Available Imaging Tools

- Spatial resolution
- Sensitivity
- XLCT
- XFCT
- PET
- SPECT
- CT
- MRI
- US
- MRSI
X-ray Fluorescence Molecular CT Imaging

Fig. 1. (left) Proposed XFCT/CT system. (top) Physical mechanism of X-ray fluorescence from K-shell electrons.


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Sensitivity

X-ray Fluorescence/Luminescence Tomography

Reconstruction: ML-EM

Noise from counting statistics:

Log-likelihood:

\[ \log p(y) = \sum_{i=1}^{p} -y_i + m_i \log(y_i) - \log(m_i) \]

maximize \[ f_m(y) = \sum_{i=1}^{p} -y_i + m_i \log(y_i) \]

subject to \[ y = Ax \]

x \geq 0

Expectation-Maximization:

\[ x^{j+1} = \frac{x^j + \sum_{i=1}^{p} \frac{m_i}{y_i} x_i^j}{\sum_{i=1}^{N} \frac{m_i}{y_i} y_i + p} \]
Sinograms (top) and reconstructed CT images (bottom) for XFCT (left) and transmission CT (right) of the low-resolution phantom loaded with gold for a 0.1 mGy imaging dose. (Magda Bozalova et al)

X-ray Fluorescence Molecular CT Imaging


Multiplexing

K. Yu et al. AAPM 2012 (best paper in imaging)

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Sensitivity vs Radiation Dose

Proton Fluorescence (In collaboration with Hokkaido Univ.)

Going Beyond K-Schell Imaging

Figure 1: Monte Carlo simulates geometry of XRF and CT imaging using 1st generation CT scanning (left). Monenergetic pixel beams with 16, 30, and 82 keV were simulated using 30 dose positions across the extent of the phantom and tilted by 30° in 1 steps. The 2.0 cm carotid phantom (middle) contained 0.04 to 0.2 mm slotted rings with 0.1 to 0.2% solutions of Gadolin. Transmission CT (top right) and XRF (bottom right) tomograms of the phantom axial (generated) CT and XRF image were then reconstructed with three different reconstruction techniques.
High-sensitivity x-ray fluorescence CT imaging of Cisplatin with L-shell x-rays

Figure 2: CT images of a liver phantom imaged at 15 keV, 30 keV, and 80 keV. The image quality is significantly improved at 80 keV compared to 15 keV. The accuracy of concentration reconstruction is increased by a factor of 3.8 compared to K-shell imaging, however, attenuation correction is needed.

Figure 3: Profiles along a horizontal (left) and vertical (right) line across the phantom for the 15 keV images reconstructed with FBP (green), ML-EM without (blue) and with (red) attenuation correction. The actual profile is marked by the black dashed line. The accuracy of concentration reconstruction is significantly increased when attenuation correction is applied.

Radioluminescence & X-ray Luminescence CT

Principle

Optical radiation

Current applications

PET and SPECT, tomosynthesis, CT, bioluminescence, scintillation imaging, high-energy physics.
Pratx, Sun, Carpenter & Xing, Optics Letters, 2011.

Modification of QD710-Dendron with a dimeric RGD peptide, RGD$_2$. B: Excellent solubility and monodispersity in aqueous solution for the QD710-Dendron (left) and QD710-RGD$_2$ (right). C: TEM image of QD710-RGD$_2$. D: UV absorbance and NIRF of the QD710-Dendron (bottom) and QD710-RGD$_2$ (top). In vivo NIRF imaging of QD710-RGD$_2$ (active targeting, E) and QD710-Dendron (passive targeting, F) in mice bearing SKOV3 tumor (Cheng’s lab).
SUMMARY

- Interaction of X-ray with endogenous or exogenous media provides the basis for highly sensitive X-ray molecular imaging.
- Highly sensitive XFCT is feasible.
- XFCT and XLCT are two examples of X-ray molecular/physiological imaging that are being developed at Stanford.