JY Division Information
Optical Spectroscopy

New Developments in Multichannel Detection Products and Software

Raymond Pini

Abstract

Jobin Yvon (JY) offers a complete line of spectroscopic multichannel detectors for scientific research. JY's multichannel detectors, including liquid nitrogen-cooled and Peltier-cooled detectors with various chip sizes, are designed to meet a wide range of customer research and development needs. These products feature the superior performance and reliability expected of JY, a world-famous manufacturer of diffraction gratings and spectroscopes. This paper will introduce the InGaAs Near-Infrared Array Detector, the "Symphony" CCD Array Detector, and "SynerJY™" Integrated Software.

1 Introduction:

The Jobin Yvon (JY) Optical Spectroscopy Division specializes in producing world-class instrumentation for spectroscopy. The product line includes all of the components required to build a spectrometer system including detectors, spectrometers, and software.

Our customers typically look for the most innovative technologies to gain advantages in making experimental measurements. Working with our wide customer base, we gain insight into their requirements and experimental requirements, and we use this customer feedback to develop market-driven products. As a result, our product line continually evolves, to meet our customers' demands, now and in the future.

In this Article, we highlight an array detector optimized for NIR measurements, as well as new platform projects in array detector hardware (the Symphony product line) and a new software platform (SynerJY™) to operate and process data from the instrumentation.

2 "Spectrum One," InGaAs Array Detectors

Many array detectors, and applications for their use, have been developed in the visible region of the spectrum. Based on silicon devices, they offer a response no higher than 1.1 μm, due to the physical properties of silicon. Extension of the wavelength response into the UV has been performed, usually by use of a luminescent coating on the array detector, or by manufacturing processes such as open electrode techniques.

These devices perform well and are well established in the marketplace. As the market and development of materials important in the semiconductor and telecommunications industries continue to become more sophisticated, there is an increased interest in the near infrared (NIR) region of the spectrum for characterization of optical fibers, light sources, semiconductors and other related materials.

As an example, erbium-doped fiber optic amplifiers, used in wavelength-division multiplexing applications, emit near 1.5 μm with structured emission. To support these applications, JY has developed the IGA-3000 linear InGaAs array family utilizing very low noise detectors optimized for spectroscopic measurements in the NIR region.

2.1 Indium Gallium Arsendide Array (InGaAs) Detectors

The JY InGaAs array detectors array detectors offer extremely high sensitivity, dynamic range, signal-to-noise performance and stability for NIR applications. They provide a tremendous multiplexing advantage over single channel NIR detectors, without the need for an optical chopper. Recall that most photoconductive and photoemissive detectors that operate in the NIR benefit from, and sometimes absolutely require, modulation of the beam followed by phase-sensitive detection, to extract a useable signal from them. Frequently, these requirements are met by using an optical chopper, followed by a lock-in amplifier. The InGaAs Array system eliminates this requirement.

InGaAs Array detectors are ideal for many demanding, low light level, multichannel spectroscopic applications including:

- NIR Raman spectroscopy
- Photoluminescence measurements
- Plasma diagnostics
- Emission spectroscopy
- Characterization of NIR laser diodes, Optical filters and Light sources
- Fiber Optic Transmission measurements in the telecommunications industry

2.2 Importance of Pixel Width for Spectroscopic Measurements in the Near Infra-red

When selecting an array detector, grating and spectrograph combination, the pixel width is one of the key elements that determines the spectral resolution. Consider that the pixel width effectively dictates the resolution, analogous to the slit width of a monochromator, and it is apparent that smaller pixels allow higher resolution of measurement in the focal plane of the spectrograph. Early designs of InGaAs array detectors allowed a 50 µm pixel width, and later developments supported the fabrication of 25 µm devices, effectively doubling the number of pixels along the focal plane, and with it, the resolution.

In addition to pixel size, the high quantum efficiency (as high as 85 %) of these devices makes InGaAs linear arrays ideal for spectroscopic analysis, as the measured signal is properly and efficiently encoded, preserving all of the spectral information.

2.3 Detector Cooling

Our InGaAs arrays are available in liquid nitrogen (LN_2) and compact thermo-electrically cooled (TE) packages. Thermionic emission is an important consideration with these devices, because they are sensitive in the NIR, and cooling reduces this noise component. There is a tradeoff, however, as the device is cooled, the red-edge sensitivity decreases at approximately one nanometer per degree Kelvin. It is possible to adjust the temperature of the detector to optimize the measurement.

2.4 Signal-to-Noise Ratio

InGaAs arrays used in spectroscopy are constructed from individual photodiodes arranged in a linear array with a silicon CMOS readout multiplexer circuit. In high precision, low-light level spectroscopic applications, it is important to understand the various noise sources which contribute to a measurement with an InGaAs array and thus affect the signal-to-noise ratio.

Each individual InGaAs photodiode pixel in an array is connected to its own capacitive transimpedance preamplifier circuit. As a result, the bias voltages are often slightly different from pixel to pixel. These small differences in the output of each element lead to a predictable and repeatable noise signal known as a "*fixed pattern response.*" This source is a strong function of both the integration time and the array operating temperature, and can be reduced by thermoelectric or liquid nitrogen cooling. Fortunately, the fixed pattern response is highly reproducible and can be almost eliminated by subtracting a dark (or blank sample, if appropriate) acquisition of the same integration time as the illuminated spectrum of interest.

The total noise contribution to the measurement contains contributions from all sources of dark, readout, fixed-pattern and shot noise. A clear understanding of the noise process, the technical specifications of the detector and how these measurements are defined plays a critical role when comparing array detector performance.

3 CCD Array Detector, the "Symphony"

3.1 CCD Array Detector for Spectroscopy

The Symphony family of array detectors from JY is a versatile platform consisting of a controller and modular, plug-and-play detector heads. Symphony CCD detectors offer a unique combination of outstanding sensitivity, high speed, low noise, ruggedness and durability, in compact and cost-effective packages. Upgradeability and flexibility, combined with outstanding reliability, provide ultimate performance for a wide range of spectroscopic applications. Fig. 1 shows the "Symphony" CCD Array Detector.

Fig. 1 CCD Detector, the "Symphony"

3.2 Controller Highlights

Symphony Controllers provide extremely low read noise and fast acquisition speeds, allowing users to obtain optimum results in minimum time. Users can easily select and store detector parameters for X and Y Binning, define areas, select gain and ADC modes. Experiment timing may also be controlled with flexible trigger options, both hardware and software.

The design of the Symphony Controller is up-gradeable, with built-in expansion slots to allow for new array sensors and electronic components as they become available.

Symphony CCDs are the critical link between our customer's experiment and the resulting data. Symphony interfaces to the user's computer with a fast TCP/IP Interface – which provides 100 % data integrity. Some competitors' CCD detectors use computer interfaces that may be subject to missing data packets. To ensure that the Symphony CCD is always working correctly, it has been designed with built-in self diagnostics that continually monitor the status of the system.

3.3 ADC Conversion Speed and Signal Processing

Scientific CCD systems are typically operated with a 16-bit analog-to-digital converter (ADC). The ADC subsystem of the Symphony Controller may be operated at different speeds, to balance the signal-to-noise ratio versus the data readout rate required for the experiment. The Symphony system allows various ADC speeds, from 20 kHz to 1 MHz.

Typically, lower ADC rates provide the highest signal-to-noise, and higher ADC speeds provide fastest data transfer. With extremely low optical signals, the dominant noise factor is readout noise of the CCD itself. For such high sensitivity measurements, we use a 20 kHz ADC rate to provide the best performance. We can select up to 1 MHz ADC speed to allow faster data transfer, such as image data, by a simple software control.

Symphony CCDs are designed for the most rigorous spectroscopic measurements. The Symphony CCD Controller has reduced the readout noise to almost the theoretical minimum. Noise performance is being limited by the noise from the CCD chip and not noise from the data acquisition electronics.

3.4 Detector Heads

In addition to read noise, there is a component of noise that is due to the thermal properties of the detector. By cooling the CCD detector, the dark signal can be sharply reduced. LN_2 provides the highest cooling performance, for the most demanding applications. A high performance TE cooling option with software settable temperature control is the solution when customers require exceptional performance but do not want to work with liquid nitrogen.

4 SynerJY™ Software - Easy to Use, Integrated Software

SynerJY™ is general purpose data acquisition and data analysis software for spectroscopic systems. SynerJY™ allows users to conduct experiments, adjust hardware parameters, collect and analyze data and prepare it for presentation. Fig. 2 shows a SynerJY™ Screen Shot.

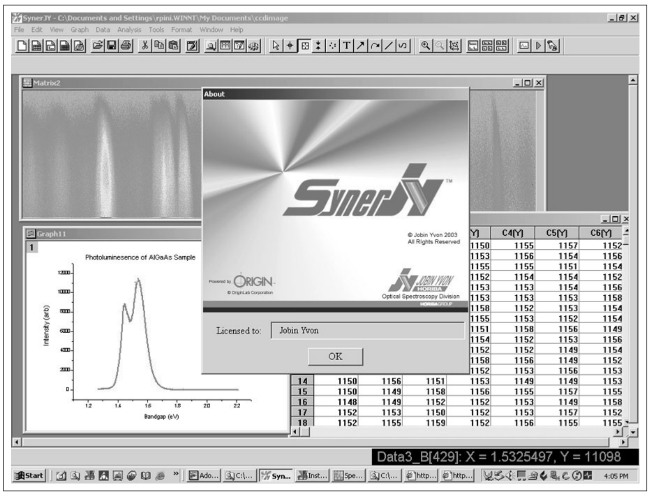

Fig. 2 SynerJY™ Screen Shot

4.1 Full Control of JY Spectroscopy Systems

SynerJY™ unlocks the full potential of your JY spectroscopy system. Users can control all aspects of a spectrograph including the grating drive, turret, slits, and shutters as well as change the entrance and exit mirror positions for sample and detector selection.

SynerJY™ software has been designed to take full advantage of the Symphony CCD. Customization of experiments for the best signal to noise can be quickly accomplished by adjusting the acquisition parameters in real time, including Integration Time, Area Selection, X and Y Binning, Gain and ADC selection.

SynerJY™ allows for simultaneous detector control and is equipped to perform complete data acquisition and analysis for both single and multichannel detectors. Using one system, you can collect data from a CCD when working in the UV-VIS region and then collect data in the IR with your single channel detector. Take advantage of Signal Algebra, using a reference photodiode to correct the spectrum collected by a CCD. Signal Algebra is an intuitive way of performing mathematical operations between datasets during the acquisition. It is easy to specify the required operations and view only the results calculated from the raw data.

4.2 Characteristic Features

(1) Data Processing and Presentation Tools

SynerJY™ is capable of performing a full range of general and advanced mathematical functions including spectral math, peak find, curve fitting, smoothing, derivative, integration, baseline subtraction, peak deconvolution, interpolation, spectral editing and splicing. Data may be presented as overlaid traces, 3-D plots, contour maps and images. Custom views are easily created by specifying line widths, styles and colors. Users can label peaks, axes and graphs, as well as add text comments to their display. Tools are available for peak selection, labeling, zooming and data selection.

(2) Data Import and Export

SynerJY™ supports a wide variety of file formats. SpectraMax and DataMax SPC files can be opened as well as other file formats including Excel™, ASCII and Origin™.

Graphic file export is possible via seventeen different image formats including, Bitmap (*.BMP), JPEG (*.JPG) and Adobe (*.PDF).

(3) Customizable Software

The full power of SynerJY™ is not only in the full general purpose application. SynerJY™ has been designed to be a modular software platform. Users can take advantage of the underlying architecture of SynerJY™ and write custom software to integrate their JY spectroscopy system into larger experimental setups, or write routines for very specific measurements. Using standard programming techniques, these measurements may be integrated into common software programs, such as Excel™ and Origin™.

With SynerJY™ software, customers can stop worrying about equipment and concentrate on their measurements.

5 Conclusion

The Optical Spectroscopy Division of JY builds top quality, high performance spectroscopic systems for our customers. Our toolbox of spectroscopic components is constantly growing and the possibilities offered to our customers are only limited by our combined imaginations.

Raymond Pini

Jobin Yvon S.A.S
Optical Spectroscopy Division
Applications Manager