Gamma-ray Imaging Techniques

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OUTLINE

- CONTEXT
- INTRODUCTION
- WHAT TECHNOLOGY?
- MAIN COMPONENTS
- GAMMA IMAGER DESIGN & DEPLOYMENT
- GAMMA IMAGER DATA REPROCESSING
- PRELIMINARY IN SITU-MEASUREMENTS
- CONCLUSIONS

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CONTEXT

- **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**

History
Portable gamma-ray imaging system

- **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

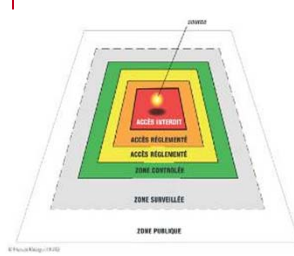


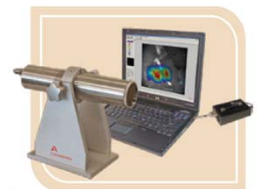
History

Portable gamma-ray imaging system (more)

- **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

robotic arm





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ROADMAP Technology

Second Generation γ Camera

(What technology?)

2010

Technology Transfer CANBERRA

First Generation bis γ Camera

(Pinhole + scintillator + CCD)

Aladin 2/3

2000

Cartogam

Aladin 1

First Generation γ Camera

(coded mask + scintillator + CCD)

1990

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What Technology for the future Gamma Imager?

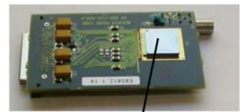
Why a new Gamma Imaging System?

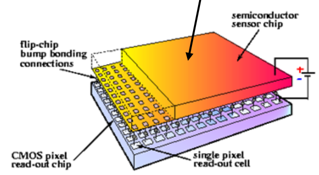
- The new generation of Gamma Imagers must possess:
  - Increased sensitivity
  - Spectroscopic capabilities
  - Light weight

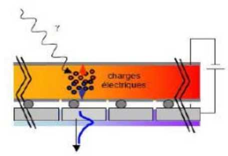
What is TimePix?

- 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**

TimePix/CdTe







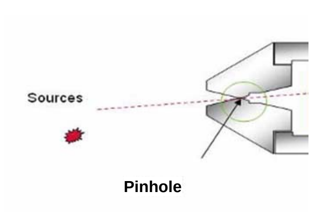
R&D For the New Generation Of *Gamma Imager*

Gamma Imager Components

- **Gamma detector**
- **Optical collection of gamma radiation**

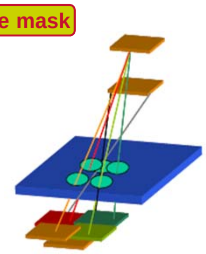
TimePix/CdTe

Pinhole



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

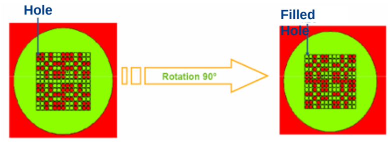
Coded Aperture mask



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)

Rank 11 | Rank 13

Several Coded Aperture mask are chosen Function of the application

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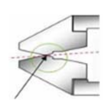
R&D For the New Generation Of *Gamma Imager*

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

TimePix/CdTe



Pinhole

Coded Aperture mask

USB Interface

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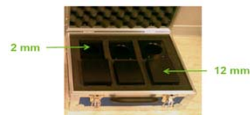
Gamma Imager Design & Deployment

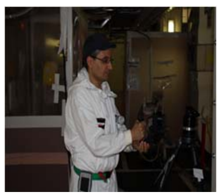
Gamma Imager First Prototype

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



Gamma Imager Deployment

Handheld Deployment



Tripod Deployment

Robotic Deployment

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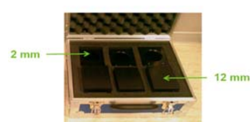
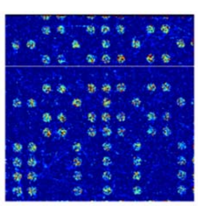
Gamma Imager Data Reprocessing

Gamma Imager First Design

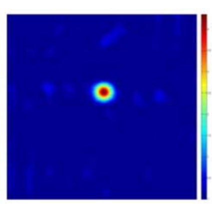
- Dimensions: HxWxL 20x15x15 cm
- Weight: Less than 2kg
- Added Shielding (2, 6, 8 kg)



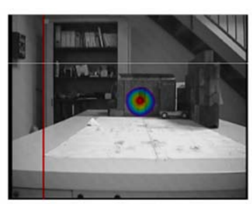
Gamma Imager Data Reprocessing



Raw Gamma Image



Coded Mask source Reconstruction



Superimposition of Visible and Gamma Image

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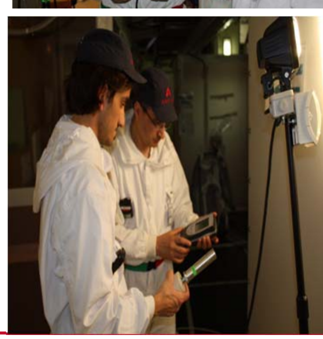
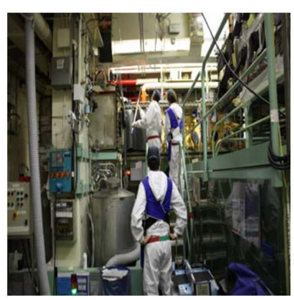
GAMPix, Colibri and In1k Measurements





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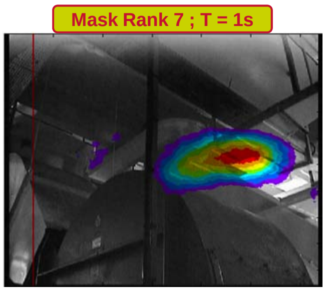
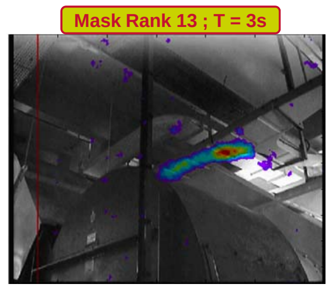
In-Situ Measurement:
Pipelines Applications (1)

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





Mask Rank Impact on the Spatial Resolution

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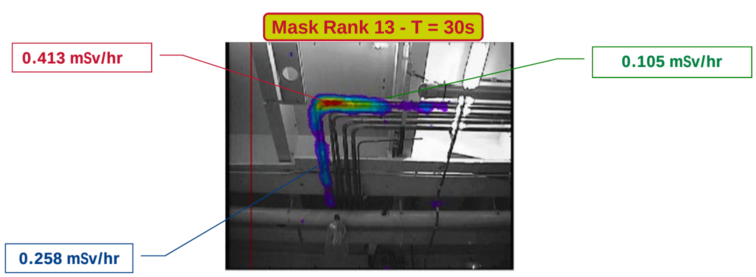
In-Situ Measurement:
Pipelines Applications (2)

- **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

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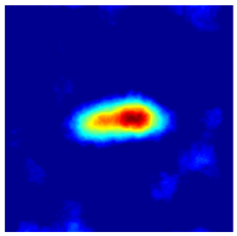
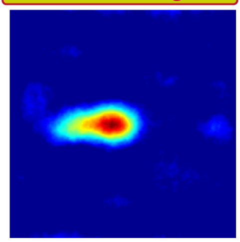
In-Situ Measurement: Pipelines Applications (3)

- 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

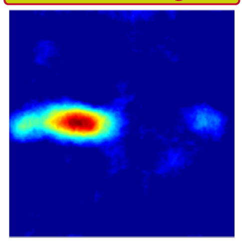
Measurement done @ 10 s



Measurement done @ 20 s



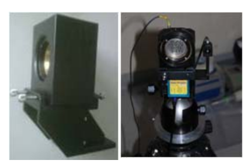
Measurement done @ 30 s



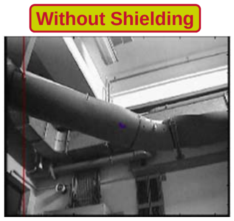
Continuous Monitoring Application

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

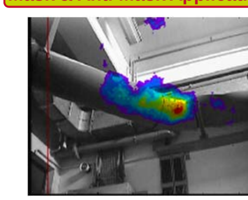


Without Shielding



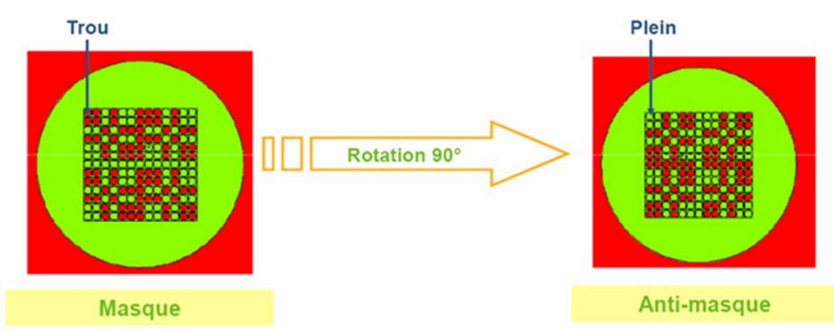
4 mm Shielding

Mask & Anti Mask Application



Background Subtraction Without Changing The Weight

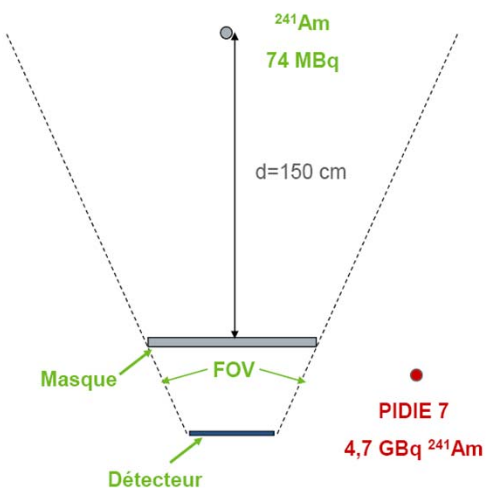
Mask/Anti-mask (1)

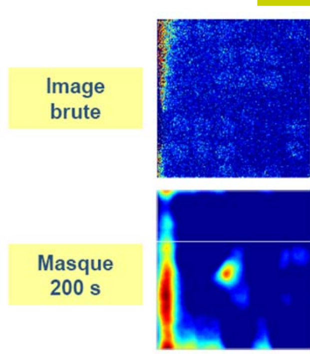


Pro: Reduced camera weight in high background media

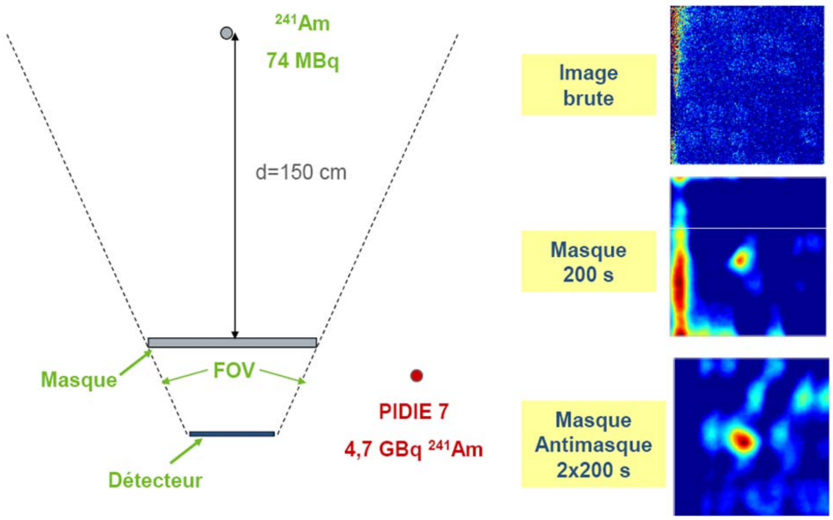
Con: Double measurement time

Mask/Anti-mask (2)



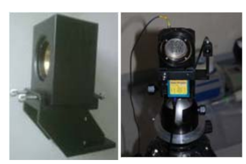


Mask/Anti-mask (3)

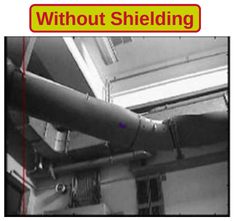


In-Situ Measurement: Pipelines Applications (4)

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

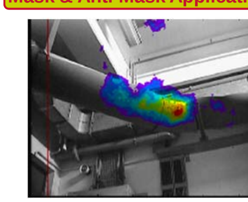


Without Shielding



4 mm Shielding

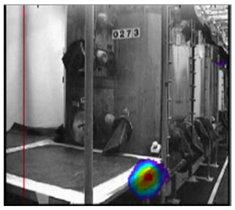
Mask & Anti Mask Application



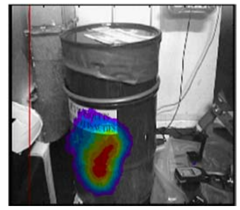
Background Subtraction Without Changing The Weight

In-Situ Measurement: Various Applications…

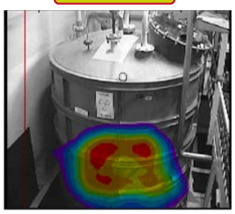
Glove Box



Drums



Tank



Pipelines

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