X-ray diffraction set to elevate security screening

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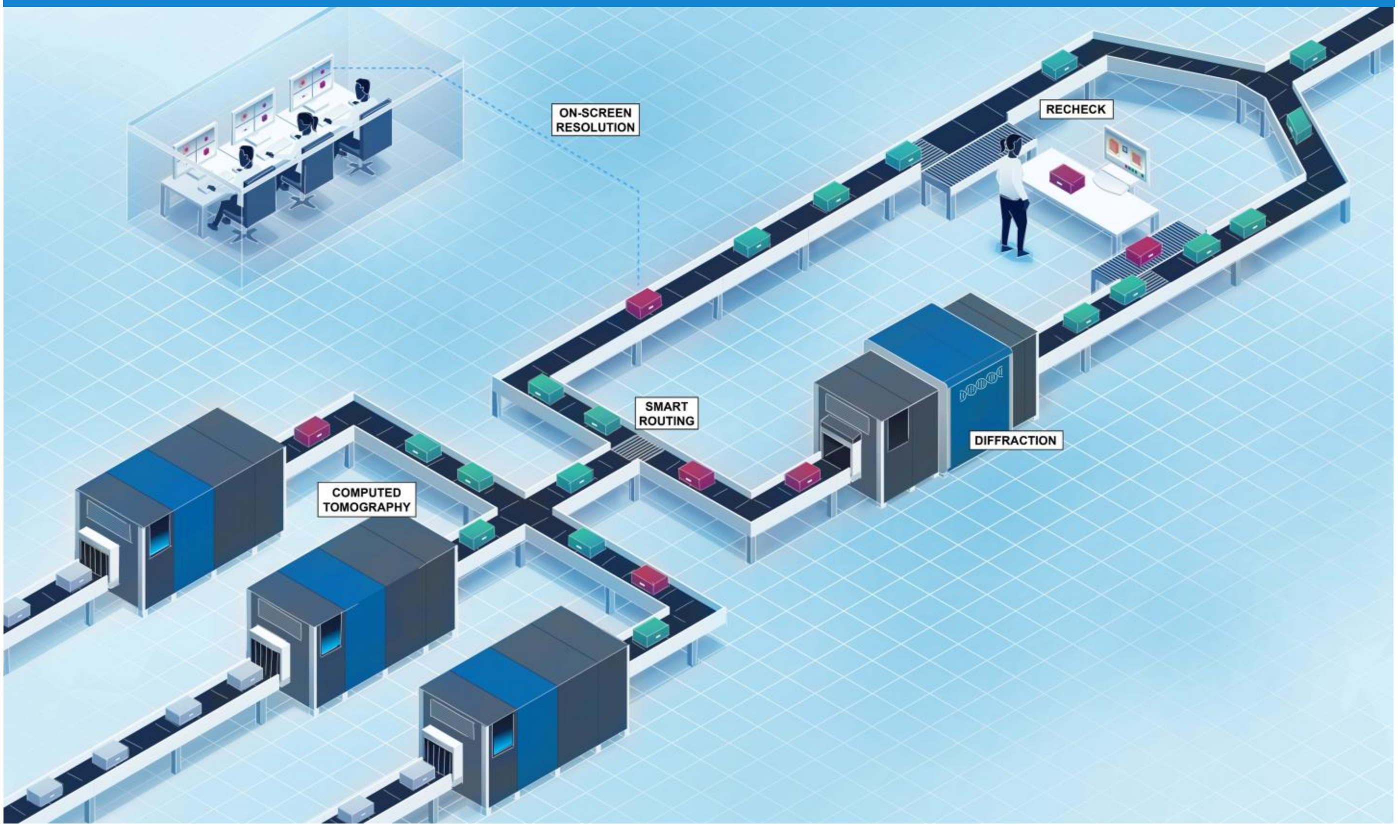

Joachim Petry, Product Manager Hold Baggage & Air Cargo Solutions

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The threat from a growing range of prohibited items including lithium batteries, fentanyl, liquid meth, cocaine, novel explosive materials and devices as well as firearms demands increasingly high standards for detection equipment. In response, efficient automatic threat resolution is likely to feature prominently in next generation screening. As well as advancing security, this will also address operational efficiency by significantly reducing the need for manual searches at a time when passenger numbers are on the increase.

Technology is constantly evolving to combat the ingenuity of those looking to evade security checks. AI and deep learning are supporting the development of sophisticated detection and object recognition algorithms but the sheer diversity of new threats and constantly changing composition of substances such as homemade explosives and narcotics will require additional approaches.

AI driven solutions incorporating screening data with passenger information and intelligence databases will help reduce false alarm rates, however operations can be further future-proofed by the introduction of material-specific screening technology.

The answer may well lie in a combination of CT, AI and X-ray diffraction (XRD) technologies. CT uses density to detect substances whereas AI leverages object recognition - XRD perfectly complements both by accurately identifying unknown materials with 'common' densities (some threat and benign substances have similar or identical densities). XRD is not new, but recent advances in the technology have made it particularly suitable for integrated security screening applications. Installing XRD in line with CT is quick to achieve and offers a clear path to certification.

Both, EDS systems (typically based on Computer Tomography) and diffraction use X-radiation to gain information about the object screened.

Image generating CT technology provides information largely about volume and density of the objects scanned.

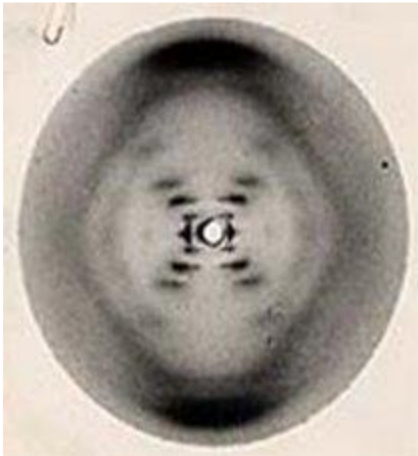
Diffraction is based on an entirely different analysis approach; it offers precise material information through spectral analysis of the materials scanned.

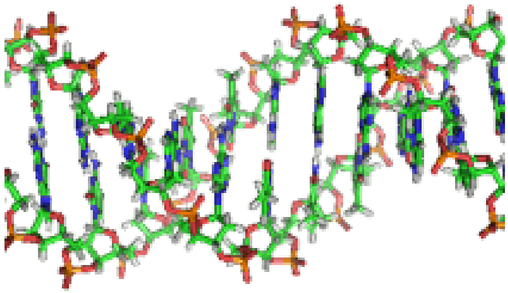
Thus, diffraction provides independent results from the preceding technology.

Well proven technology

XRD has a long and illustrious history which began in 1895 when X-rays were discovered by Wilhelm Conrad Röntgen who received the first Nobel Prize in Physics in 1901 for his work. Ten years later, the significance of atoms in crystals was discovered by Max von Laue who developed a mathematical theory modelling the diffraction of X-rays to reveal the structure of crystalline matter at an atomic level. Many scientists have since used X-ray diffraction to study crystallography and a long list have subsequently been awarded Nobel Prizes for physics, chemistry, medicine or physiology – probably the most well-known was awarded in 1962 for discovering the molecular structure of DNA.

Today XRD is a well proven and established method of identifying unknown crystalline materials (for example, inorganic/organic compounds and minerals) based on molecular structure. A valuable tool for measurement and analysis, it is used in a broad range of industries and disciplines including pharmaceuticals, forensics, microelectronics, glass, geology and engineering.





1950´s: Franklin, Crick, Watson, Wilkins Noble prize for DNA structure revealed by X-ray diffraction

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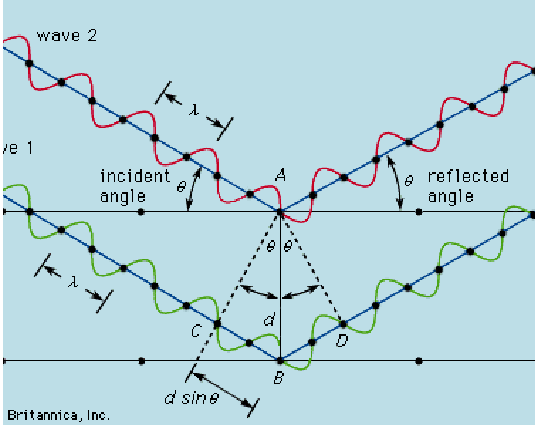
Creating a ‘diffraction fingerprint’

Conventional X-ray and Computed Tomography (CT) scanners have been very effective in detecting explosives and more recently, contraband, prohibited items, dangerous goods and other targeted items. There are, however, some unique challenges when it comes to improvised explosives and narcotics, which combine to make detection of these items very complex. For example, inconsistencies in physical characteristics, when drugs are cut with other substances or different substances and densities introduced into explosives. Unlike explosives stemming from military and industrial applications, ‘home-made explosives’ vary enormously in composition and content.

CT technology differentiates materials by their densities and the so-called Zeff value. This describes the average atomic number of a material – i.e. whether it is mainly ‘organic’ (containing light elements such as carbon, nitrogen or oxygen) or more ‘metallic’ (containing aluminium or iron). Densities and the Z_{eff} value are measured using dual-energy X-ray absorption (or attenuation), which is common in medical imaging. XRD is a completely different approach, identifying substances via the interference of electromagnetic waves on atoms.

The spacing between atoms within a molecule interferes with the X-ray waves and the signals from this interference provide data on the spacing. As each substance has a different pattern of spacing, the XRD uses the measurements to create a ‘diffraction fingerprint’ and hence differentiate between materials – even those with very similar densities.



X-ray diffraction utilizes interference of X-ray waves diffracted on crystal planes to determine distances of the atoms. This leads to material specificity.

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XRD was developed to investigate crystalline solids which have a very orderly structure. However, it is equally effective in identifying amorphous solids (e.g. glass) and liquids despite their more disorderly configuration which can still be well described with statistical parameters.

For security screening, it offers automatic, non-invasive detection and delivers superior levels of material analysis and substance identification. This makes it particularly suited to detecting constantly changing compounds (e.g. home-made explosives) and narcotics in powder, liquid or solid forms.

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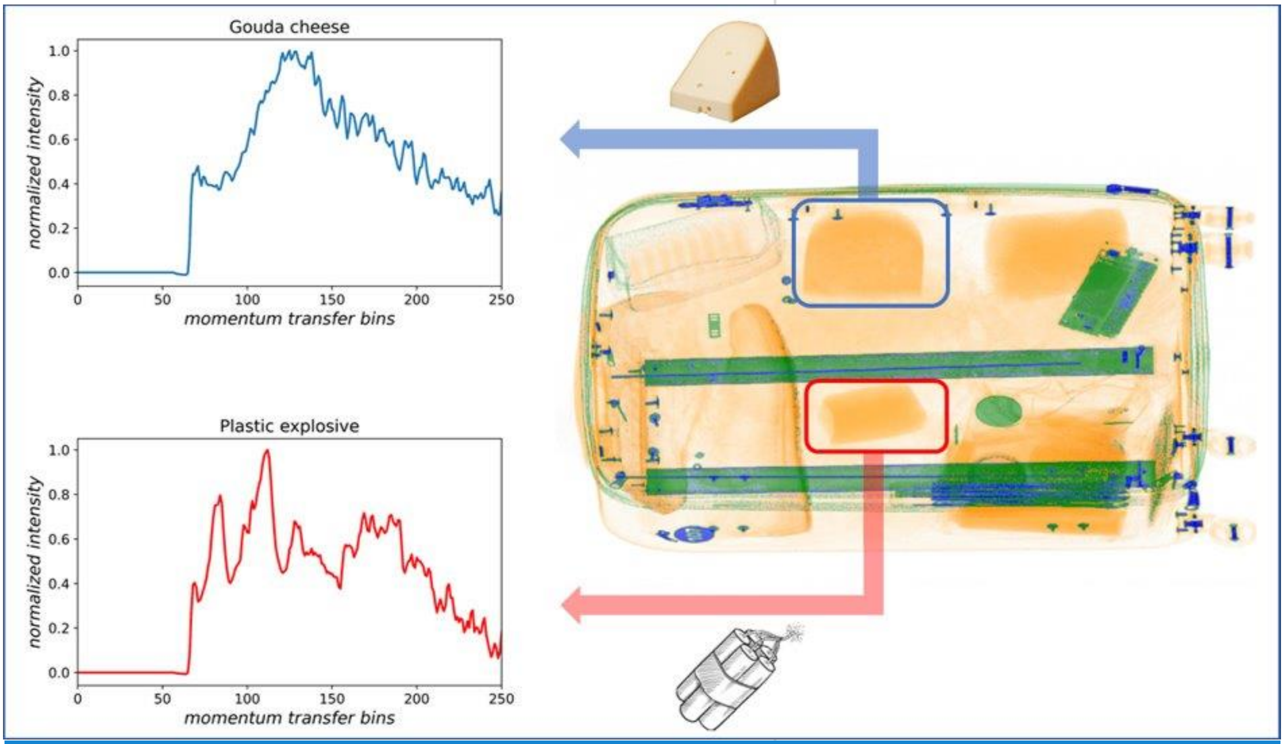
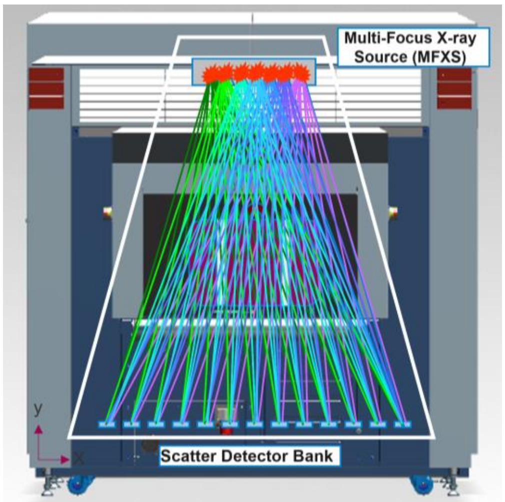
X-ray diffraction can separate cheese from explosive



New generation technology

Early XRD security screening systems have demonstrated increased efficiency in alarm resolution; and already shown exceptional sensitivity in finding and identifying narcotics in incoming aircraft luggage. Recent new advances now mean the technology is ready for broader deployment including parcels and goods as well as luggage.

By replacing legacy X-ray sources with multi focus X-ray sources and applying novel solid-state detectors, the latest systems are faster and more efficient with a continuous belt feeding multiple diffraction beams. Full tunnel coverage enables highly parallel data acquisition, reducing the required electrical energy per scanned item by a factor of 10. Reliability has been improved and maintenance streamlined by locating components on a fixed frame with moving parts restricted to the belt. Efficiency, sustainability and simpler maintenance all contribute to a low TCO.



XDi principle and enabling components

Multi-Focus-X-ray-Source:

- Facilitates faster (parallel) data acquisition, resulting in
  higher scanning speed
- Full tunnel coverage using multiple beams
- No need of physical movement resulting in Lower maintenance effort

Multiple semiconductor X-ray (scatter) detectors:

- Operational at room temperature

Primary use cases

At this stage, two primary use cases have been identified for XRD. Firstly, as an orthogonal technology to existing, multi-level EDS applications; and secondly, for inbound contraband detection.

High volume in-line screening

Regulating bodies define orthogonal technology as a system which can be deployed for alarm resolution of objects diverted from Level 1. In effect, XRD becomes a Level 2 process, using diffraction technology to analyse and ideally clear suspect items flagged up at the first automatic EDS stage (typically CT based). In this configuration, an XRD scanner is incorporated into the main handling system and a single device can be fed by several first level EDS scanners.

Typical applications include multi-level hold baggage screening at airports and also high speed operations such as fast-forwarding small parcels. Automatically clearing false alarms or benign objects via XRD has been shown to reduce the FAR rate from 20% down to an impressive 4%. The result is a significant reduction in operator online resolution, manual searches or trace detection – which, in such high volume applications, translates into substantial operational cost savings.

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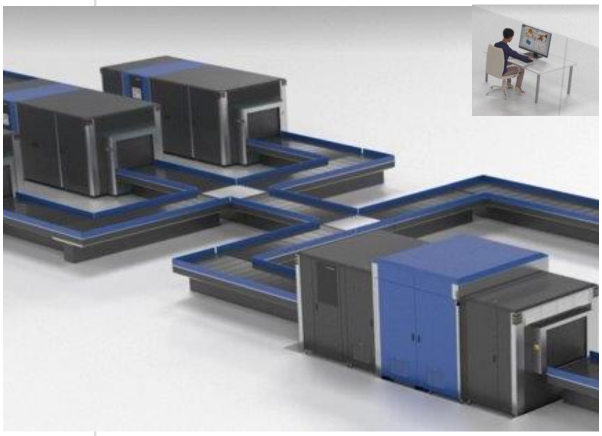
Customer benefits:

- Reduced operational costs (manpower savings)
- Increased efficiency and security
- Reduced human factor (insider threat)
- Contraband detection

Conventional EDS set-up



Diffraction for alarm resolution (Level 2), reducing operator onscreen resolution

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Further reductions in the FAR will in future be achieved by deeper integration of the two technologies. This is known as a System-of-Systems, where the CT and XRD information is combined for a joint decision and even more accuracy. The CT system delivers its detection result downstream to the XRD which adds the diffraction fingerprint for any potential threat item.

This data fusion approach will bring together the strengths of the two systems eventually leading to the best possible detection performance at very low false alarm rate. Adding AI delivers the most accurate result and therefore the lowest possible alarm rate. Prohibited items identified by the AI algorithm based on shape information, do not require Level 2 screening and are transferred directly to Level 3.

Level 1 contraband detection

Precise material analysis also makes XRD an effective detector in helping customs agencies to intercept the increasing volume of narcotics and other prohibited items heading across borders. In this type of application, items are generally picked out for in-bound investigation based on intelligence, data analysis or suspect X-rays taken at the point of departure. As screening is selective, the XRD is deployed as a Level 1 scanner.

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What comes next?

XRD perfectly complements the strengths of CT technology and together they can take detection accuracy to new levels demanded by the regulatory authorities in response to tomorrow's evolving threats. Further automation will also improve security and operational efficiency.

The technology will continue moving forwards with developments in tubes and detectors and generally less expensive components. More algorithms will be introduced to deal with an expanding list of targets and for future-proofing, the XRD detection algorithms will be upgradeable in the field to meet new, yet to be devised, regulatory standards.

Ultimately, we are also likely to see the two technologies combined into one unit with the CT and XRD technologies working in parallel. In this scenario, each item will be checked by both technologies simultaneously, leveraging the strengths of both techniques.
XRD will be the way forward in elevating security and enabling more sophisticated automated detection – particularly when combined with CT technology and AI-based algorithms.

GET IN TOUCH

If you would like to know more about x-ray diffraction technology and how we help make the world a safer place, you can get in touch at;

Email address: aviation-solutions@smithsdetection.com

www.smithsdetection.com