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NIRQuest NIR Spectrometers Data Sheet

Description

A high-performance optical bench, low-noise electronics and various grating options make NIRQuest Spectrometers the best choice for modular NIR spectroscopy. This small footprint spectrometer is available in several different models that cover various wavelength ranges between 900 nm and 2500 nm. As with most Ocean Optics designs, the NIRQuest can be customized for your specific application with various grating, slit and mirror options. The NIRQuest is ideal for applications ranging from analyzing moisture content in food and beverage products to analyzing trace metals in wastewater and laser characterization among others.

The NIRQuest communicates via the Universal Serial Bus (USB) connection with an external 5V power source. A 30-pin interface provides several GPIO ports as well as the possibility of RS-232 communications.

Key Features

- High signal-to-noise ratio: 15,000:1 to 7500:1, depending on model. Combined with high dynamic range this means that you can achieve the highest accuracy and precision, important for modeling.
- Deep TEC cooling to 35°C or 50°C below ambient (model-dependent). This means lower dark current and improved signal to noise.
- High Resolution: from <1nm to 12nm (slit and detector dependent) to suit your application.
- Small and lightweight: 182 x 110 x 47 mm and 1.2 kg.
- Configurable with a range of detectors, gratings and slits for your specific application. Interchangeable slits are available.
- Rugged and proven diode array technology with no moving parts.
- Continuous and simultaneous collection of spectral data in the field, on the line or in the lab. All wavelength data is collected simultaneously.
- Fast data transfer via USB and optional RS-232. GPIO pins support I2C.
- Access to Ocean Optics' unrivaled range of software, light sources, sampling and fiber accessories.

Specification Summary

- Detector: Hamamatsu G9204-512 (NIRQuest512-1.7), G9205-512 (NIRQUEST512-1.9), G9206-512W (NIRQuest512-2.2), G9208-512W (NIRQuest512-2.5), G9206-256 (NIRQuest256-2.1), G9208-256 (NIRQuest256-2.5)
  - TE Cooled
- Spectrometer Design
  - Symmetrical Crossed Czerny Turner
  - 101mm focal length
  - F number: f/4
  - 8 gratings (model-dependent)
  - 6 slit widths
- Electrical Performance
  - 16 bit, 500KHz A/D converter
  - Integration times from 1 ms to 120 seconds
- Embedded microcontroller allows programmed control of all operating parameters and standalone operation
  - USB 2.0 480Mbps
  - Communication standard for digital accessories (I2C)
- Onboard Pulse Generator
  - 3 programmable strobe signals for triggering other devices
  - Software control of nearly all pulse parameters
- Onboard GPIO
  - 10 user-programmable digital I/Os
- EEPROM storage for

    - Wavelength Calibration Coefficients
    - Linearity Correction Coefficients
    - Absolute Irradiance Calibration (optional)
- Plug-and-play interface for PC applications
- 30-pin connector for interfacing to external products
- Kensington® security slot
- Optional shutter for dark measurements requiring a fast integration time and good throughput – Specify when ordering
- CE certification

Example Applications

- On-line absorbance measurement of moisture and protein content in grain
- Component analysis of soils in a portable laboratory
- Laser beam characterization
- QA/QC inspection of pharmaceutical powders
- Through tissue blood oxygenation measurements
- Photoluminescence measurements of coated silicon wafers
- Monitoring of CO, CO2, NO2 and other emissions gases
- Octane measurements of hydrocarbons

NIRQuest Detectors

NIRQuest-512-1.7

The NIRquest is available with a series of different detectors that cover various wavelength ranges. Pure InGaAs detectors are very responsive from 900 – 1700 nm but for higher wavelengths require different dopants. The extended range detectors are harder to produce and this means that the signal to noise ration of these detectors is reduced the further up in wavelength that you go. The other major difference between the detectors is the number of pixels.

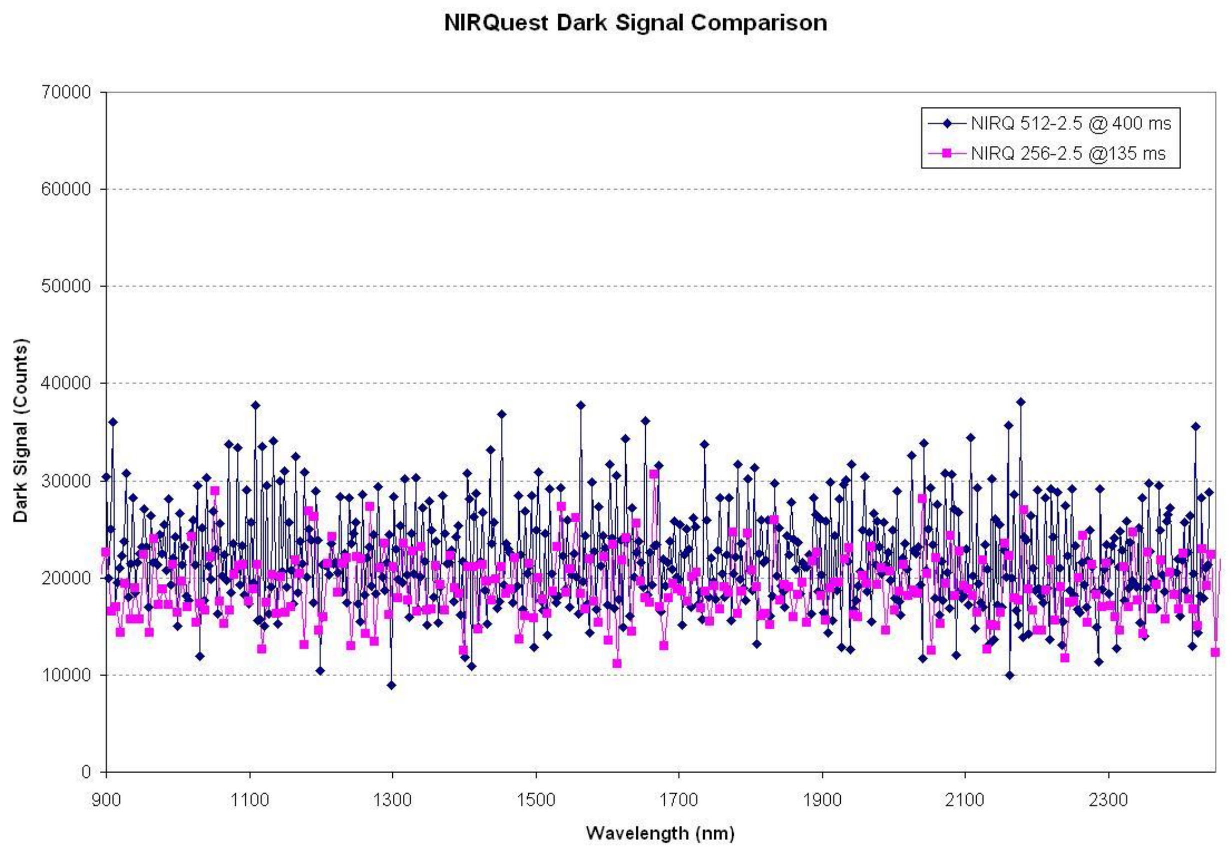
The NIRquest detectors have either 512 or 256 pixels but all have the same active area of 12.8mm x 0.5mm. The larger pixel size on the 256 pixel detectors allows them to collect over a wider area, gathering sensitivity at the expense of resolution. See the table below for a summary of the NIRquest detectors. Unless you need the extended range, the extra sensitivity and flexibility of the NIRquest-512-1.7 detector make this the best choice for most NIR applications.

	Pixels	Wavelength Range	Integration Time
NIRquest-512-1.7	512	900 – 1700nm	1 ms – 120 s
NIRquest-512-1.9	512	900 – 1900nm	1 ms – 1s
NIRquest-256-2.1	256	900 – 2100nm	1ms – 2s
NIRquest-512-2.2	512	900 – 2200nm	1ms – 1s

NIRquest-256-2.5	256	900 – 2500nm	1ms – 400 ms
NIRquest-512-2.5	512	900 – 2500 nm	1ms – 200ms

When configuring a system for operation out to 2500 nm, it's important to consider the following details:

- **Short Integration Times:** In order for the detector to be sensitive out to 2.5µm, the detector's band gap energy must be small. Unfortunately this raises the absolute level of the detectors dark signal. Typical dark signals at 400ms (NIRQuest512-2.5) and 135ms (NIRQuest256-2.5) are shown below. These detectors should only be used with short integration times as specified in this document.
- **Fiber Selection:** For maximum signal intensity, alternative fiber materials should be used for wavelengths greater than 2200 nm. Standard fibers will suffer from significant attenuation at these wavelengths. Fluoride fibers are available from Ocean Optics which remain transmissive from 300 to 4500 nm.



Typical Baseline Dark Current Signals for the NIRQuest256 and 512-2.5 Extended Range

NIRQuest Optical Resolution for Standard Setups

The following table lists the optical resolution (FWHM) by slit width for standard (preconfigured) setups that are configured to use the entire useful wavelength range of the fitted detector. Interchangeable slits are also available from Ocean Optics.

Optical Resolution by Slit Width

Slit	NIRQuest512-1.7[1]	NIRQuest512-2.2[2]	NIRQuest512-2.5[3]	NIRQuest256-2.1[2]	NIRQuest256-2.5[3]
SLIT-10	~2.0 nm	~3.0 nm	~4.1 nm	~6.7 nm	~9.4 nm
SLIT-25	~3.1 nm	4.7 nm	~6.3 nm	~7.6 nm	~10.6 nm
SLIT-50	~3.6 nm	~5.4 nm	~7.2 nm	~8.9 nm	~12.5 nm
SLIT-100	~6.6 nm	~9.8 nm	~13.1 nm	~11.2 nm	~15.6 nm
SLIT-200	~12.3 nm	~18.5 nm	~25 nm	~17.9 nm	~25.0 nm

[1] Grating NIR3 used (900-1700 nm)
[2] Grating NIR2 used (900-2050 nm)
[3] Grating NIR1 used (900-2500 nm)

NIRQuest512 Spectrometer Specifications

	NIRQuest512-1.7	NIRQuest512-1.9	NIRQuest512-2.2	NIRQuest512-2.5
PHYSICAL				
Dimensions (mm):	182 x 110 x 47			
Weight (kg):	1.18 (w/o power supply)			
DETECTOR				
Detector:	Hamamatsu G9204-512 InGaAs linear array	Hamamatsu G9205-512 InGaAs linear array	Hamamatsu G9206-512 InGaAs linear array	Hamamatsu G9208-512W InGaAs linear array
Detector range:	850-1700 nm	1000-1900 nm	900-2200 nm	900-2550 nm
Useable range[1]:	900-1700 nm	1000-1900 nm	900-2200 nm	900-2500 nm
Pixels:	512			
Pixel size:	25 µm x 500 µm	25 µm x 250 µm		
Saturation charge:	30 pC (~188 Me- electrons)			
Defective pixels:	0 pixels	<20 pixels		

	NIRQuest512-1.7	NIRQuest512-1.9	NIRQuest512-2.2	NIRQuest512-2.5
OPTICAL BENCH				
Design:	f/4, symmetrical crossed Czerny-Turner			
Entrance aperture (standard):	25 µm			
Entrance aperture (custom options):	10 µm, 50 µm, 100 µm and 200 µm (or no slit)			
Grating options (standard):	Grating NIR3, 150 l/mm, 900-1700 nm	Grating NIR3, 100 l/mm, 150 l/mm, 900-1700 nm	Grating NIR2, 100 l/mm, 900-2050 nm	Grating NIR1, 75 l/mm, 1075-2500 nm
Grating options (custom)[2]:	NIR10, NIR11, NIR12, NIR13 and NIR14		NIR2, NIR3, NIR10, NIR11, NIR12 and NIR13	
Longpass filter[3]:	OF1-RG830 longpass NIR filter (optional)	OF1-CGA1000 longpass NIR filter (standard)	OF1-RG830 longpass NIR filter (optional)	
2nd Order filter[3]:	N/A	Standard		
Collimating and focusing mirrors:	Gold-coated for enhanced NIR reflectivity			
Fiber optic connector:	SMA 905 to 0.22 numerical aperture single-strand optical fiber			
SPECTROSCOPIC				
Wavelength range:	900-1700 nm w/Grating NIR3	1100-1900nm w/Grating NIR3	900-2200nm w/Grating NIR2	900-2500nm w/Grating NIR1
Optical resolution (FWHM)[4]:	~3.1 nm w/25 µm slit		~5 nm w/25 µm slit	~6.3 nm w/25 µm slit
Signal-to-noise ratio at full signal[5]:	>15000:1 @ 100 ms integration >13000:1 @ 1000 ms integration		10000:1 @ 100 ms integration	
A/D resolution:	16-bit			
Dark noise:	6 RMS counts @ 100 ms			16 RMS counts@ 10ms
	12 RMS counts @ 1000 ms	12 RMS counts @ 250 ms		24 RMS counts@ 30ms
Dynamic range:	150×10^6 (system); 15K:1 for a single acquisition	7.5M (system); 10K:1 for a single acquisition		100K (system); 7.5K:1 for a single acquisition
Integration time[6]:	1 ms – 120 s	1 ms – 1 s		1 ms – 200 ms
Corrected linearity:	>99.8%			>99.6%

	NIRQuest512-1.7	NIRQuest512-1.9	NIRQuest512-2.2	NIRQuest512-2.5
Optional shutter activation time	11ms			
ELECTRONICS				
Power consumption	DC input jack +5V, 3 A maximum			
Data transfer speed:	Full scan to memory every 5 ms with USB 2.0 port			
Inputs/ Outputs:	External trigger input + single strobe output			
Breakout box compatibility:	Yes			
Trigger modes:	2 modes (Normal/Free Run + External Hardware Edge Trigger) FPGA version 1088 and above: 3 modes (Normal/Free Run + External Hardware Edge Trigger + External Hardware Level Trigger)			
Strobe functions:	Yes			
Gated delay:	Yes, with external hardware trigger delay			
Connector:	30-pin connector			
TEMPERATURE & THERMOELECTRIC COOLING				
Temperature limits (environmental):	10-35 ºC (0-90% non-condensing)			
TEC range[7]: Guaranteed range is 20 ºC	21 -- 37ºC below ambient	33.5 -- 48ºC below ambient		
TEC stability:	+/-0.5 ºC of set temperature in <1 minute; typical long-term stability +/-0.1 ºC			
COMPUTER				
Computer interfaces:	USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud (custom configuration)			
Peripheral interfaces:	I2C inter-integrated circuit			

[1] "Useable range" is defined in the context of the NIRQuest model's detector response and its typical grating response. For example, the 512-element detector has response at 850 nm, but grating response begins at 900 nm. The G9206 256-element detector response is sensitive to TEC temperature, and has response only to 2050 nm when the TEC is set to -20 ºC. The G9208 256-element and 512-element detector has response to 2550 nm, but the grating efficiency drops off at 2500 nm.

[2] See *NIRQuest Gratings* for more information.

[3] Other filter options are available for order-sorting in the NIRQuest 512-2.5. NIRQuest 512-2.5 ship with a 2nd-order filter. See an Applications Scientist for details.

[4] Optical resolution (FWHM) depends on grating and slit selection.

[5] SNR will decrease at longer integration times.

[6] Maximum integration times: longest amount of time the spectrometer integrates before the dark level rises to half of full scale.
[7] See *Thermo-Electric Cooler (TEC)* for more information

NIRQuest256 Spectrometer Specifications

	NIRQuest256-2.1	NIRQuest256-2.5
PHYSICAL		
Dimensions (mm):	182 x 110 x 47	
Weight (kg):	1.18 (w/o power supply)	
DETECTOR		
Detector:	Hamamatsu G9206-256 InGaAs linear array	Hamamatsu G9208-256 InGaAs linear array
Detector range:	900-2100 nm	900-2550 nm
Useable range[1]:	900-2050 nm	900-2500 nm
Pixels:	256	
Pixel size:	50 µm x 250 µm	
Saturation charge:	30 pC (~188 Me- electrons)	
Defective pixels:	<12 pixels	
OPTICAL BENCH		
Design:	f/4, symmetrical crossed Czerny-Turner	
Entrance aperture (standard):	25 µm	
Entrance aperture (custom):	10 µm, 50 µm, 100 µm and 200 µm (or no slit)	
Grating options (standard):	Grating NIR2, 100 l/mm, 900-2050 nm	Grating NIR1, 75 l/mm, 1075-2500 nm
Grating options (custom)[2]:	NIR2, NIR3, NIR10, NIR11, NIR12 and NIR13	
Longpass filter[3]:	OF1-RG830 longpass NIR filter (optional)	
2^{nd} Order filter[3]:	Standard	
Collimating and focusing mirrors:	Gold-coated for enhanced NIR reflectivity	
Fiber optic connector:	SMA 905 to 0.22 numerical aperture single-strand optical fiber	
SPECTROSCOPIC		
Wavelength range:	900-2050 nm w/Grating NIR2	900-2500 nm w/Grating NIR1
Optical resolution (FWHM)[4]:	~7.6 nm w/25 µm slit	~ 9.5 nm w/25 µm slit
Signal-to-noise ratio at full signal[5]:	10000:1 @ 100 ms integration	7500:1 @ 10 ms integration
A/D resolution:	16-bit	
Dark noise:	6 RMS counts @ 100 ms	8 RMS counts @ 10 ms
	12 RMS counts @ 250 ms	12 counts RMS @ 30 ms

	NIRQuest256-2.1	NIRQuest256-2.5
Dynamic range:	15M (system); 10K:1 for a single acquisition	500K (system); 7.5K:1 for a single acquisition
Integration time[6]:	1 ms – 2 s	1 ms – 400 ms
Corrected linearity:	>99.8%	>99.6%
Estimated Peak Noise Equivalent Power (NEP) (default configuration)	5 pW	25 pW
Optional shutter activation time	11ms	
ELECTRONICS		
Power consumption	DC input jack +5V, 3 A maximum	
Data transfer speed:	Full scan to memory every 5 ms with USB 2.0 port	
Inputs/ Outputs:	External trigger input + single strobe output	
Breakout box compatibility:	Yes	
Trigger modes:	2 modes (Normal/Free Run + External Hardware Edge Trigger) FPGA version 1088 and above: 3 modes (Normal/Free Run + External Hardware Edge Trigger + External Hardware Level Trigger)	
Strobe functions:	Yes	
Gated delay:	Yes, with external hardware trigger delay	
Connector:	30-pin connector	
TEMPERATURE & THERMOELECTRIC COOLING		
Temperature limits (environmental):	10-35 ºC (0-90% non-condensing)	
TEC range[7]: Guaranteed range is 20 ºC	33.5 -- 48ºC below ambient	
TEC stability:	+/-0.5 ºC of set temperature in <1 minute; typical long-term stability +/-0.1 ºC	
COMPUTER		
Computer interfaces:	USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud (custom configuration)	
Peripheral interfaces:	I2C inter-integrated circuit	

[1] "Useable range" is defined in the context of the NIRQuest model's detector response and its typical grating response. For example, the 512-element detector has response at 850 nm, but grating response begins at 900 nm. The G9206 256-element detector response is sensitive to TEC temperature, and has response only to 2050 nm when the TEC is set to -20 ºC. The G9208 256-element and 512-element detector has response to 2550 nm, but the grating efficiency drops off at 2500 nm.

[2] See *NIRQuest Gratings* for more information.

[3] Other filter options are available for order-sorting in the NIRQuest256-2.1, NIRQuest256-2.5 and NIRQuest 512-2.5. NIRQuest256-2.5 and NIRQuest 512-2.5 ship with a 2nd-order filter. Contact Ocean Optics for details.

[4] Optical resolution (FWHM) depends on grating and slit selection.

[5] SNR will decrease at longer integration times.

[6] Maximum integration times: longest amount of time the spectrometer integrates before the dark level rises to half of full scale.

[7] See *Thermo-Electric Cooler (TEC)* for more information

NIRQuest Gratings

The following tables show the NIRQuest gratings available for preconfigured (standard) setups and for all options. Additional grating options, adjustments to starting and ending wavelengths and similar customization may be available. Please contact an Applications Scientist for details.

NIRQuest Gratings for Preconfigured Setups

Spectrometer	Standard Grating	Groove Density (lines/mm)	Spectral Range	Blaze Wavelength	Best Efficiency (>30%)
NIRQuest512-1.7	NIR3	150	~800 nm	1100 nm	900-1700 nm
NIRQuest512-1.9	NIR3	150	~800 nm	1100 nm	1100-1900 nm
NIRQuest512-2.2	NIR2	100	1150 nm	1600 nm	900-2200 nm
NIRQuest512-2.5	NIR1	75	1425 nm	1700 nm	1075-2500 nm
NIRQuest256-2.1	NIR2	100	1150 nm	1600 nm	900-2050 nm
NIRQuest256-2.5	NIR1	75	1425 nm	1700 nm	1075-2500 nm

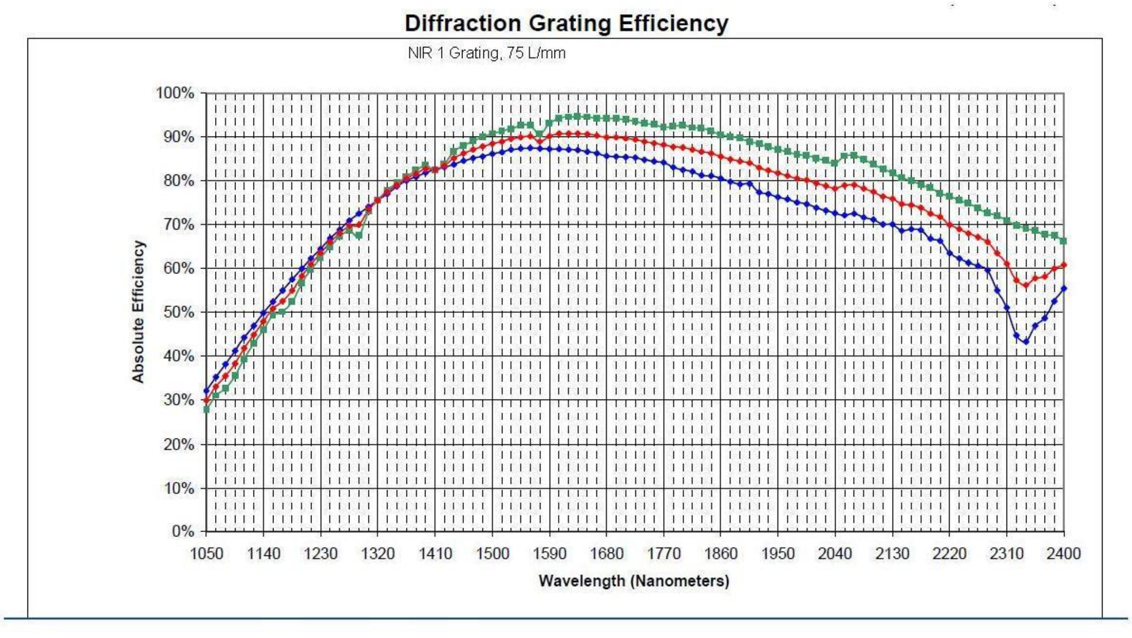
NIRQuest Gratings – All Options

Grating	Intended Use	Groove Density (lines/mm)	Spectral Range*	Blaze Wavelength	Best Efficiency (>30%)
NIR1	NIRQuest512-2.5 NIRQuest256-2.5	75	1600 nm	1700 nm	1075-2500 nm
NIR2	NIRQuest 512-2.2 NIRQuest512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	100	1200 nm	1600 nm	900-2050 nm
NIR3	NIRQuest512-1.7 NIRQuest512-1.9 NIRQuest512-2.2 NIRQuest 512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	150	~800 nm	1100 nm	900-1700 nm
NIR10	NIRQuest512-1.7 NIRQuest512-2.2 NIRQuest512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	300	350-380 nm	1200 nm	750-2200 nm
NIR11	NIRQuest512-1.7, NIRQuest512-2.2 NIRQuest512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	400	240-290 nm	1600 nm	980-2500 nm

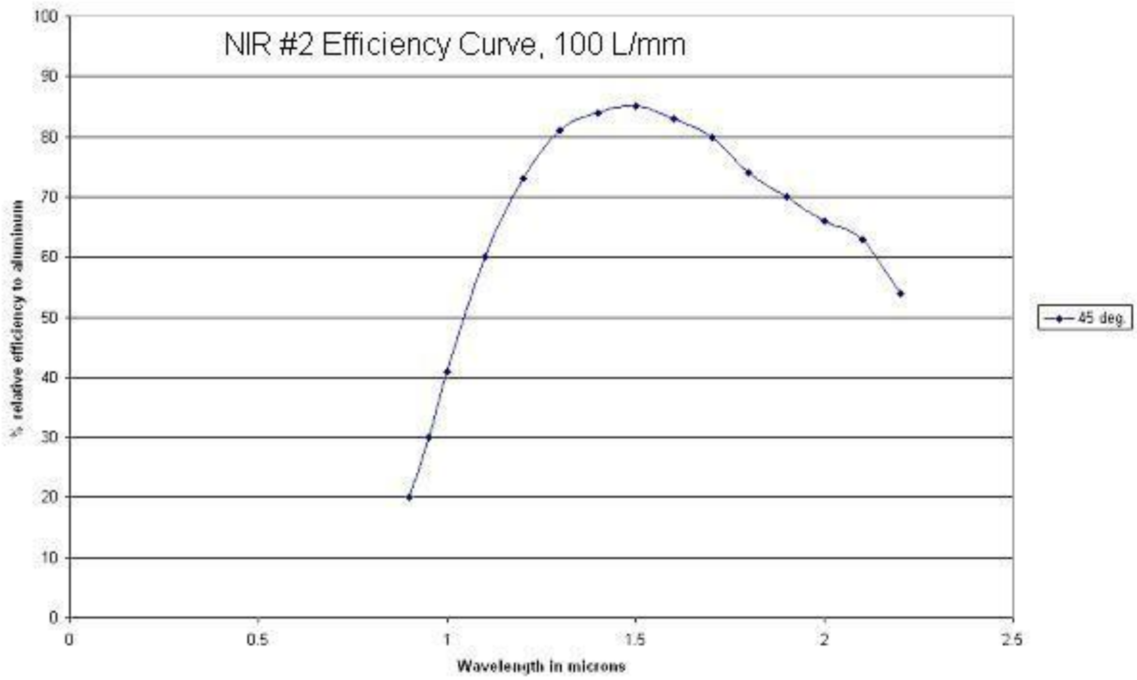
NIR12	NIRQuest512-1.7 NIRQuest512-2.2 NIRQuest512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	500	160-220 nm	1370 nm	900-2500 nm
NIR13	NIRQuest512-1.7 NIRQuest512-2.2 NIRQuest512-2.5 NIRQuest256-2.1 NIRQuest256-2.5	600	100-180 nm	1200 nm	800-2500 nm
NIR14	NIRQuest512-1.7	1000	50-90 nm	1310 nm	900-1700 nm
* The spectral range is a function of the starting wavelength; the longer (i.e., the farther out in the NIR) the starting wavelength, the smaller the spectral range possible.					

Grating Efficiency Curves

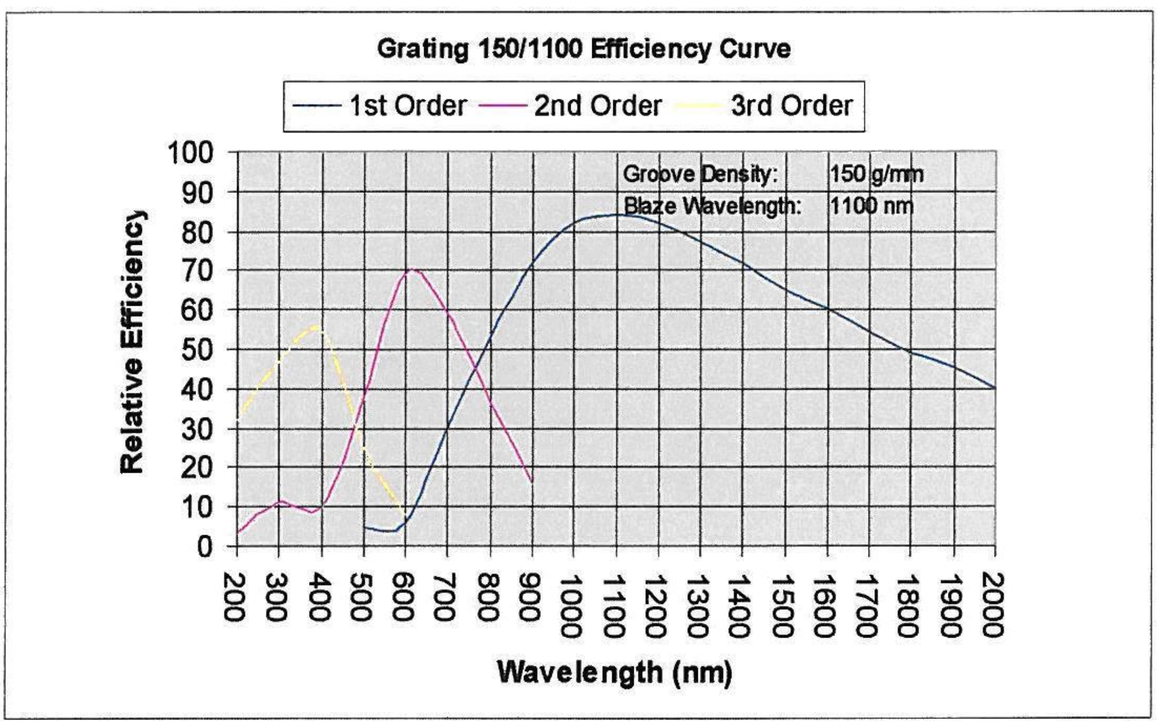
The following graphs show grating efficiency only. System sensitivity is due to several factors, including detector response and grating efficiency.



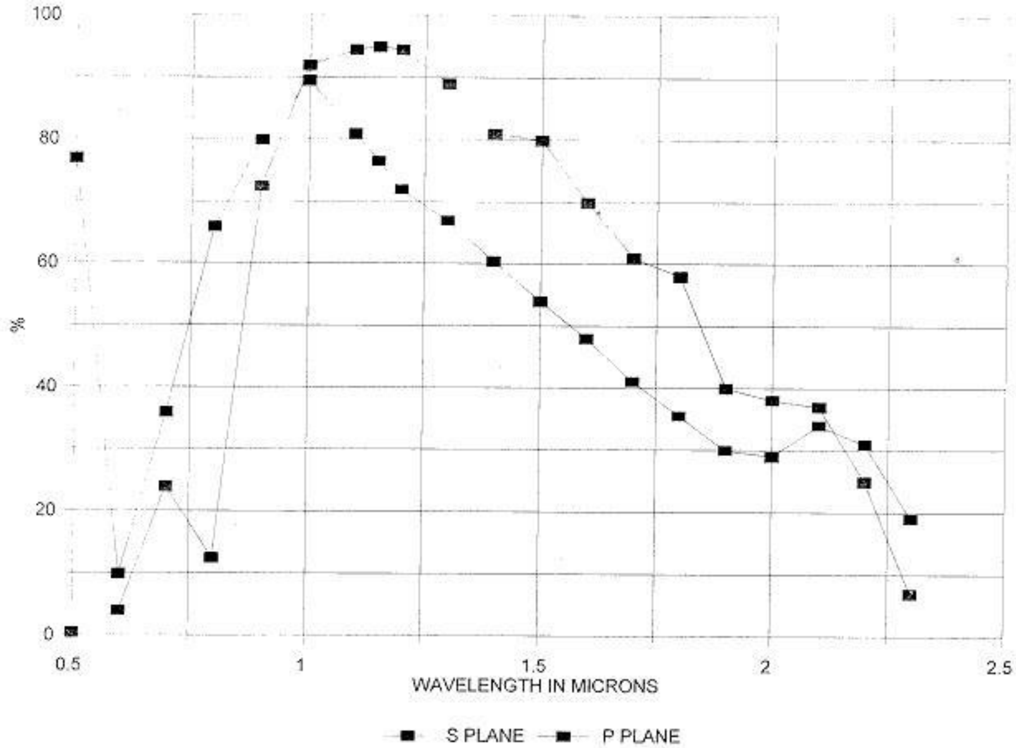
Grating NIR1, 1075 – 2500 nm, 75 l/mm, Blazed at 1700 nm



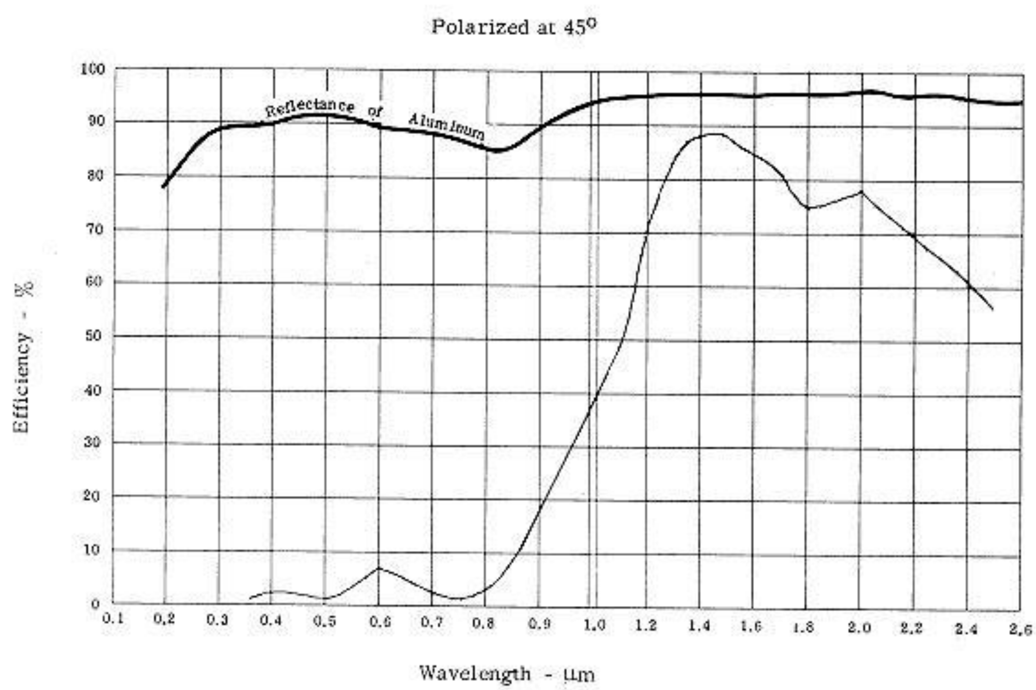
Grating NIR2, 900 – 2050 nm, 100 l/mm, Blazed at 1600 nm



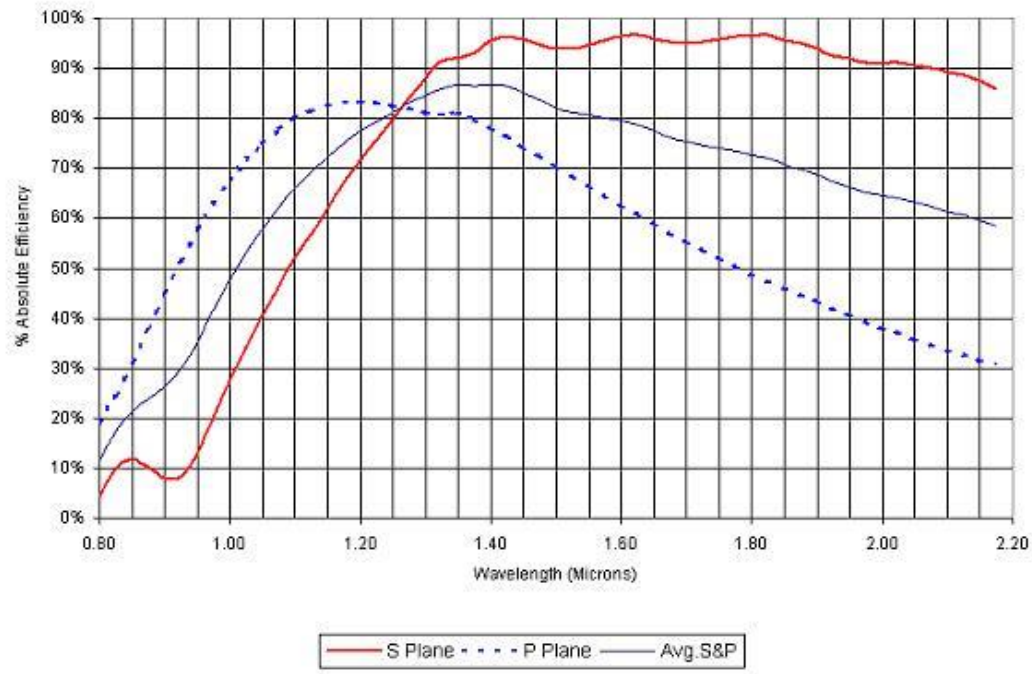
Grating NIR3, 900 – 1700 nm, 150 l/mm, Blazed at 1100 nm



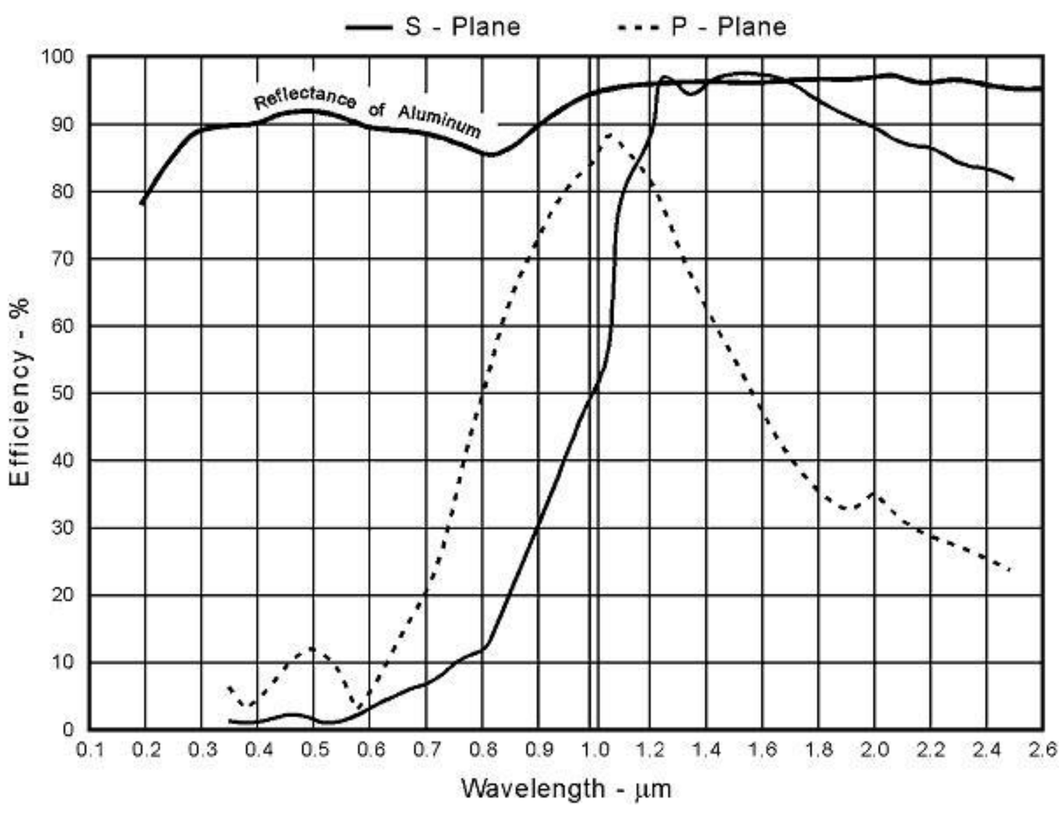
Grating NIR10, 750 – 2200 nm, 300 l/mm, Blazed at 1200 nm



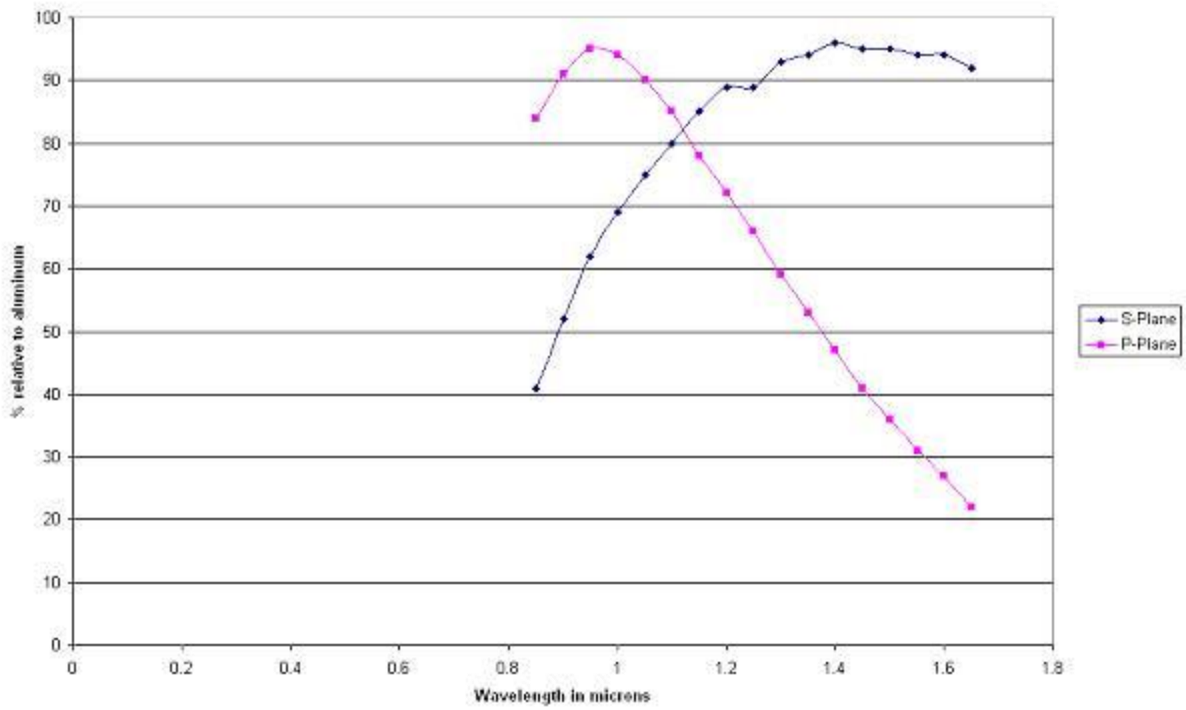
Grating NIR11, 980 – 2500 nm, 400 l/mm, Blazed at 1600 nm



Grating NIR12, 900 – 2500 nm, 500 l/mm, Blazed at 1370 nm



Grating NIR13, 800 – 2500 nm, 600 l/mm, Blazed at 1200 nm



Grating NIR14, 900 – 1700 nm, 1000 l/mm, Blazed at 1310 nm

High Gain / Low Gain Settings

The NIRquest is available from the factory with two possible gain settings, high gain and low gain. Low gain is the default setting and, unless specified in the order, your NIRquest will be delivered with the low gain settings.

High gain amplifies the signal from the detector, making it easier to see low level or weak signals. When high gain mode is employed the range of intensities to which the spectrometer will respond is correspondingly reduced. High gain can be useful where low integration times are required to see relatively weak signals but can be a disadvantage where precision and dynamic range are more important, such as when building calibration models.

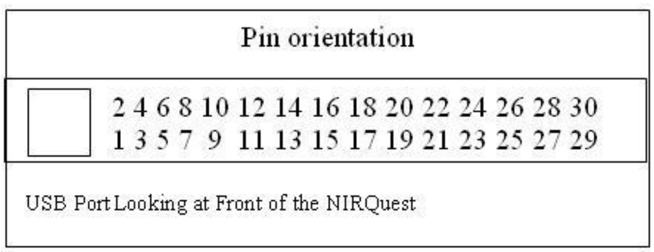
There is also further consideration of the noise situation at the detector. If your measurement is readout noise limited (the electronic noise in the circuit is the limit of the signal-to-noise ratio), then the high gain mode will improve the sensitivity of your measurement. However, if it is thermal noise limited, high gain will simply amplify the noise as well as the signal. The noise limit is dependent on the temperature of the detector and the integration time as well as the detector type. The >2000nm extended range detector types are generally thermally limited, even from the minimum 1ms integration times. As a result, it is not recommended to specify high gain mode for these detectors.

	Low Gain Mode (Default)	High Gain Mode
NIRquest-512-1.7	✓	On Request
NIRquest-512-1.9	✓	On Request
NIRquest-256-2.1	✓	Not Recommended
NIRquest-512-2.2	✓	Not Recommended
NIRquest-256-2.5	✓	Not Recommended
NIRquest-512-2.5	✓	Not Recommended

To use high gain mode, the NIRquest must be calibrated with the correct settings at the factory. At this time it is not possible to change between modes on the device. Please specify when ordering or contact your local Ocean Optics representative for more information.

Electrical Pinout

30-pin Accessory Connector Pinout



Pin #	Function	Input/Output	Description
1	RS232 Rx	Input	RS-232 receive signal. RS-232 functionality is not implemented in software.
2	RS232 Tx	Output	RS-232 transmit signal. RS-232 functionality is not implemented in software.
3	GPIO (2)	Input/Output	GPIO
4	N/A	N/A	Reserved
5	Ground	Input/Output	Ground
6	I2C SCL	Input/Output	I2C clock signal for communication to other I2C peripherals
7	GPIO (0)	Input/Output	GPIO
8	I2C SDA	Input/Output	I2C data signal for communication to other I2C peripherals
9	GPIO (1)	Input/Output	GPIO
10	Ext. Trigger In	Input	TTL input trigger signal
11	GPIO (3)	Input/Output	GPIO

Pin #	Function	Input/Output	Description
12	VCC or VIN	Input or Output	Input power pin–See note[1]
13	SPI Data Out	Output	Reserved
14	VCC or VIN	Input or Output	Input power pin – See note[1]
15	SPI Data In	Input	Reserved
16	GPIO (4)	Input /Output	Controls optional shutter
17	Single Strobe	Output	TTL output pulse used as a strobe signal – Has a programmable delay relative to the beginning of the spectrometer integration period
18	GPIO (5)	Input/Output	GPIO
19	SPI Clock	Output	Reserved
20	Continuous Strobe	Output	TTL output signal used to pulse a strobe – with user-specified parameters
21	SPI Chip Select	Output	Reserved
22	GPIO (6)	Input/Output	GPIO
23	N/A	N/A	Reserved
24	N/A	N/A	Reserved
25	Lamp Enable	Output	TTL signal driven Active HIGH when the Lamp Enable command is sent to the spectrometer
26	GPIO (7)	Input/Output	GPIO
27	Ground	Input/Output	Ground
28	GPIO (8)	Input/Output	GPIO
29	Ground	Input/Output	Ground
30	GPIO (9)	Input/Output	GPIO

[1] When an external power supply is connected to the NIRQuest power plug, this pin is an output power supply. When no external power is connected, this pin can be used as an input to power the spectrometer. It cannot supply power for the TEC. Do not supply power to both the external connector and the pin at the same time. The maximum voltage on any pin is 3.6V.

Thermo-Electric Cooler (TEC)

The NIRQuest contains a Thermo Electric Cooler (TEC) to reduce noise and maintain a stable operating temperature. Users can set the TEC temperature setpoint (in °C); it is critical to select a setpoint that is appropriate for the local operating conditions.

Note that the TEC drive electronics can only cool the device, so no heating is possible. In fact, when the TEC is on, there will always be some amount of cooling present. Therefore, the TEC setpoint has an allowable range, which is defined as the minimum temperature below ambient and the maximum temperature below ambient. Outside of this range, temperature control is unstable.

- For the NIRQuest512-1.7, the minimum stable temperature is 35 degrees below ambient, and the maximum stable temperature is 20 degrees below ambient.
- For the NIRQuest-1.9, NIRQuest-2.2, and NIRQuest-2.5, the minimum stable temperature is 50 degrees below ambient, and the maximum stable temperature is 30 degrees below ambient.

To set the TEC setpoint, note the minimum and maximum ambient temperature that you expect to observe during your testing, and then select a TEC setpoint that will not exceed the capabilities of the device. In a typical laboratory, ambient temperatures are between 20°C to 30°C.

The following table shows the acceptable ambient conditions for various setpoints for the NIRQuest512-1.7. For example, a setpoint of -10°C would be a bad choice for a laboratory environment with a 25 degree nominal temperature since the temperature may drift slightly out of the acceptable range. A setting of -5°C is recommended for laboratory environments.

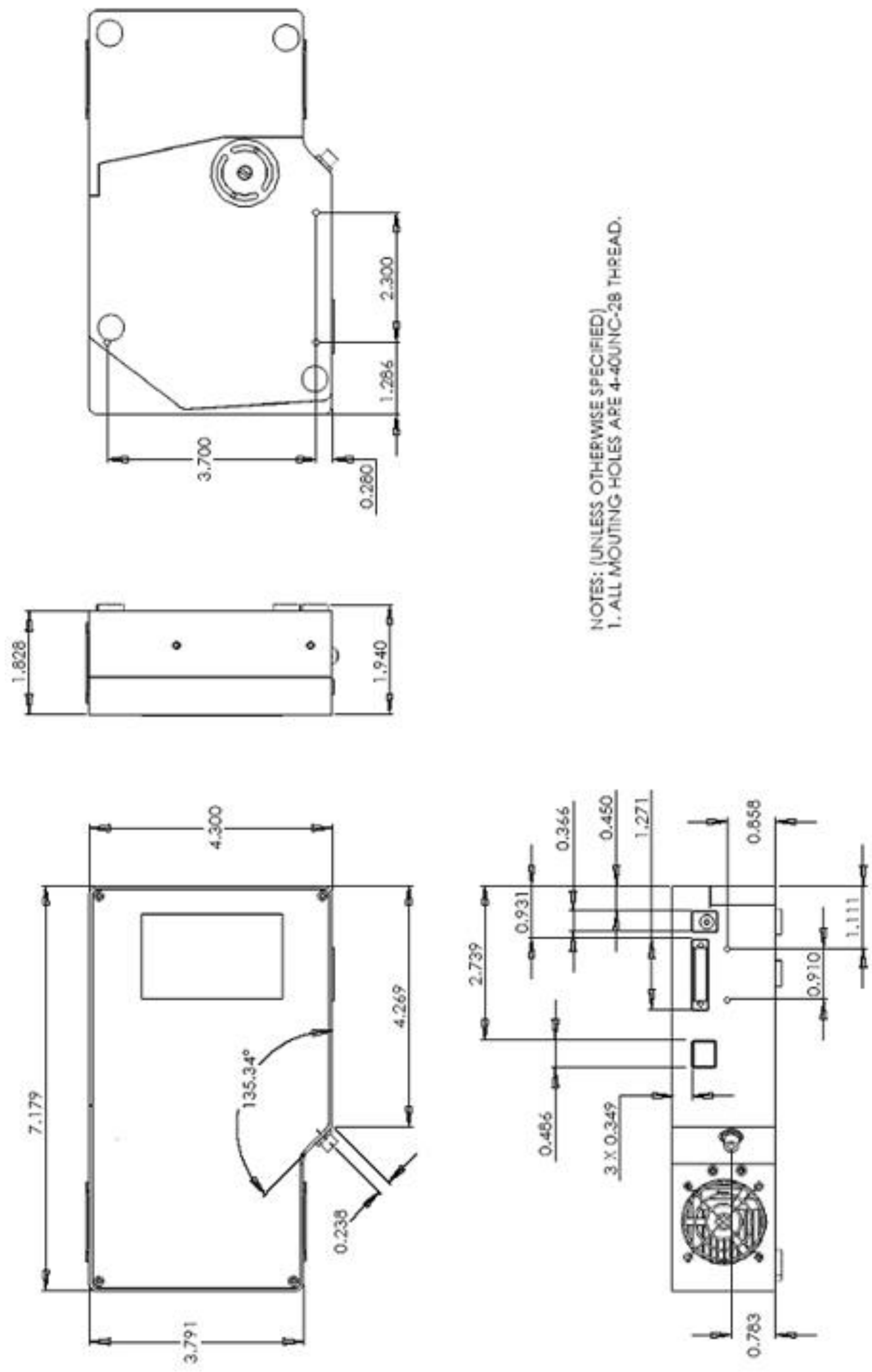
TEC Setpoint (°C)	Minimum Ambient (°C)	Maximum Ambient (°C)
-20	0	15
-15	5	20
-10	10	25
-5	15	30
0	20	35

The following table shows the acceptable ambient conditions for various setpoints for the NIRQuest-1.9, NIRQuest-2.2, and NIRQuest-2.5:

TEC Setpoint (°C)	Minimum Ambient (°C)	Maximum Ambient (°C)
-25	5	25
-20	10	30
-15	15	35
-10	20	40
-5	25	45
0	30	50

The default TEC temperature at startup can be saved to the device with the **Save TEC Settings** button in SpectraSuite, but there is no way to do this in Ocean View. If you are using OceanView, you must manually set the TEC temperature each time you run the device.

Mechanical Diagram



Hardware Description

The NIRQuest is controlled by a Cypress FX2LP microcontroller. This device has an 8051 processor core combined with an integrated USB 2.0 peripheral physical layer. Program code is stored in an external flash memory chip, and is loaded into the microcontroller at power-up via an I2C interface.

USB Information

Ocean Optics Vendor ID number is 0x2457. The NIRQuest512's Product ID is 0x1026 and the NIRQuest256 Product ID is 0x1028. The NIRQuest supports USB 2.0 interface which is specified at 12Mbps.

Instruction Set

Command Syntax

The list of the commands is shown in the following table followed by a detailed description of each command. The length of the data depends on the command. All commands are sent to the NIRQuest through End Point 1 Out (EP1). Spectral data are acquired through End Point 2. All other queries are retrieved through End Point 1 In (EP1).

Pipe #	Description	Type	Full Speed Size (Bytes)	Endpoint Address
0	End Point 1 Out	Bulk	512	0x01
1	End Point 1 In	Bulk	512	0x82
2	End Point 6 In (unused)	Bulk	512	0x86
3	End Point 1 In	Bulk	512	0x81

USB Command Summary

EP2 Command Byte Value	Description
0x01	Initialize Device
0x02	Set Integration Time
0x03	Set Strobe Enable Status
0x04	Reserved
0x05	Query Information
0x06	Write Information

EP2 Command Byte Value	Description
0x07	Write Serial Number
0x08	Get Serial Number
0x09	Request Spectra
0x0A	Set Trigger Mode
0x71	Set TEC Controller State
0x0C	Set Detector Gain Mode
0x6A	Write Register
0x6C	Read PCB Temperature
0x70	Set Fan State
0x1E	Stop Spectral Acquisition
0x73	TEC Controller Write
0x72	TEC Controller Read
0xFE	Query Status

Command Descriptions

A detailed description of all NIRQuest commands follows. While all commands are sent to EP1 over the USB port, the byte sequence is command dependent. The general format is the first byte is the command value and the additional bytes are command specific values.

Byte 0	Byte 1	Byte 2	…	Byte n-1
Command Byte	Command Specific	Command Specific	…	Command Specific

Initialize NIRQuest

Initializes the device and aborts a scan if in progress. This command should be called at the start of every session.

Byte Format

Byte 0
0x01

Set Integration Time

Sets the NIRQuest's integration time in milliseconds. The acceptable range is 1 – 1,600,000. If the value is less than 1ms then the integration time is set to 1ms.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4
0x02	Integration Time LSW LSB	Integration Time LSW MSB	Integration Time MSW LSB	Integration Time MSW MSB

Set Strobe Enable Status

Sets the NIRQuest Lamp Enable line (DB15 pin 13) as follows. The Single Strobe and Continuous Strobe signals are enabled/disabled by this Lamp Enable Signal.

Data Byte = 0 ➔ Lamp Enable Low/Off
Data Byte = 1 ➔ Lamp Enable HIGH/On

Byte Format

Byte 0	Byte 1	Byte 2
0x03	Data byte LSB	Data Byte MSB

Query Information

Queries any of the 19 stored spectrometer configuration variables. The Query command is sent to EP1 and the data is retrieved through EP1 In. When using Query Information to read EEPROM slots, data is returned as ASCII text. However, everything after the first byte that is equal to numerical zero will be returned as garbage and should be ignored.

The 19 configuration variables are indexed as follows:

Data Byte - Description 0 – Device Serial Number 1 – 0th order Wavelength Calibration Coefficient 2 – 1st order Wavelength Calibration Coefficient 3 – 2nd order Wavelength Calibration Coefficient 4 – 3rd order Wavelength Calibration Coefficient 5 – Stray light constant 6 – 0th order non-linearity correction coefficient 7 – 1st order non-linearity correction coefficient 8 – 2nd order non-linearity correction coefficient 9 – 3rd order non-linearity correction coefficient 10 – 4th order non-linearity correction coefficient 11 – 5th order non-linearity correction coefficient 12 – 6th order non-linearity correction coefficient 13 – 7th order non-linearity correction coefficient 14 – Polynomial order of non-linearity calibration 15 – Optical bench configuration: gg fff sss gg – Grating #, fff – filter wavelength, sss – slit size 16 – Detector Serial Number 17 – Configuration Parameter Return 18 – Reserved 19 – Reserved

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4, 5	Byte 6, 7
0x05	Configuration Parameter Return	0 = TEC Off 1 = TEC On	0 = TEC Off 1 = TEC On	LSB, MSB TEC Setpoint in tenths °C	LSB, MSB Saturation value

Return Format (EP7)

The data is returned in ASCII format and read in by the host through EP1 In.

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 17
0x05	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

Write Information

Writes any of the 19 stored spectrometer configuration variables to EEPROM. The 19 configuration variables are indexed as described in the Query Information. The information to be written is transferred as ASCII information. This command requires ~150ms to complete.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 17
0x06	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

Write Serial Number

Writes the serial number to EEPROM. The information to be written is transferred as ASCII information. This command requires ~150ms to complete.

Byte Format

Byte 0	Byte 1	Byte 2	…	Byte 16
0x07	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

Query Serial Number

Queries the unit's serial number. The Query command is sent to EP1 and the data is retrieved through End Point 1. The information to be read is transferred as ASCII information.

Byte Format

Byte 0
0x08

Return Format

The data is returned in ASCII format and read in by the host through End Point 1.

Byte 0	Byte 1	Byte 2	…	Byte 16
0x08	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

Request Spectrum

Initiates a spectrum acquisition. The NIRQuest will acquire a complete spectrum. The data is returned in bulk transfer mode through EP2 in packets each containing 64 bytes in USB 1.1 mode or 512 bytes in USB 2.0 mode. The total number of bytes returned is twice the number of pixels (2 bytes per pixel) plus one trailing byte. The pixel values are decoded as described below.

Byte Format

Byte 0
0x09

Return Format

The data is returned in bulk transfer mode through EP2 in packets each containing 64 bytes (USB 1.1) or 512 bytes (USB 2.0). There is an additional packet containing one value that is used as a flag to insure proper synchronization between the PC and NIRQuest. Bit 15 has to be flipped before converting to an integer. The pixel values are decoded as described below.

The format for the first packet is as follows (all other packets except the synch packet has a similar format except the pixel numbers are incremented by 256 pixels for each packet). NOTE: Bit 15 has to be flipped for every pixel before converting to an integer.

Packet 0

Byte 0	Byte 1	Byte 2	Byte 3
Pixel 0 LSB	Pixel 0 MSB	Pixel 1 LSB	Pixel 1 MSB

…

		Byte 510	Byte 511
		Pixel 255 LSB	Pixel 255 MSB

Packet 15 – Synchronization Packet (1 byte)

Byte 0
0x69

Set Trigger Mode

Sets the NIRQuest Trigger mode to one of three states. If an unacceptable value is passed then the trigger state is unchanged (Refer to the External Triggering manual for a description of the trigger modes).

Data Value = 0 ➔ Normal (Free running) Mode Data Value = 3 ➔ External Hardware Edge Trigger Mode

Byte Format

Byte 0	Byte 1	Byte 2
0x0A	Data Value LSB	Data Value MSB

Note

For FPGA version 1088 and above:

0x00 – Free Run Mode (default)

0x01 – External Hardware Level Trigger Mode

0x03 – External Hardware Edge Trigger Mode

Write Register

Most all of the controllable parameters for the NIRQUEST are accessible through this command (e.g., GPIO, strobe parameters, etc). A complete list of these parameters with the associate register information is shown in the table below. Commands are written to End Point 1 Out typically with 4 bytes (some commands may require more data bytes). All data values are 16 bit values transferred in LSB | MSB order. This command requires 100us to complete; the calling program needs to delay for this length of time before issuing another command. In some instances, other commands will also write to these registers (i.e., integration time), in these cases the user has the options of setting the parameters through 2 different methods.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3
0x6A	Register Value	Data Byte LSB	Data Byte MSB

Register Address	Description	Default Value	Min Value	Max Value	Time Base
0x00	Master Clock Counter Divisor	24	1	0xFFFF	48MHz
0x04	FPGA Firmware Version (Read Only)				N/A
0x08	Continuous Strobe Timer Interval Divisor	48000	0	0xFFFF	Continuous Strobe Base Clock (see Register 0x0C)
0x0C	Continuous Strobe Base Clock Divisor	4800	0	0xFFFF	48MHz
0x10	Integration Period Base Clock Divisor	480	0	0xFFFF	48MHz
0x14	Set base_clk or base_clkx2 0: base_clk 1: base_clkx2	0	0	1	N/A
0x18	Integration Clock Timer Divisor	600	0	0xFFFF	Integration Period Base Clock
0x28	Hardware Trigger Delay – Number of Master Clock cycles to delay when in External Hardware Trigger mode before the start	0	0	0xFFFF	
0x2C	Trigger Mode 0 = Free Running 1 = External HW Level Trigger 2 = External HW Sync Trigger 3 = External HW Edge Trigger	0	0	0x0003	
0x38	Single Strobe High Clock Transition Delay Count	1	0	0xFFFF	2MHz
0x3C	Single Strobe Low Clock Transition Delay Count	1	0	0xFFFF	2MHz
0x40	Lamp Enable	0	0	1	N/A

Register Address	Description	Default Value	Min Value	Max Value	Time Base
0x44	Detector High Gain Select	0	0	1	N/A
0x48	GPIO Mux Register 0: pin is GPIO pin 1: pin is alternate function	0	0	0x03FF	N/A
0x50	GPIO Output Enable 1: pin is output 0: pin is input	0	0	0x03FF	N/A
0x54	GPIO Data Register For Ouput: Write value of signal For Input: Read current GPIO state	0	0	0x03FF	N/A

Read PCB/Read Heatsink Temperature

Description: Read the Printed Circuit Board Temperature and the heat sink temperature. The NIRQuest contains two DS1721 temperature sensor chips—one of which is mounted to the main PCB and the other which is mounted close to the heat sink. This command is sent to End Point 1 Out and the data is retrieved through End Point 1 In. The values returned are two signed 16-bit A/D conversion value which is equated to temperature by:

$$\text{Temperature } (^{o}\text{C}) = .003906 * \text{ADC Value}$$

Byte Format

Byte 0
0x6C

Return Format (EP1In)

Byte 0	Byte 1	Byte 2
Read Result for PCB Temperature	ADC Value LSB	ADC Value MSB
Byte 3	**Byte 4**	**Byte 5**
Read Result for Heatsink Temperature	ADC Value LSB	ADC Value MSB

If the operation was successful, the Read Result byte value will be 0x08. All other values indicate the operation was unsuccessful

Set TEC Controller State

Enables/Disables the detectors TEC controller. This command takes between 20 and 40 milliseconds to complete. If you issue a command immediately after setting the TEC temperature, the command is queued until the Set TEC Temperature command has completed.

Data Byte = 0 → TEC Controller Disabled Data Byte = nonzero → TEC Controller Enabled

Byte Format

Byte 0	Byte 1	Byte 2
0x71	Data byte LSB	Data Byte MSB

Set Fan State

Description: Enables/Disables the FAN inside the NIRQuest. The fan should run all of the time to insure proper cooling of the electronics and heat sink.

Data Byte = 0 → Fan Off Data Byte = Nonzero → Fan On

Byte Format

Byte 0	Byte 1	Byte 2
0x70	Data Byte LSB	Data Byte MSB

TEC Controller Write

Performs a write command to the TE controller. This command is used to set the detectors TEC set point temperature. The set-point value is a signed 16-bit value that is expressed in tenths of a degree Celsius. For example to set the temperature to –5.0°C a value of –50 or 0xFFCD is sent. This command takes between 20 and 40 milliseconds to complete. If you issue a command immediately after setting the TEC temperature, the command is queued until the Set TEC Temperature command has completed.

Byte Format Set Point LSB

Byte 0	Byte 1	Byte 2
0x73	Set-point LSB	Set-point MSB

TEC Controller Read

Returns the detector temperature. This command is sent to EP1 and a total of 2 bytes data is retrieved through End Point 1 In. This command takes between 20 and 40 milliseconds to issue a response.

Byte Format

Byte 0
0x72

Return Format

Byte 0	Byte 1
Temp LSB	Temp MSB

The Detector Temperature is a 16-bit signed value representing tenths of a degree Celsius as described in the TEC Controller Write command.

Query Status

Returns a packet of information, which contains the current operating information. The structure of the status packet is given below.

Byte Format

Byte 0
0xFE

Return Format

The data is returned in Binary format and read in by the host through End Point 1. The structure for the return information is as follows:

Byte	Description	Comments
0	LSB (NUMPIXELS)	
1	MSB (NUMPIXELS)	
2	LSB (LSW(Integrationperiod))	
3	MSB (LSW(Integrationperiod))	
4	LSB (MSW(Integrationperiod))	
5	MSB ((MSW(Integrationperiod))	
6	(BYTE) bLampEnable	
7	(BYTE) LSB (TrigMode)	

Byte	Description	Comments
8	(BYTE) SpectraState	#define SS_IDLE 0x00 #define SS_STARTACQUISITION 0x01 #define SS_WAITFOR_FF_TOGOLOW 0x02 #define SS_WAITFORFIFOSTOFILL 0x03 #define SS_READINGDATA 0x04 #define SS_READINGFIRST2K 0x05 #define SS_READINGDATA_FS 0x06 #define SS_SENDLASTBYTE 0x08 #define SS_WAITFORTRIGGER 0x09 #define SS_SERIAL 0x0a
9	(BYTE) NumPackets	
10	(BYTE)((power Down?) ? 0 : 1); 10 Power Down	
11	(BYTE)PacketCount	
12	(BYTE)0;// 12 Gain Select	
13	(BYTE)ReadFPGAStatusByte()	
14	(BYTE)EZUSB_HIGHSPEED()	
15	(BYTE)ReadoutMode8Channel	

NIRQuest External Hardware Trigger and Single Strobe Performance

The NIRQuest FPGA has been enhanced to support External Hardware Trigger and Single Strobe Output generation. Under External Hardware Trigger Mode, the FPGA will hold off detector acquisition for the following start condition:

1. FX2 Microcontroller ready for new data (ReadEnable).
2. Rising edge on external input ExtTrigIn.
3. Programmed IntegrationDelay + Fixed DetRechgDly Time has elapsed.

The FPGA will also hold off Single Strobe Output generation for the following start condition:

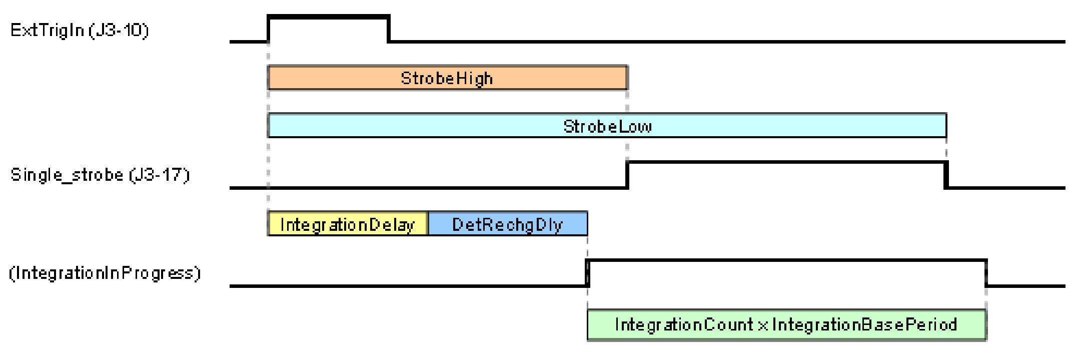
1. FX2 Microcontroller ready for new data (ReadEnable).
2. Rising edge on external input ExtTrigIn.
3. Programmed StrobeHi Time has elapsed before setting Single Strobe high.
4. Programmed StrobeLo Time has elapsed before returning Single Strobe low.

DetRechgDly is a minimum delay required to completely charge all of the detector's pixels before acquisition. This translates into a minimum trigger response time limitation (515 microseconds for NirQuest256 and 1030 microseconds for NirQuest512). The soonest the FPGA can start an acquisition would be the minimum trigger response time after the rising edge on ExtTrigIn.

An application can use the Single Strobe output to synchronize an event (for example, a light flashing) with the actual detector acquisition time. See the figure below:

SPI Register	Register Address	ns/count
IntegrationBasePeriod	0x10	1000
IntegrationCount	0x18	IntegrationBasePeriod
IntegrationDelay	0x28	500
TriggerMode	0x2C	0-Norm, 3-ExtTrig
StrobeHigh	0x38	500
StrobeLow	0x3C	500
LampEnable	0x40	0-LampOff, 1-LampOn

DetRechgDly (256 pixels) - 515 us
DetRechgDly (512 pixels) - 1030 .us



Known Issues

CAUTION

If you are using SpectraSuite, be sure to use the latest version for full functionality for the NIRQuest Spectrometer.

Other issues for the NIRQuest include the following:

- High Gain mode requires independent linearity correction, and this should be specified when ordering.
- On older versions of firmware (PSOC earlier than 2030 and FX2 earlier than 3020) and software, the TEC Temperature continuous display update causes the scan to pause and can crash the system if the integration time is changed rapidly (e.g., scrolling with up/down arrows).
- On older versions of some firmware (PSOC earlier than 2030 and FX2 earlier than 3020) and software, the TEC Temperature control can be lost after reading the temperature several hundred or several thousand times (and as a result the temperature will no longer be updated correctly). The TEC temperature is still controlled at the last setpoint under these conditions, but to fix the problem you must unplug both the USB and TEC power for 15s before repowering the device.

Contact Ocean Optics for more information.

Appendix A: NIRQuest Serial Port Interface Communications and Control Information

Overview

The NIRQuest is a microcontroller-based miniature fiber optic spectrometer, which can communicate via the Universal Serial Bus or RS-232. This document contains the necessary command information for controlling the NIRQuest via the RS-232 interface.

Hardware Description

The NIRQuest utilizes a Cypress FX2 microcontroller, which has a high speed 8051, combined with an USB ASIC. Program code and data coefficients are stored in external EEPROM, which are loaded at boot-up via the I^2C bus.

Note

Updates to the RS232 communication protocol are currently pending. Contact Ocean Optics for information about how to communicate with this device via RS232.

Application Tips

- During the software development phase of a project, the operating parameters of the NIRQuest may become out-of-synch with the controlling program. It is good practice to cycle power on the NIRQuest when errors occur.
- If you question the state of the NIRQuest, you can transmit a space (or another non-command) using a terminal emulator. If you receive a NAK, the NIRQuest is awaiting a command; otherwise, it is still completing the previous command.
- For Windows users, use HyperTerminal as a terminal emulator after selecting the following:

5. Select **File | Properties**.
6. Under Connect using, select Direct to Com x.
7. Click Configure and match the following Port Settings:

Bits per second (Baud rate): Set to desired rate

Data bits: 8

Parity: None

Stop bits: 1

Flow control: None

Click **OK** in **Port Settings** and in **Properties** dialog boxes.

Technical Note 1: NIRQuest Data Compression

Transmission of spectral data over the serial port is a relatively slow process. Even at 115,200 baud, the transmission of a complete 3840 point spectrum takes around 600 msec. The NIRQuest implements a data compression routine that minimizes the amount of data that needs to be transferred over the RS-232 connection. Using the "G" command (Compressed Mode) and passing it a parameter of 1 enables the data compression. Every scan transmitted by the NIRQuest will then be compressed. The compression algorithm is as follows:

1. The first pixel (a 16-bit unsigned integer) is always transmitted uncompressed.
2. The next byte is compared to 0x80.
3. If the byte is equal to 0x80, the next two bytes are taken as the pixel value (16-bit **unsigned** integer).
4. If the byte is not equal to 0x80, the value of this byte is taken as the difference in intensity from the previous pixel. This difference is interpreted as an 8-bit **signed** integer.
5. Repeat step 2 until all pixels have been read.

Using this data compression algorithm greatly increases the data transfer speed of the NIRQuest. Compression rates of 35-48% can easily be achieved with this algorithm.

The following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

Pixel Value	Value Difference	Transmitted Bytes
185	0	0x80 0x00 0xB9
2151	1966	0x80 0x08 0x67
836	-1315	0x80 0x03 0x44
453	-383	0x80 0x01 0xC5
210	-243	0x80 0x00 0xD2
118	-92	0xA4
90	-28	0xE4
89	-1	0xFF
87	-2	0xFE
89	2	0x02
86	-3	0xFD
88	2	0x02
98	10	0x0A
121	23	0x17

Pixel Value	Value Difference	Transmitted Bytes
383	262	0x80 0x01 0x7F
1162	779	0x80 0x04 0x8A
634	-528	0x80 0x02 0x7A
356	-278	0x80 0x01 0x64
211	-145	0x80 0x00 0xD3
132	-79	0xB1
88	-44	0xD4
83	-5	0xFB
86	3	0x03
82	-4	0xFC
91	9	0x09
92	1	0x01
81	-11	0xF5
80	-1	0xFF
84	4	0x04
84	0	0x00
85	1	0x01
83	-2	0xFE
80	-3	0xFD
80	0	0x00
88	8	0x08
94	6	0x06
90	-4	0xFC
103	13	0x0D
111	8	0x08
138	27	0x1B

In this example, spectral data for 40 pixels is transmitted using only 60 bytes. If the same data set were transmitted using uncompressed data, it would require 80 bytes.

Technical Note 2: NIRQuest Checksum Calculation

For all uncompressed pixel modes, the checksum is simply the unsigned 16-bit sum (ignoring overflows) of all transmitted spectral points. For example, if the following 10 pixels are transferred, the calculation of the checksum would be as follows:

Pixel Number	Data (decimal)	Data (hex)
0	15	0x000F
1	23	0x0017
2	46	0x002E
3	98	0x0062
4	231	0x00E7
5	509	0x01FD
6	1023	0x03FF
7	2432	0x0980
8	3245	0x0CAD
9	1984	0x07C0

Checksum value: 0x2586

When using a data compression mode, the checksum becomes a bit more complicated. A compressed pixel is treated as a 16-bit **unsigned** integer, with the most significant byte set to 0. Using the same data set used in Technical Note 1, the following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

Data Value	Value Difference	Transmitted Bytes	Value added to Checksum
185	0	0x80 0x00 0xB9	0x0139
2151	1966	0x80 0x08 0x67	0x08E7
836	-1315	0x80 0x03 0x44	0x03C4
453	-383	0x80 0x01 0xC5	0x0245
210	-243	0x80 0x00 0xD2	0x0152
118	-92	0xA4	0x00A4
90	-28	0xE4	0x00E4
89	-1	0xFF	0x00FF

Data Value	Value Difference	Transmitted Bytes	Value added to Checksum
87	-2	0xFE	0x00FE
89	2	0x02	0x0002
86	-3	0xFD	0x00FD
88	2	0x02	0x0002
98	10	0x0A	0x000A
121	23	0x17	0x0017
383	262	0x80 0x01 0x7F	0x01FF
1162	779	0x80 0x04 0x8A	0x050A
634	-528	0x80 0x02 0x7A	0x02FA
356	-278	0x80 0x01 0x64	0x01E4
211	-145	0x80 0x00 0xD3	0x0153
132	-79	0xB1	0x00B1
88	-44	0xD4	0x00D4
83	-5	0xFB	0x00FB
86	3	0x03	0x0003
82	-4	0xFC	0x00FC
91	9	0x09	0x0009
92	1	0x01	0x0001
81	-11	0xF5	0x00F5
80	-1	0xFF	0x00FF
84	4	0x04	0x0004
84	0	0x00	0x0000
85	1	0x01	0x0001
83	-2	0xFE	0x00FE
80	-3	0xFD	0x00FD
80	0	0x00	0x0000
88	8	0x08	0x0008
94	6	0x06	0x0006
90	-4	0xFC	0x00FC
103	13	0x0D	0x000D
111	8	0x08	0x0008
138	27	0x1B	0x001B

The checksum value is simply the sum of all entries in the last column, and evaluates to 0x2C13.