Crystal clear

Dr Gary Gibson, Integrated Systems Manager at Kromek, looks at the increased need for multi-spectral digital detection and its innovative application to the transport security industry

Recent transport industry conferences have done much to focus on the security challenges facing the sector and the technological requirements needed to overcome the threats to cargo security.

At the recent *TranSec* conference, held in Amsterdam in June, **Kromek**, which specialises in the development of disruptive technology solutions, launched its *311+ Scanner*, a revolutionary x-ray scanning system which the company believes will have a major impact on transportation security.

Security screening for sea cargo transport requires a specialist approach and x-ray machines have been adopted as the preferred choice for screening due to their ability to non-destructively penetrate pallets of material, containers and vehicles. The x-ray image, created in less than a minute, gives a view of the cargo that an operator can examine. This will almost immediately show inconsistencies in the internal structure, i.e. possible security risks. Crucially, objects that are otherwise hidden may be quickly seen, particularly if their density is very different to that of the surrounding materials.

X-ray detection can clearly reveal many different types of illegal cargo.

These types of x-ray systems typically use x-ray energies ranging from 320 kilo electron volts (keV) for cargo pallet screening through to 9 mega electron volts (MeV) for screening sea containers and Unit Load Devices (ULDs) with high density cargoes, such as fruit and vegetables.

The original reasons for sea container screening included manifest verification, checking for illegal passengers, and weapons and narcotic smuggling detection. Recently, however, various governments have been increasingly concerned about the possibility of terrorist attacks via seaports.

Terrorist attacks have become a major concern for security professionals and authorities because of the potentially enormous destructive possibilities of such an attack. For instance, former US **Customs and Border Protection**

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(CBP) Commissioner, Robert Bonner, said in a speech at the **Center for Strategic and International Studies** in Washington in 2002 that a major attack on a seaport would have devastating consequences for the global economy. Some estimates suggest that there could be up to $1 trillion of direct and indirect damage as well as the loss of between 50,000 and 1 million lives if a 10 kilotonne nuclear bomb was exploded in a major port.

Air cargo is another major area of concern for government and security authorities. In most airports, air cargo screening is becoming much more of a priority for governments and their approach to managing the terror threat.

Since February 2009, the US **Transportation Security Administration (TSA)** has had to ensure that a minimum of 50% of all air cargo on passenger aircraft is screened using x-ray explosives detection systems. This legislative requirement will be increased to 100% by August 2010. The total volume of cargo shipped on passenger aircraft in the United States is around 250 million units, or around 7% of the total air cargo volume, thereby creating a huge security screening requirement. In Europe, all air cargo flown on passenger planes must be screened.

Current protocols for air cargo screening for explosives generally use transmission x-ray technology, at a variety of energies (from 170 KeV up to 6-8 MeV). This methodology has been a

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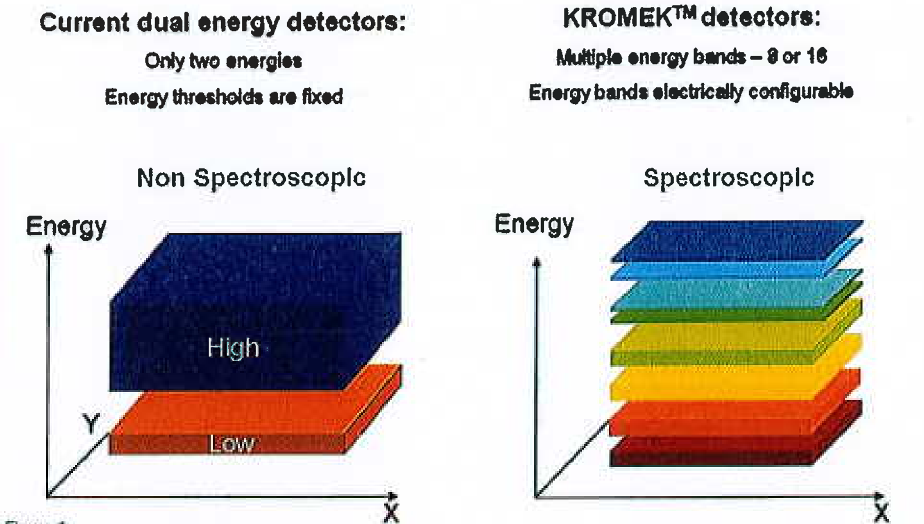


Figure 1

success in the past, however there is now a requirement for a more sophisticated approach to cargo screening. Low throughput and high infrastructure costs are seen as the main problems using the current screening solutions.

Another problem, particularly in the United States, is that the airport infrastructure is not set up for large amounts of cargo screening. Consequently, the TSA has proposed that air cargo should be screened prior to delivery to the airport. TSA assistant administrator, John Sammon, has given his view on this approach: 'Most screening would be done by the 12,000 companies that truck goods from manufacturing plants to airports. The companies, called freight forwarders, would screen packages with x-ray machines and explosive sensors in warehouses where they are packed into large containers that are driven to nearby airports. Manufacturers would also be capable of screening boxes in factories.'

X-ray screening technology has seen considerable improvements over the last few decades and much of the fundamental science behind the systems has already been exploited. A core area that hasn't significantly changed for many years, however, is the area of x-ray detectors, and this is the technology Kromek is seeking to develop.

Current systems use scintillation materials that convert x-rays into visible light which is then detected by the silicon photo-receptors of the detector array. Sometimes a filter is placed in part of the beam, just before the scintillation material which shifts the incoming x-ray spectrum before it hits the scintillator. This effectively gives images at two different average x-ray energies, commonly known as dual energy or multi-energy screening.

The main advance, which Kromek has pioneered in x-ray detector technology, is the use of Cadmium Telluride (CdTe) or Cadmium Zinc Telluride (CZT) as the detecting crystal. The unique advantage of using these crystals is that they are direct converters of x-ray radiation, i.e. they do not need any scintillation crystals.

This has a number of significant benefits, the most important of which is that the *full energy spectrum* can be detected as opposed to using a filter to give you only two bands of energy. In CdTe, the energy spectrum tends to be split into groups of eight or 16 energy bins, and these bins are electronically configurable so they can be placed anywhere in the spectrum. The diagram in Figure 1 portrays the difference between a scintillator detector and a CdTe detector, with respect to energy resolution.

X-rays interact with matter in different ways at different energies. Most people would recognise that the x-ray image of a human would show the skeleton more clearly than the soft tissue. This is because the bones are denser than the soft tissue and so absorb more x-rays than the soft flesh, giving a good contrast in the transmission image. If the x-ray energy was changed however, the relative contrast between the soft tissue and the skeleton would also change.

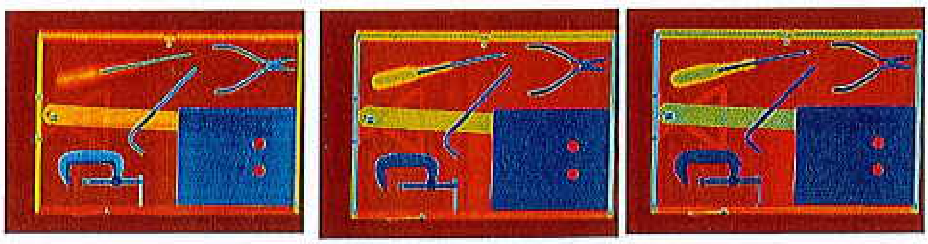
The change in transmission gives critical information about the objects that the x-rays have passed through. By examining the change in x-ray transmission at different energy levels it is possible to deduce the density and elemental composition of the object in question far more accurately than by current dual energy techniques.

All materials can be considered to have a spectral fingerprint, which is their particular response to x-rays at different energies. This information gained from examining an image at multiple energy levels can be checked against a database, thus allowing the identification of the different materials which are present.

As an illustration of just how significant the shift in transmission can be with energy, the picture in Figure 2 below shows a number of tools imaged simultaneously at three different energy levels.

It can be seen that not only do the different materials show significant transmission shifts, but that the rate of change in the transmission varies from material to material. The plastic triangular clip on the left hand side of the box is clearly visible behind the metal ruler, at the 120 to 140 keV

Figure 2 **120 – 140 keV** **100 – 120 keV** **60 – 80 keV**



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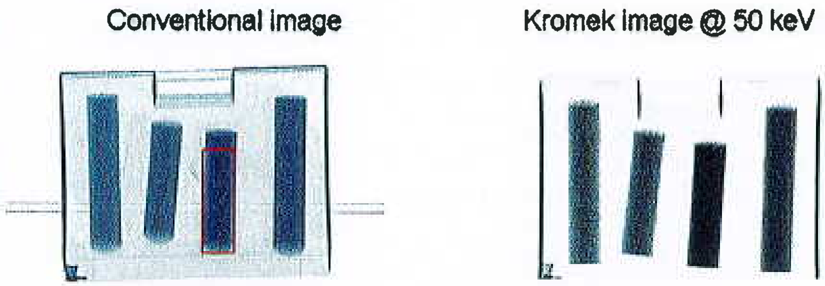

Figure 3 **Sample rods left to right are: PA12, PA66, PVDF and PET**

range, but not shown at the lower 60 to 80 keV energy band. The ruler behind the drilled steel plate to the right hand side of the box is easier to determine at the highest and lowest energy levels shown.

The ability to identify materials by examining the x-ray spectrum has enormous implications for the use of x-rays in the transport security industry, especially for ports. For instance, it could be used for counterfeit detection, or to detect narcotic smuggling. Also, by looking at the signature gamma ray peaks, the detectors could be used to identify different types of radioactive isotopes, thus separating materials that might be used in nuclear bombs from other types of radiation.

It could also enhance manifest verification by not only looking at the symmetry of a cargo in an image but by identifying the materials that the cargo is made up from. Carefully trying to hide the shape of a non-declared cargo therefore would no longer be sufficient as the systems would be able to detect a change in the material composition. As well as being a direct converter of x-rays, CdTe also has the advantage that it is able to absorb very high energy x-rays. Just 4 mm of CdTe is sufficient to achieve reasonable detection performance at 9MeV.

Finally, the benefit of using CdTe x-rays over conventional detectors can be seen in the contrast of an object's image. The scintillation conversion process that is used in current technology basically averages out the intensity response as a function of energy.

By using a narrow energy range, which is possible in CdTe detectors, it is possible to achieve much better contrast resolution. This effect can be seen in the image in Figure 3, where four similar plastic rods are scanned in a suitcase in a conventional dual energy scanner and then in a scanner using CdTe technology. The conventional image, taken in the range of 80 to 140 KeV, shows little difference in the materials as the scintillator-based detectors average out the energy response. Imaging at one single energy level of 50 KeV, however, shows marked differences between the materials.

In conclusion, advances in detector technology mean it is now possible to revolutionise the use of x-ray technology in both air and sea ports.

Direct materials identification offers three main security benefits: it can help to combat narcotic and counterfeit goods smuggling; improve manifest verification by checking for material consistency across cargo loads; and be used to detect both conventional and liquid explosive threats.

Having developed this specific, more advanced type of x-ray detection, Kromek's technology is at the forefront of cargo security measures available to transport security personnel. Indeed, the company is currently involved in a number of worldwide initiatives, showcasing how the use of multi-spectral detection can benefit the transport security industry.