution: 1366 * 768 and above.
- ◆ IDE: Microsoft Visual Studio 2017
- ◆ C# Language Version: v7.0
- ◆ Microsoft .NET Framework: v4.7.2
- ◆ Microsoft Visual C++ Redistributable (x86/x64): 2010 or 2017

2.1.2 Download Software

ISC provides the **NIRScan GUI**, which supports **STD/EXT/EXT PLUS** devices. Please download ISC-NIRScan-GUI from <https://github.com/InnoSpectra/ISC-NIRScan-GUI>.

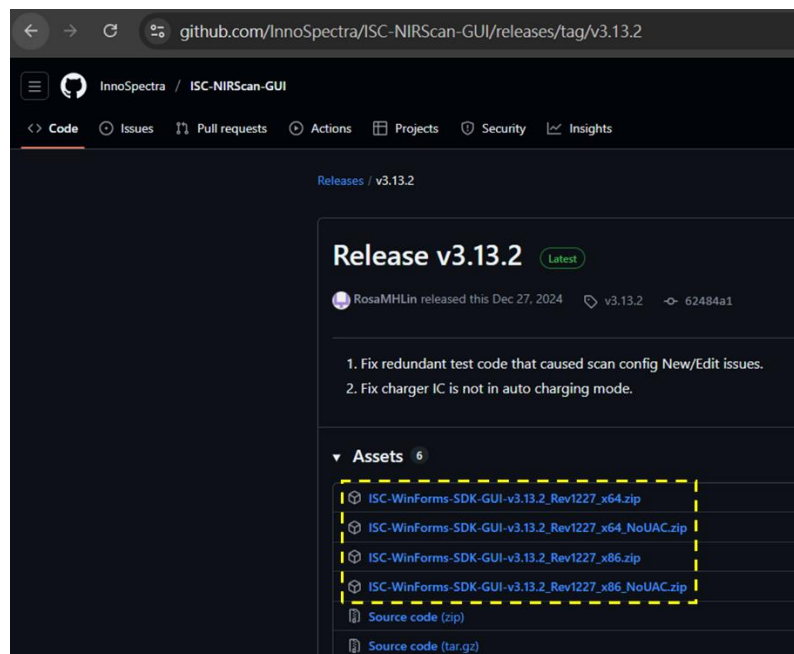


Figure 2.1 Download NIRScan GUI from GitHub

For **Full-Range** device, please download **ISC-GUI-Full_Range** from https://github.com/InnoSpectra/ISC-GUI-Full_Range/releases/tag/v1.4.0.

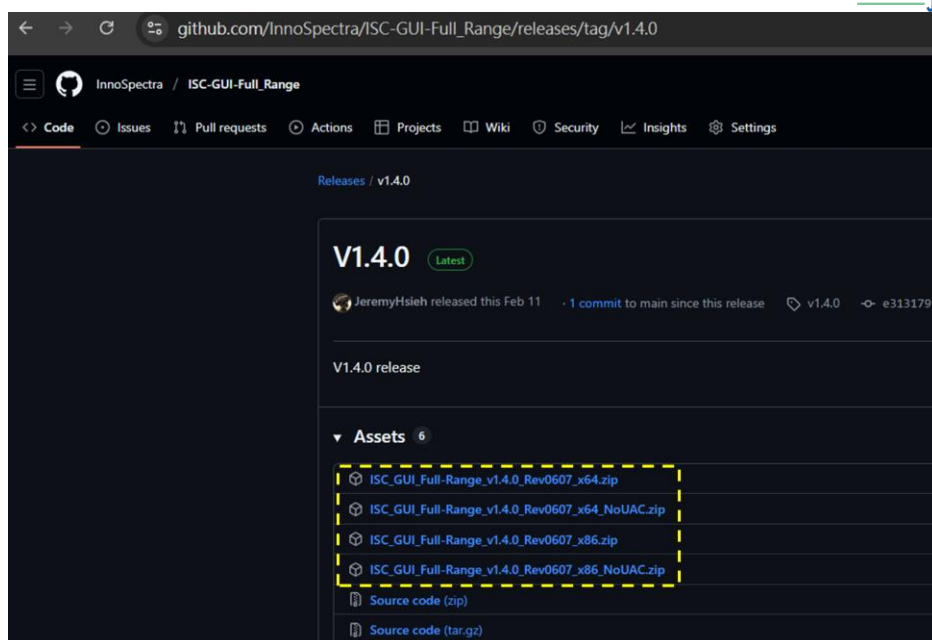


Figure 2.2 Download ISC-GUI-Full_Range from GitHub

2.1.3 Install Software

After downloading the software package from GitHub, you can unzip it and run the executable file directly. Please note that for some reasons, antivirus software may quarantine executable files. When the executable file is found to be quarantined, please try to restore it through the antivirus program settings.



2.1.4 Regional Settings

The software will store spectrum data into a CSV file which is a delimited text file that uses a comma to separate values. If you use a comma as the decimal point symbol, an error will occur when opening the CSV file in Excel.

Decimal symbol -> dot .

List separator -> comma ,

Decimal symbol -> comma ,

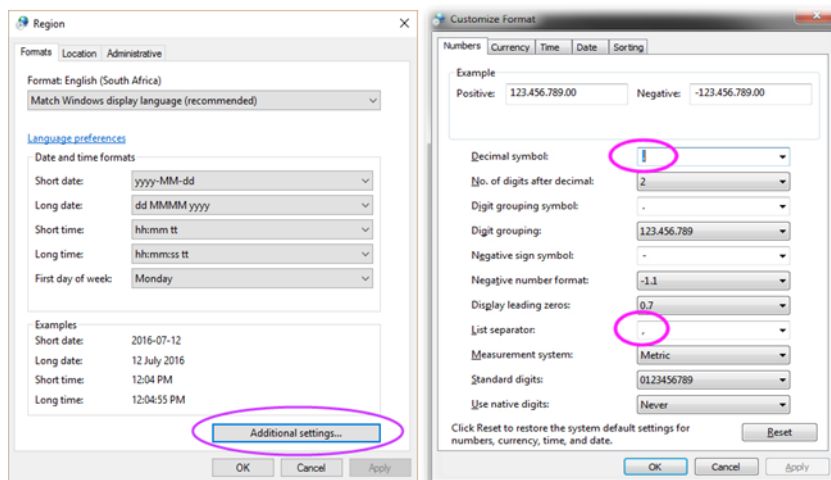
List separator -> comma ,

Please ensure the regional settings of Windows as follows:

- ◆ Decimal symbol → dot (.)
- ◆ List separator → comma (,)

You can refer to the following website to learn how to set decimal symbol and list separator properly.

<https://resrequest.helpspot.com/index.php?pg=kb.page&id=279>



2.1.5 USB Requirement

All ISC NIRScan products can be controlled via Micro-B or USB-C interfaces. Please use the power adapter and USB cable included with your NIRScan product to ensure safe and stable operation.

Some NIRScan products do not come with a power supply and can be powered and controlled via the USB interface.

Some products do not include a USB cable. Please use a USB cable that can carry at least 1A of current to power your NIRScan product.

To ensure stable operation when powered via USB, it is recommended to use a high-power USB hub. R11/R12/R13/R14 products especially require at least 1.2A (DC5V) of current.

2.1.6 LED Indication

For products with an operation panel (OP) and BLE module, such as the NIR-S-G1, you can check the device status via LED indicators. As shown in the following figure, when you power on the NIR-S-G1, the green and blue LEDs will light up, indicating that the NIR-S-G1 is ready for BLE or USB connection. If the NIR-S-G1 is connected to the ISC NIRScan GUI via a USB cable, the BLE function will be turned off and the blue LED will also be turned off.

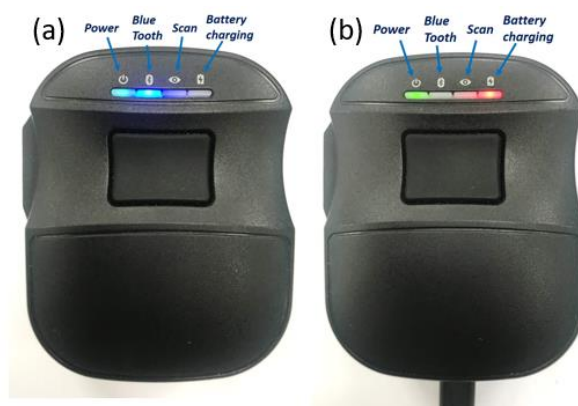


Figure 2.3 LED indicator of ISC NIRScan Device

For all the details of the LED indications, please refer to the following table.

Table 2.1 ISC NIRScan LED indicators

LED	Condition	Description
Green	ON	Indicates system is powered and active
	Pulse on and off, twice per second	Indicates any of the following errors occurred: ADC data access error Tiva EEPROM access error Spectrum data calculation error Hardware error Temperature & humidity sensor access error Insufficient memory error System error
Blue	ON	Bluetooth circuits are active and advertising *OFF: When USB connection or no BLE function
	Pulse on and off, once per second	Bluetooth Low Energy connection has been established
	Pulse on and off, twice per second	Bluetooth communications error
Yellow	ON	Scan is being performed
	Pulse on and off, twice per second	Scan error
Red	ON	System is charging a battery
	Pulse on and off, every 250 milliseconds	Battery Low

2.2 Software Operation

After connecting NIRScan device via USB, turning on the power switch and executing the ISC-NIRScan-GUI.exe, the software will check ISC NIRScan device automatically. Please note that the following is a brief introduction to the NIRScan GUI. For more details, please refer to the NIRScan GUI user guide.

There are three tabs in the upper left corner of the GUI:

- ◆ Scan: You can edit the scan configuration and scan settings, perform reference scans and sample scans, and view the saved scan data.
- ◆ Utility: You can check device information and sensor readings, manage calibration coefficients and built-in reference data, update firmware, and activate advanced functions.
- ◆ About: You can view the license agreement and obtain ISC contact information.

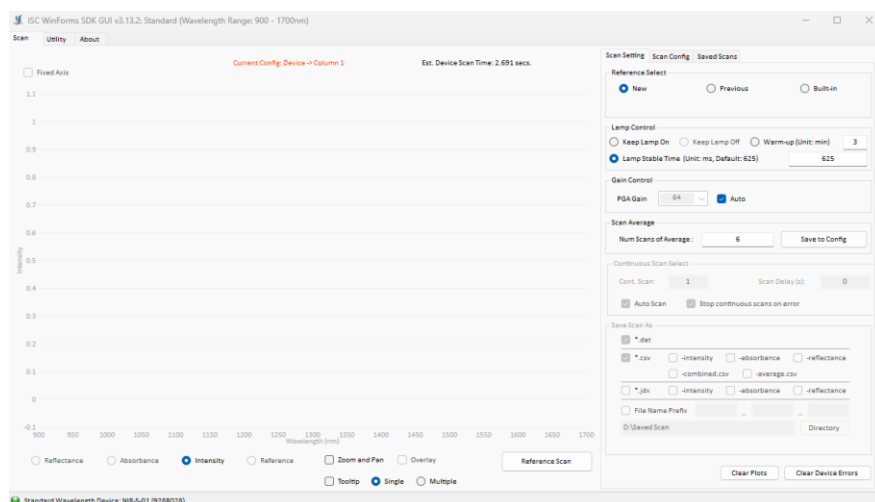


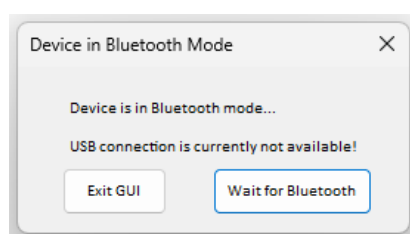
Figure 2.4 The NIRScan GUI is connected to a NIRScan device.

If you are not able to operate a NIRScan device via the NIRScan GUI, please check the following guidelines:

- ◆ If it's the first time for a NIRScan device to connect to the computer, it will take a little time for driver installation. The driver will be installed automatically by Windows.
- ◆ After installing the driver, please use the Device Manager to check whether the NIRScan device has been correctly identified as HID compatible device (HID \ VID_0451 & PID_4200) and USB input devices (USB \ VID_0451 and PID_4200).
- ◆ If the NIRScan GUI fails to connect the NIRScan device correctly, but your

computer recognizes the NIRScan device as an HID-compliant USB input device, please use device manager to uninstall NIRScan driver and then reboot your computer. After restarting, plug in the NIRScan device, Windows will attempt to recognize and install the driver for the NIRScan device. Once the driver is successfully installed, the NIRScan GUI can connect to the NIRScan device.

- ◆ If the device is in Bluetooth mode but you connect it to your computer, the NIRScan GUI will pop up a message reminding you that you need to disable Bluetooth before running the NIRScan GUI.



2.2.1 Scan Configuration

You need to select or create a new scan configuration before scanning. The NIRScan device is pre-built with one or two scan configurations. You can customize the following parameters in the scan configuration dialog box according to your application.

- ◆ Name: Type the name of the scan configuration.
- ◆ Num Scans to Avg: Enter the number of scans to average for corresponding amount of back-to-back scans averaged together. Increasing this amount results in longer scan with the noise averaged out through several back-to-back scans.
- ◆ Num Sections: Use one section for a scan with the same pattern width and digital resolution in the desired wavelength range. Use more than one section to perform a fast scan with less resolution on wavelengths with little information and a slow scan with higher resolution on wavelengths with areas of interest. A scan can be broken up into 1-5 sections.
- ◆ Scan Type: Select "Column" or "Hadamard" for each section.
- ◆ Spectral Range: The desired spectral range can be defined for each section.
- ◆ Width (nm): Pattern width corresponds to the smallest wavelength content that

you want to resolve.

- ◆ Exposure time (ms): The exposure time can be set in the range of 0.635 to 60.960 ms.
- ◆ Digital Resolution: This number defines how many wavelength points (number of sampling points) are captured across the defined spectral range. In general, the recommend digital resolution is (wavelength range/pattern width) x2 or 2.5 (oversampling). For example, $((1700\text{nm}-900\text{nm})/7.03\text{nm}) \times 2 = 228$.

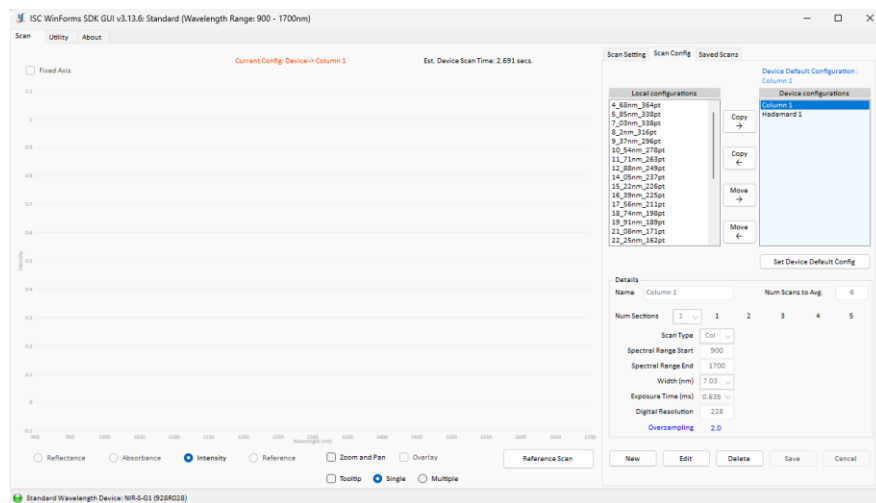


Figure 2.5 Scan Configuration Dialog Box

2.2.2 Scan Setting

After selecting the scan configuration, you can start to scan the sample through the “Scan Setting” tab as shown below. Take diffuse reflective measurement as an example:

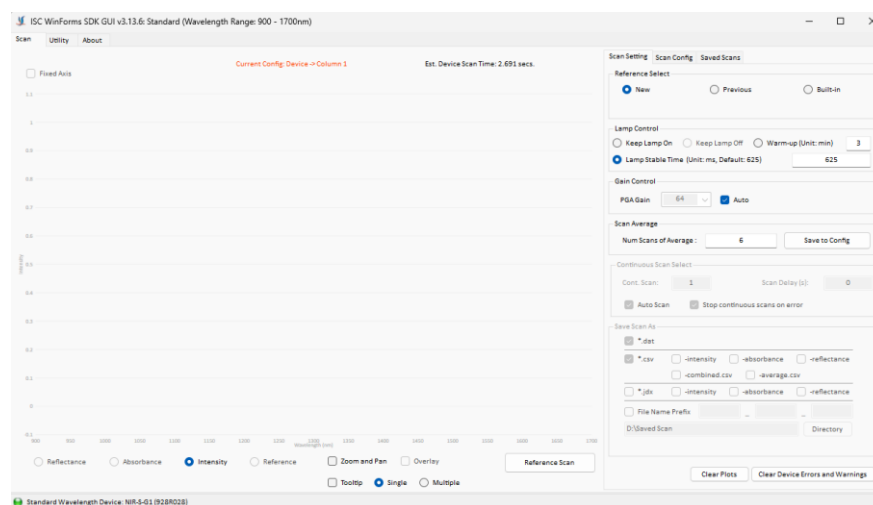


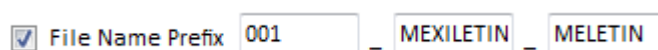
Figure 2.6 Scan Setting

- ◆ Reference Select: This option allows users to select the source of reference data, including:
 - (a) New: For diffuse reflectance measurements, place a white reference material (e.g., NIR-RM-1/2/3) on the sample window and perform a new reference scan. The scan results will be stored in your computer's user folder (C:\Users\Username\Documents\InnoSpectra\Reference Data).
 - (b) Previous: Select the reference data previously created using the "New" option.
 - (c) Built-in: The reference data stored in the internal memory of the NIRScan device will be interpolated to match the current scan configuration parameters.
- ◆ Lamp control: This function allows users to control the ON/OFF/Warm-up of the lamp and change the "Lamp Stable Time".
- ◆ Gain control: This function allows users to select Auto or Fixed PGA (Programmable Gain Amplifier) Gain.
 - (a) Auto: When set to Auto, each scan performs a quick scan to set the programmable gain amplifier to the highest possible amount that does not cause overflow. When scanning a new material, please choose "Auto" setting first.
 - (b) Fixed PGA Gain: When set to a specific number, the PGA is set to that value for all scans. This avoids the quick scan. Care must be taken to not set the PGA to a value that causes overflow. An overflow would show a flat scan with the highest possible intensity value. This option is useful when scanning a material with an intensity that lies at the border of two PGA settings where some scans might select a PGA setting while other scans select the next higher PGA setting. After you are experienced with your device or sample condition, you can choose "Fixed PGA Gain" setting.
- ◆ Scan Average: This function allows users to quickly set the number of scans to average to check the spectrum quality. SNR can be improved by increasing this number.

- ◆ Continuous Scan Select: This function allows users to set the back-to-back scans to be completed once the Scan button is pressed. The “Scan Delay(s)” indicates the amount of seconds to wait between consecutive scans.
- ◆ Save Scan As: This function allows the user to select the data format and file directory to save the spectrum.
- ◆ File Name Prefix: Before starting the scan, the user can set a file name prefix, which will help the management of spectrum data. For example, select “Column 1” scan configuration to perform a scan. The saved file name could be with or without prefix as follows:

Without prefix: Column 1_20210712_160057

Append prefix: 001_MEXILETINE100_MELETIN_Column 1_20210712_160057



2.2.3 Saved Scans

Under the "Saved Scans" tab, users can view scan data saved in *.csv or *.dat file format.

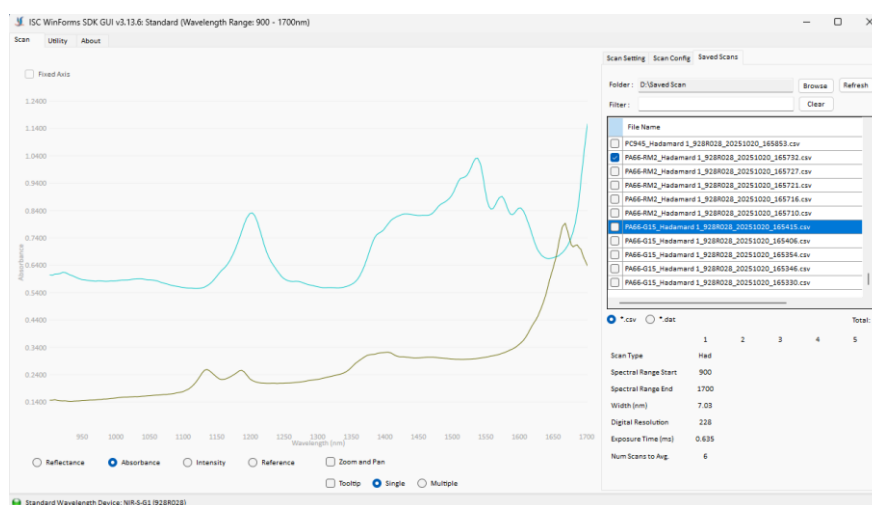


Figure 2.7 Saved Scans

2.2.4 Utility

The Utility screen provides tools to manage the NIRScan device.

- ◆ Model Name: get the model name
- ◆ Serial Number: get the serial number.

- ◆ Date and Time: get or synchronize date and time.
- ◆ Lamp Usage: get or set lamp usage.
- ◆ Sensors: read and display sensor data.
 - Battery charger status and battery capacity (only when lithium-ion battery is connected).
 - System Humidity: Displays the readings from the onboard humidity sensor.
 - System Temp: Displays the readings from the onboard temperature sensor.
 - Tiva Temp: Displays the internal temperature of the Tiva SOC.
 - Lamp Indicator: Display the readings from lamp driver and sensor.
- ◆ TIVA Firmware Update: search TIVA firmware file and update it.
- ◆ DLPC150 Firmware Update: search DLPC firmware file and update it.
- ◆ Calibration Coefficients: read or write calibration coefficients (Pixel-to-Wavelength and Shift Vector).
- ◆ Device information: displays GUI Version, Tiva SW Version, DLPC Flash Version, Main Board Version, Detector Board Version, Model Name, Device Serial Number, Manufacturing Serial Number, Device UUID, Lamp Usage and BLE Advertising Name.
- ◆ Activation Key: input and set activation key.
- ◆ Bluetooth LE Advertising Name: get or set BLE advertising name.
- ◆ Device: reset system, update the built-in reference, restore the factory reference, perform factory data reset, lock or unlock the scan button.
- ◆ Log File: Enable or disable the log function. After enabling this function, the GUI will record the running status in the log file. When you find any errors, please provide both log files and CSV files for further analysis.

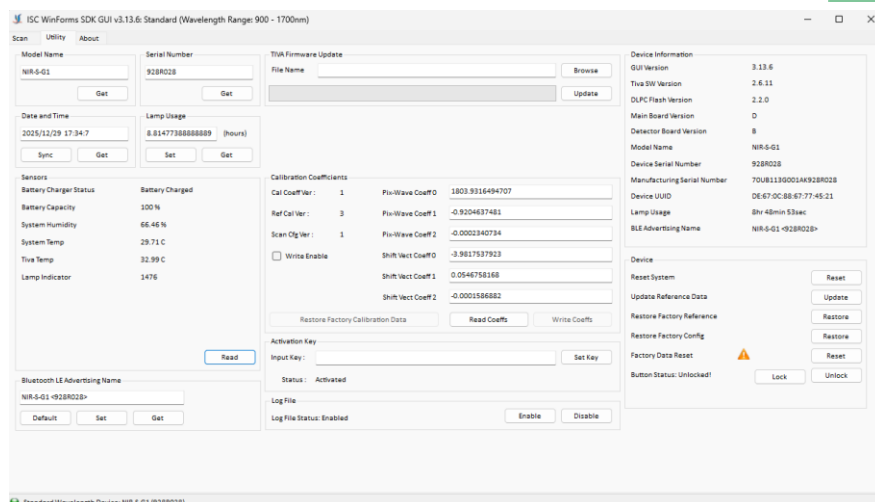


Figure 2.8 Utility Screen

2.2.5 CSV File

The CSV (Comma Separated Values) file can be imported into a spreadsheet application. The CSV file contains the following information:

- ◆ Scan Config Information: Scan Config Name, Scan Config Type, Num Section, Section Config Type, Start Wavelength (nm), End Wavelength (nm), Pattern Width (nm), Exposure (ms), Digital Resolution, Num Repeats, PGA Gain, System Temp (C), Humidity (%), Lamp Indicator, Data Date-Time, Total Measurement Time in sec.
- ◆ General Information: Model Name, Serial Number, GUI Version, TIVA Version, DLPC Version, UUID, Main Board Version, Detector Board Version.
- ◆ Scan Data: Wavelength (nm), Absorbance (AU), Reference Signal, Sample Signal.
- ◆ Reference Scan Information: Scan Config Name, Scan Config Type, Num Section, Section Config Type, Start Wavelength (nm), End Wavelength (nm), Pattern Width (nm), Exposure (ms), Digital Resolution, Num Repeats, PGA Gain, System Temp (C), Humidity (%), Lamp Indicator, Data Date-Time.
- ◆ Calibration Coefficients: Shift Vector Coefficients, Pixel to Wavelength Coefficients, Versions (Cal/Ref/Cfg).
- ◆ Lamp Usage: Total Time (HH:MM:SS).
- ◆ Device/Error/Activation Status.

```

***Scan Config Information***
Scan Config Name: Column 1
Scan Config Type: Slew Num Section: 1
Section Config Type: Column
Start Wavelength (nm): 900
End Wavelength (nm): 1700
Pattern Width (nm): 7.03
Exposure (ms): 0.635
Digital Resolution: 228
Num Repeats: 6
PGA Gain: 64(FixedPGA)
System Temp (C): 30.24
Humidity (%): 65.03
Lamp Indicator: 1494
Data Date-Time: 2025/12/29T17:44:11
Total Measurement Time in sec: 3.3905213

***General Information***
Model Name: NIR-S-G1
Serial Number: 928R028 [70UB113G001AK928R028]
GUI Version: 3.13.6 Revision: 1216
TIVA Version: 2.6.11
DLP Version: 2.2.0
UIID: DE:67:OC:88:67:77:45:21
Main Board Version: D
Detector Board Version: B

***Reference Scan Information***
Scan Config Name: Local New Reference
Scan Config Type: Slew Num Section: 1
Section Config Type: Column
Start Wavelength (nm): 900
End Wavelength (nm): 1700
Pattern Width (nm): 7.03
Exposure (ms): 0.635
Digital Resolution: 228
Num Repeats: 6
PGA Gain: 64(AutoPGA)
System Temp (C): 30.08
Humidity (%): 65.23
Lamp Indicator: 1499
Data Date-Time: 2025/12/29T17:43:48

***Calibration Coefficients***
Shift Vector Coefficients: -3.981753792 0.05467582 -0.000158688
Pixel to Wavelength Coefficients: 1803.951649 -0.92046375 -0.000234073
Versions (Cal/Ref/Cfg): 1 3 1
***Lamp Usage***
Total Time(hh:mm:ss): 8hr 48min 59sec
***Device/Error/Activation Status***
Device Status: 0x00000001 Activation Status: Activated
Error status: 0x00000000 Error Code: 00
Error Details: Not found

***Scan Data***
Wavelength (nm) Absorbance (AU) Reference Signal (unitless) Sample Signal (unitless)
901.5208362 0.345185522 61611 27821
905.4302286 0.366434561 68308 29379
909.3264077 0.362893308 73694 31955
913.2183734 0.378027347 80694 33792
917.1061259 0.378888046 88549 37008
920.989665 0.378513645 98987 41425
924.8689908 0.379673516 111658 46386
930.0348712 0.378140706 131451 55033
933.9043659 0.379790756 145973 60881
937.7696473 0.380024286 160251 66800
941.6307153 0.379250023 172042 71843
945.4875701 0.381267449 183839 76410
949.3402115 0.376335681 194093 81597
953.1886397 0.377191215 203809 85513
957.0328544 0.376780205 213855 89813
960.8728559 0.377690378 224311 94007
964.7086441 0.377741532 235248 98579
969.6164742 0.380460805 250315 104238
973.5424313 0.380078166 261067 108611
977.4641175 0.382723804 271639 112530
981.2817055 0.385363818 282954 116507
985.0950226 0.387085821 293212 120253
988.9041263 0.38845847 302667 123739

```

Figure 2.9 CSV File Content

2.3 Obtaining High-Quality Spectra

With proper configuration and operation, high-quality spectra can be obtained.

2.3.1 Reference Signal

To calculate the absorbance of a sample, you need a reference signal.

$$Absorbance = \log_{10} \frac{\text{reference signal intensity}}{\text{sample signal intensity}}$$

There are two options for reference signal: Built-in or New/Previous.

- ◆ Built-in: The “built-in” reference signal is stored in the internal memory of the device. The “built-in” reference signal of the diffuse reflective module is obtained by scanning the Spectralon® diffuse reflectance standard (SRS-99) or equivalent materials. The scan configuration of the “built-in” reference signal is as follows.

Reference Select	Built-in
Section Config Type:	Column
Start Wavelength (nm)	900
End Wavelength (nm)	1700
Pattern Width (nm)	7.03
Exposure (ms)	0.635
Digital Resolution:	228
Num Repeats	30
PGA Gain	64

- ◆ New/Previous: The “previous” reference signal is obtained by performing a “new” reference scan. You can place a high diffuse reflectance material (SRS-99 or NIR-RM-x) on the scan window of the diffuse reflective module and perform a “new” reference scan. The “new” scan data will be stored in the computer and become a “previous” reference signal. The scan configuration of the “new / previous” reference signal can be edited and saved in the scan configuration dialog box. For example, you can perform a “new” reference scan with a different pattern width and digital resolution, as shown below.

Reference Select	New / Previous
Section Config Type:	Column
Start Wavelength (nm)	900
End Wavelength (nm)	1700
Pattern Width (nm)	10.54
Exposure (ms)	0.635
Digital Resolution:	160
Num Repeats	30
PGA Gain	64

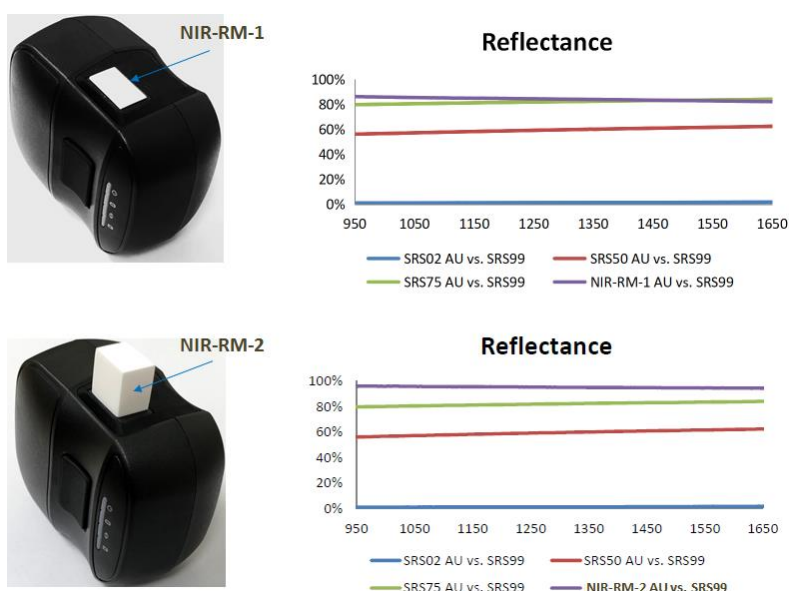


Figure 2.10 Reference Materials

After performing the reference scan, you can scan the sample to obtain the absorbance data of the sample. If the scan configuration of the sample signal is different from the scan configuration of the reference signal, the reference signal may not perfectly match the sample signal in terms of wavelength point and signal intensity. It may be necessary to interpolate or scale the reference signal to accommodate different pattern widths and digital resolutions of the sample signal. Please refer to the following three different situations. To simplify the discussion, we scan SRS-99 to obtain the reference signal and the sample signal, so the absorbance should theoretically be zero.

Case #1: The “built-in” reference signal is selected. The sample signal is scanned by using the same pattern width and digital resolution as the “built-in” reference signal. As a result, the absorbance is flat and very close to zero.

Case #2: The “built-in” reference signal is selected. The sample signal is scanned by using different pattern width and digital resolution. As a result, the “built-in” reference signal is interpolated and scaled to match the settings of sample signal and the absorbance is not flat.

Case #3: It is similar to case #1, but the “built-in” reference signal is replaced by the “new/previous” reference signal. Both the reference signal and the sample signal are scanned with the same pattern width and digital resolution. Therefore, the absorbance is flat and very close to zero.



Figure 2.11 Cases with Matched or Unmatched Scan Configuration

The “built-in” reference signal is suitable for user doing a scan when there is no reference sample available in hand. In order to match with the “built-in” reference signal, please choose same scan configuration to minimize the absorbance variation.

You can choose any scan configuration which perfectly matches your sample conditions. Please periodically perform a “new” reference scan and then you can select the “previous” reference signal to match your current scan configuration, and then the absorbance variation will be minimized.

Unless you can use SRS-99 or NIR-RM-1/2/3 to scan the reference signal, do not replace the "built-in" reference signal. The built-in reference signal can be replaced by the following procedure. However, we do not recommend that you change this reference signal unless you have reliable reference materials on hand and are very familiar with the purpose of the built-in reference signal.

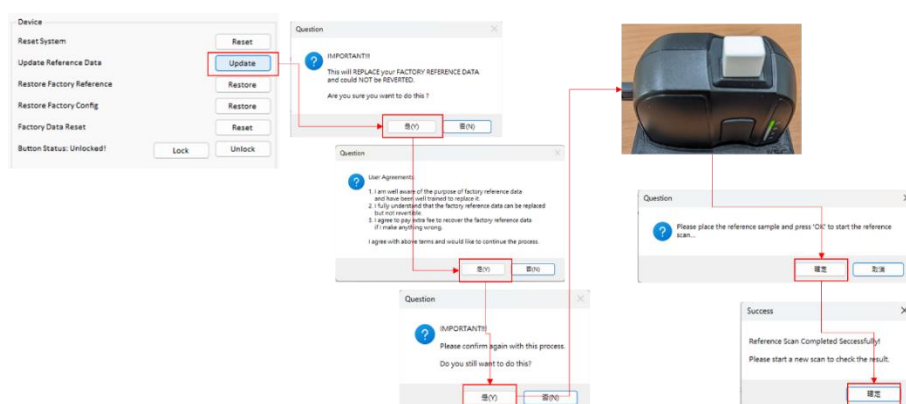


Figure 2.12 Updating Built-in Reference Data for Diffuse Reflective Modules

2.3.2 Black Level

The ISC NIRScan device uses a digital micromirror device (DMD) as a wavelength selector. The DMD's micromirror array is programmed to reflect light into or away from the single-element InGaAs detector. Because the micro mirrors of the DMD operate in dynamic mode, the stray light phenomenon of the ISC NIRScan device differs from that of the conventional design, and black level measurements (dark scans) are performed in a completely different manner. The ISC NIRScan device performs periodic black level measurement which is handled by software automatically. By inserting a periodic pattern of all turned off pixels in the sample scan, the black level will be calculated and compensated automatically. You only need to perform a reference scan before the sample scan. No dark scan is required before the sample scan.

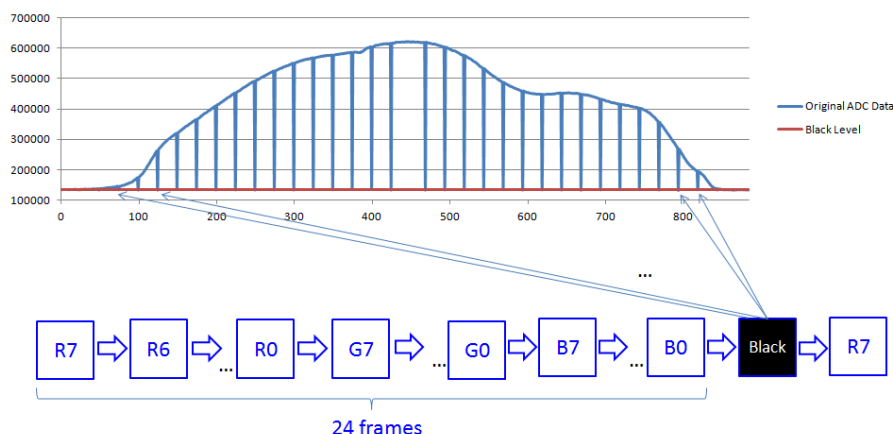


Figure 2.13 Black Level Measured with Black DMD Pattern

When measuring the black level, the light source and input signal are not blocked, and all DMD mirrors are set to OFF state. As a result, the black level contains all noise information. Therefore, the sample signal is equal to the raw data minus the black level (Sample signal = raw data – black level).

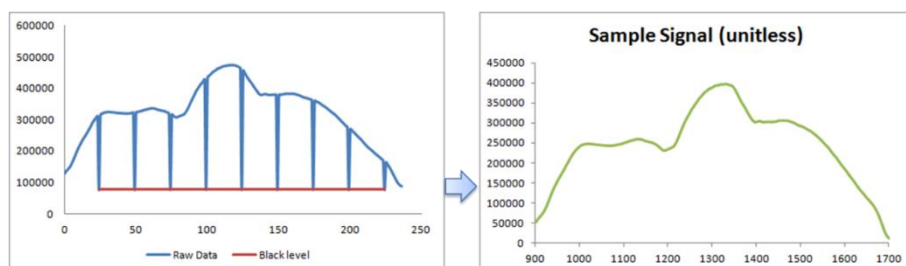


Figure 2.14 Sample Signal=Raw Data - Black Level

Please note that when the measurement is performed under low light conditions or the sample is a strong NIR absorber, the raw data of the measurement may be very weak and interfered. The calculated sample signal (=raw data-black level) may become negative. As a result, the absorbance data ($AU = \log_{10}(\text{reference signal}/\text{sample signal})$) will become NaN (Not a Number) because the operand of the absorb calculation must be a positive number. When AU is NaN, the software will replace NaN with 0 in order to display AU in the GUI.

For example, when measuring water in transmissive mode, the absorbance level will reach saturation when the path length is up to 5mm. If the path length is increased to 10mm, the raw signal become very weak and interfered, and the sample signal

may become negative after 1450nm.

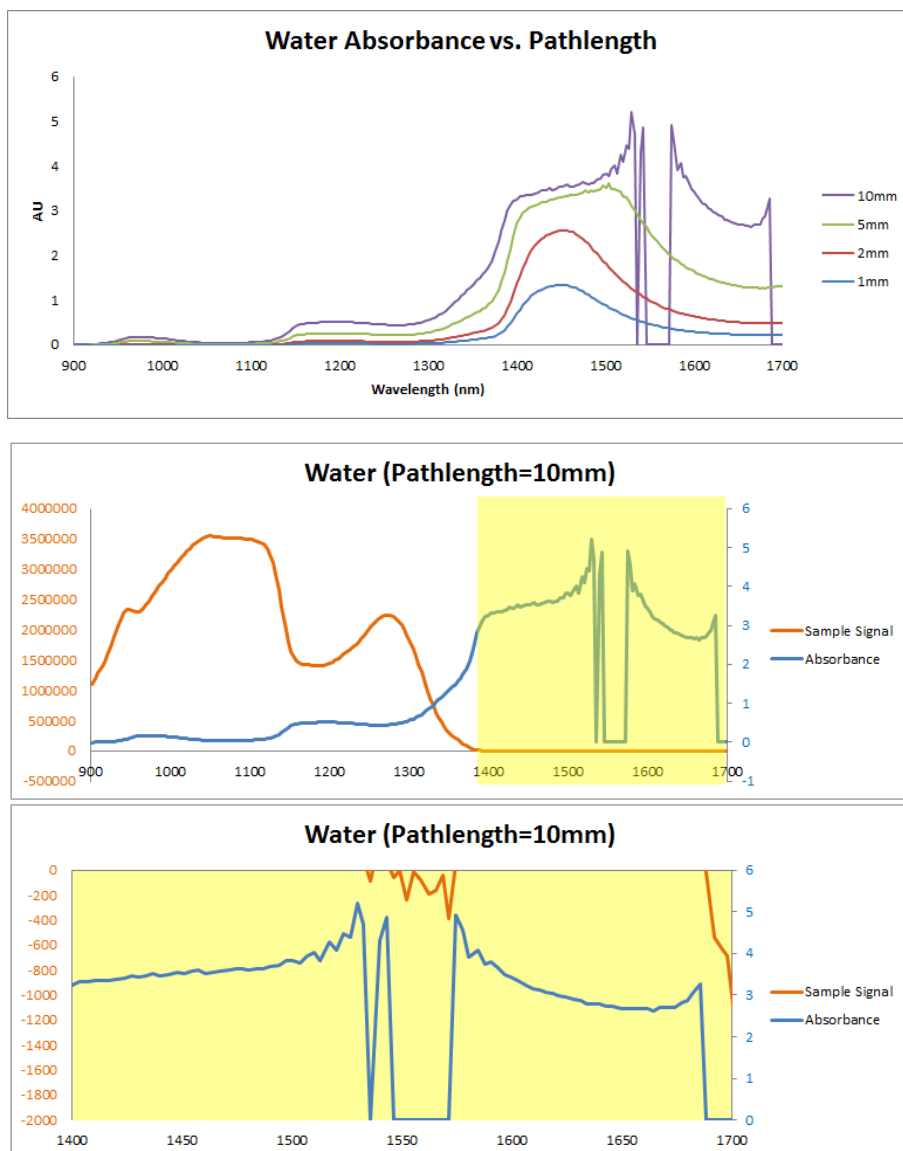


Figure 2.15 Water Measured at Different Path Length

2.3.3 PGA Gain Control

GainControl

PGA Gain ☐ Auto

The NIRScan device uses a single-element InGaAs detector to receive light of different wavelengths reflected by the DMD. InGaAs detector generates a small amount of current when a photo impacts the P-N junction of the semiconductor. The NIRScan device uses a transimpedance amplifier to convert the photodiode current into a voltage and then digitize the voltage with ADC. The ADC has a Programmable

Gain Amplifier (PGA), which increases the dynamic range by amplifying low-amplitude signals before they are fed to the 24-bit ADC. There are two options for PGA setting: "Auto" or "Fixed". To evaluate a new sample, please choose "Auto" first. The software will set a proper PGA value to optimize the dynamic range automatically. If you are familiar with the device and sample conditions, you can try to assign an appropriate value to the PGA. The options for the PGA values are 1, 2, 4, 8, 16, 32 and 64.

The PGA value set by you cannot be greater than the PGA value obtained in "Auto" PGA mode, otherwise the signal will become saturation. For example, if the auto PGA value is 16, you cannot set the PGA value to 32.

If one PGA value (e.g., 16) is used to scan the reference signal, but another PGA value (e.g., 64) is used to scan the sample signal, the reference signal value will be scaled up ($\times 4$) to match the PGA value of the sampled signal before the absorbance is calculated.

The following is an example of comparing PGA settings for different scan types. When scanning white reference material with NIR-S-G1, the Auto PGA of "Column 1" is 64, but the Auto PGA of "Hadamard 1" is 16. In the Hadamard scan, the DMD pattern is wider, so the InGaAs detector will capture higher optical energy. The PGA value in the Hadamard scan must be reduced to avoid saturation of the ADC reading.

Scan Config Name	Column 1	Hadamard 1
Scan Type	Column	Hadamard
Start Wavelength (nm)	900	900
End Wavelength (nm)	1700	1700
Pattern Width (nm)	7.03	7.03
Exposure (ms)	0.635	0.635
Digital Resolution	228	228
Num Repeats	6	6
PGA Gain	64 (Auto)	16 (Auto)

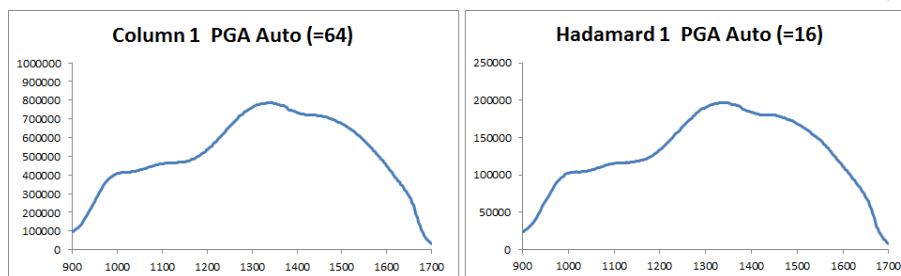


Figure 2.16 Auto PGA vs. Scan Type

Below is an example that demonstrates the side effects of fixed PGA. PGA gain affects the signal intensity obviously, a larger PGA gain will increase signal intensity, but the specified PGA gain can't be set more than auto PGA gain. To evaluate a new sample, please tick "auto" first. After you are experienced with your device and sample condition, you can try to fix the PGA gain. The PGA gain can be fixed at 1, 2, 4, 8, 16, 32 or 64. In case (a), when scanning white reference material using "Hadamard 1", the NIR-S-G1's auto PGA function selects 16 as the appropriate PGA gain. In case (b), the PGA gain is reduced and fixed to 8, and there is no problem. In case (c), the PGA gain is increased and fixed to 32, which will cause signal saturation at multiple wavelength points. In case (d), the PGA gain is further increased to 64, which is very large and will cause signal saturation at all wavelength points.

Scan Configuration	(a)	(b)	(c)	(d)
Scan Config Name	Hadamard 1	Hadamard 1	Hadamard 1	Hadamard 1
Scan Type	Hadamard	Hadamard	Hadamard	Hadamard
Start Wavelength (nm)	900	900	900	900
End Wavelength (nm)	1700	1700	1700	1700
Pattern Width (nm)	7.03	7.03	7.03	7.03
Exposure (ms)	0.635	0.635	0.635	0.635
Digital Resolution	228	228	228	228
Num Repeats	6	6	6	6
PGA Gain	16 (Auto)	8 (Fixed)	32 (Fixed)	64 (Fixed)

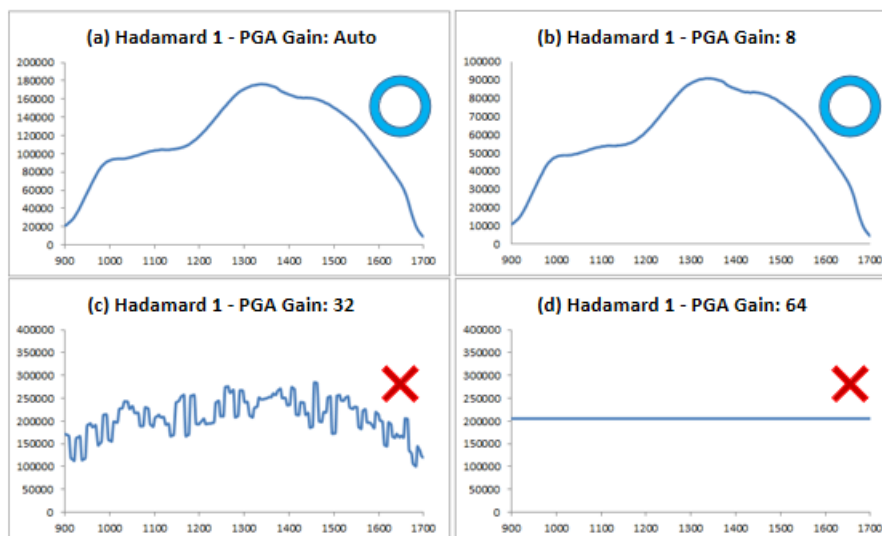


Figure 2.17 Side Effect of Fixed PGA

As mentioned above, scan configuration and PGA gain affect measurement results. Please ensure you set an appropriate PGA value.

2.3.4 Pattern Width and Digital Resolution

Besides light source intensity, pattern width can be increased to enhance signal level. You can increase pattern width to the maximum width which still produces good enough spectrum resolution. For example, a plastic sample is scanned with different pattern width settings as follows. The AU still looks fine when pattern width is not increased too much.

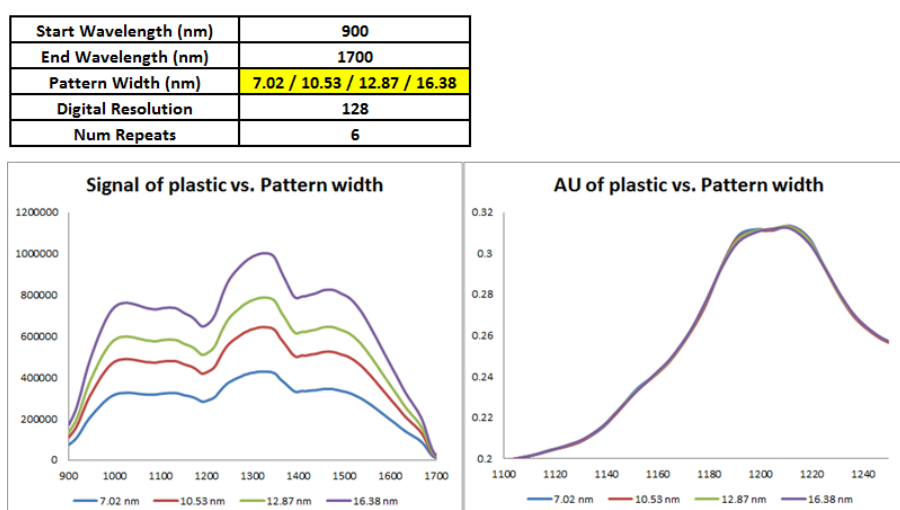


Figure 2.18 Signal and AU vs. Pattern Width

If the pattern width increases too much, the spectral resolution will become unacceptable.

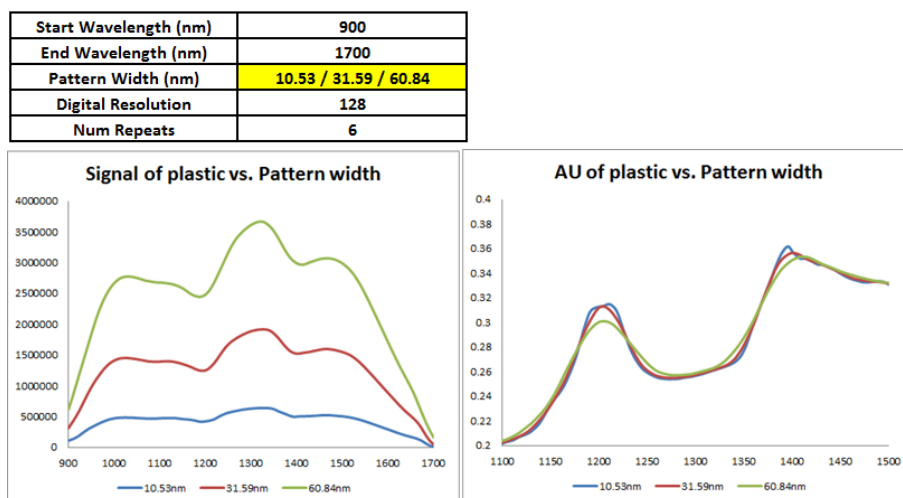


Figure 2.19 Signal and AU vs. Pattern Width

Appropriately increasing the digital resolution (= number of sampling points) can enhance spectral information. If the resolution is still good enough, the digital resolution can be reduced to save scanning time. For example, 128pts and 160pts don't make much difference in the following case.

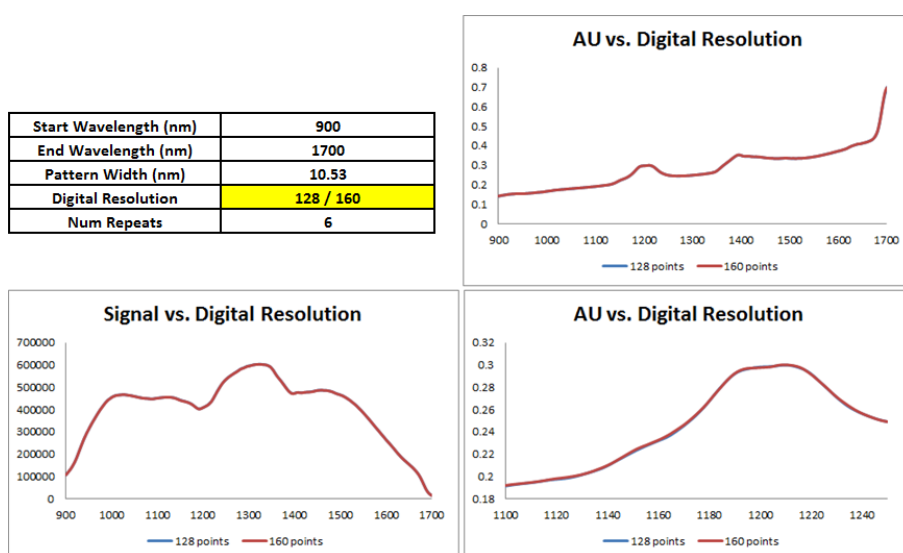


Figure 2.20 Signal and AU vs. Digital Resolution

When the digital resolution is further reduced to 64pts or even 32pts, absorbance distortion is observed, which is unacceptable.

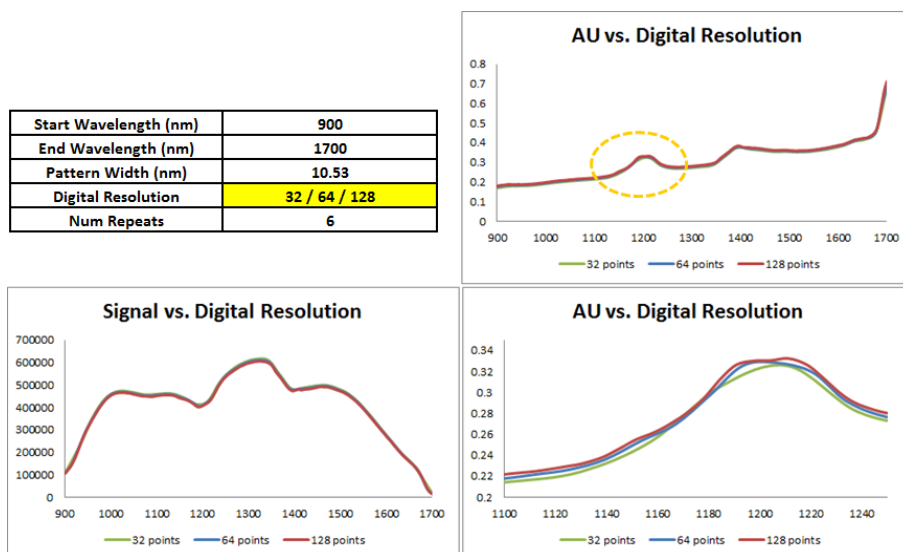


Figure 2.21 Signal and AU vs. Digital Resolution

2.3.5 Exposure Time

InGaAs photodiodes generate a small amount of current when a photon impacts the P-N junction of the semiconductor. The following architectures amplify and digitize the small current of the photodiode:

- Transimpedance amplifier through discrete components or an integrated photodiode and amplifier. This architecture converts the photodiode current into a voltage and then digitizes the voltage with an ADC. The voltage is typically oversampled by the ADC to average out the noise.
- Charge integration through discrete components or a charge digitizing ADC. This architecture utilizes capacitors for charge accumulation and then converts this charge into a digital value. The converted digital value is dependent on the integration time.

The NIRScan device uses a transimpedance amplifier to convert the photodiode current into a voltage. During each DMD pattern display time (the so-called exposure time), the ADC samples the voltage multiple times. Therefore, increasing the exposure time will increase the number of samples to be averaged, but will not increase the voltage level at the ADC input.

In theory, Hadamard mode should still also benefit from increased exposure time. However, it may be less noticeable if the SNR is already high. Depending on the Hadamard scan configuration, it will likely increase the SNR by 2x-7x. Increasing the exposure time will increase the SNR relative to the square root of the exposure time. The difference between 0.635ms pattern exposure time Column scan and 0.635ms pattern exposure time Hadamard scan may be similar to the difference between 0.635ms exposure time Column scan and 5.08ms exposure time Column scan. This function may be cooperated with slew scan to enhance the spectra quality.

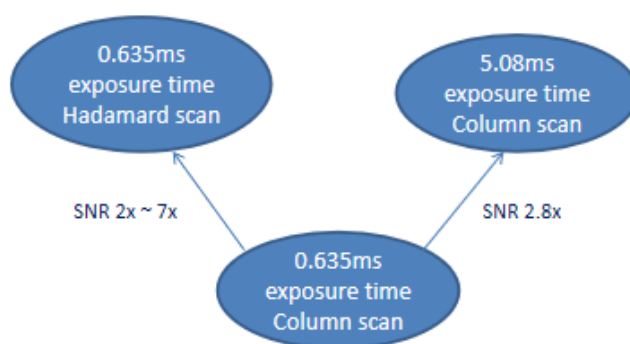


Figure 2.24 The Impact of Scan Mode and Exposure Time on SNR

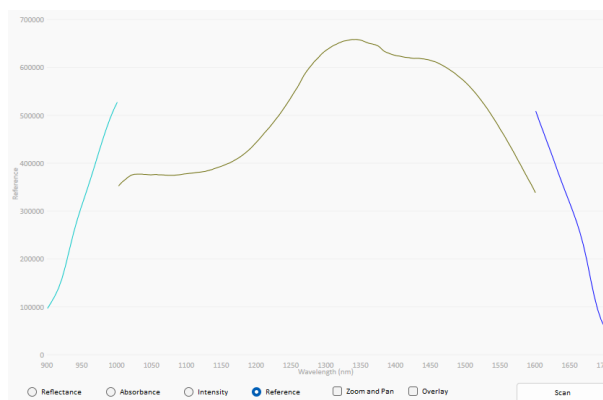
2.3.6 Slew Scan

Compared with traditional linear array spectrometers, DLP-based spectrometers can be configured to scan samples using the so-called slew scanning method. The slew scan configuration can consist of multiple sections. Each section has its own scanning type, wavelength range, pattern width, exposure time and digital resolution.

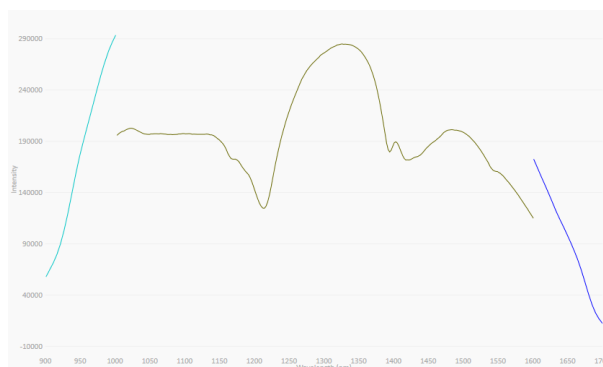
Slew scans can be configured in up to 5 sections. Below is a 3-section example. Sections 1 and 3 have a larger pattern width to increase signal intensity and a lower sampling rate (lower digital resolution) to save scanning time. Section 2 has a smaller pattern width but a higher sampling rate (higher digital resolution) to ensure spectral quality. As shown in the figure below, the reference signal and sample signal are not continuous curves, but AU is continuous.

Details						
Name	SlewScan					
Num Scans to Avg.	6					
Num Sections	3	1	2	3	4	5
Scan Type	Col	Col	Col			
Spectral Range Start	900	1001	1601			
Spectral Range End	1000	1600	1700			
Width (nm)	10.54	7.03	10.54			
Exposure Time (ms)	1.27	1.27	1.27			
Digital Resolution	20	252	20			
Oversampling	2.0	3.0	2.2			

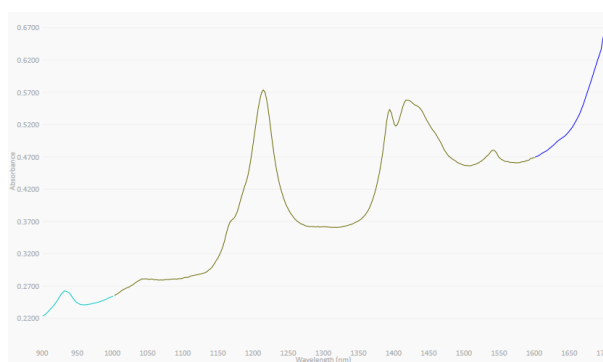
Figure 2.25 Slew Scan Configurations



(a) Reference Signal



(b) Sample Signal



(c) Absorbance

Figure 2.26 Slew Scan Results

2.3.7 Photosensitivity

The following figure shows the typical photosensitivity of an uncooled InGaAs detector within the standard wavelength range. When the wavelength is greater than 1650nm, the photosensitivity will change with temperature. Therefore, when the temperature changes, the absorbance data at 1650-1700nm will be unstable. On the other hand, when the wavelength is less than 950nm, the photosensitivity is low. As mentioned above, the DLP-based spectrometer is configurable, so you can consider setting the wavelength range to 950nm to 1650nm.

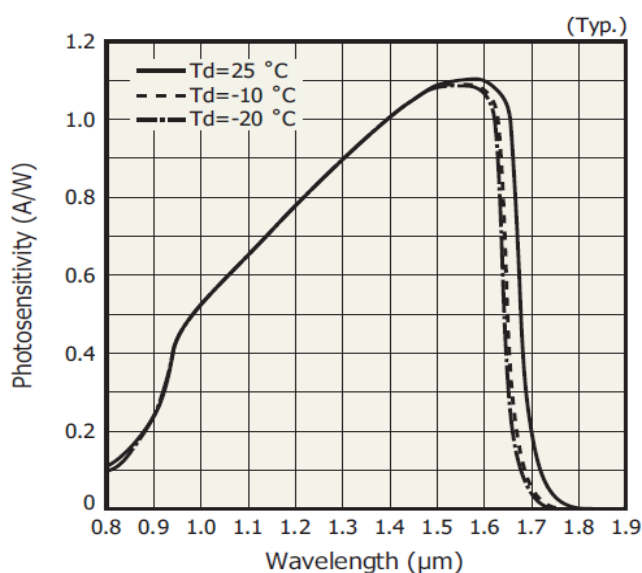


Figure 2.27 Photosensitivity of InGaAs Detector

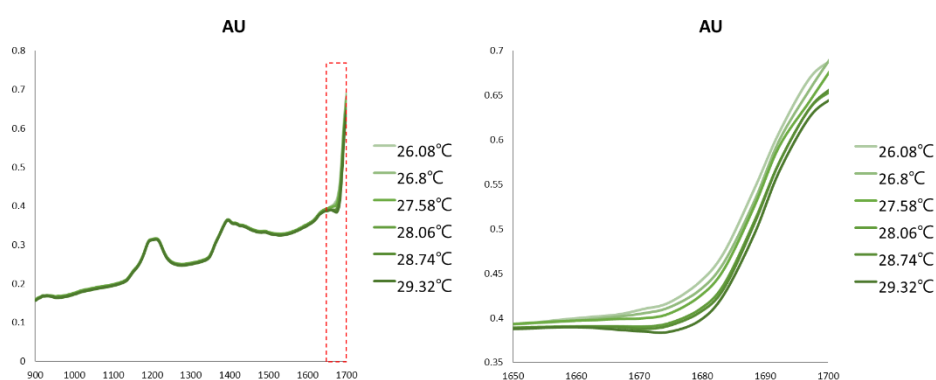


Figure 2.28 AU vs. Temperature

2.3.8 Operating Point

The operating point is a specific point within the operating characteristics of the spectrometer. The operating point of the spectrometer is closely related to the state of the tungsten filament lamp. The lamp has just been cold-started or has been warmed up represents two different operating points. The following is an experiment to demonstrate the changes of AU at different operating points. Perform 200 scans continuously, set a 5s delay before the next scan, and start from the cold start, the total time is about 46 minutes. Spectrum intensities of the initial reference scan and 200 sample scans are shown below: R stands for the initial reference signal (cold start), S1 stands for the 1st sample signal, S2 for the 2nd sample signal, and S200 stands for the 200th sample signal. The spectrum change is observed as follows.

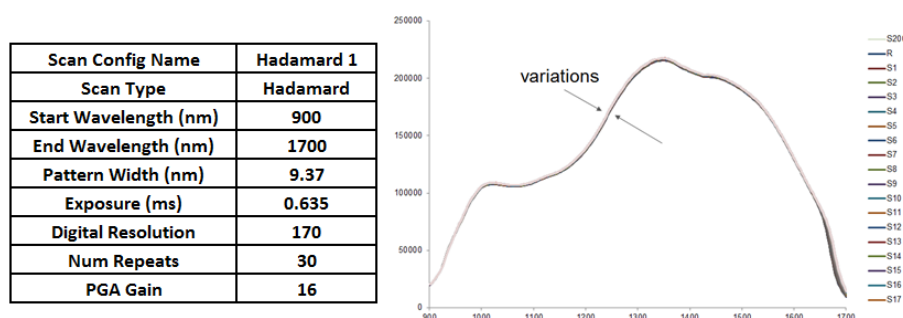


Figure 2.29 Spectral Changes in Cold Start

By using the initial reference signal R as the reference signal and S_n ($n=1$ to 200) as sample signal to calculate AU, the 1st AU and the 200th AU are shown below. The 200th AU not only has level shift but also has spectrum distortion.

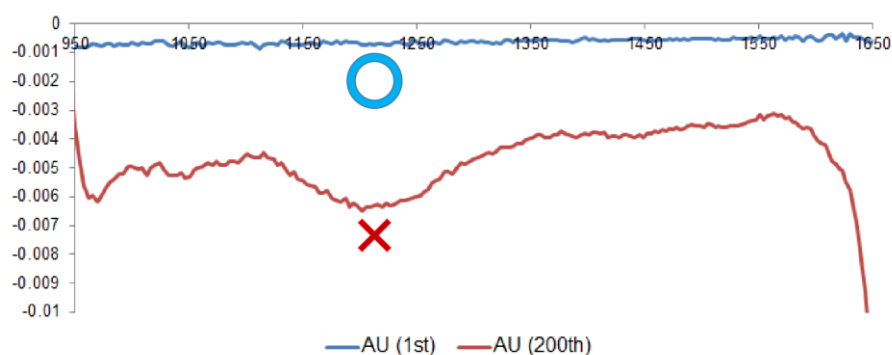


Figure 2.30 AU (1st) vs. AU (200th)

The spectrum intensity at 1300nm during 200 scans is shown below.

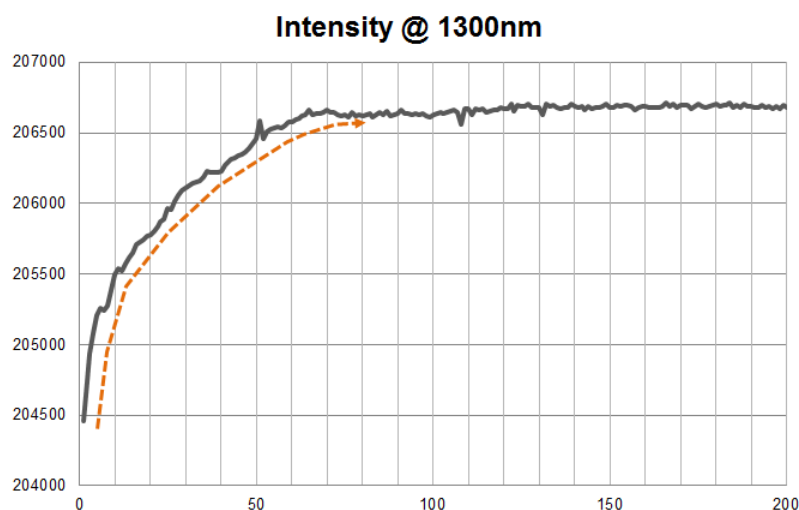


Figure 2.31 Spectral Intensity at 1300nm of 200 Scans

Obviously, it is not proper to take R (reference signal at cold-start) as the reference signal for calculating the AU for all the following 200 sample signals because the spectrum intensity will change rapidly from cold-start. By using R (reference signal at cold start) as the reference signal, the calculated AU is affected by the warm-up process obviously. AU (S10 vs. R) shows the following nonlinear behavior.

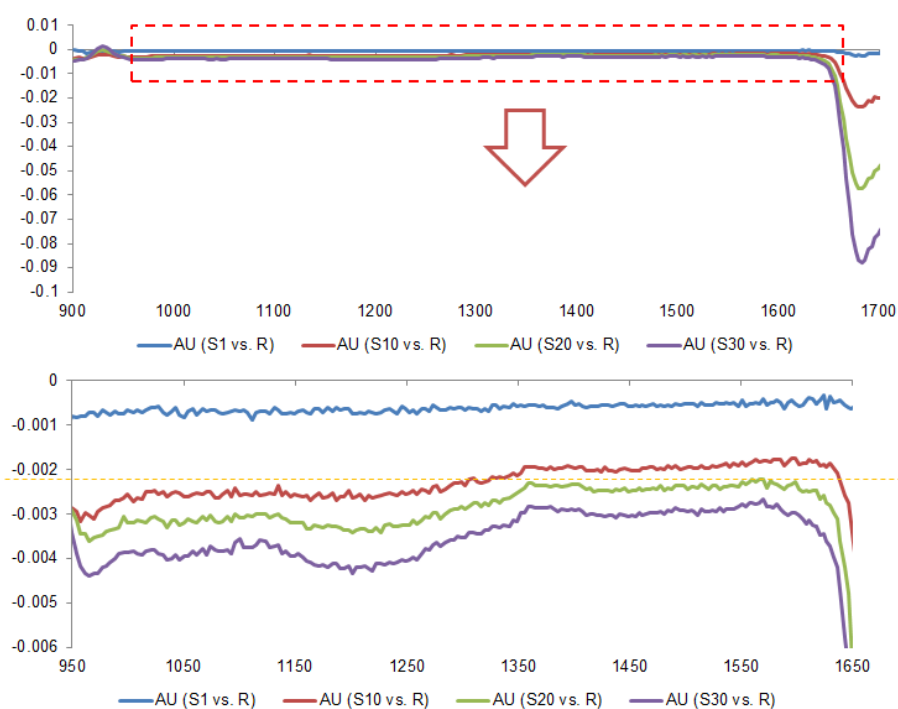


Figure 2.32 AU Changes in Cold Start

If S100 is used as a new reference signal, the result will be much better. By using S100 as reference signal, the AU deviations are within 0.0005 for the following 100 scans.

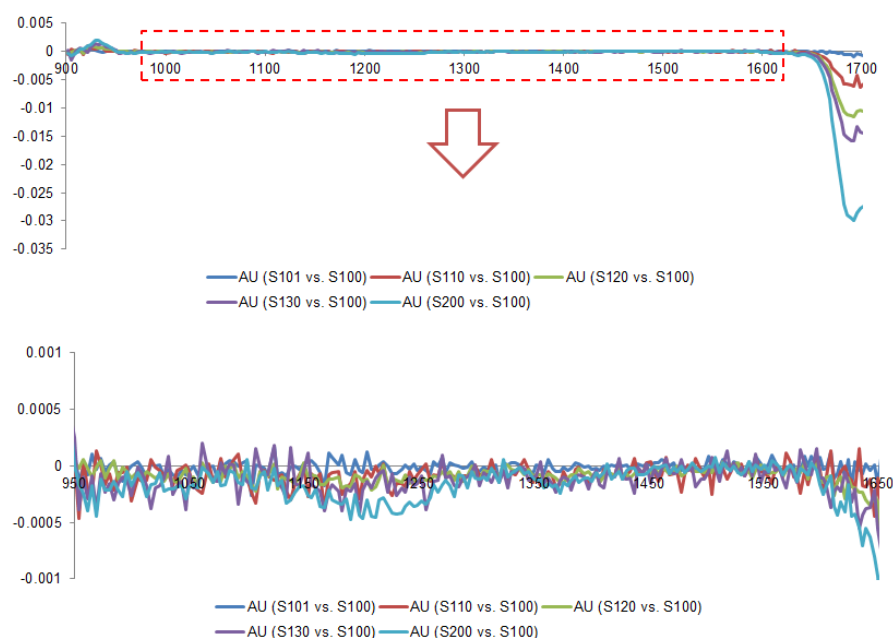


Figure 2.33 AU Changes after Warm Up

As above, if both reference and sample scans are taken after sufficient warm-up time, the calculated AU will be much stable. If device is operated randomly among different operating points, then a frequent reference scan is required to get stable AU. As shown below, the NIRScan GUI provides a lamp warm-up option. The default warm-up time is 3 minutes. Sufficient warm-up time can stabilize the lamp output and set a proper operating point for the spectrometer.

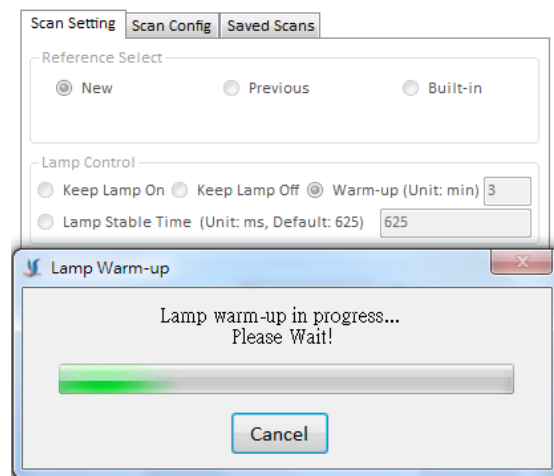


Figure 2.34 Lamp Warm-up Option

Chapter 3 Spectrometer Operation and Calibration

In this chapter, we will introduce the operation of the spectrometer in different measurement modes.

3.1 Diffuse Reflection Mode

3.1.1 Diffuse Reflection Sampling Module

For example, NIR-M-R2, NIR-S-G1 and NIR-S-RT1 are designed for diffuse reflective measurement within the standard wavelength range. The diffuse reflection sampling module operates by illuminating the sample under test at an angle so that specular reflections are not collected, while gathering and focusing diffuse reflections to the slit. Each lens-end lamp produces a beam of light at 40 degree angles that intersect past the sapphire window at about 0.75mm. There is about ± 0.25 mm tolerance to the beam intersection due to the mechanical tolerances of the chassis, the variations of lens-end from lamp to lamp, the variations of lamp shape, and the placement of the lamps. The lens-end lamps focus the light beam at about 3 mm away from the lamps and create a spot size that covers the sapphire sample window. The collection lens gathers light from a 2.5 mm diameter region at the sample window. The size of the collection region was matched to the nominal illumination spot size created by the lens-end lamps. This requires that the sample be placed directly against the sapphire window, where the two angled light source paths intersect the collection vision cone of the lens. If the sample is shifted farther away from the window, the sample may not receive enough illumination for the system to perform an accurate scan. For best performance, place sample against sapphire window during a scan.

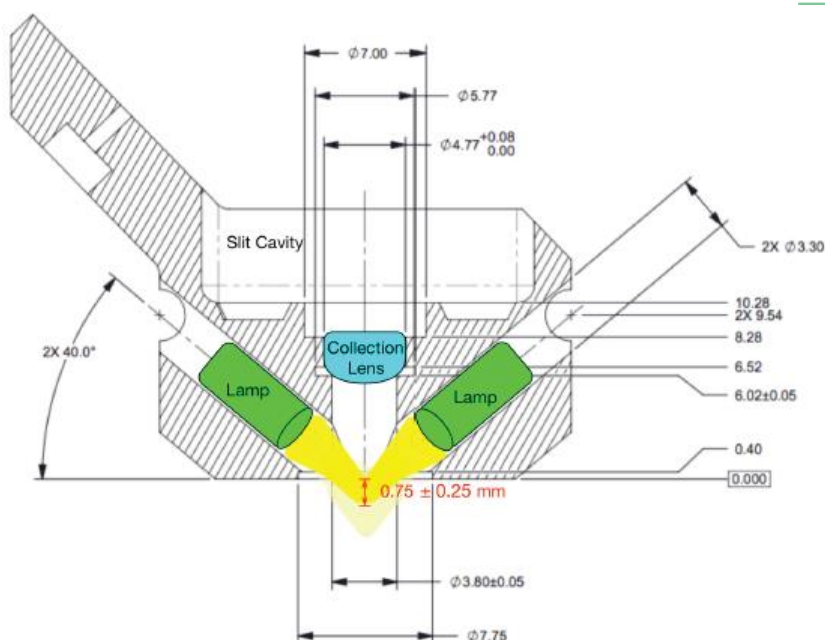


Figure 3.1 Diffuse Reflection Sampling Module

3.1.2 Diffuse Reflection Measurement

Users can easily find an opaque plastic bottle cap (HDPE) and use it to learn NIR spectrum measurement in diffuse reflection mode.



Figure 3.2 Diffuse Reflective Measurement of Plastic Bottle Cap (HDPE)

1. Please connect the NIRScan device to the PC. After launching the NIRScan GUI, please check "Warm-up" to start the lamp warm-up process for at least 3 minutes.

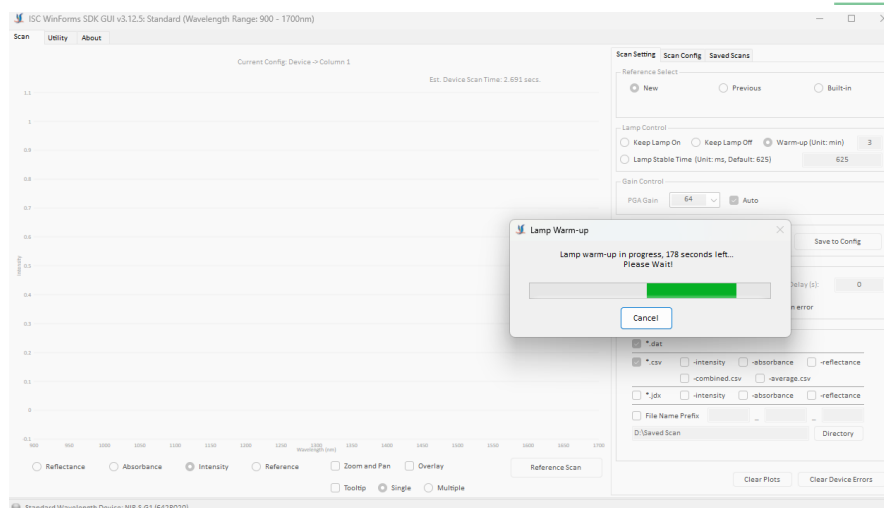


Figure 3.3 Warm-up for 3 Minutes

2. Select "Column 1" as the scan configuration. Place the reference material (SRS-99 or NIR-RM-1/2) on the scan window. Select "New" from "Reference Select" menu. Then, click "Reference Scan" to execute "New" reference scan. The reference signal will be displayed as follows:

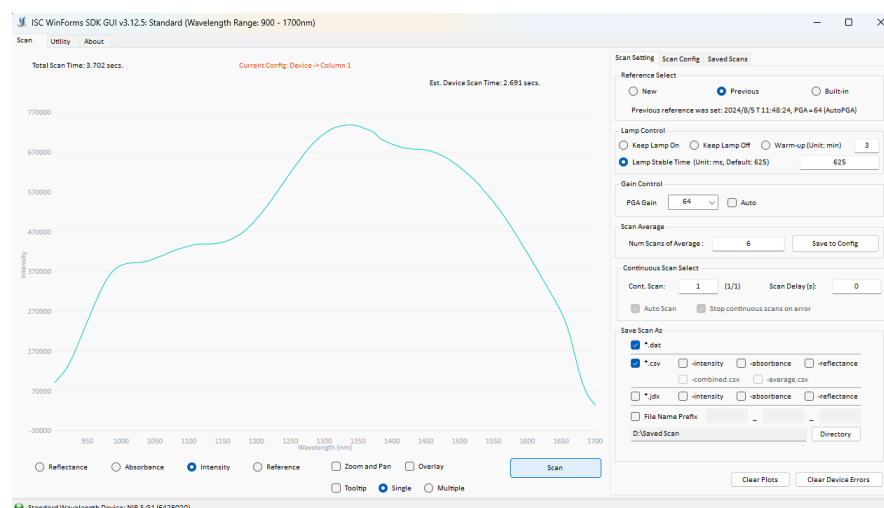


Figure 3.4 New Reference Scan

3. Place the plastic cap made of HDPE on the scan window, select "Previous" from "Reference Select" menu and click "Scan" to execute sample scan. The absorbance of the plastic cap will be displayed as follows:

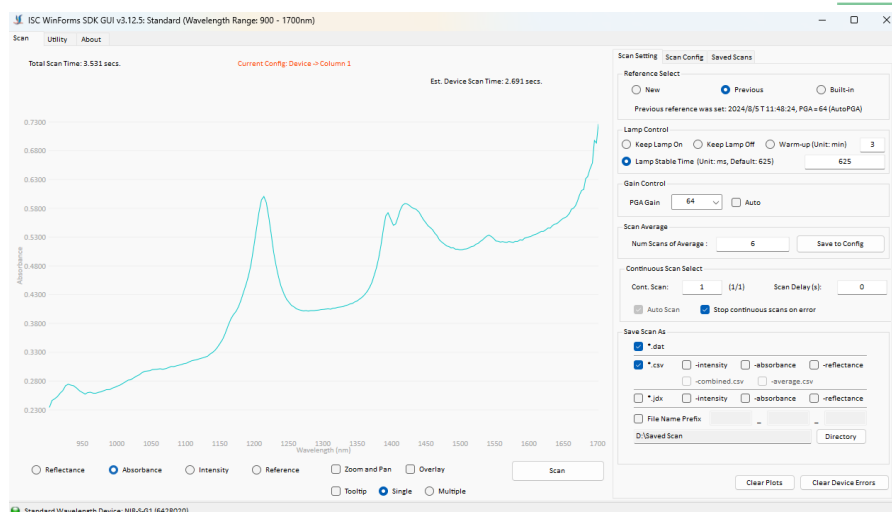


Figure 3.5 Sample Scan and HDPE Absorbance

4. Now, you can find the saved CSV file in the default directory (C:\Users\User Name\Documents\InnoSpectra\ Scan Results\). Then you can see and plot the spectral data as shown below.

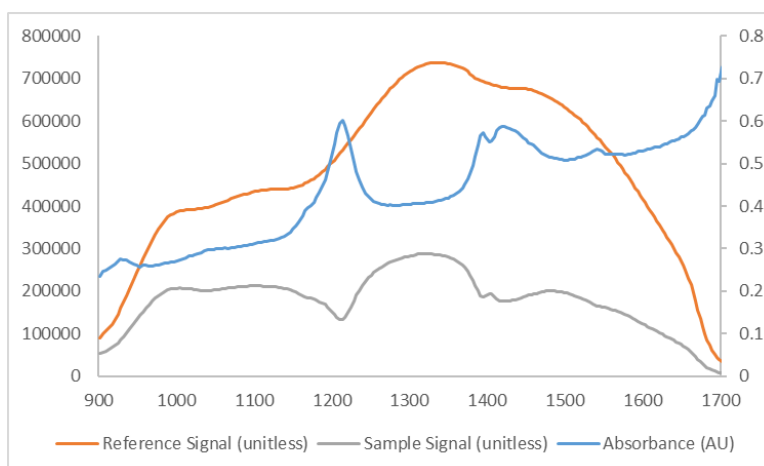


Figure 3.6 Spectral Data Saved in CSV File

3.2 Transmission Mode

3.2.1 Transmission Sampling Module

The NIR-M-Tx and NIR-S-Tx series are designed for transmission measurements in different wavelength ranges. The working principle of the transmissive illumination module is to illuminate the sample under test through a collimating lens, and at the same time gather and focus the transmission light to the slit. The NIR-M-Tx and NIR-S-Tx series are designed with a sample holder to support cuvettes or vials with an optical path length of up to 10 mm. The sample holder is designed with two screw holes, and the sample position can be fixed by ball plunger screws. For vials or short path cuvettes, you can load them into an adapter first, and then put them into the sample holder. The Z-axis dimension (beam height) is 4.5 mm or 15 mm. The transmission sampling module is illuminated by a tungsten filament lamp, which consumes only 0.7 watts. Please refer to the figure below to load enough samples into the cuvettes or vials for measurement. It is recommended that the sample height is 5mm higher than the Z-dimension value.

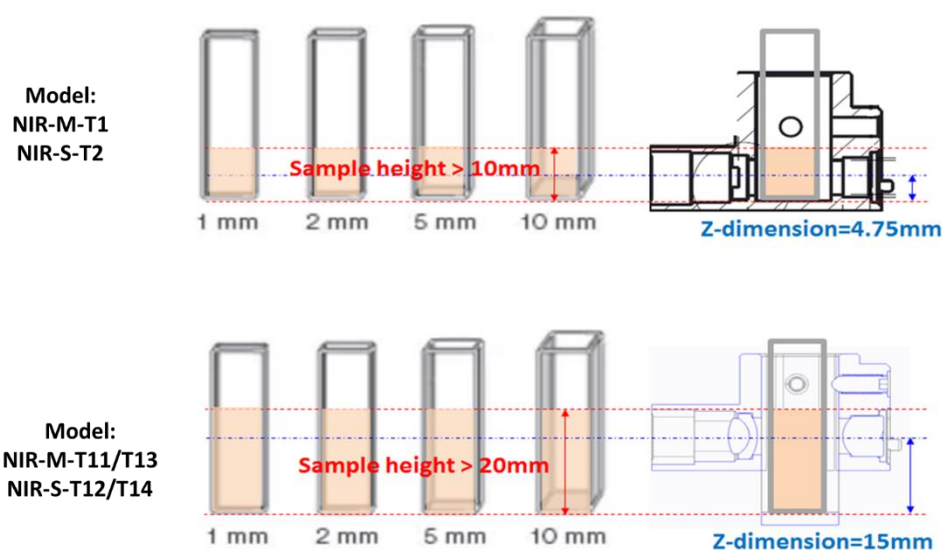


Figure 3.7 Z-dimension and Sample Height

Please refer to the figure below to align the standard 10mm cuvette with the optical axis. Please adjust the ball plunger screws until the ball end contacts the cuvette and starts to compress, do not over tighten the ball plunger screws.

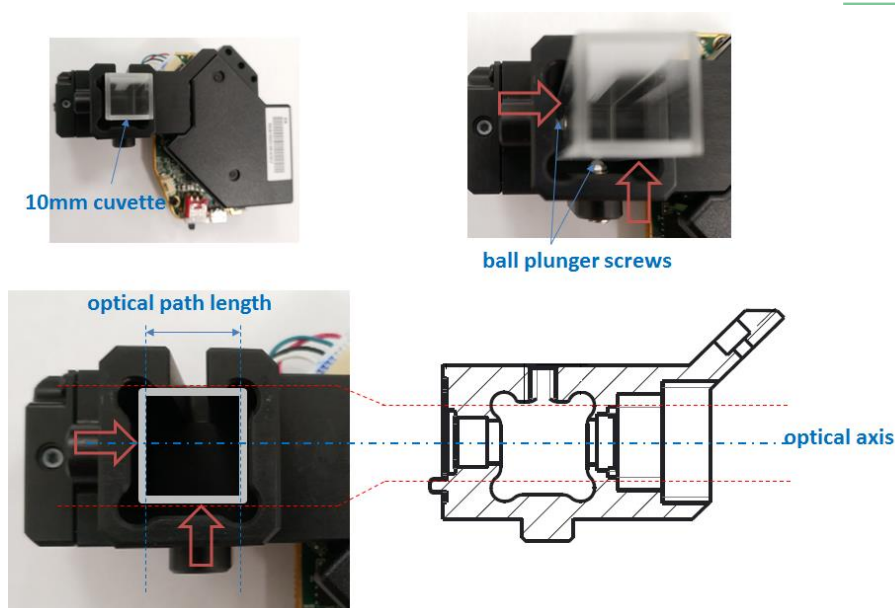


Figure 3.8 Alignment of Standard Cuvette

Please refer to the figure below for the alignment of sample vials and short path length cuvettes. Please contact ISC to obtain the CAD file of the adapter.



Figure 3.9 Alignment of Sample Vial and Short Path Length Cuvette

3.2.2 Transmission Measurement

The NIR-M-Tx and NIR-S-Tx series can be used not only to measure liquid samples, but also to measure transparent solid materials, such as water, wine, edible oil, milk, syrup, gasoline, plastic sheets, filters, sunscreen window films, etc. Note, please use

glass or quartz cuvette instead of plastic cuvette for liquid measurement. In addition, please select cuvettes with an appropriate optical path to avoid absorbance distortion.

Here is an example of plastic measurement and identification by means of NIR-M-T1. We will show you the measurement of PET and PMMA plates (thickness = 3mm).

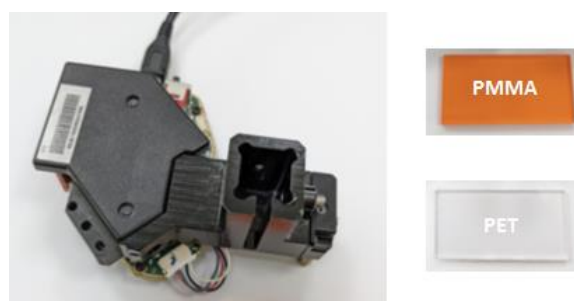


Figure 3.10 NIR-M-T1 and Plastic Plates

1. Connect the NIRScan device to the PC. After launching the NIRScan GUI, check "Warm-up" to start the lamp warm-up process for at least 3 minutes. After that, select "Column 1" as the scan configuration. Scan air to get the new reference signal as follows:

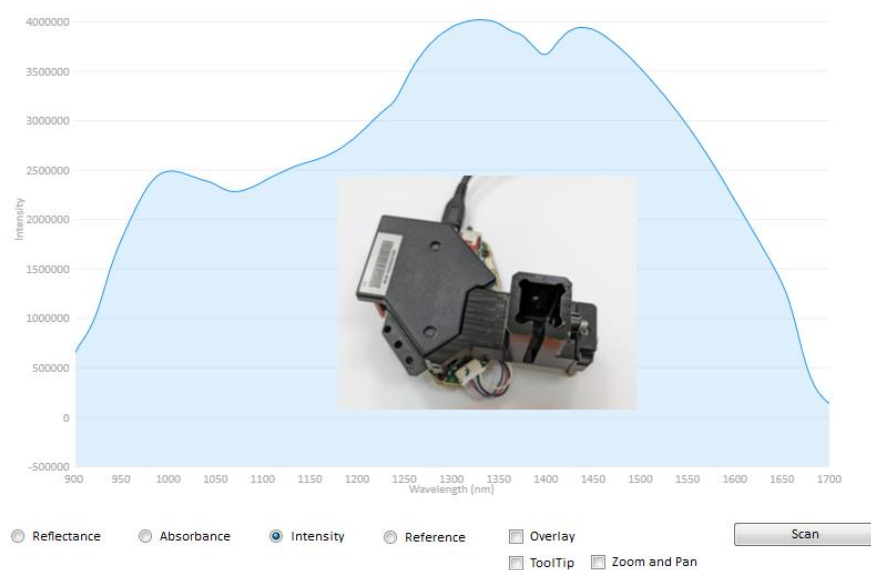


Figure 3.11 New Reference Scan

2. Insert the plastic plate into the sample holder and measure the sample signal. The absorbance data of the two samples are shown below.

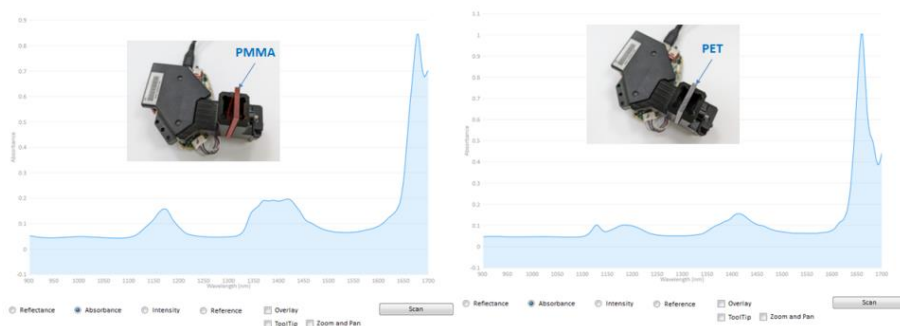


Figure 3.12 Sample Scan

3. By comparing the absorbance data, it is easy to identify different plastic plates.

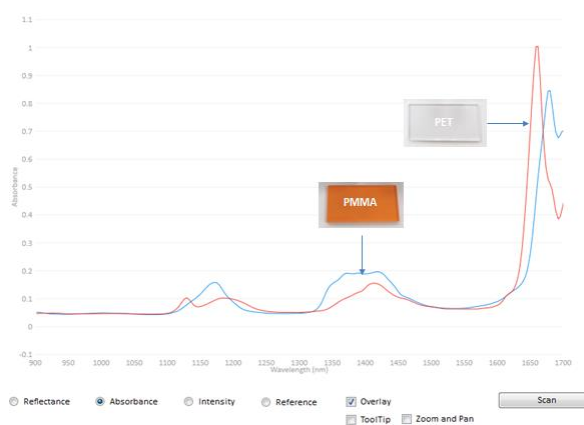


Figure 3.13 Comparison of Absorbance of PET and PMMA

The following is an example of absorbance at different alcohol concentrations.

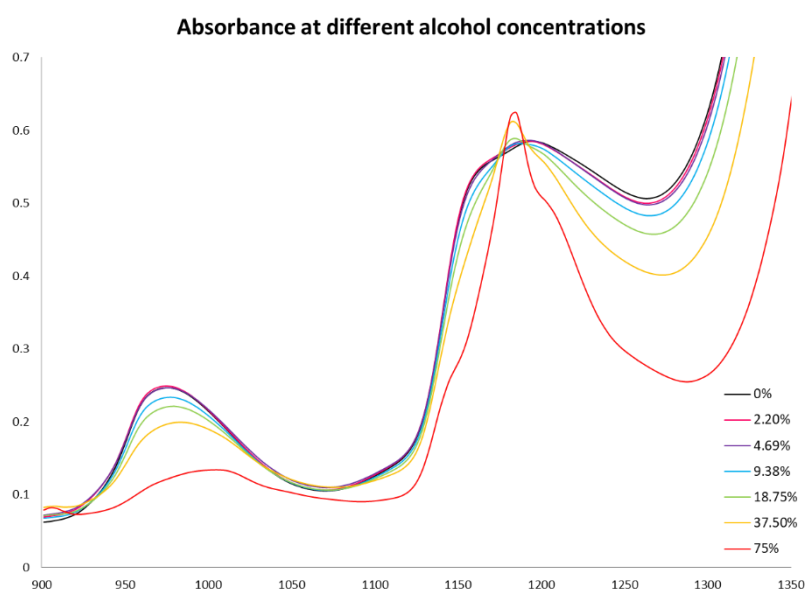


Figure 3.14 Different Alcohol Concentrations

The following is an example of the absorbance of water measured using different

path lengths. Obviously, an optical path of more than 5 mm is too long for this application because the absorbance is already distorted.

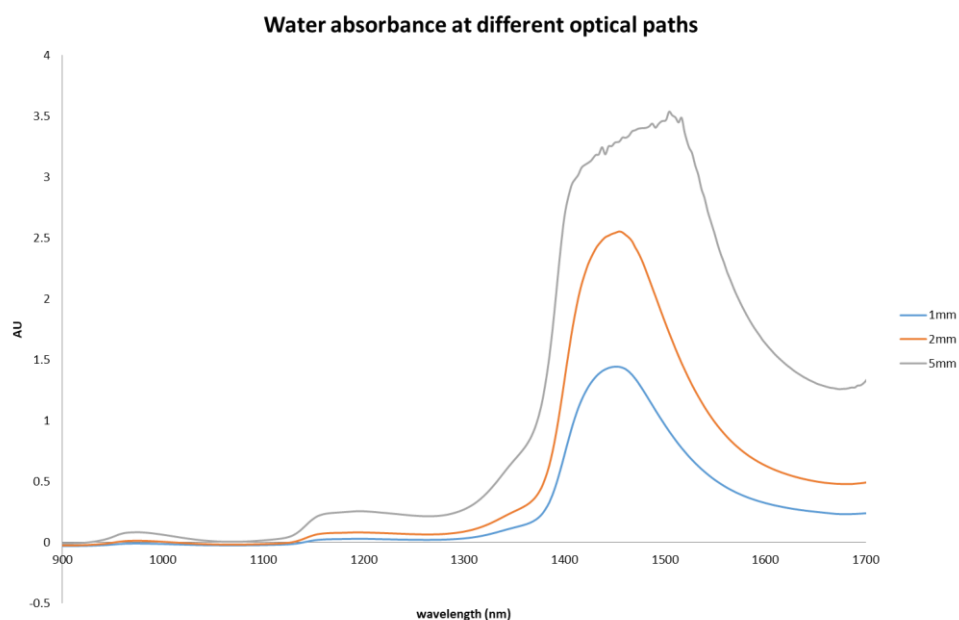


Figure 3.15 Water Absorbance vs. Path Length

If the sample analyzed is water-rich and the constituent of interest has absorption bands overlapped with water absorption, the appropriate physical path length would be 0.2mm for the combination region measurement (1800–2100 nm), 1.0mm for the first overtone region (1400–1500 nm), and 10mm for the second overtone region (900–1000 nm). However, the decision for optical path length is also dependent on the molar absorptivity, that is, the ability of a particular substance to absorb light at a given wavelength, and the concentration of that constituent of interest. In many cases, the constituent of interest has absorption bands on the shoulder of water bands such as in the region of 2100–2300 nm. In such cases, sample cells with longer physical path length, say 1mm, could be more appropriate than the 0.2mm sample cell due to lower absorptivity of substances in this region.

Soy milk and dairy milk are generally opaque, white or off-white in color, and are strong scattering materials. If you plan to measure milk in transmissive mode, you need to apply a very short path length. Here is an example of the absorbance of soy milk measured using 100um path length.

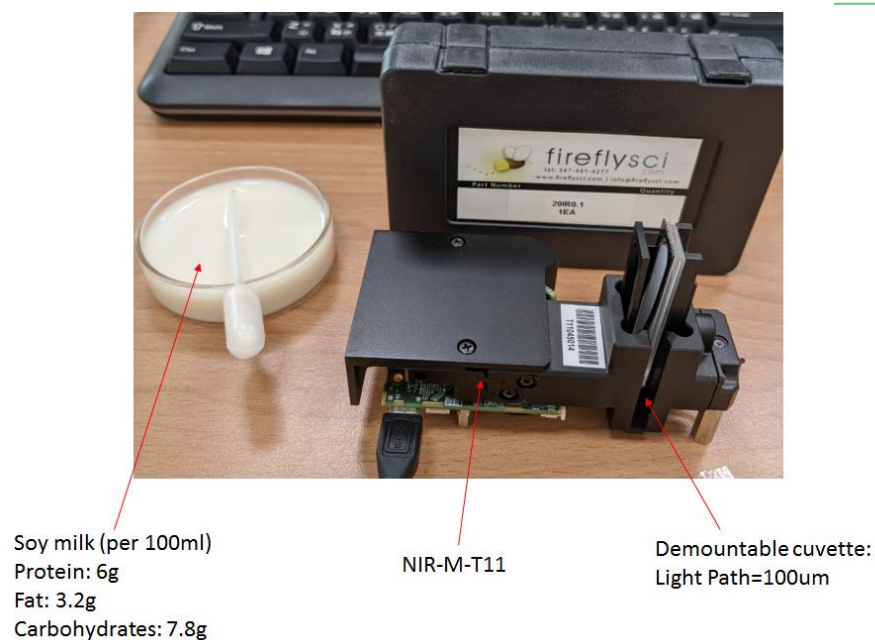


Figure 3.16 Use 100um Cuvette to Measure Soy Milk in Transmissive Mode

The following is the scanning configuration and scanning results of soy milk in transmissive mode.

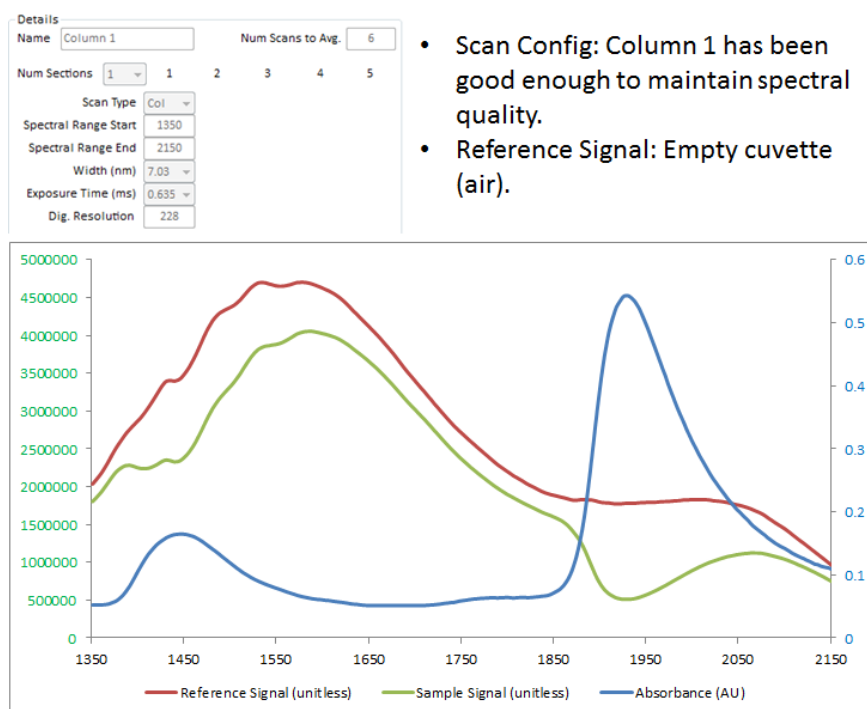


Figure 3.17 Scan Configuration and Absorbance of Soy Milk

With NIR-M-Tx and NIR-S-Tx, we do not suggest using the Hadamard mode because it is very possible to cause reference signal saturation even when PGA=1 (without ND filter). Once signal is saturated, the absorbance calculation will never be correct.

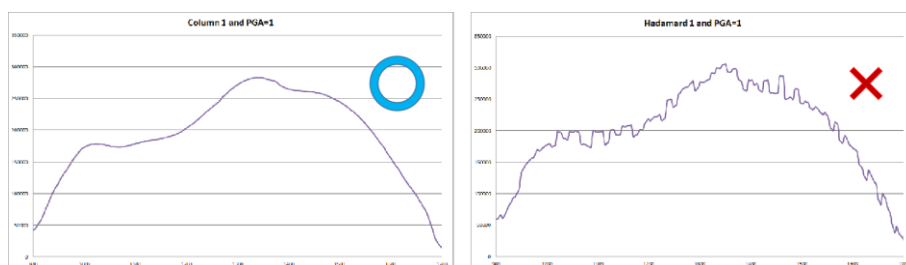


Figure 3.18 Column Mode vs. Hadamard Mode

3.3 Fiber Input

3.3.1 Fiber Input Module

The NIR-M-Fx and NIR-S-Fx series are designed with SMA905 connectors, which can couple light to the entrance slit of the spectrometer through an optical fiber. The dimensions and tolerances of SMA905 connector are designed according to IEC 61754-22: 2005. The length of the optical fiber ferrule should not exceed 9.812mm to prevent it from hitting the slit plate. The SMA905 connector is designed with a V-shaped notch and a key slot, which can be used to align the fiber bundle with the entrance slit of the spectrometer.

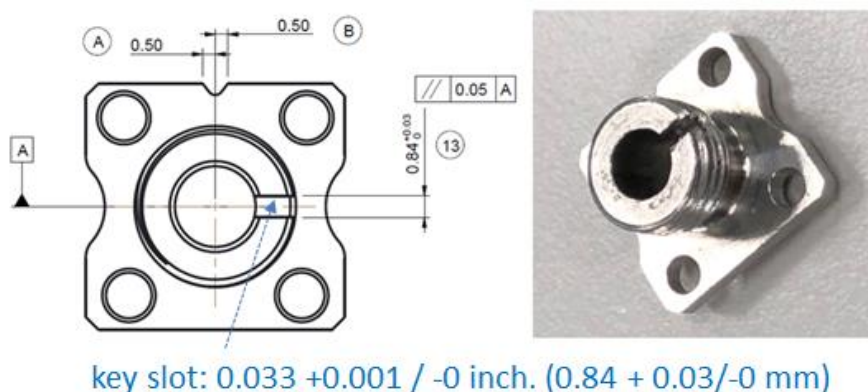


Figure 3.19 SMA905 Connector with V-shaped Notch and Key Slot

The ISC NIRScan device has taller entrance slits than array detector systems because the DMD is taller than the array detector. This allows for increased signal throughput, but can make fiber coupling more complex. Standard optical fibers can be utilized, but will only illuminate a small section of the entrance slit. In order to take advantage of the DLP-based spectrometer's large etendue, a round-to-linear fiber bundle should be used. These optical fibers have multiple cores arranged in a circular pattern at one end, and a linear configuration at the opposite end. The round end can be utilized at the sample as in typical spectroscopy illumination modules, while the linear end can be more effectively coupled to the slit.

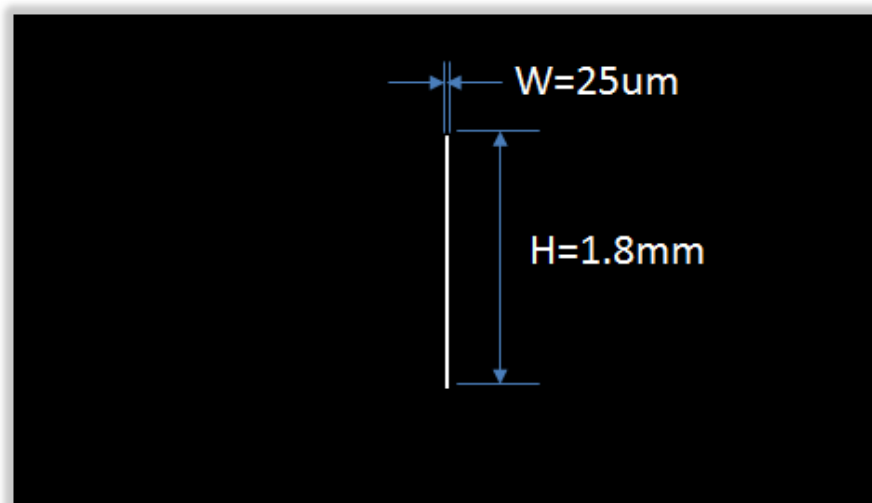


Figure 3.20 Entrance Slit

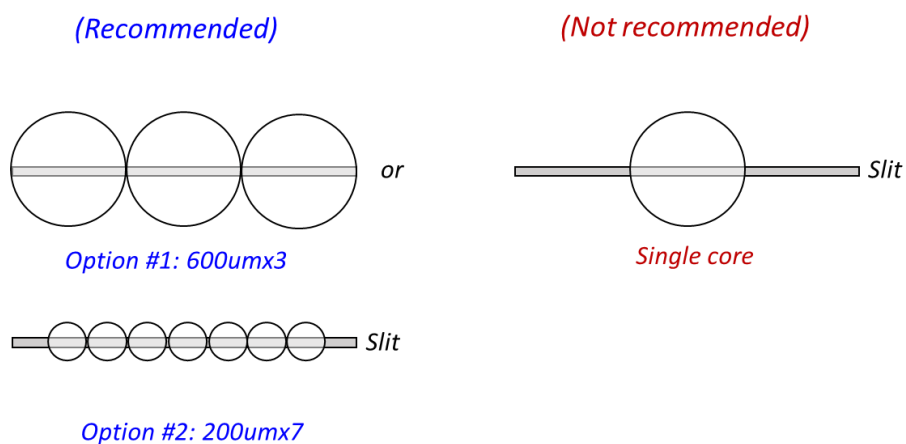


Figure 3.21 Slit Fill Factor with Single Core Fiber and Round-to-Linear Fiber Bundle

It is recommended to use round-to-linear fiber bundle (e.g., NIR-A-R2L1 or equivalent). For alternative fiber options, please select 0.22 NA step-index multimode fibers and low hydroxyl ion (Low-OH) cores for NIR applications.

Figure 1 consists of two photographs. The left photograph shows a fiber optic cable being aligned into a metal connector. An orange arrow points to a 'V-shaped notch' on the fiber, and another orange arrow points to an 'Alignment mark on linear end'. A dashed yellow line indicates the alignment path. The right photograph shows a close-up of the fiber end, with an arrow pointing to an 'Engraved mark indicates the axis of the linear fiber array' and a label 'Linear end' pointing to the fiber tip.

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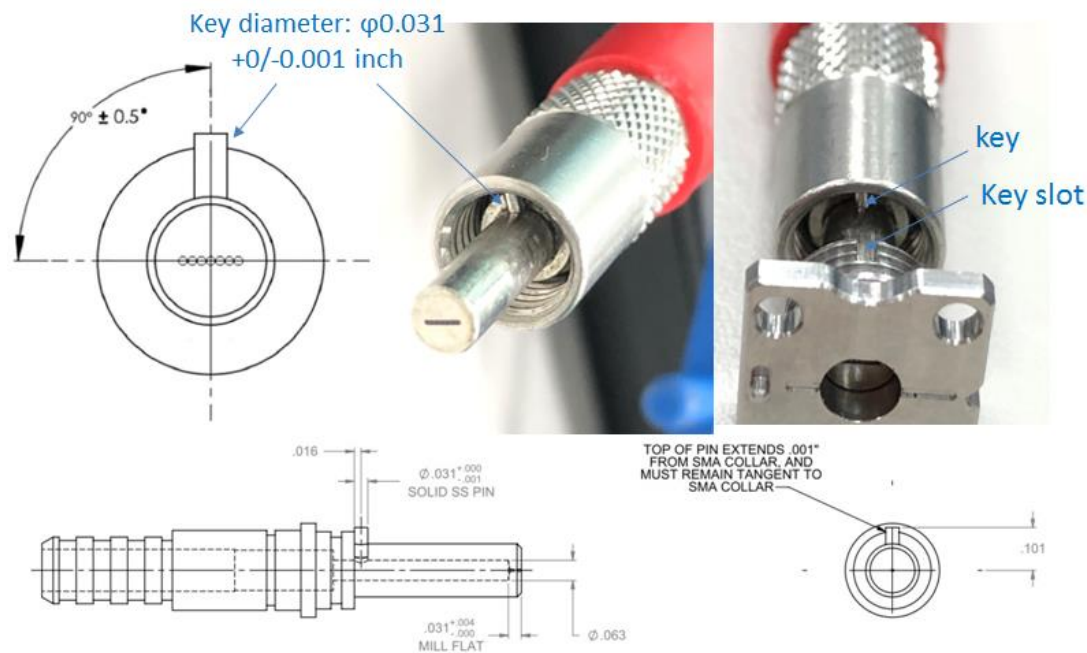


Figure 3.24 Linear End Bundle with Key

3.3.2 Fiber Input Measurement

The following is an example of transmission measurement using a fiber input module. The light source and cuvette holder are integrated into one accessory (e.g., NIR-A-LS1). The NIR-A-LS1 features a 5W light source and a 10mm cuvette holder.

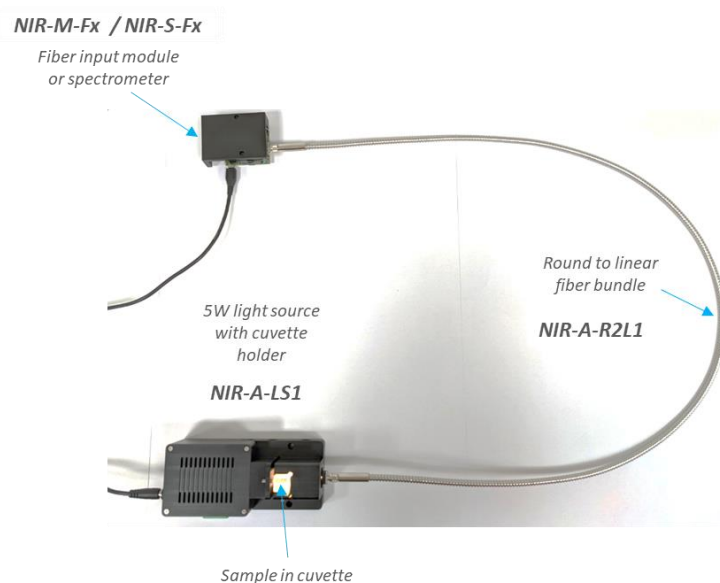


Figure 3.25 Transmission Measurement with Fiber Input Module

The following is an example of diffuse reflection measurement using a fiber input module. The light source and sampling module are integrated into one accessory (e.g., NIR-A-DRP1). The diffuse reflection probe (NIR-A-DRP1) integrates a collimated 5W light source, a collecting lens and an SMA905 connector. When using optical fiber input spectrometer, NIR-A-DRP1 greatly simplifies the diffuse reflective measurement setup. NIR-A-DRP1 supports both contact and non-contact measurement. By using the recommended scan configuration to scan the white reference material and the sample (e.g., HDPE cap), the absorbance of plastic bottle cap is displayed as follows.

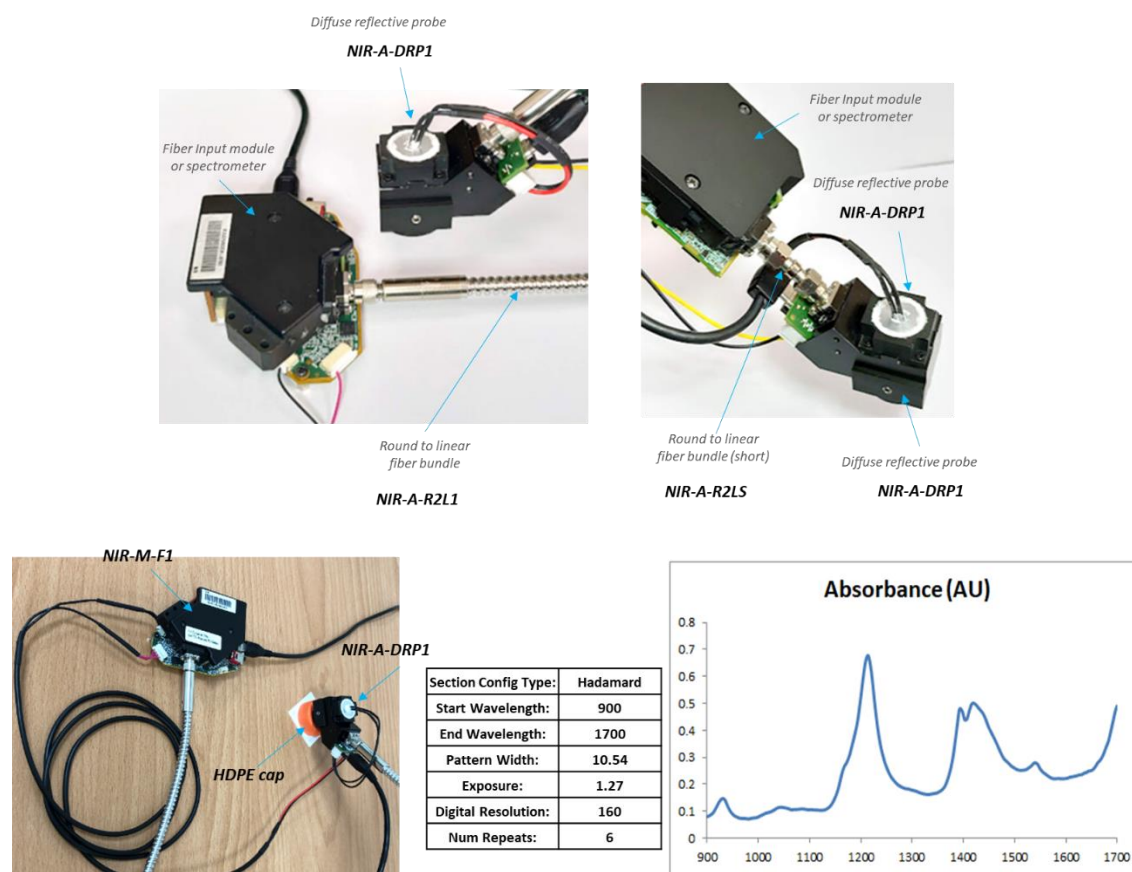


Figure 3.26 Diffuse Reflection Measurement with Fiber Input Module

The following is an example of transfection measurement using a fiber input module.

This setup includes a Y-shaped dip probe (e.g., NIR-A-DIP1).

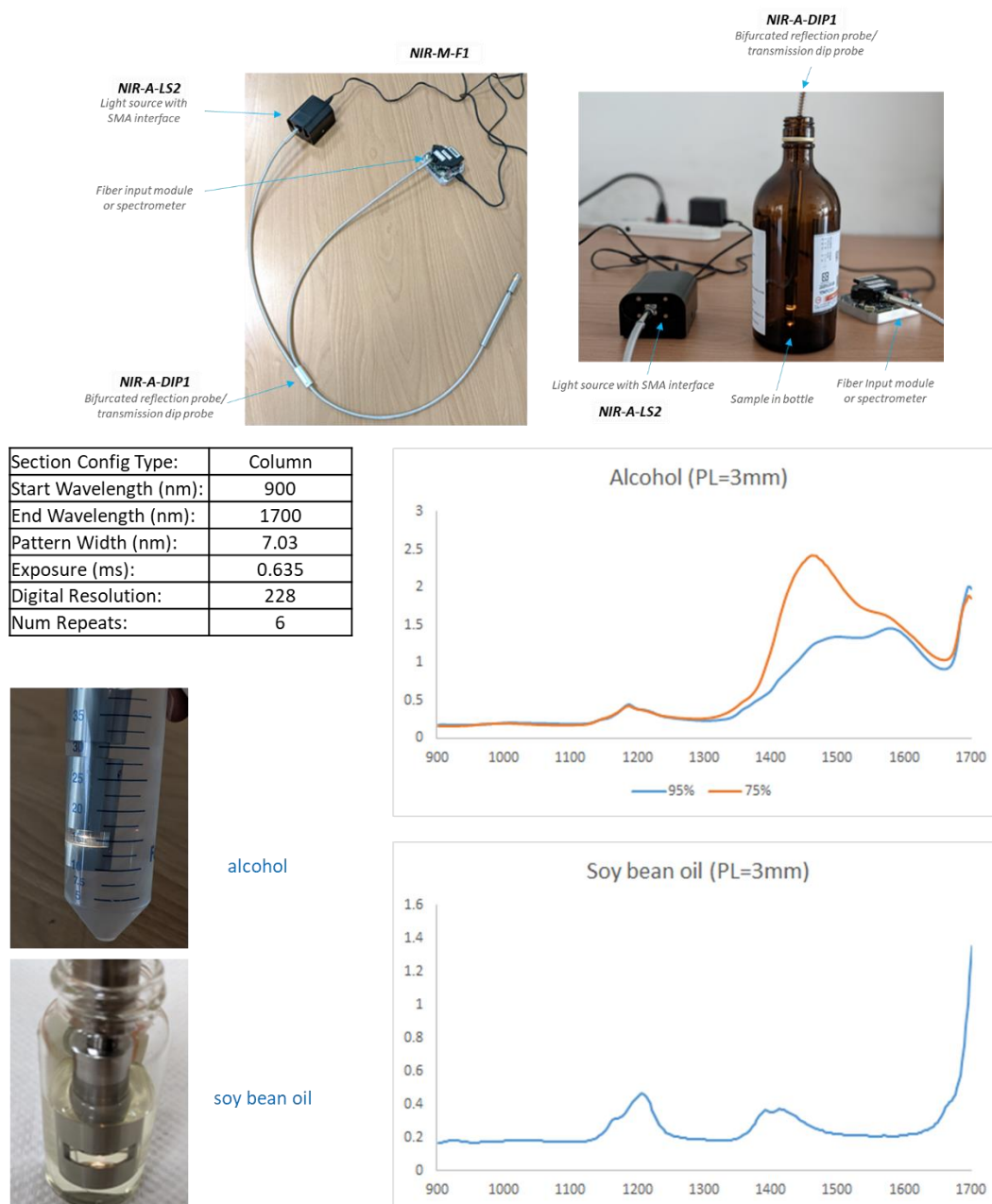


Figure 3.27 Transfectance Measurement with Dip Probe

3.4 Spectrometer Calibration

By using DMD as the wavelength selector, the wavelength of the spectrum is a mapping of DMD pixels. The mapping between each pixel and wavelength is determined by the pixel-to-wavelength coefficients (a, b, and c). The corresponding wavelength of each pixel is calculated from $\lambda = a * P^2 + b * P + c$, where λ is a wavelength and P is the DMD pixel position. It is recommended that the user checks the wavelength accuracy regularly. Once any offset is found between the expected and observed peak wavelength points, the user can consider re-calibrating the spectrometer. In order to check the wavelength accuracy and re-calibrate the NIRScan devices, users have to prepare standard reference material and test sample. For diffuse reflective module and spectrometer, users are advised to prepare **SRS-99** (Labsphere) or **NIR-RM-x** (ISC) and **SRM2036** (NIST) or **WCR-2066** (Avian Technologies). For transmissive module and spectrometer, users are advised to prepare **RM-NIR** (Starna Scientific). For fiber input module and spectrometer, it depends on your application to prepare standard reference material and test sample for wavelength accuracy check and wavelength calibration.

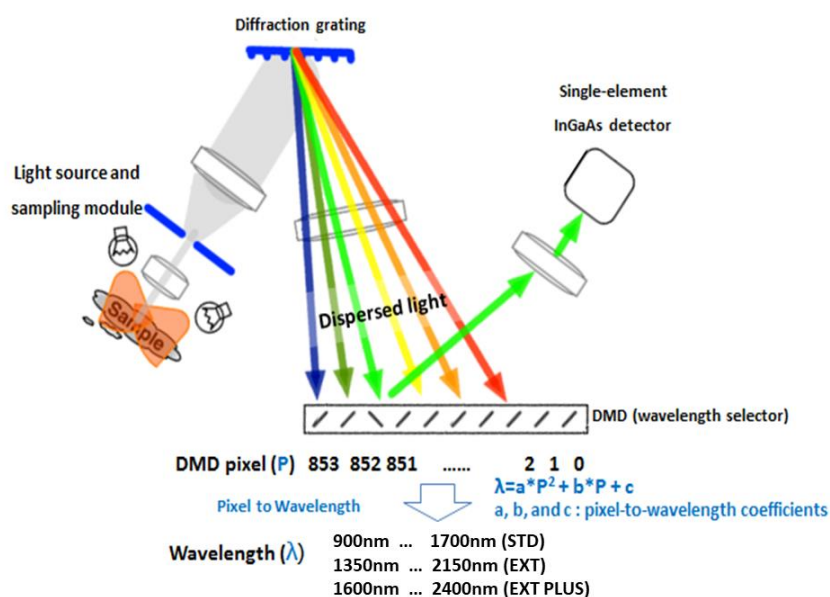


Figure 3.28 Pixel-to-Wavelength Mapping

3.4.1 Diffuse Reflection Mode

Here we use NIR-S-G1 as an example. Please warm up the device first and use the following scan configuration to perform scan test. Please scan SRS-99 or NIR-RM-x to get the reference signal, scan SRM2036 or WCR-2066 to get the sample signal, and then you will get the absorbance data of SRM2036 or WCR-2066 to check the wavelength accuracy.

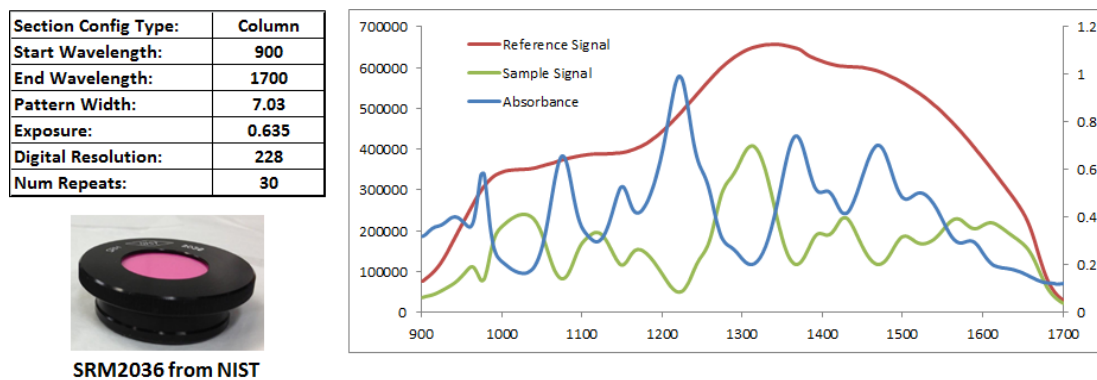


Figure 3.29 Scanning of Standard Reference Material and Test Sample

For example, there is one spectrometer found with wavelength offset as follows:

Expected (SRM2036 AU)	Observed	Offset
975.900	977.356	1.456
1075.800	1077.025	1.225
1222.100	1223.280	1.180
1367.300	1368.811	1.511
1469.500	1471.405	1.905

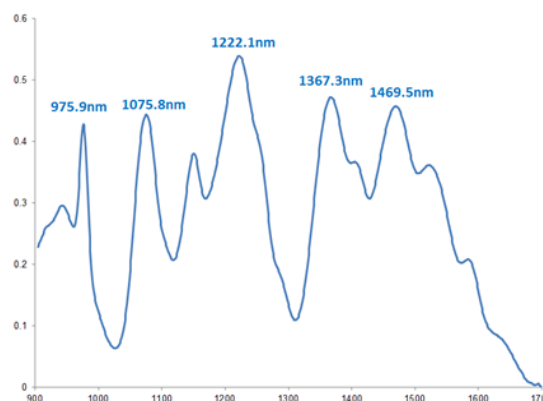


Figure 3.30 Observed Peak Position and Offset

Note: The Lagrange polynomial can be used to find the peak position of NIR absorbance. Three data points near the peak position are used to form a quadratic Lagrange polynomial. The vertex (maximum point) of the quadratic Lagrange polynomial is the peak position we want to find.

Linear regression can be applied to come out a transfer function between the expected wavelength points and the observed wavelength points as below. The linear regression has a perfect fit between two vectors. You can use Excel to

calculate the slope and intercept of a linear transfer function as follows:

- **Slope** (Expected wavelength list, Observed wavelength list)
- **Intercept** (Expected wavelength list, Observed wavelength list)

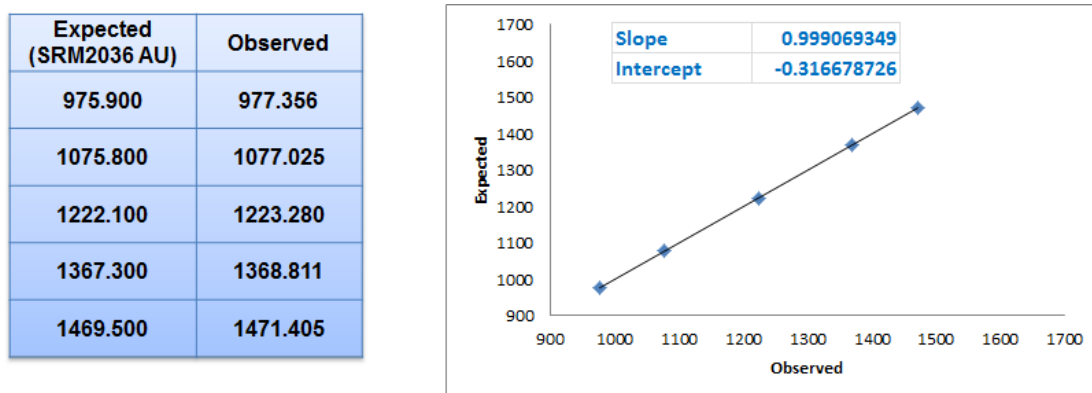


Figure 3.31 Linear Regression of Expected and Observed Wavelength Points

New calibration coefficients are calculated as below:

$$a3 = a2 * a1$$

$$b3 = a2 * b1$$

$$c3 = a2 * c1 + b2$$

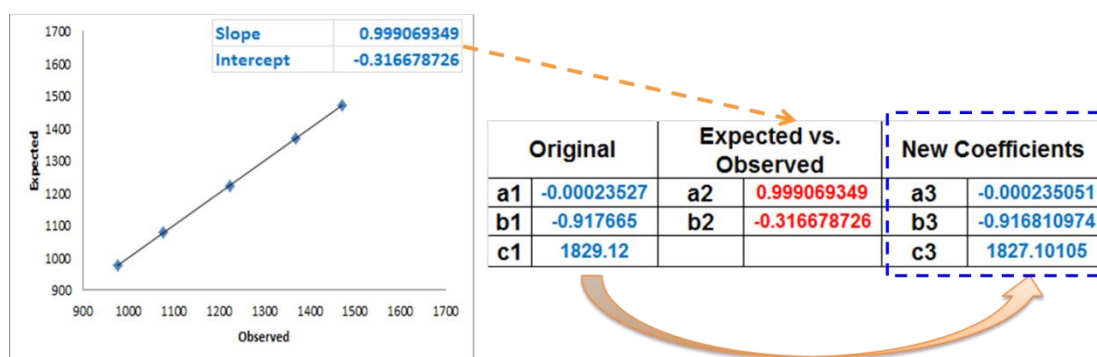


Figure 3.32 Calculate New Calibration Coefficients

Use the NIRScan GUI to update the calibration coefficients:

Original		Expected vs. Observed		New Coefficients	
a1	-0.00023527	a2	0.999069349	a3	-0.000235051
b1	-0.917665	b2	-0.316678726	b3	-0.916810974
c1	1829.12			c3	1827.10105

NIRScan GUI / Utility:

Steps:

1. Read Coefficients
2. Write enable
3. Input new coefficients
4. Write Coefficients

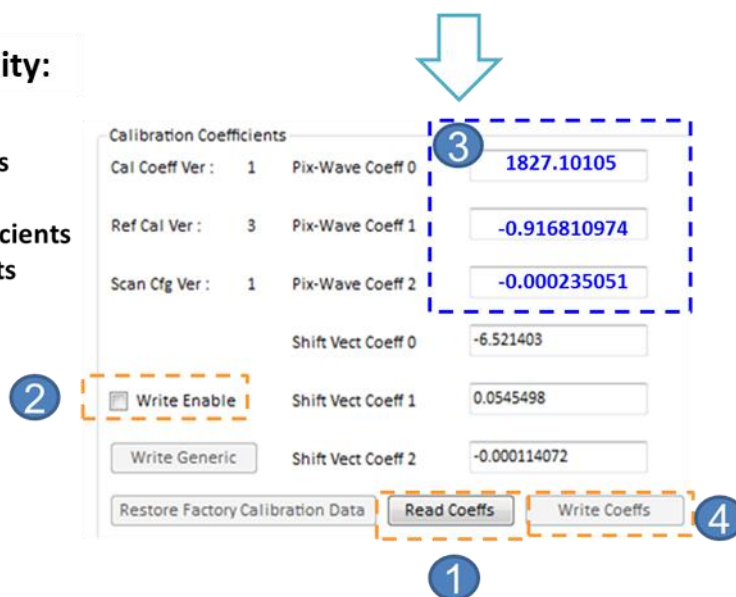


Figure 3.33 Update Calibration Coefficients

After updating the calibration coefficients, please also update the built-in reference data as below:

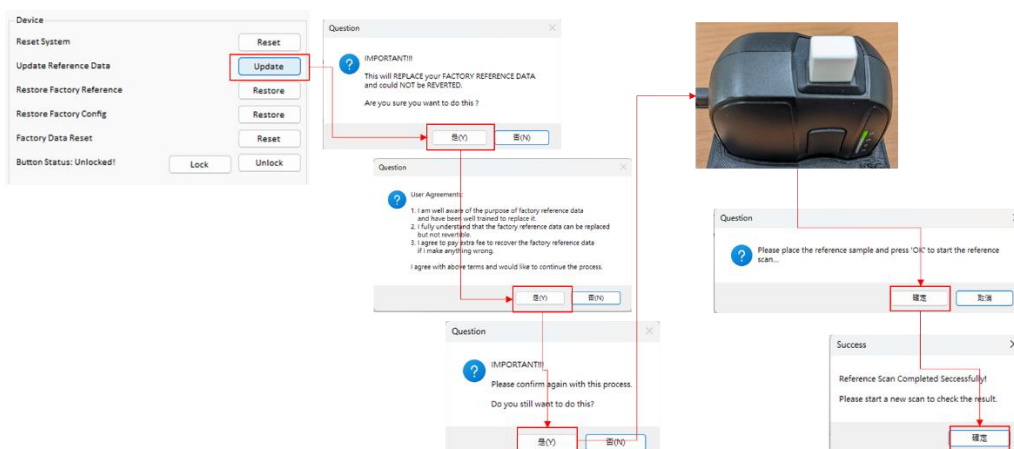


Figure 3.34 Update Built-in Reference Data

3.4.2 Transmission Mode

Here we use NIR-S-T2 as an example. Please warm up the device first and use the following scan configuration to perform scan test. Please scan air to get the reference signal, scan RM-NIR to get the sample signal, and then you will get the absorbance data of RM-NIR to check the wavelength accuracy.

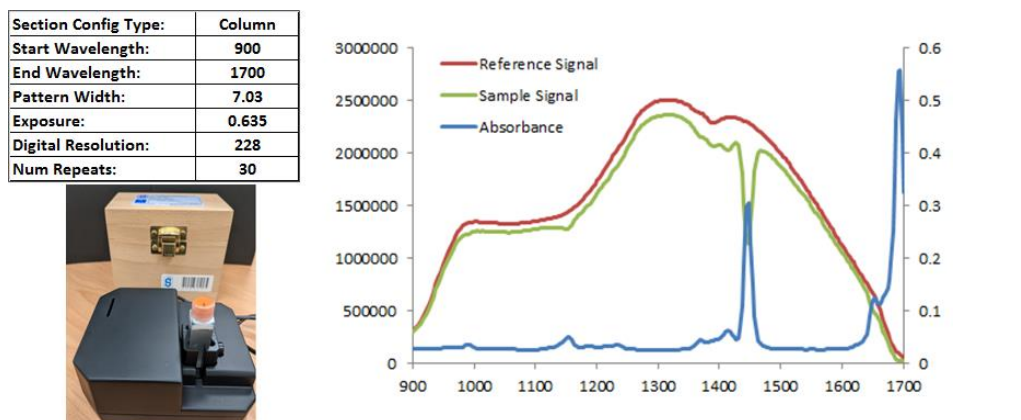


Figure 3.35 Scanning of Standard Reference Material and Test Sample

For example, there is one spectrometer found with wavelength offset as follows:

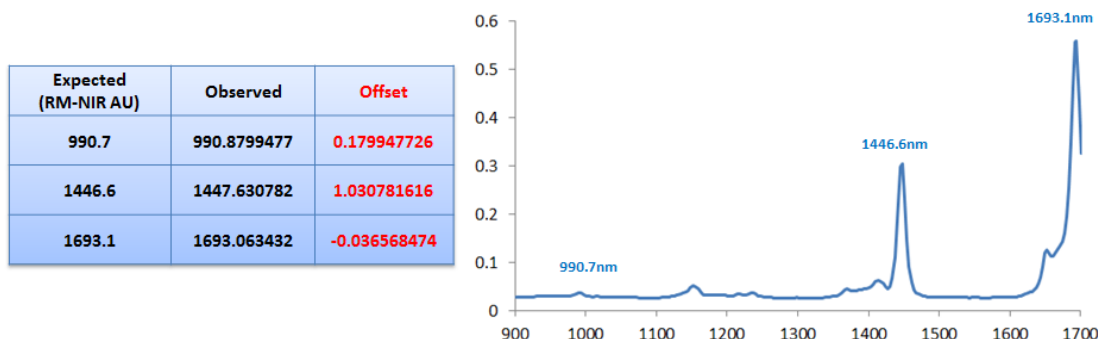


Figure 3.36 Observed Peak Position and Offset

Note: The Lagrange polynomial can be used to find the peak position of NIR absorbance. Three data points near the peak position are used to form a quadratic Lagrange polynomial. The vertex (maximum point) of the quadratic Lagrange polynomial is the peak position we want to find.

Linear regression can be applied to come out a transfer function between the expected wavelength points and the observed wavelength points as below. The linear regression has a perfect fit between two vectors. You can use Excel to calculate the slope and intercept of a linear transfer function as follows:

- **Slope** (Expected wavelength list, Observed wavelength list)
- **Intercept** (Expected wavelength list, Observed wavelength list)

Expected (RM-NIR AU)	Observed
990.7	990.8799477
1446.6	1447.630782
1693.1	1693.063432

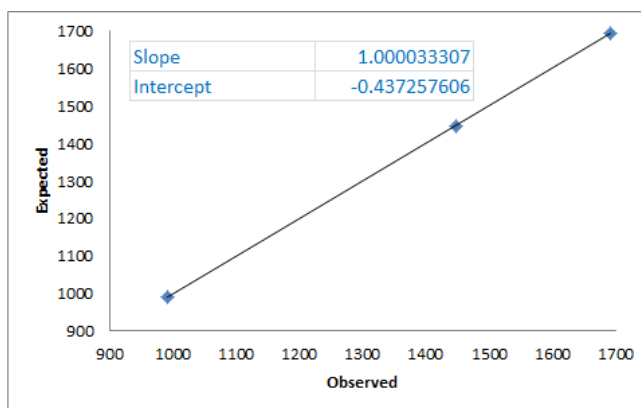


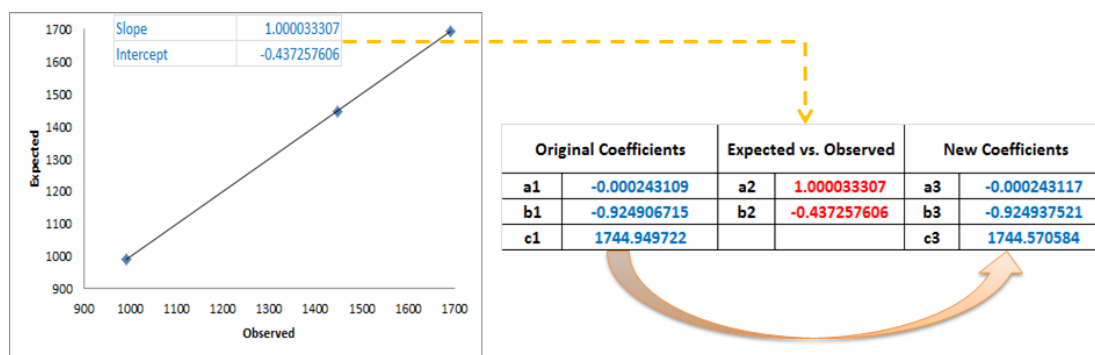
Figure 3.37 Linear Regression of Expected and Observed Wavelength Points

New calibration coefficients are calculated as below:

$$a3 = a2 * a1$$

$$b3 = a2 * b1$$

$$c3 = a2 * c1 + b2$$



Calculate new calibration coefficients

Figure 3.38 Calculate New Calibration Coefficients

Use the NIRScan GUI to update the calibration coefficients:

Original Coefficients		Expected vs. Observed		New Coefficients	
a1	-0.000243109	a2	1.000033307	a3	-0.000243117
b1	-0.924906715	b2	-0.437257606	b3	-0.924937521
c1	1744.949722			c3	1744.570584

NIRScan GUI / Utility:

Steps:

1. Read Coefficients
2. Write enable
3. Input new coefficients
4. Write Coefficients

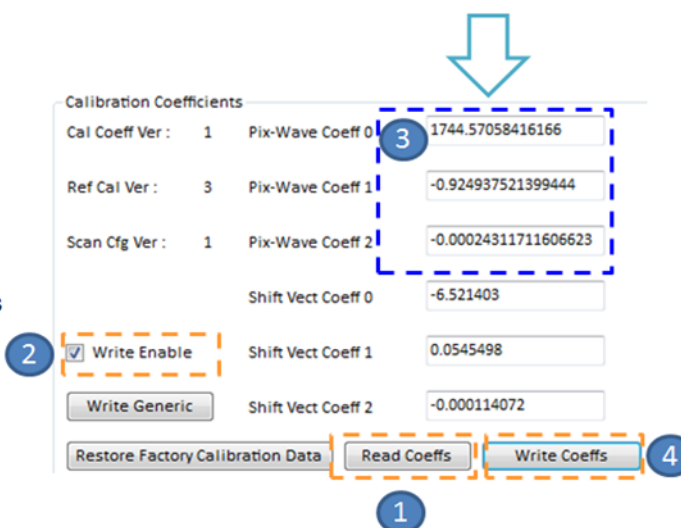


Figure 3.39 Update Calibration Coefficients

After updating the calibration coefficients, please also update the built-in reference data as below:

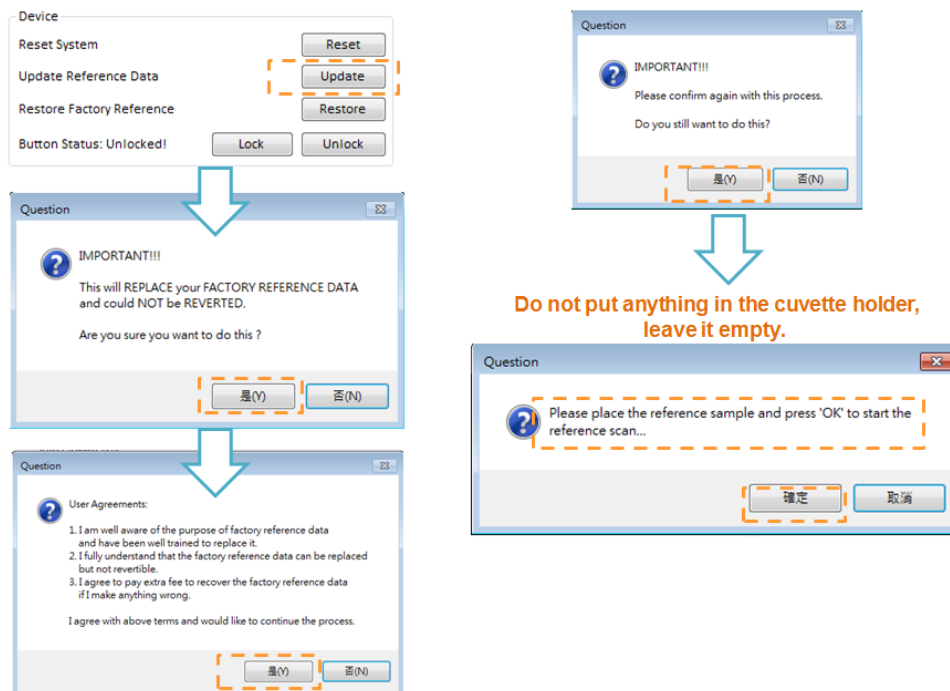


Figure 3.40 Update Built-in Reference Data

3.5 Consistency of NIR Absorbance

The consistency of the NIR absorbance is demonstrated by checking the photometric reproducibility, spectral resolution and wavelength accuracy. Here we take the diffuse reflective module NIR-M-R2 as an example to review the consistency of NIR absorbance. We collect system test data from more than 500 NIR-M-R2 modules. The standard reference materials and scan configuration for system testing are shown below.

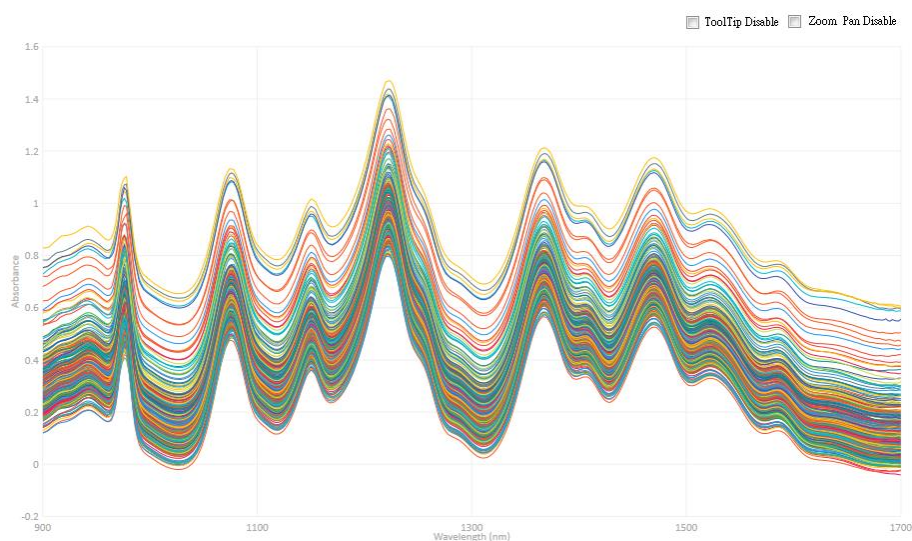
- **Reference signal: measure the SRS-99 (Labsphere)**
- **Sample signal: measure the SRM2036 (NIST)**
- **Scan Configuration:**

Section Config Type:	Column
Start Wavelength:	900
End Wavelength:	1700
Pattern Width:	7.03
Exposure:	0.635
Digital Resolution:	228
Num Repeats:	30
PGA Gain:	64

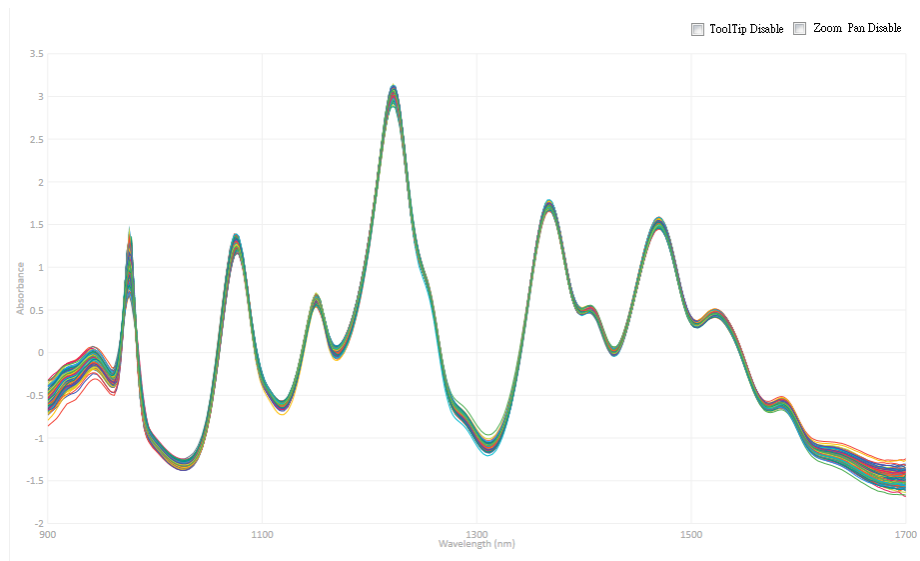


Figure 3.41 Standard Reference Materials and Scan Configuration for System Testing

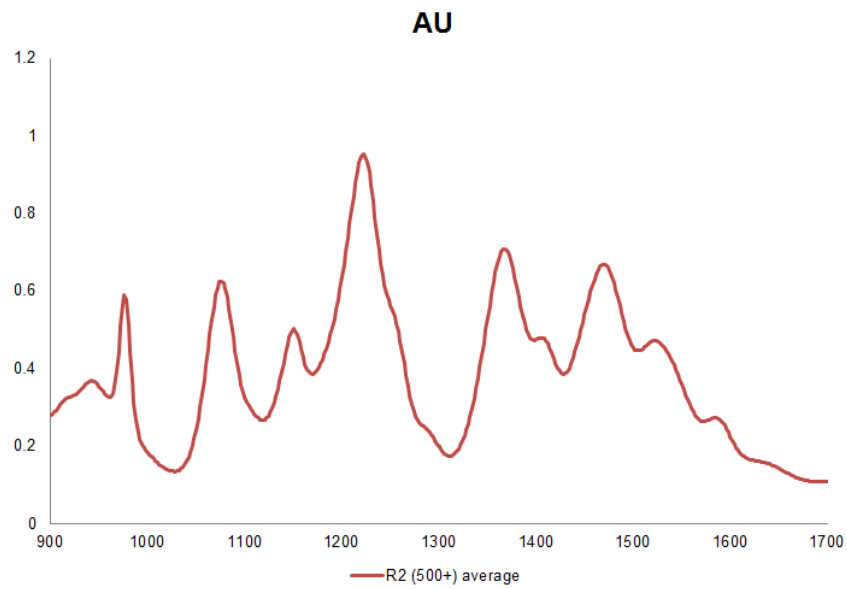
The SRM2036 AU data measured from more than 500 NIR-M-R2 modules are shown below.



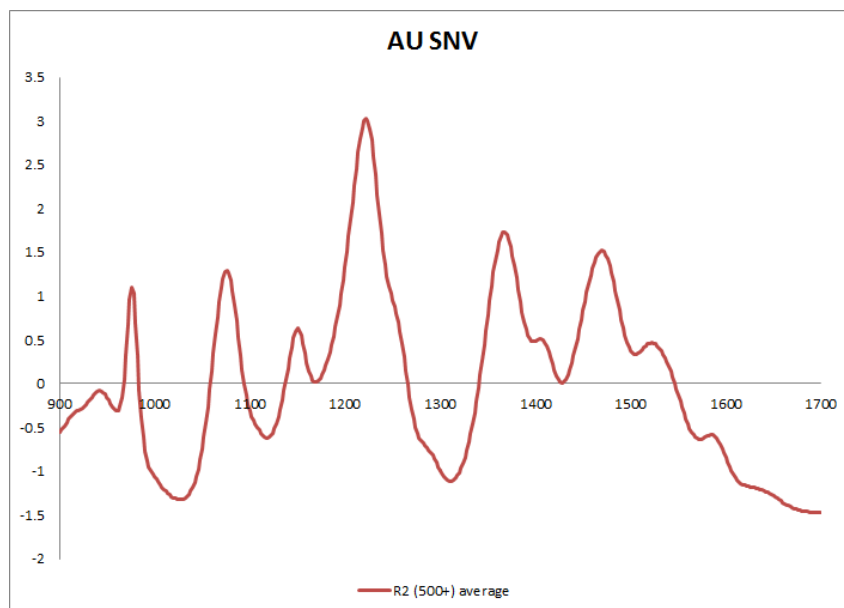
(a) AU Data



(b) AU after SNV



(c) AU average



(d) AU Average and SNV

Figure 3.42 SRM2036 AU Measured by NIR-M-R2

The SRM2036 AU measured by FOSS6500 is shown below for comparison.

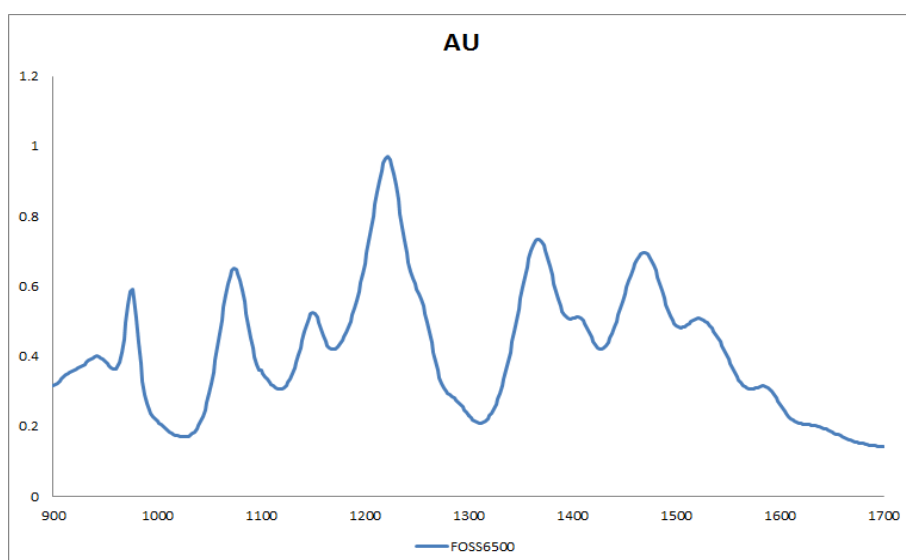


Figure 3.43 SRM2036 AU Measured by FOSS6500

The SRM2036 AU measured by NIR-M-R2 is compared with the data measured by FOSS6500 as shown below. They are very close to each other.

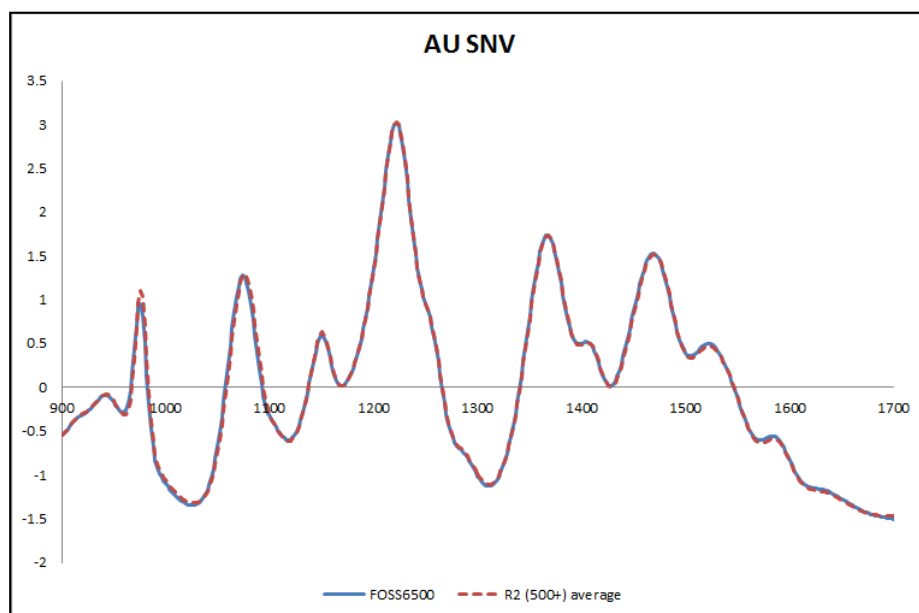


Figure 3.44 NIR-M-R2 Exhibits Good Photometric Reproducibility

The following is a comparison of the spectral resolution with reference to the data measured by MicroNIR. Obviously, the spectral resolution of NIR-M-R2 is as good as the data shown in the SRM2036 specification. However, the spectral resolution of MicroNIR is worse than the data shown in the SRM2036 specification.

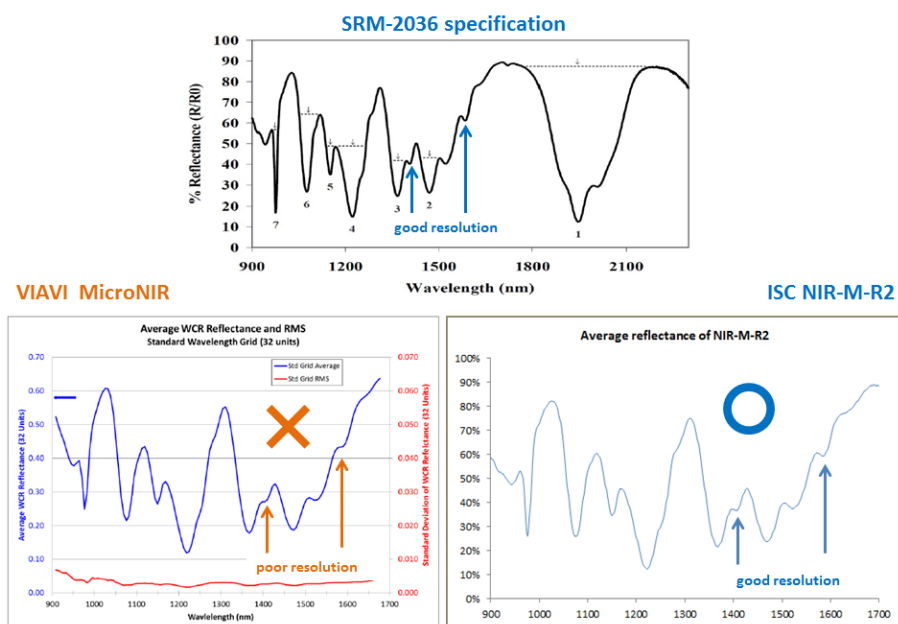


Figure 3.45 NIR-M-R2 Exhibits Good Spectral Resolution

3.6 Consistency of Wavelength Accuracy

By referring to the certified band position of SRM2036, each NIR-M-R2 module maintains a wavelength accuracy of +/-1nm with an optical resolution of 10nm.

Table 2. Certified Band Locations^(b,c), Air Wavelength

Band	3 nm SSW $\pm U_{95}$ (nm)	Standard Error of Mean ^(c) (nm)	5 nm SSW $\pm U_{95}$ (nm)	Standard Error of Mean ^(c) (nm)	10 nm SSW $\pm U_{95}$ (nm)	Standard Error of Mean ^(c) (nm)
7	976.0 $\pm$ 0.3	(0.02)	976.0 $\pm$ 0.2	(0.01)	975.9 $\pm$ 0.6	(0.01)
6	1075.7 $\pm$ 0.2	(0.01)	1075.7 $\pm$ 0.9	(0.01)	1075.8 $\pm$ 2.2	(0.03)
5	1151.4 $\pm$ 0.1	(0.01)	1151.2 $\pm$ 1.0	(0.01)	1151.0 $\pm$ 3.4	(0.01)
4	1222.1 $\pm$ 0.4	(0.02)	1222.1 $\pm$ 0.3	(0.02)	1222.1 $\pm$ 0.9	(0.03)
3	1367.1 $\pm$ 0.4	(0.01)	1367.2 $\pm$ 0.5	(0.01)	1367.3 $\pm$ 0.2	(0.02)
2	1469.6 $\pm$ 0.4	(0.02)	1469.6 $\pm$ 1.7	(0.02)	1469.5 $\pm$ 3.7	(0.03)
1 ^(d)	1945.7 $\pm$ 0.3	(0.04)	1945.8 $\pm$ 0.7	(0.02)	1945.6 $\pm$ 1.5	(0.01)

^(a) Band locations determined using a centroid method with a band fraction of 0.1; see Figure 1 for band identification.

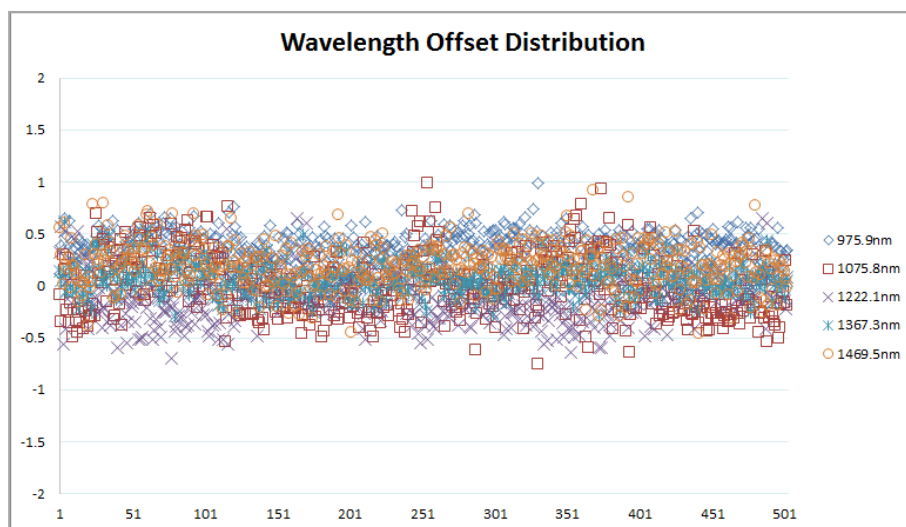
^(b) Uncertainties represent U_{95} , the expanded uncertainty calculation using a T statistic where $n = 3$, $T = 4.3$, in accordance with reference 12. The 95 % confidence interval of the air-wavelength bands of SRM 2036 is determined by the uncertainty of the calibration of the reference instruments with SRM 2065.

^(c) The number in parentheses is the standard error of the mean centroid band location.

^(d) See Information Values section for additional information pertaining to Band 1 centroid location.

Figure 3.46 Certified Band Locations of SRM2036

Here is the wavelength offset distribution from more than 500 NIR-M-R2 modules.



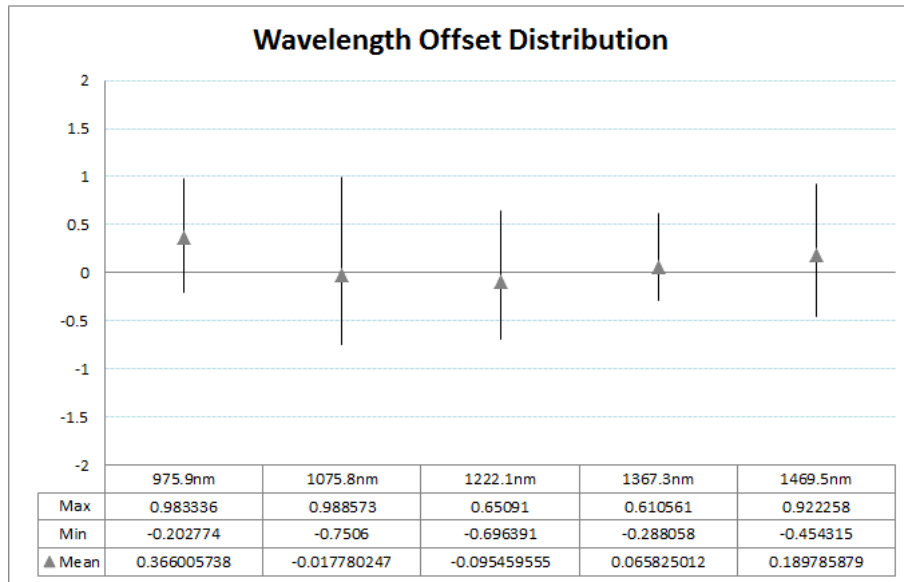


Figure 3.47 NIR-M-R2 Wavelength Offset Distribution

Chapter 4 Spectrum Analysis and Application

4.1 Data Preprocessing

By using DMD as the wavelength selector, the wavelength of the spectrum is a mapping of DMD pixels. The mapping between each pixel and wavelength is determined by the pixel-to-wavelength coefficients (a, b, and c). The corresponding wavelength of each pixel is calculated from $\lambda = a \cdot P^2 + b \cdot P + c$, where λ is a wavelength and P is the DMD pixel position.

When performing a scan, the software will first determine the start pixel and the end pixel. Then according to the digital resolution setting (equivalent to the number of sampling points), the software will assign the middle pixel position for each scanning pattern. After completing a scan, the wavelength of each middle pixel is calculated by $\lambda = a \cdot P^2 + b \cdot P + c$. Each spectrometer has its specific pixel-to-wavelength coefficients, so you will not be able to see two spectrometers generate spectral data with the same wavelength point. For example, there are two devices with different coefficients as follows:

Device	Pixel-to-Wavelength Coefficients		
	a	b	c
#1	-0.000239298	-0.919962291	1778.580967
#2	-0.000243134	-0.915248692	1787.415668

Figure 4.1 Devices with Different Coefficients

Apply the same scan configuration to both devices to scan the same material. For example, start wavelength=900 nm, end wavelength=1700nm, pattern width=7.03nm, and digital resolution=228. The software will calculate start pixel and end pixel, and then calculate the middle position of each scan pattern as follows. Device #1 starts with pixel 790.5 (901.81554nm), and device #2 starts with pixel 798.5 (901.56655nm). Device #1 ends with pixel 82.5 (1701.055353nm), and device #2 ends with pixel 92.5 (1700.674845nm).

Device #1			Device #2		
DMD pixel	Wavelength	Absorbance	DMD pixel	Wavelength	Absorbance
790.5	901.81554	0.224794	798.5	901.56655	0.22138
787.5	905.708266	0.232175	795.5	905.474964	0.231596
784.5	909.596684	0.245492	792.5	909.379003	0.24565
781.5	913.480795	0.259135	789.5	913.278665	0.258412
778.5	917.360598	0.266282	786.5	917.17395	0.265871
775.5	921.236094	0.269959	783.5	921.064859	0.269994
772.5	925.107283	0.273843	780.5	924.951392	0.274457
769.5	928.974164	0.281498	776.5	930.126628	0.288476
765.5	934.123305	0.296326	773.5	934.002949	0.300204
762.5	937.980136	0.306333	770.5	937.874893	0.310624
.			.		
.			.		
.			.		
120.5	1664.250839	0.053256	129.5	1664.813538	0.069266
116.5	1668.157543	0.048699	126.5	1667.746011	0.065344
113.5	1671.082545	0.044957	123.5	1670.674108	0.062005
110.5	1674.003241	0.041965	120.5	1673.597828	0.05733
107.5	1676.919629	0.037606	117.5	1676.517173	0.056222
104.5	1679.831709	0.034546	113.5	1680.402823	0.0525
101.5	1682.739483	0.032343	110.5	1683.311956	0.049599
98.5	1685.642949	0.032504	107.5	1686.216712	0.050973
95.5	1688.542107	0.028426	104.5	1689.117091	0.049983
91.5	1692.400951	0.025595	101.5	1692.013095	0.051087
88.5	1695.29006	0.024631	98.5	1694.904721	0.047496
85.5	1698.17486	0.024875	95.5	1697.791972	0.049891
82.5	1701.055353	0.026545	92.5	1700.674845	0.04342

Figure 4.2 DMD Pixel vs. Wavelength

The figure below shows that the sampling points of different devices have different distributions. In addition, the step lengths of the sampling points are not equally spaced.

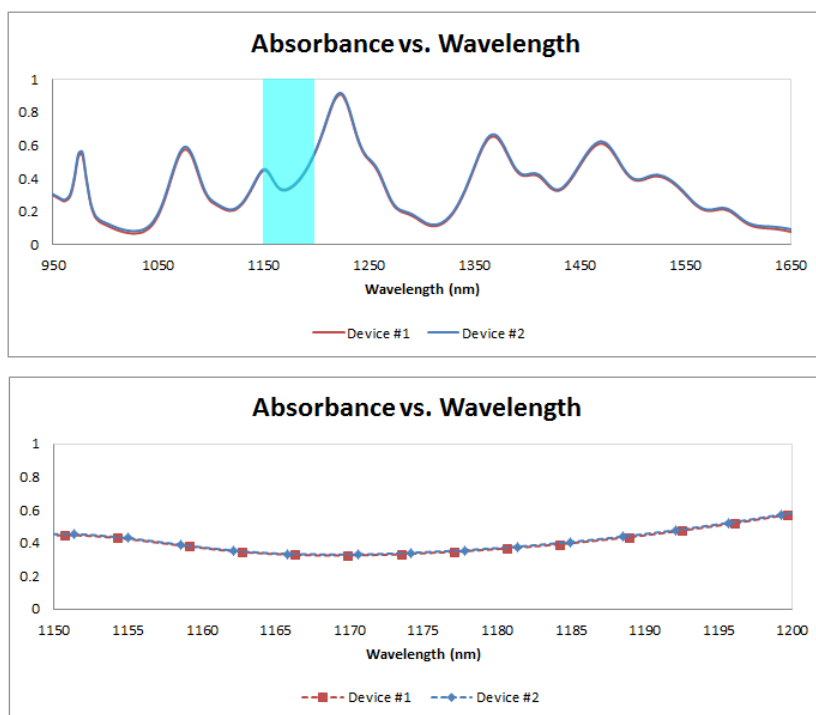


Figure 4.3 Absorbance vs. Wavelength Point

Before importing absorbance data from different devices into the same application, it is important to resample and interpolate different datasets to a common wavelength location vector. As shown below, the absorbance data from devices #1 and #2 are resampled and interpolated in a uniform wavelength space.

	Device #1	Device #2
Wavelength	Absorbance	Absorbance
950	0.296034	0.301419
952	0.288592	0.294427
954	0.280868	0.287115
956	0.273425	0.279977
958	0.266677	0.27386
960	0.261763	0.26998
962	0.260839	0.270064
964	0.267741	0.277903
966	0.28798	0.299363
•		
•		
•		
1628	0.09542	0.107619
1630	0.094578	0.106753
1632	0.093435	0.105809
1628	0.09542	0.107619
1630	0.094578	0.106753
1632	0.093435	0.105809
1634	0.092073	0.104933
1636	0.09065	0.103871
1638	0.08885	0.102471
1640	0.086697	0.100803
1642	0.084429	0.099106
1644	0.082139	0.097262
1646	0.079766	0.095085
1648	0.077008	0.092514
1650	0.073867	0.089731

Figure 4.4 Re-sampled Absorbance Data

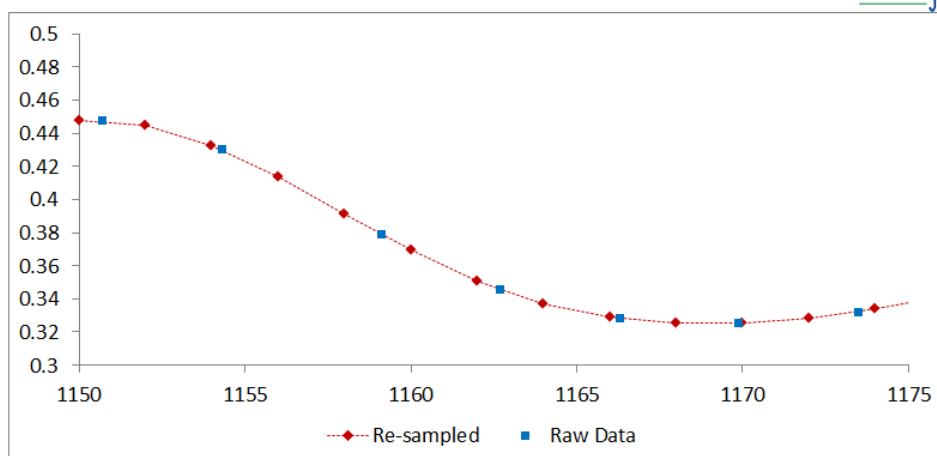


Figure 4.5 Re-sampled Data vs. Raw Data

An appropriate interpolation method is important to NIR analysis. We recommend using piecewise cubic spline interpolation instead of linear interpolation. As shown below, by using the piecewise cubic spline interpolation, re-sampled data and raw data have a better fit.

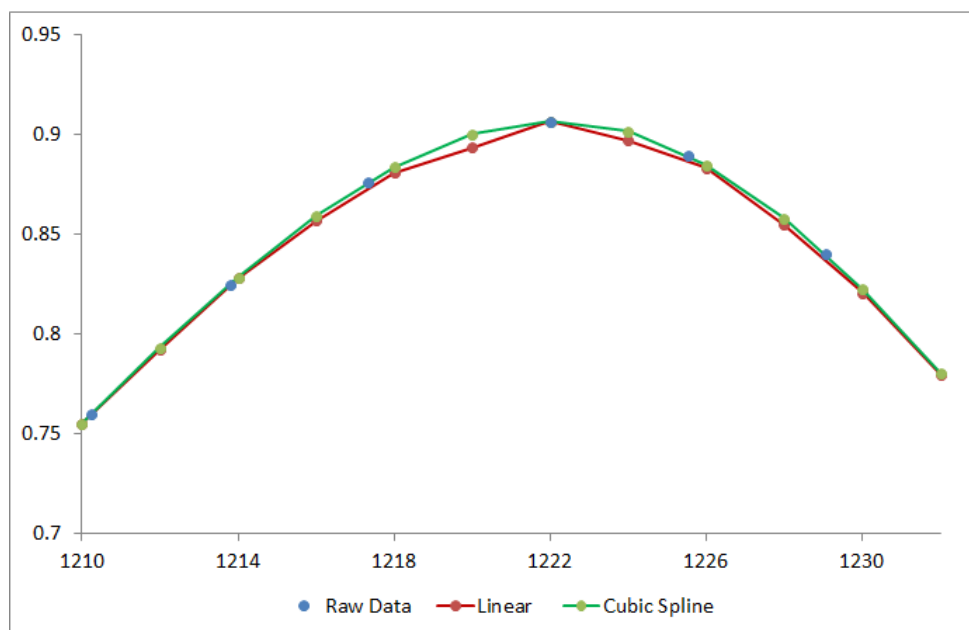


Figure 4.6 Linear Interpolation vs. Cubic Spline Interpolation

A smoothing algorithm like Savitzky-Golay is also commonly applied after the interpolation process. Once all the datasets are interpolated to a common wavelength vector, comparison between multiple units will become more straightforward.

After interpolation and smoothing, derivatives are commonly applied to correct the

baseline effect, provide a better understanding of the data, and emphasize small spectral variations not evident in the raw data. The first derivative is usually applied to correct the baseline effect in the spectrum, while the second derivative is effective to remove both baseline offset and slope in the spectrum. The second derivative can also help resolve nearby peaks and sharpen spectral features. Another important feature of the second derivative is that the intensities of the original curves can be seen in the second derivatives in order of intensity. This is a very useful feature for quantitative method such as regression analysis.

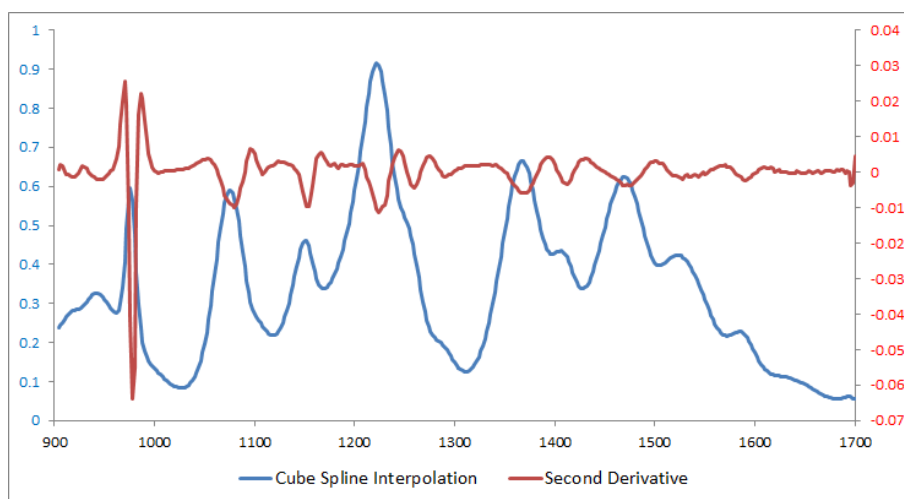


Figure 4.7 Second Derivative

However, by simply calculating derivatives between adjacent data points, there is a potential noise enhancement problem. Both Savitzky-Golay and Gap-Segment are alternative methods by using information from a localized segment of the spectrum to calculate the derivative at a particular wavelength to avoid the problem of noise enhancement.



Figure 4.8 Savitzky-Golay and Gap-Segment Avoid Noise Enhancement

4.2 Qualitative Analysis

NIR spectroscopy can be applied to different types of qualitative analysis, including authentication, classification, identification, etc. Identification and classification of plastic resins is a typical application of qualitative analysis by using NIR spectroscopy. For identification and separation among resins, a linear discriminant analysis (LDA) method is proposed that is capable to distinguish among polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polymethyl methacrylate (PMMA), polycarbonates (PC) and polylactic acid (PLA).

First, the NIR absorption spectrum of plastic resin needs to be resampled and interpolated to a common wavelength location vector.

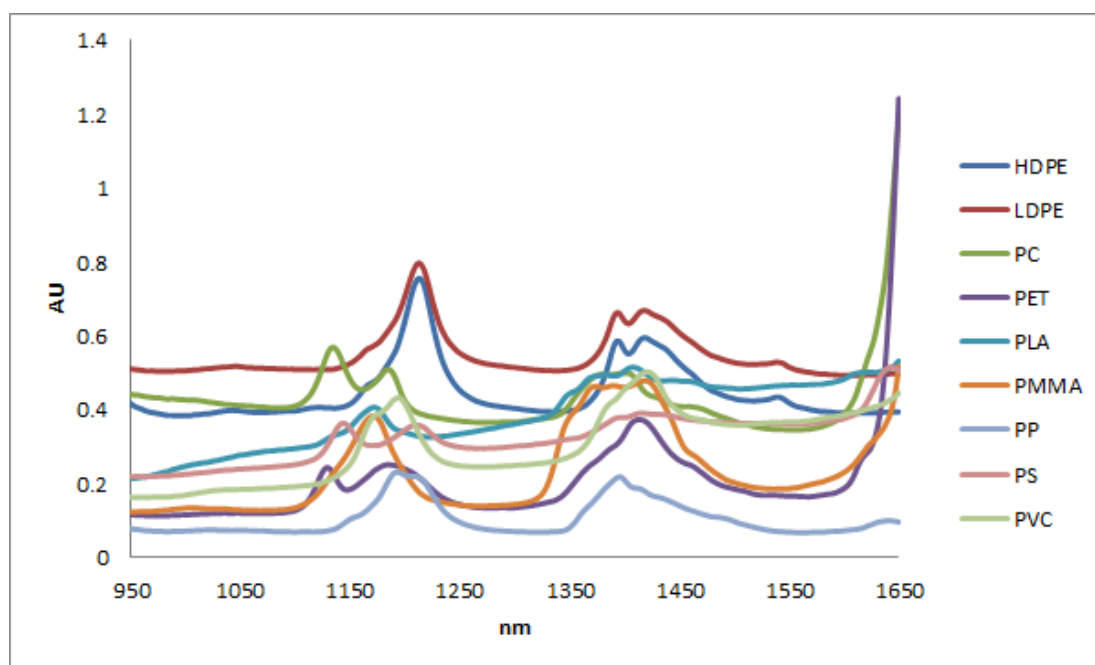


Figure 4.9 NIR Absorption Spectrum of Plastic Resin

Secondly, Savitzky-Golay derivative is applied to correct the baseline effect, provide a better understanding of the data, and emphasize small spectral variations.

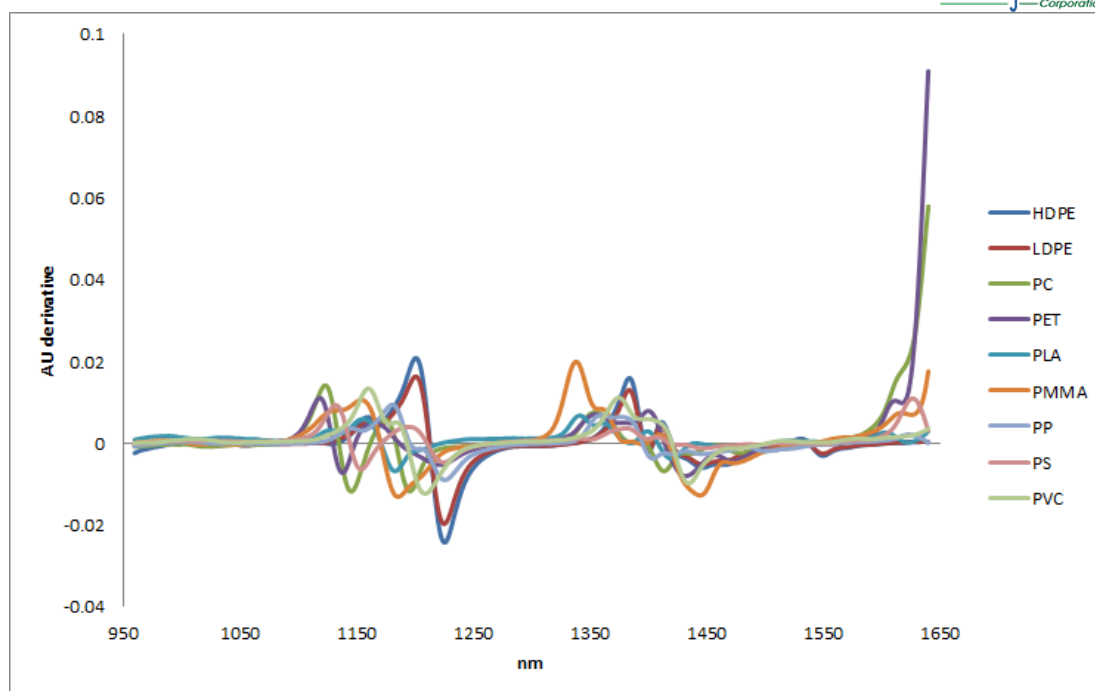


Figure 4.10 Savitzky-Golay Derivatives of NIR Absorption Spectrum

Third, use principal component analysis (PCA) to project the multi-dimensional spectral data set into a low-dimensional space to remove the relevant components in the spectral data set. Finally, linear discriminant analysis (LDA) is applied to the low-dimensional spectral data to distinguish plastic resins.

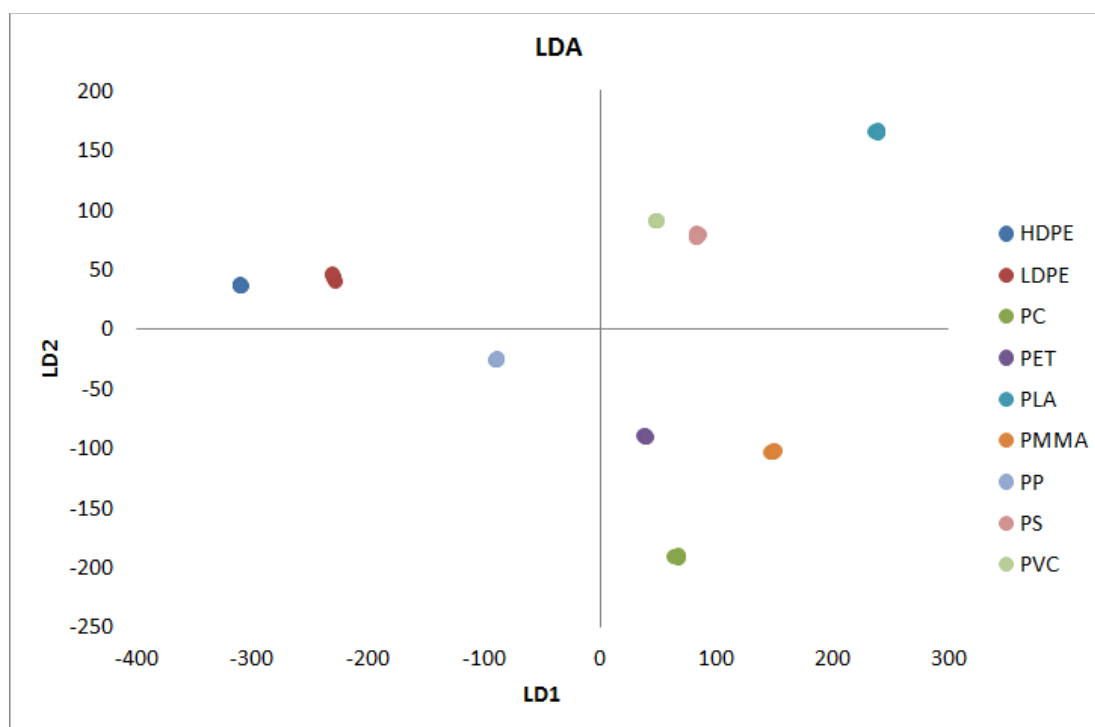


Figure 4.11 Linear Discriminant Analysis of Plastic Resin

4.3 Quantitative Analysis

Near infrared spectroscopy (NIRS) has been widely applied in both qualitative and quantitative analysis. For example, NIRS can be used for quantitative determinations of drug concentration, moisture and other important applications. For another example, NIRS can be used in agricultural operations to determine crop parameters such as water content, sugar content, and other indicators of ripeness.

The following is an example of quantitative analysis using near-infrared spectroscopy to determine the sugar content of apples.

First, the spectra of apples are resampled and interpolated to a common wavelength location vector.

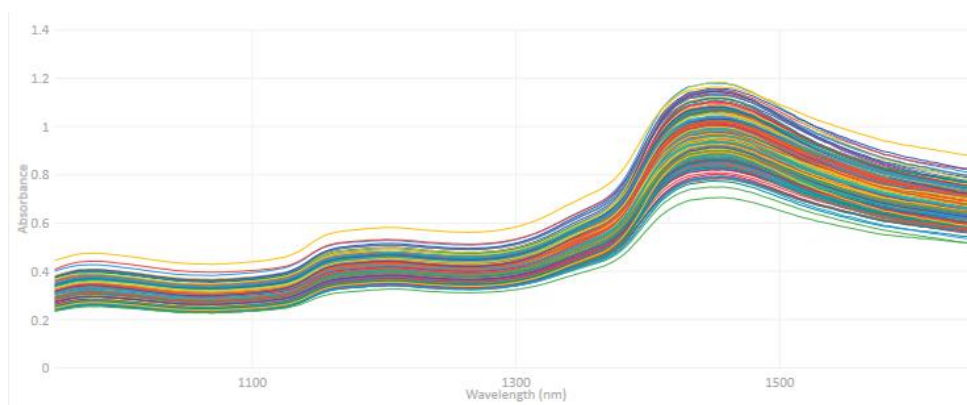


Figure 4.12 NIR Absorption Spectrum of Apple

Secondly, Savitzky-Golay derivative is applied to correct the baseline effect, provide a better understanding of the data, and emphasize small spectral variations.

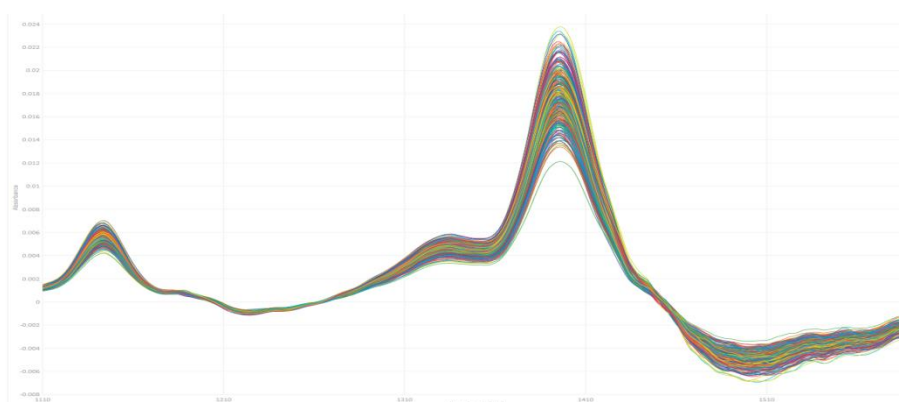


Figure 4.13 Savitzky-Golay Derivatives of NIR Absorption Spectrum

Finally, partial least squares (PLS) regression is applied to generate a calibration model for predicting Apple's Brix.

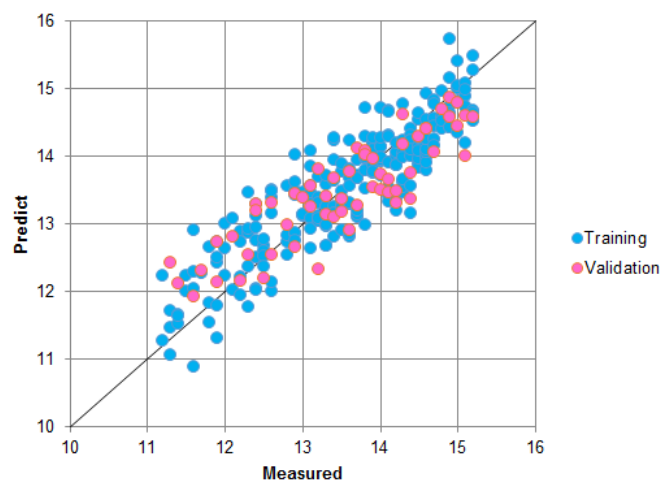


Figure 4.14 Training and Validation of Calibration Model

Appendix A

Frequently Asked Questions

A.1 Data on GitHub

Public

ISC-NIRScan-GUI Public InnoSpectra NIRScan PC Software ● Rich Text Format ☆ 3 🍴 2	ISC_NIRScan_Tiva_FW_STD Public This repo stores the ISC Tiva Firmwares for the products of standard wavelength range (900nm-1700nm). ● Rich Text Format ☆ 1 🍴 3
ISC_NIRScan_Tiva_FW_EXT Public This repo stores the ISC Tiva Firmwares for the products of extended wavelength range (1350nm-2150nm). ● Rich Text Format 🍴 3	ISC-MetaScan Public ISC MetaScan Windows PC Version
ISC-NIRScan-Windows-BLE Public	

Please contact ISC to learn more about our repositories.

A.2 MTBF Test Report



MTBF Test Report

Model	NIR-S-G1
Quantity	2
Time	4147 hrs
Date	Feb. 7, 2020 to Jul. 28, 2020
Temperature/Humidity	32±3℃/90%
MTBF&90%	65000 hrs(7.42 yrs)

1. MTBF Formula

$$MTBF = \frac{2T \times Af_1 \times Af_2}{\chi^2(\alpha \times 2\gamma + 2)}$$

2. Parameter Description

T	Accumulative test time
Af_1	Temperature acceleration factor = 1.429 @ 32℃
Af_2	Scan acceleration factor = 12.672 (number of continuous scan in 24 hrs/averaged scan number in daily usage=6336/500=12.672)
χ^2	Sign of Chi-Square
α	1- C (Confidence level)
γ	Accumulative failure number

3. Parameter value

Reliability	90%
T	8294 hrs
Af_1	1.429
Af_2	12.672
$\chi^2(\alpha \times 2\gamma + 2)$	4.605

4. Calculation results

MTBF&90%=2*8294*1.429*12.672/4.605=65229 > 65000 hrs(7.42 yrs)

Test Dept.	DMT	Test Engineer	Steven	Approved by	Patrick
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A.3 Reliability Test Items

1	Thermal Shock (Non-Operating)	Lower stress level: -40°C Higher stress level: 70°C Dwell time at each level: 20 min. Ramp rate: 20°C/min. Number of cycles: 100 cycles
2	Thermal Cycling Test (Operation)	Lower Temp. stress level: -10°C Higher Temp. stress level: 50°C Humidity: 20%~90%RH Ramp rate at 1°C/min. Dwell time at each level: 6 hours , Number of cycles: 12
3	Storage (Packing)	-20°C ~ 60°C , 20%~90%RH, 96 Hrs
4	Vibration Test	a. Non-Operating(non-packing): Random vibration 0.0082G ² /Hz, 10 ~ 500Hz, 2Grms, 1hr/axis
		b. Non-Operating (Packing) : Sinusoidal vibration sin-wave, 1.5G, zero to peak, 10~500~10Hz, 1.0 oct/min. 60min/axis
		c. Non-Operating(Packing) : Random vibration 0.025G ² /Hz, 10~500Hz, 3.5Grms, 1hr/axis
5	Drop Test	a. w/ Packing b. Single carton : 97 cm , 6 faces 1 corner, 3 edges, 1pulse / direct. Steel plate
6	Mechanical Shock Test (non-packing)	Half-sine wave, 100G, 2ms, 1 pulse/face, 6faces (non-operating)