Application of Raman spectroscopy in the security industry

The advancement of Raman spectroscopy technology and its applications has consistently garnered significant attention. Driven by market demand, leading domestic instrument manufacturers have continuously developed new products and technologies, making Raman spectroscopy one of the most active categories in molecular spectroscopy. As technology progresses, the range of applications for Raman spectroscopy instruments continues to broaden, with rapid market growth, particularly in the area of fast detection.

As an example, in the field of safety inspection in China, the national standard "General Technical Requirements for Safety Inspection Equipment for Hazardous Chemicals Based on Raman Spectroscopy" (GB/T 41086-2021) was introduced for the inspection of liquid hazardous chemicals using Raman spectroscopy.

This standard applies to Raman spectroscopy-based inspection equipment for liquid hazardous chemicals, explosives, explosive chemicals, drugs, precursor chemicals, solid hazardous chemicals, and pesticides.

What role can Raman spectroscopy play in the field of security? Today, we will explore this innovative technology and discuss how Raman spectroscopy can address key challenges in the security sector

1 Developments in security screening technology

The world’ s earliest metal detection security equipment, according to legend, dates back to 212 B.C. when Jing Ke attempted to assassinate the King of Qin. To ensure his safety, Emperor Qin Shi Huang installed a "magnetic door" in Afang Palace, which is considered the prototype of the earliest metal detection security gate. This gate, known as the "Northern Gate," was equipped with magnets that reacted to iron weapons to detect potential threats.

Since the 1970s, metal detector security gates have gradually become essential tools for detecting prohibited items in public places like airports and customs facilities. These security gates, along with other screening machines, have become indispensable for large-scale events, exhibitions, sports games, and important government institutions.

Following the 9/11 attacks, counter-terrorism measures became a top priority for global security, and security inspection equipment has become vital in places such as airports, train stations, customs, public venues, and large events.

In 2008, the security measures implemented for the Beijing Olympics significantly boosted the security industry. The introduction of channel X-ray security detectors became widespread, and cities like Beijing, Shanghai, and Guangzhou began to implement these systems in their subway networks. This technology rapidly expanded to major transportation hubs across the country.

2 Technical means of security checks

In the context of today's frequent global terrorist attacks, subway security faces the challenge of managing large crowds in confined spaces with high density, making evacuation difficult. As a result, subway security inspection equipment needs to be comprehensive, technologically advanced, and capable of handling large volumes of people while ensuring rapid detection.

So, what type of security equipment is commonly used in subway security?

Subway security systems typically rely on a "four-piece set" of detectors: dangerous liquid detectors, explosives detectors, X-ray detectors, and handheld metal detectors. These tools have been extensively tested in real-world conditions, proving their effectiveness in enhancing security and ensuring public safety in subway environments.

X-ray machine

X-rays are used to penetrate the item being inspected, and the signal generated from this penetration is transmitted to a processor for signal analysis. The processed signal is then sent to the controller, which displays the image on a monitor. The security inspector reviews the displayed image and determines whether the item contains any prohibited materials based on the visual information provided.

Liquid detectors

Liquid detectors are specialized instruments used for security inspections to detect flammable and explosive hazardous liquids. There are various liquid detection technologies in use around the world. For instance, microwave identification technology is suitable for detecting liquids in non-metallic containers, while heat conduction, dielectric constant, and conductivity methods are ideal for metal containers.

In this scenario, Raman spectroscopy is highly effective for detecting hazardous liquids due to its fast, non-destructive, and accurate properties. It has already been adopted for use in subway security inspections, providing a reliable method for identifying dangerous substances.

Explosives detection

Explosives detectors are capable of quickly identifying various dangerous explosives and flammable chemicals. They are widely used in security checks at airport entrances. Security personnel typically use white wipes to swab luggage, packages, or passengers' clothing. The wipes are then inserted into the explosives detection device, which completes the analysis within seconds. If explosives residues are detected, the system immediately triggers an alarm.

With the continuous development of fluorescence detection technology, the new generation of this technology offers improved sensitivity and ease of use. Fluorescence detectors have a quicker recovery time compared to ion mobility detectors, which may take anywhere from a few minutes to several hours to reset. As a result, fluorescence-based detection systems are gradually replacing ion mobility explosives detectors.

Raman spectroscopy is also highly effective in detecting explosives and their precursors, making it a viable alternative to traditional explosives detectors. However, it currently cannot match the capability of some explosives detectors in detecting trace amounts of explosives.

Metal detectors

The hand-held metal detector is typically used as an emergency screening tool. Security personnel use the device by scanning or "sweeping" it around a person. If metal objects are detected, the detector emits an alarm. The primary purpose of this tool is to identify contraband, such as concealed weapons or prohibited items like controlled knives, that may be carried on a person's body.

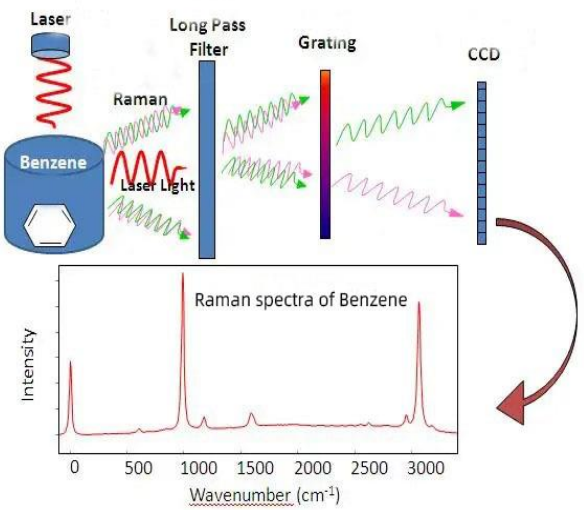
Modern security inspections rely on various technologies to ensure safety. Among these, Raman spectroscopy stands out for its fast, accurate, and non-destructive analysis, making it a valuable tool in detecting hazardous materials in places like airports and subways.

3 Application of Raman spectroscopy

Raman spectrometers are valued for their speed, simplicity, reproducibility, and non-destructive nature, making them widely applicable in fields such as safety, materials science, and pharmaceuticals. In recent years, the technology has seen significant advancements, with improvements in the detection capabilities of laboratory Raman spectrometers, as well as the emergence of portable and handheld models. The domestic Raman spectroscopy manufacturing industry has also experienced rapid growth, further enhancing its application across various sectors.

Handheld Raman spectroscopy equipment can meet the needs of on-site rapid detection for safety testing.

Raman spectroscopy has gained wide market acceptance due to its accuracy, high detection sensitivity, and ability to analyze a diverse range of samples—covering over 90% of compounds. It plays a crucial role in safety and rapid detection applications. As an analytical method, Raman spectroscopy examines the scattering spectrum that differs from the incident light frequency to gather information about molecular vibrations and rotations, making it ideal for studying molecular structures. In essence, the Raman scattered light produced when a substance is irradiated provides valuable molecular information. Since each substance has a unique Raman spectrum, much like a human fingerprint, it allows for precise identification of materials.



The Raman scattered light from an irradiated substance can be collected by an optical instrument and converted into a spectrum, allowing for detailed analysis of material composition. In the field of safety inspection, the national standard "General Technical Requirements for Safety Inspection Equipment for Hazardous Chemicals Based on Raman Spectroscopy" (GB/T 41086-2021) has been established. This standard applies to Raman spectroscopy-based inspection equipment for liquid hazardous chemicals, explosives, drugs, precursor chemicals, solid hazardous chemicals, and pesticides.

Raman spectrometers have entered the security market and are now used in high-security environments. For example, the Insight100 system, developed by a UK manufacturer of Raman spectrometers later acquired by Agilent, is widely deployed at airports across the European Union. It offers outstanding detection performance and an ultra-low false alarm rate, especially for non-metallic containers.

Many manufacturers are also actively promoting the wider use of Raman spectroscopy technology, particularly in the upgrade of subway and airport security systems. They have taken a leading role in ensuring rapid detection for large crowds and have addressed the limitation of Raman spectroscopy in detecting materials in metal packaging by introducing responsive technologies. As these technologies continue to be optimized, they will become even more suited to meet the evolving demands of modern security inspections.

4 What exactly can Raman spectroscopy do

Subway security checks primarily focus on ensuring that passengers and their luggage do not carry firearms, ammunition, explosives, corrosive substances, toxic materials, radioactive items, or other dangerous goods. These checks are essential for maintaining the safety of both the subway system and its passengers. Security screening must be completed before passengers are allowed to enter the subway. Individuals who refuse to comply with the security check will be denied entry, and in certain cases, they may be referred to the police for further action.

Raman spectroscopy technology is capable of detecting a wide range of contraband, including ammunition, flammable and explosive substances, corrosive agents, toxins, and oxidants—many of the dangerous items listed in subway security regulations. It is particularly well-suited for identifying unknown chemicals and materials in public transportation and passenger inspection areas, addressing the diverse demands of public safety, anti-terrorism efforts, environmental protection, and emergency monitoring of sudden incidents.In subway security, Raman spectroscopy plays a critical role in detecting contraband, enhancing overall safety and security measures.

Hazardous Liquid Testing

Flammable chemicals such as alcohol, gasoline, and thinner are all prohibited items that cannot be brought onto the subway. The active ingredient in alcohol, ethanol, is classified as a Class A fire hazard.

For instance, 75% alcohol can ignite or even explode at temperatures as low as 22 degrees Celsius, making it extremely dangerous and therefore banned from subway systems. Commonly restricted items include lotions, nail polish, nail remover, makeup remover, perfume, and hair dye in quantities no greater than 100 ml.

Raman spectroscopy technology offers a rapid and accurate method for detecting flammable substances like alcohol (ethanol), gasoline, and thinner. It can precisely identify ethanol concentrations above 5%, making it an ideal tool for detecting flammable and explosive contraband in high-security environments such as subway stations.

Explosives detection

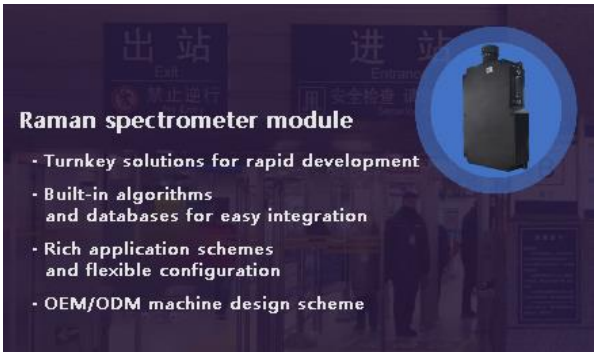
Raman spectroscopy is not only effective in detecting dangerous liquids but also in identifying solid unknowns. When suspicious solids or powders are flagged by X-ray machines, Raman spectroscopy can quickly determine their material properties on-site. This includes identifying explosives and dangerous chemicals commonly used to manufacture explosives.

It can accurately detect and differentiate between standard explosives, civilian explosives, homemade explosives, and liquid explosives.

5 The development of Raman spectroscopy in the field of security

The application of Raman spectroscopy to the field of security inspection might seem like "overkill," but its detection capabilities are more than sufficient for the rapid and accurate identification of flammable and explosive contraband on-site. With its fast detection speed, non-destructive testing (leaving the substance intact), and no need for sample pretreatment, Raman spectroscopy has become a critical tool in safety inspections.

As the demands for higher accuracy and real-time results in various security scenarios increase, and with the integration of technologies like the Internet of Things (IoT), big data, and artificial intelligence (AI), security inspections are becoming more precise. By leveraging big data, security systems can achieve more accurate and flexible detection of contraband compared to traditional manual methods. The data collected from each security checkpoint can be integrated into a network for comprehensive big data analysis. This, combined with multi-dimensional management data and visual simulation, positions Raman spectroscopy to play an increasingly important role in the future of security inspections.



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