Gamma-ray Imaging Techniques

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Gamma Imaging has huge benefits in Maintenance, Decontamination and Dismantling operations
- Locate radioactive sources remotely
- Reduction of personnel dose and project costs
- Financial and Dose budgets

LPC: Chemical Purification Laboratory at Cadarache:
- Optimize the dismantling scenario
- Hot Spot localizing and operational uncertainty reduction

New gamma imager:
- Easy and fast host spot investigations
- Fast cartography (today done manually)
- Reduction of Financial costs and Dose budgets

In the 1990 « AREVA/CANBERRA » strategy was to:
- Minimize the time « of radiation exposure » of workers
- Be situated in the « outer of zones » in suspected cases (ALARA)
- Identify problems remotely
The projects of common interest were launched by “AREVA & CEA” and the ideas are:

- Making robotic arms to access to hot spots
- Investing in portable gamma-ray imaging system

**ROADMAP Technology**

- First Generation γ Camera (1990)
- Aladin 1
  - (coded mask + scintillator + CCD)
- Aladin 2/3 (1997)
- Cartogam (2000)
- Second Generation γ Camera (2010)
  - Technology Transfer CANBERRA
  - (What technology?)
What Technology for the future Gamma Imager?

Why a new Gamma Imaging System?
- The new generation of Gamma Imagers must possess:
  - Increased sensitivity
  - Spectroscopic capabilities
  - Light weight

What is TimePix?
- Made as CMOS technology 0.25 µm
- Total Surface: 1.4 x 1.4 cm²
- 256 x 256 pixels
- In every pixel: Preamp./shaper, Discri./hit counter (14bits)
- Counting rate up to 1 MHz/pixel
- A clock distributed on each pixel
- Counting Mode: energy/time
- Total chip size: 4 x 7 cm²
- Coupled to a CdTe (Cadmium Telluride) wafer

R&D For the New Generation Of Gamma Imager

Gamma Imager Components
- Gamma detector
- Optical collection of gamma radiation

Good compromise between FOV and Resolution.
Low detection efficiency of gamma radiation

A coded mask is a collimator with multiple holes.
Improve the gamma radiation detection efficiency.
The resulting image must be decoded.
R&D For the New Generation Of Gamma Imager
Coded-Aperture mask characteristics

- MURA (Modified Uniformly Redundant Array) Masks were chosen:
  - Uniform hole distribution
  - 50% of the mask is filled with holes
  - Inverse of the MURA mask is a rotation of 90°

- Hole Size
  - Number of holes: impact on the angular resolution
  - More time needed to reconstruct the image.

- Mask Rank
  - Different mask ranks exist (5, 7, 11, 13, ...).
  - A higher mask rank means more holes

- Mask thicknesses
  - Different mask thicknesses exists (1 mm, 2 mm)

Several Coded Aperture mask are chosen Function of the application

R&D For the New Generation Of Gamma Imager

- Gamma Imager Main Components
  - Gamma detector
  - Optical collection of gamma radiation
    - Pinhole
    - Coded Aperture Mask
  - Data acquisition board
    - USB Interface
  - Other components:
    - Visible camera
    - Shielding
Gamma Imager Design & Deployment

Gamma Imager First Prototype
- Dimensions: HxWxL 20x15x15 cm
- Weight: Less than 2kg
- Added Shielding (2, 6, 8 kg)

Gamma Imager Deployment
- Handheld Deployment
- Tripod Deployment
- Robotic Deployment

Gamma Imager Data Reprocessing

Gamma Imager First Design
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Gamma Imager Data Reprocessing
- Raw Gamma Image
- Coded Mask source Reconstruction
- Superimposition of Visible and Gamma Image
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GAMPix, Colibri and In1k Measurements
In-Situ Measurement: Pipelines Applications (1)

- Pipelines Application (Pu Sources):
  - Tripod Mode
  - Distance 5m
  - Dose rate @ source level 6 mSv/h
  - Dose rate @ detection head 7 µSv/h

In-Situ Measurement: Pipelines Applications (2)

- Pipelines Application (Pu Sources):
  - Tripod Mode
  - Distance 2.8 m
  - Different Dose rate @ pipeline level
  - Dose rate @ detection head 13.5 µSv/h

Validation Of Intensity Using Independent Dose Rate Measurement

Mask Rank Impact on the Spatial Resolution

0.413 mSv/hr
0.258 mSv/hr
0.105 mSv/hr
In-Situ Measurement: Pipelines Applications (3)

- Pipelines Application (Pu Sources):
  - Tripod Mode
  - Distance 5m
  - Dose rate @ source level 6 mSv/h
  - Camera moving during the measurement
  - Image Reconstruction in 1 s

  Measurement done @ 10 s  
  Measurement done @ 20 s  
  Measurement done @ 30 s

Continuous Monitoring Application

In-Situ Measurement: Pipelines Applications (4)

- Pipelines Application (Pu Sources):
  - Tripod Mode
  - Distance 5m – Measurement Time = 120 s
  - Dose rate @ source level 0.6 mSv/h
  - High Background Level

  Without Shielding  
  4 mm Shielding  
  Mask & Anti Mask Application

Background Subtraction Without Changing The Weight
Mask/Anti-mask (1)

Pro: Reduced camera weight in high background media
Con: Double measurement time

Mask/Anti-mask (2)

$^{241}$Am 74 MBq
$d=150$ cm

Image brute
Masque 200 s

PIDIE 7 4.7 GBq $^{241}$Am

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Mask/Anti-mask (3)

In-Situ Measurement:
Pipelines Applications (4)

- **Pipelines Application (Pu Sources):**
  - Tripod Mode
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**Background Subtraction Without Changing The Weight**
In-Situ Measurement: Various Applications...

Gamma Imaging For Various Applications

Conclusions

The new generation of Gamma Imagers must possess:
- Increased sensitivity
- Light weight
- Spectroscopic capabilities

In-Situ Measurement Results Shows:
- Different deployment mode with adapted shielding weight
- Fast Responses (few seconds)
- Gamma Imager response from few nSv/h up to Several Sv/h
- Mask Rank Impact on the Spatial Resolution
- Validation Of Intensity Using Independent Dose Rate Measurement
- Real Time Gamma Imaging
- Mask Anti-Mask Effect: Background Subtraction Without Changing The Weight
- Gamma Imaging For Various Applications (pipelines, tank, drums, …)

On Going Development...
- Spectroscopic Tests
- Size Optimization
- Handheld Application

Thank you for your Attention!
Questions