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HANDHELD RAMAN SPECTROMETERS

Handheld Raman spectrometers are rugged, field-portable instruments that provide emergency responders with the ability to analyze unknown powders and liquids without destroying the sample during hazardous materials (HAZMAT) operations. Handheld Raman spectrometers may be used to perform direct sampling of a loose solid or liquid material or to conduct sampling on containerized material. Common applications include identification of illicit drugs or drug production precursors, explosives or explosive production precursors, industrial chemicals, or common household materials. Handheld Raman spectrometers fall under AEL reference numbers: 07CD-01-DPRS, 07ED-01-LASR and 07ED-04-LASR.

Overview

Handheld Raman spectrometers are smaller, easier-to-use, and less costly than their laboratory-sized counterparts. These ruggedized products can weigh less than 5 pounds and allow emergency responders to perform rapid chemical analyses to identify a suspect material without destroying or coming into contact with them. Some instruments provide standoff measurements from distances of up to one meter. Raman spectroscopy utilizes a laser to interact with the molecular vibrations of a target compound resulting in scattered light.

A fraction of the scattered light experiences a change in frequency, lower or higher, from that of the laser. This change is referred to as the Raman effect. Different Raman spectrometers use different wavelength lasers ranging from ultra-violet to near infrared, which can affect how susceptible the measurement is to colored or fluorescent sample components.

A Raman spectrum, which is like a fingerprint for different chemicals, is created by plotting scattered light intensity against frequency shift. Raman spectrometers identify samples using an algorithm to compare the measured Raman spectrum with a reference spectral library. The outcome is a match quality measure which describes the degree of similarity between the sample spectrum and an algorithm-selected library spectrum. Depending on an instrument's spectral library and algorithm, it can identify explosives, toxic industrial materials, chemical warfare agents, and narcotics. With some systems, a user-developed library can be created and used to accommodate special sample types/compounds that are not in the equipment's existing spectral library. Raman spectroscopy is not affected by strong infrared absorbers like glass or water. Therefore, Raman measurements of a sample can be obtained through most translucent or transparent glass, bags and envelopes, with some devices having the capability to measure through opaque materials.



Figure 1. Examples of Handheld Raman Spectrometers

Images courtesy of EnviroNics USA, Metrohm USA, Smiths Detection, Inc., Rigaku Analytical Devices, Inc., and Thermo Scientific Portable Analytical Instruments, Inc.

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions.

Located within the Science and Technology Directorate (S&T) and managed by the National Urban Security Technology Laboratory (NUSTL), the SAVER Program conducts objective assessments on commercial equipment and systems and develops knowledge products that provide relevant equipment information to the emergency responder community.

SAVER Program knowledge products provide information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, ensuring responders are prepared to make operational and procurement decisions.

For more information on the SAVER Program, contact NUSTL by e-mail, NUSTL@hq.dhs.gov, or visit the SAVER website, www.dhs.gov/science-and-technology/SAVER.

Instrument Features

User Interface

The ease of carrying the device, manipulating buttons and viewing the screen in personal protective equipment (PPE) and high/low light environments is critical for effective use in hazardous environments. To minimize overall size, handheld Raman spectrometers have relatively small screen sizes, so it is important that the screen has sufficient resolution, brightness and clarity, particularly during data analysis or closer examination of spectra.



Figure 2. A user operates a handheld Raman spectrometer with heavy gloves and other PPE
Photo courtesy of Agilent

Data Transfer

Data transfer is required if significant further spectral manipulation and analysis on a computer or reach-back support is needed. Handheld Raman spectrometers may transfer data via a wireless connection, or through a Universal Serial Bus (USB) port or Secure Digital (SD) card, although these small devices can be difficult to manipulate while wearing heavy gloves.

Data Analysis

Multi-component, complex samples may be more difficult to accurately identify. More advanced data manipulations include spectral subtraction and spectral overlays, but handheld systems typically require that these operations be conducted on a separate laptop computer.

Library Capacity

The ability of each spectrometer to accurately analyze and report on a given sample is partly dependent on the equipment's spectral library. Manufacturers often provide different libraries, which vary in number and type of known compounds depending on the intended application. Most products offer library expansion upgrades and updates. Devices may utilize proprietary libraries only or allow installation of other commercially available or user-developed libraries.

Enhanced Detection

Some products offer a compound-specific Surface-enhanced Raman Scattering (SERS) disposable ticket comprised of a roughened metal substrate. The enhanced effect provided by this technique enables greater sensitivity when the sample is adsorbed onto the metal substrate.

Limitations

Users seeking handheld Raman spectrometers should understand the features and limitations of the devices and how they apply to their intended use. For example, handheld devices are typically used by emergency responders for presumptive testing and later followed by confirmatory laboratory testing. Handheld devices may also have relatively low sensitivity; it may not be suitable for samples with low concentrations, complex matrices or highly pigmented or fluorescent samples. The sensitivity of Raman spectrometers can also vary, depending on sample complexity and components.

Published Standards

Users should also be aware of available standards, guides, and recommended practices. For example, ASTM International has published [standards](#) applicable to Raman spectroscopy.

Additionally, available chemical databases for hazardous substances may be considered for adding chemical spectra to device libraries such as the Environmental Protection Agency's [Cameo Database for Chemical Emergencies and Responders](#) and the United States Coast Guard's [CHRIS Hazardous Chemicals Database](#).