120kV Hand-Held Backscatter X-Ray Imager

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Traditional Transmission X-Ray Imaging

• Two-sided inspection
• X-Ray source and detectors are on opposite sides of the object being imaged
• Need access to near and far side of object
• Measure the intensity of x-rays transmitted through the object

TRADITIONAL X-RAY
Image produced by original photons. X-rays absorbed throughout the body.
Backscatter X-Ray Imaging

• One-sided inspection
• X-Ray source and detectors are on the same side of the object being imaged
• Need access to only one side of the object
• Measure the intensity of x-rays reflected backwards from the object as a function of the beam position

BACKSCATTER X-RAY
Image produced by original photons after scattering from the body. Most scattering occurs close to the surface.
X-Ray Source

Fan Beam

Tungsten Chopper Disk with Slits

Backscatter Detectors

COMPTON SCATTER

incoming photon $k_{i\mu}^i$

scattered photon $k_{f\mu}^f$

scattering electron $p_{f\mu}$

$\theta$

$\psi$
Energy of Scattered X-ray Photon

Energy of Incident X-Ray Photon [keV]

Energy of Scattered X-ray Photon [keV]

0°  90°  180°  45°  135°

Forward Scatter  Back Scatter
Example: Imaging Plastic Behind Steel

- 1” cube of plastic behind 1mm Fe
- Use X-ray source energies of 70 – 120 kV
- Look at the average energy of the primary beam penetrating the steel ($E_p$)
- Look at the average energy of the detected backscatter that penetrates back through the steel ($E_s$)
- The Mean Free Path (MFP) of the scatter in the steel along with the primary beam intensity determines the steel penetration of the imaging system
Energy of Detected Scatter vs. Energy of Beam Penetrating 1mm Steel

Av. Energy of Beam Penetrating the Steel [keV]

Av. Energy of Detected Scatter from Plastic [keV]

X-ray Source Energy

- 70kV
- 80kV
- 90kV
- 100kV
- 110kV
- 120kV

Mean free path of Scatter in Fe [mm]

- 0.98
- 0.86
- 0.74
- 0.55
- 0.25
- 0.41
HBI-120: World’s first hand-held backscatter imager that can see through steel

- 2.5mm Steel penetration (car panels are 1.0 – 1.5mm thick)
- Built-in high resolution touch screen
- Android™ operating system
- Downloads image data via WiFi and BlueTooth
- Built-in camera and flashlight
- Laser illumination shows extent of x-ray beam
- 4 hour battery life (25% duty cycle)
- 6”/sec nominal scan speed
- 9.1”(L) x 8.5”(W) x 6.6”(H);
- -10°C to +50°C operating range
- Weighs only 6.5 lbs
- IP54 Rated
Energy Dependence of 1mm Steel Penetration

Imaging of 1kg Cocaine Simulant Behind A Car Panel (1.0mm Steel)
Energy Dependence of 2mm Steel Penetration

Imaging of 1kg Cocaine Simulant Behind Two Car Panels (2.0mm Steel)
Backscatter Imaging Behind Wood

Imaging of 1kg Cocaine Simulant Behind High-Density Chip Board
Pipe Bomb in Suitcase
Pressure Cooker IED
Orange and a Sandwich
Controls on a Car Dashboard
1Kg Cocaine
Behind
1.5mm Steel
Car Panel
Bottles of Wine & Water in Refrigerator
Conclusions

• Backscatter imaging only requires access to one side of the inspection object
• Useful when transmission imaging is not an option
• Steel penetration with backscatter imaging increases by ~0.25mm / 10kV
• The HBI-120 operating at 120kV is a very versatile hand-held imaging device that can rapidly image objects behind more than 2mm of steel
• Backscatter imaging is particularly useful for fast anomaly detection
• It excels at detecting organic materials in places where it is known that they should not be present (e.g. drugs in vehicles or currency behind walls)
• It may also prove quite useful for detecting concealed defects ~5mm or greater in non-metallic surfaces