IBEX

WHITE PAPER:

# IBEX MATERIALS DETECTION TECHNOLOGY

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Quality Management System accredited to ISO9001:2008 and ISO13485:2012

## Abstract

The absorption of X-rays by a material depends on the material type (its electron density), its thickness and the energy of the X-rays. The most widely-used detectors integrate the signal received over the spectrum of the X-ray beam and return a single value. Information relating to thickness and material has become degenerate: the X-ray transmission through a thin, dense material can give the same signal as lighter, thicker material. IBEX technology recovers energy-dependent information using a single sample image acquisition at a single kVp using conventional integrating detectors, giving access to materials information independently of sample thickness.

## Introduction

The integrating nature of most X-ray detectors means that information on material density and thickness in the sample is lost in an absorption contrast image, since a single grey-scale intensity is returned despite the absorption of X-rays by a material depending on the X-ray energy, material electron density and material thickness. Thick, light material can give the same grey-level as thin, dense material.

Energy-dependent information is required if this degeneracy is to be overcome. This can be obtained using spectroscopic detectors or image acquisitions at multiple energies. However, this requires either multiple scans or multiple X-ray sources and detectors, while spectroscopic detectors are often expensive, and cover a small area.

IBEX technology enables energy-dependent information to be recovered from single exposures on conventional, integrating detectors such as silicon flat panels or line-scanners. X-ray inspection need no longer rely on absorption contrast, but can make use of the difference between materials in the sample.

## IBEX Technology

The Beer-Lambert Law (Figure 1, Equation 1) gives a basic description of X-ray absorption by a material:

$$I(E) = I_0(E)\exp(-\mu(E)t) \qquad \text{Eq. 1}$$

Where $I_0(E)$ is the intensity of the X-ray beam incident on the material as a function of energy, $E$; $I(E)$ is the intensity exiting the material, and $\mu(E)$ is the linear attenuation coefficient of the material — all of these vary with the energies in the X-ray spectrum. $t$ is the thickness of the material.

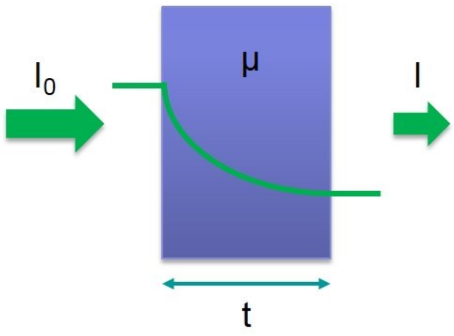


*Figure 1: Illustration of the Beer-Lambert Law, describing the absorption of X-rays by a material.*

The most widely-used X-ray imaging detectors are based on silicon with a thin layer of scintillator in front. These are relatively inexpensive, available in large areas, and read out data quickly. An intensity proportional to the integrated signal is given by each pixel — spectral information is lost. There is

 

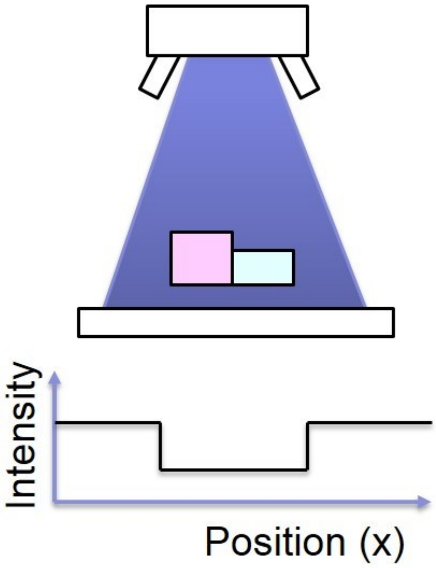


*Figure 2: Thicker, less dense material can look the same as thin, dense material in a conventional X-ray system.*

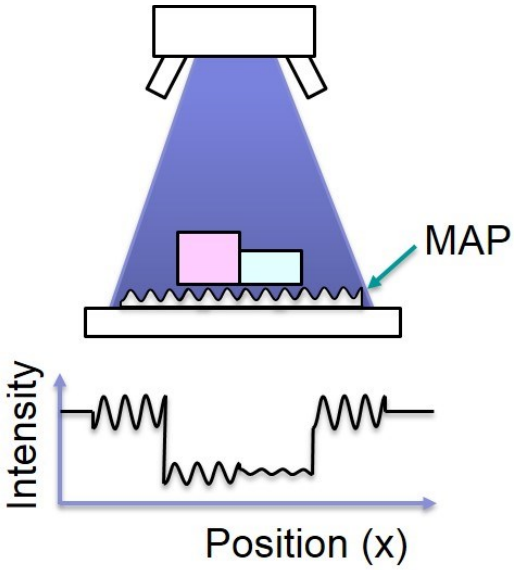


*Figure 3: The IBEX MAP introduces modulations into the X-ray absorption image, enabling energy-dependent information to be obtained which gives access to material information.*

therefore no direct way to determine both material and thickness from the signals obtained (Figure 2). While spectroscopic detectors are available, they are generally slower than silicon detectors, more expensive and are not usually available in large areas.

IBEX overcomes the limitations of integrating detectors by placing a patented Multi-Absorption Plate (MAP) in front of a standard X-ray imaging detector, which could be a flat-panel or a line scanner or other configuration (Figure 3). The MAP is a 3D periodic structure which modulates the X-ray spectrum in a predictable manner over a few pixels, repeating the pattern across the area of the detector.

When samples are placed in the system, different materials of different thicknesses affect the signal through the different levels of the MAP in different ways, by different amounts. Materials information is thus extracted from the modulated image, enabling generation of an image based on differences between *materials*, rather than on X-ray absorption contrast.

The analysis system is "trained" on selected materials over a range of thicknesses, and the materials signatures plotted in a "materials space" IBEX has defined (Figure 4).

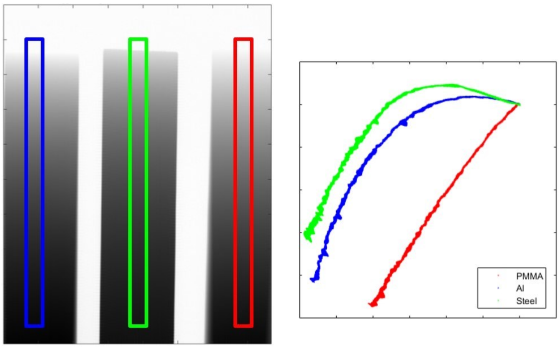


*Figure 4: Left: regions of interest covering the thickness ranges of training wedges of (from left to right) aluminium, steel and PMMA. Right: the materials signatures traced in IBEX materials space, showing the materials clearly distinguished.*

 

In classifying an image of a test object, the materials signals across the image are assessed, and compared to the training set. To each pixel is then assigned a material classification or, for signals outside the trained range or too close to the open-beam point where all materials curves converge, no classification is given.

Once the material has been identified, thickness information is then also available. This may be qualitative or, with a suitably-trained system, quantitative.

The results can be presented in a variety of ways, depending on the requirements of the application. Through stripping out the shadow of the MAP from the data, a high resolution, conventional absorption contrast image is also returned (Figure 4).

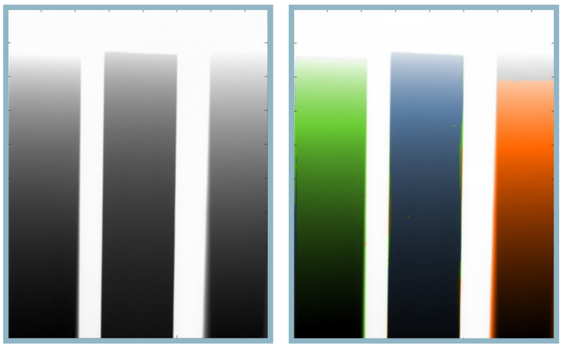

*Figure 4: Left: absorption contrast image produced by stripping out the effect of the MAP from the image data. The range of grey levels is similar for each wedge — the grey-level cannot be used to distinguish the materials. Right: IBEX materials classification overlaid on the absorption contrast, which gives a qualitative indication of material thickness. Classification Limits have been applied, which avoid classifying very low-absorbing material or very thick material. Green: light metal; blue: denser metal; orange: organic (plastic).*

Where the materials contrast is low, for example, in detecting plastic contaminants in chocolate bars, the repeatable nature of the product in terms of size, shape and material can be exploited to generate a mathematical model of "normal" product. Deviations from this can then be detected, and the system can distinguish between contaminants and other deviations (e.g. differences in shape, or bubbles in the chocolate).

## Applications

IBEX materials discrimination technology adds information to X-ray imaging in many domains. For example:

- In medical imaging, IBEX technology enables image features arising from, say, bone

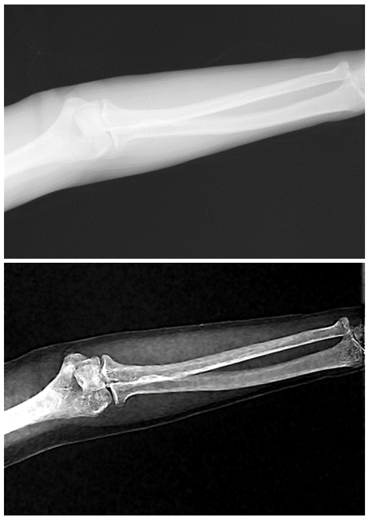

*Figure 5: Top: absorption contrast radiograph produced by stripping out the effect of the MAP from the image data. Bottom: IBEX materials difference image. Having identified the signals arising from soft tissue, the effect of this can be "flattened" in order highlight features which are materially different, which highlights the image of the bone and enhances the differences between muscle, fatty tissue and skin.*

 

to be enhanced compared to those from soft tissue, bringing additional clarity to diagnostic radiographs (Figure 5).

- In addition, quantitative measures of bone mineral density can be obtained from an IBEX-equipped radiograph (Figure 6) rather than requiring a DEXA scan (Dual Energy X-ray Absorptiometry). This makes this important information, key for assessing osteoporosity and fracture risk, available more quickly and more widely, and saves the patient a second visit to the clinic.

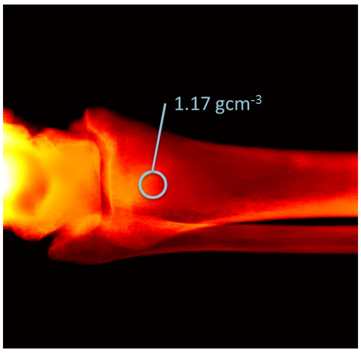


*Figure 6: A colour map representing the Bone Mineral Density of this ankle joint, with a specific value of BMD highlighted.*

- Security scanning uses a Dual Energy approach to distinguish organic materials from metals. IBEX technology applied to portable security scanning systems enables materials to be discriminated in a single acquisition (example in Figure 7).

- X-ray absorption imaging is routinely used in food safety inspection. However, some contaminants, such as bone fragments in chicken, glass in glass jars of puréed food, and

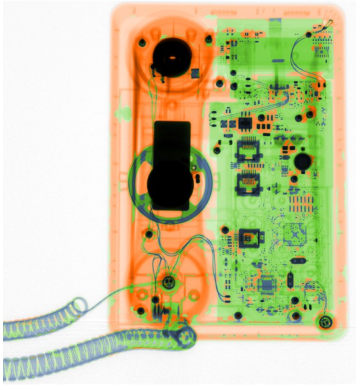

*Figure 7: An IBEX classified image of a telephone. Plastics appear orange, lighter metals appear green, and denser metals blue. Where the X-ray beam passes through multiple materials, the classification reflects the average material type.*

plastic in chocolate, can be indistinguishable from good product in an absorption contrast image. Obtaining materials contrast using the IBEX MAP enables these contaminants to be highlighted (Figure 8). A quantitative contaminant "score" enables pass/fail thresholds to be set on a processing line.

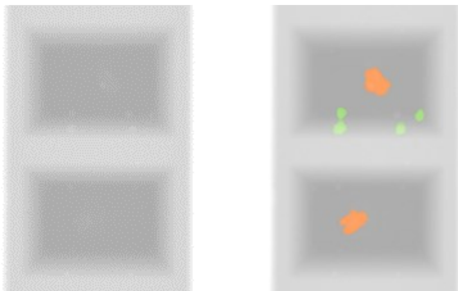

*Figure 8: A MAP-stripped absorption contrast image (left) of chocolate chunks deliberately contaminated with plastic fragments. The contaminants are difficult to see. Right: IBEX technology identifies departures from "normal" product and distinguishes between unusual bubbles (green) and contaminants (orange).*

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## About IBEX

IBEX Innovations Limited was created in 2010 to develop and commercialise an innovative X-ray detector technology.

IBEX is based in modern facilities on the NETPark Science Park in the North-East of England, where it employs a team of highly skilled scientists, engineers and business professionals.

IBEX is supported by private venture capital investment and grant funding from both the UK Government and the European Commission.

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