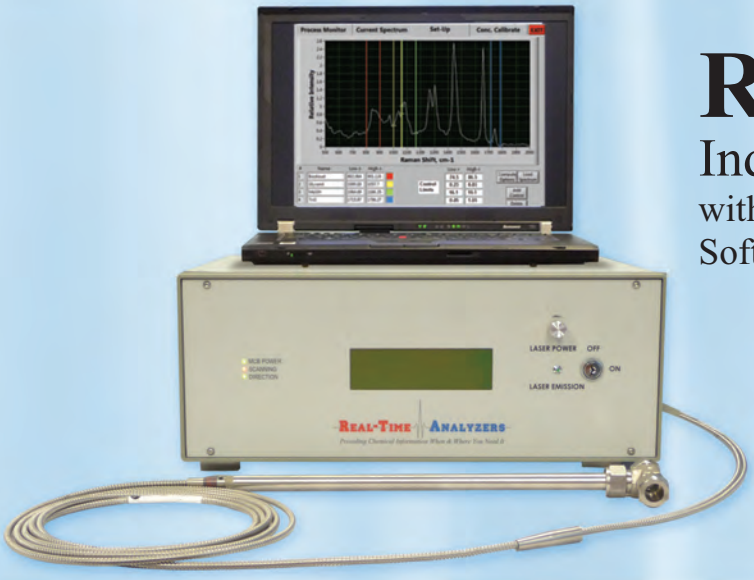
Real-Time Analyzers

Providing Chemical Information When & Where You Need It



RamanPro™

Industrial Raman Analyzer

with Process Controller
Software Package

From Lab to Plant

The RamanPro™ Advantage

"Today, Raman spectroscopy may be the most valuable Process Analytical Technology"

Raman spectroscopy has many advantages over infrared spectroscopy, such as no path-length dependence, linear response to concentration, sharper, less-overlapped peaks, and no interference from water. But most importantly, highly transmitting fiber optics can be used such that a probe can be placed directly into process reactors and streams remote from the analyzer. Only Real-Time Analyzers' (RTA) Raman analyzer, the RamanPro™, employs an x-axis stable interferometer. While other competitors employ dispersive devices with unstable x-axes, attempting to correct this deficiency with software and frequent re-calibration.

Real-Time Analyzers' RamanPro™ Industrial Raman Analyzer is a Process Analytical Technology (PAT) designed to provide Statistical Process Control (SPC) of both batch and continuous-feed reactors. Our vibration and temperature immune analyzer is contained in a standard 19" rack mount suitable for process control rooms or in-plant NEMA enclosures. Steel-jacketed fiber optic cables allow integrating probes into processes up to 200 meters away. A standard NeSSI compatible fiber optic probe allows rapid at-line integration, while a standard ruggedized probe made of 316 SS or Hastelloy C allows in-reactor integration and measurements in corrosive environments up to 200 °C and 1500 psi.

Hard wired and wireless computer controls are available. The 28-pound RamanPro™ can be used in the lab, in pilot plants, and in production facilities. Furthermore, the invariant x-axis means that any data processing model developed on any lab analyzer can be used for all plant analyzers.

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Statistical Process Control (SPC) is Critical to All Manufacturing.

In the early 1980's the Chemical Manufacturing Industry began replacing lab analysis of grab samples with continuous on-line analysis using Process Analytical Technology (PAT). One of the greatest (PAT) successes, the installation of Fourier transform infrared analyzers (FT-IRs) to control chemical manufacturing, was led by RTA's President while employed by Dow Chemical. Crucial to this success was an x-axis that never changed, which allowed developing concentration curves and chemometric models in the lab that could be transferred to FT-IRs in the pilot and production facilities without fear. Only systems utilizing interferometers, which employ internal reference lasers, have exact, invariant x-axis registration to satisfy this requirement.

REAL-TIME ANALYZERS

Routine Applications

Chemical Manufacturing:
Chemical Synthesis, Polymerization, Composites

Petrochemical Manufacturing:
Distillation, Fuel Blending, Product Purity

Pharmaceutical Manufacturing:
Drug and Intermediate Synthesis, Crystallization

Quality Control:
Raw Materials, Intermediates and Finished Products

Batch & Continuous-Feed Reactors:
Biofuel Production, Reactor Optimization

Pilot Plant:
Scale-up, Yield Analysis

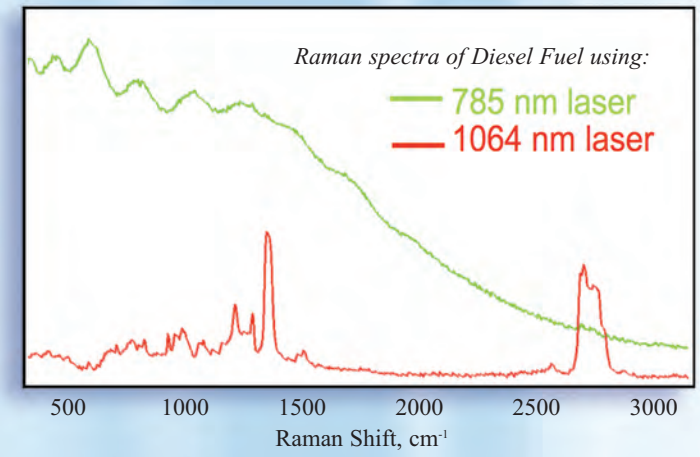
R&D:
Reaction Kinetics, New Product Development,
Reaction Endpoint Determination

Process Controller with 5 meter steel-jacketed cable with 316 SS probe capable of 200 °C and 1500 psi operation.

Features & Benefits

- **Monitor up to 10 target concentrations inside reactors in real-time**
- **Qualify raw materials and products**
- **No sample preparation required**
- **Avoid fluorescence interference**
- **No analyzer calibration required**
- **Use the same analyzer for lab, pilot-plant and production**
- **Use the same concentration model for all analyzers**
- **Obtain complete spectral coverage with every scan**
- **Use fiber optic cables up to 200 meters long**
- **Integrate into any process through in-situ, high pressure, high temperature probes (e.g. blind flange) or a standard NeSSI interface**
- **Industrial hardened, battery back-up**
- **19" Rack-mount standard, NEMA enclosure compatible**
- **Operate analyzer from 35 to 100 °F**
- **Transmit data wirelessly**
- **Easy-to-use software for both continuous-feed and batch reactors**

How It Works



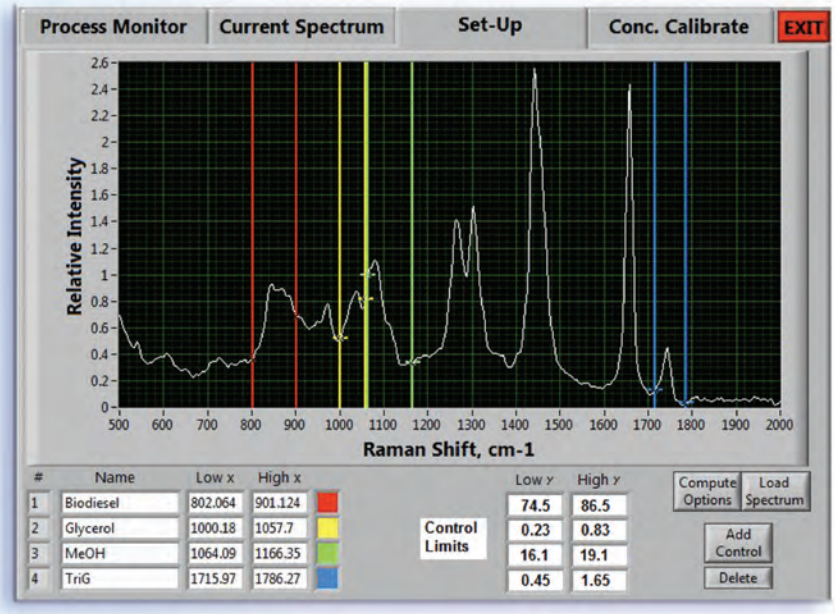
Excitation with a 785 nm laser produces featureless fluorescence in this diesel fuel, while excitation with RTA's 1064 nm laser produces a quantifiable Raman spectrum.

The **RamanPro™ Industrial Raman Analyzer** is the only process Raman analyzer that employs a rugged interferometer that provides 0.1 cm^{-1} wavenumber (x-axis) accuracy and calibrated y-axis intensity to guarantee correct peak intensity analysis (height or area). Each system is calibrated at the factory using a NIST reference material and never needs to be re-calibrated. Other process Raman analyzers require frequent re-calibration.

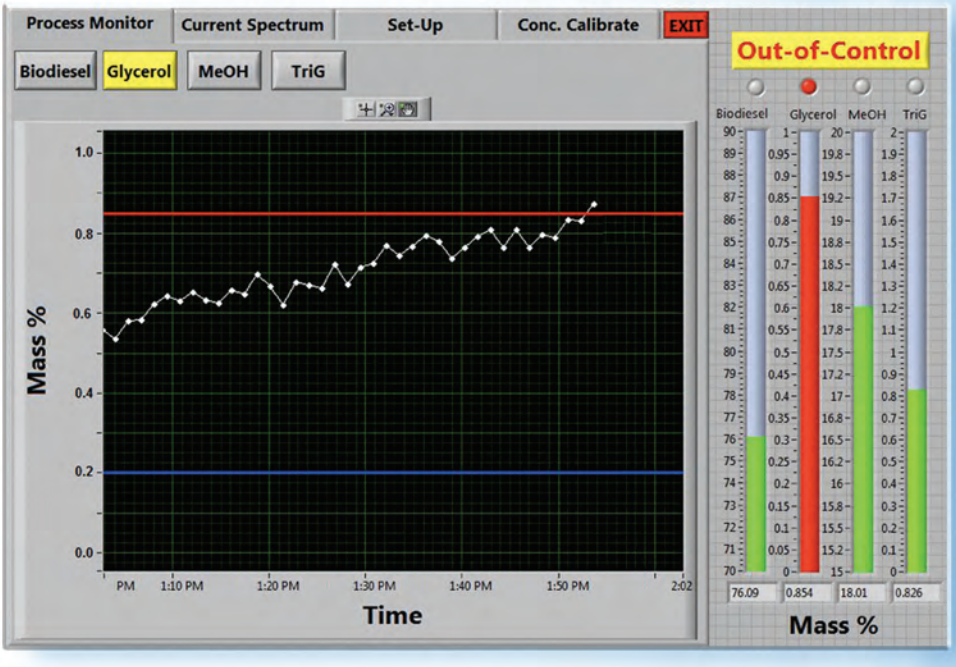
The **RamanPro™** is also the only process Raman analyzer that employs a 1064 nm laser excitation to avoid fluorescence interference. All other process Raman analyzers use shorter wavelengths to generate Raman spectra (e.g. 785 nm), which very frequently generate fluorescence in the sample. This is especially true for natural substances such as raw materials used in bio-reactors and petroleum distillation. If a sample fluoresces, the Raman spectrum is completely obscured (lost), which makes analysis impossible. *See the example in the figure to the left.* Other manufacturers recognize this limitation and attempt to "correct" the spectrum using data manipulation software. But this is only possible in the case of "mild" fluorescence when Raman peaks are still recognizable. They "approximate" what the spectrum would look like if their instrument did not induce the fluorescence. Which do you want to use to control your process, real data or an approximation?

The **RamanPro™** measures the Raman spectra of the reactor solution continuously as the product is made. The intensities of the peaks associated with each reactant, intermediate, and/or product are used to continuously quantify the amount of each component as the reaction proceeds. Every solid and liquid has a unique Raman signature that almost always provides one or more peaks that can be used for quantization. *See the example in the figure to the right.*

Once the spectral peaks are identified the software described on the next page can be used to set up the process monitoring software.



Raman spectrum representative of biodiesel production. Colored lines indicate spectral regions used to monitor biodiesel, glycerol, methanol and triglycerides for a batch reactor.



Software

The RamanPro™ Process Controller software environment is designed for fast and simple operation.

It includes five basic windows:

- **Process Monitor**
- **Current Spectrum**
- **Set-Up**
- **Concentration Calibration**
- **Exit**

Process Controller software interface **Process Monitor** ***window shown for continuous-feed reactor.***

The **Process Monitor** window provides a complete view of the reactor chemistry. The main plot shows the changing concentration (Mass %) of a selected chemical (by identification name or number) as a function of time (clock or from start) as well as the upper and lower control limits (set or sigma values). It also shows real-time concentrations for all chemicals along with their control limits. It also has a visual alarm indicator for out-of-control conditions, which can be tied to control room audible alarms, as appropriate. In fact all data can be exported as digital or analog computer signals to the control room mainframe process control computer.

The **Current Spectrum** window allows the user to take a quick look at the most recently collected Raman spectrum. This can provide valuable insight regarding out-of-control conditions.

The **Set-Up** window allows the user to load a process representative spectrum, select and name the Raman peaks (height or area) that will be used to monitor concentration for each chemical, and set the upper and lower control limits (see figure to left). It also allows setting the laser power, the spectral resolution, and the process time resolution (e.g. update every minute). The x-axis time is also set here as either clock time or time from the start of the reaction, either as a scrolling or auto-scaling window.

The **Concentration Calibration** window allows the selection of one of three models:

1) ***Pure Spectra***,
2) ***Concentration Curves***, or
3) ***Partial Least Squares (PLS)***

Selecting a model launches a spectral collection program that determines how the concentration calibration curve is constructed.

1) For ***Pure Spectra***, the user simply collects a spectrum of each chemical to be monitored. The peak intensities in this spectrum are assigned a value of 100%, and the peak intensities measured in the reactor are scaled to this value (e.g. half-height equals 50% chemical concentration). Since the Raman peak intensity-to-concentration is linear, to a first approximation, this approach provides reasonable data.

2) For ***Concentration Curves***, the user prepares a series of sample concentrations, measures the Raman spectra, and defines some parameters, such as the peak to use. The software plots the appropriate concentration versus peak intensity, performs a linear least squares fit to the data, and uses the equation to calculate concentration. Ideally, the reactant and products can be prepared in a process solvent at concentrations covering the expected process range. This method is more exact, as it accounts for density, colligative and solvent properties.

3) For ***PLS***, the same series of samples is prepared and their Raman spectra measured, but the entire spectrum is used to develop a Raman-to-concentration correlation in which each Raman spectral segment is appropriately weighted to maximize the correlation. We also provide software to develop similar chemometric relationships to properties other than concentrations, such as physical properties including cloud point and heat content.

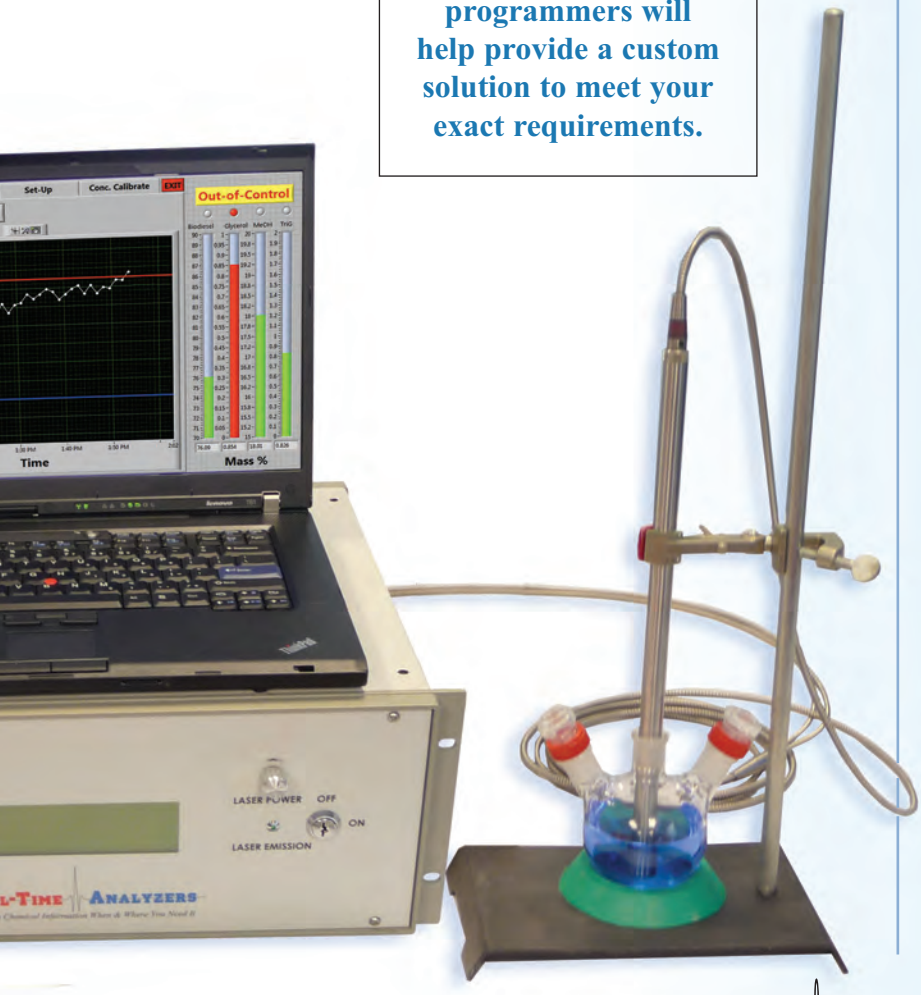
Hardware

The **RamanPro™ Industrial Raman Analyzer** is a fully-contained, rack-mountable system using a 19" standard framework. Status indicator lights and laser safety interlocks are easy to access as they are conveniently positioned on the front face of the unit.

The **RamanPro™** is specifically designed for routine operation in process or plant environments, but provides performance typically found only in research-grade laboratory systems. This translates to worry-free operation and results that you can trust to be accurate.

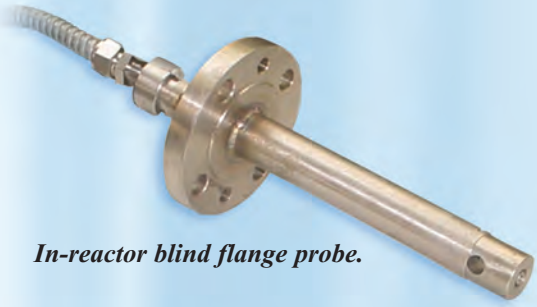
Flexible sampling accessories ensure that you can measure a wide variety of samples and interface to virtually any process stream.

Need an application-specific analyzer?
Our engineers and programmers will help provide a custom solution to meet your exact requirements.



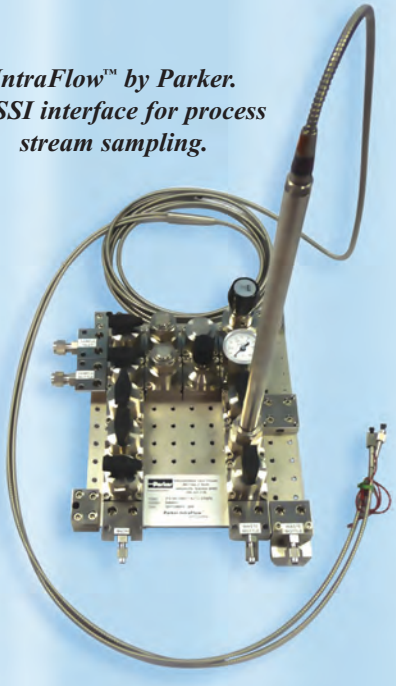
Common Configuration Accessories

RamanPro™ ***with 5 meter steel-jacketed cable and 200°C/1500 psi 316 SS probe.***



In-reactor blind flange probe.

IntraFlow™ by Parker. NeSSI interface for process stream sampling.



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Specifications

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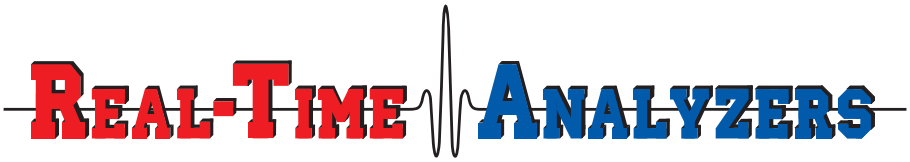
Specification	RamanPro™
Modulator System	
Measurement Principle	Fourier Transform Raman Spectroscopy
Detector	InGaAs (thermo-electrically cooled, optional Si with 785 nm laser)
Spectral Resolution	Selectable at 4, 8, 16, or 32 cm^{-1}
Calibration	Factory set using NIST traceable material (no recalibration necessary)
Raman Laser and Probe	
Laser Type	1W CW 1064 nm Nd:YAG (line width <0.08 nm, optional 785 nm)
Warm-up Time	30 seconds
Spectral Range	150 to 3350 cm^{-1}
Probes	316 SS or Hastelloy C, 2008 °C, 1500 psi, NeSSI compatible, or custom
Control System	
Software Control	Raman Vista Suite, RamanPro™ Process Controller
Spectrometer Interface	10/100 Ethernet and wireless
OS Supported	Windows 2000/XP/Vista
PC Requirement	Pentium or better >1 GHz, 128MB RAM
Data Export	Various formats supported, including: *.spc, *.csv and *.lab
Environment	
Dimensions	19.78 x 15.77 x 7.41" (502 x 400 x 188 mm)
Weight	28 lbs (12.73kg)
Power Supply	120/240 VAC 50/60Hz
Battery Operation	5 hours (standard charge) rechargeable
Operating Temperature Range	35 to 100 °F Probe to 390 °F
Purge Gas	Not Required



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