Computed Radiography System Simulation Focusing on the Optical Readout Process

Min YAO
Valérie KAFTANDJIAN
Philippe DUVAUCHELLE
Angéla PETERZOL-PARMENTIER
Andreas SCHUMM
Peter WILLEMS

INSA de Lyon
INSA de Lyon
INSA de Lyon
AREVA
EDF
GE

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Outline

1. Computed radiography principle, advantages and limitations

2. Optical readout simulation
   - Involved phenomena
   - Simulation method
     - Laser spreading inside imaging plate (Monte Carlo tool)
     - Laser scanning (Analytical model)

3. Illustration of different optical effects

4. Conclusion
What is Computed Radiography (CR)?

1. X-Ray Exposure

- X-ray source
- Imaging Plate (IP)
- object
- IP irradiation → Latent image

2. Readout

- Laser
- ADC
- Digitized Signal
- Imaging Plate Moved Translationally

3. Erasure

- Intense Light
Advantages and limitations

• **Advantages**
  + Flexibility of detector
  + Direct digital image
  + Reusability
  + High dynamic range up to $10^5$

• **Limitations**
  - Poor efficiency at high energies
  - Poor spatial resolution
    
    due to the optical readout process
Objective

- **CR imaging chain modeling**

\[ \text{Source} \rightarrow \text{X-ray} \rightarrow \text{latent image} \rightarrow \text{Scanner} \rightarrow \text{CR final image} \]
Optical readout simulation: involved phenomena

- **Flying spot scanner**
  Latent image read by a scanning laser

* AAPM Task Group 10 (2006)
Optical readout simulation: involved phenomena

- **Static laser**
  - Photo-stimulation by laser beam
  - Light emission: photo-stimulated luminescence (PSL)
Optical readout simulation: involved phenomena

- **Scanning laser**
  - PSL emission
  - Latent image modification

![Diagram showing optical readout simulation with time steps: t+Δt, t+2Δt, t+3Δt]
Optical readout simulation: method

- Analytical operator using a Monte Carlo optical response model

Latent image $L_{img}(x,y,z)$

Scanning parameters

Optical response model $f(x,y,z)$

$H_2$

CR final image $D_{img}(x,y)$

$$D_{img}(x_m, y_n) = H_2(L_{img}, f, \text{scanning parameters})$$
Optical readout simulation: method

\[ D_{img}(x_m, y_n) = H_2(L_{img}, f, \text{scanning parameters}) \]

\[ = \int P(z)dz \int \int_{x,y} L_{img}^{(mod)}(x, y, z) \left[ 1 - \exp \left( -\sigma \cdot f(x-x_m, y-y_n, z) \cdot P_{laser} \cdot t_{scan} \right) \right] dx dy \]

PSL detection probability

latent image modified by scanning

optical cross section of photostimulation

Scanning parameters

optical response (Monte Carlo)

* Modified from Thoms (1996)
Optical readout simulation: method

- **Monte Carlo tool to obtain the optical response** \( f(x,y,z) \)
  
  IP is described by
  
  - Absorption coefficient
  - Scattering coefficient
  - Anisotropic factor:
    - Forward peaked scattering
    - Isotropic
    - ...
  - Boundary conditions

- **Output**

  light intensity function \( f(x,y,z) \)

* Wang et al. (1995)  
Fasbender et al. (2003)
Different optical effects illustration: absorption coefficient

- Great absorption coefficient: small scattering region
  - Bad efficiency, good resolution

![Diagram showing absorption coefficient and intensity distribution](image)
Different optical effects illustration: anisotropy factor

- **Forward peaked scattering**: great penetration depth
  - Good efficiency, good resolution

![Diagram of laser scattering](image-url)

\[ I(x,y,z) \]
Different optical effects illustration: laser intensity

- **Great intensity: great penetration depth**
  - Good efficiency, bad resolution

![Diagram showing intensity distribution with labels for IP depth (µm), Radius (µm), and laser intensity](image)
Different optical effects illustration: IP thickness

- **Small thickness:** small scattering region
  - Bad efficiency, good resolution
Different optical effects illustration: scanning effect

Example of latent image (reference test object with various holes)

Readout factor = Laser power $\times$ scanning time
Different optical effects illustration: scanning effect

- Influence of readout factor
Conclusion

• Simulation of optical readout process combining analytical and MC tool

  ▪ Interest of the tool
    → study of different optical effects
    – absorption and scattering factors, IP thickness …
    – scanning parameters

  ▪ Modeling of the complete CR system is now available
    → in use at industrial site AREVA and EDF

  ▪ To be done in the future : structural noise of IP
Thank you for your attention!