Contrast Agent Estimation Result of 2-dimensional Photon Counting CT Detector which Combined MPPC and YGAG-scintillator Array

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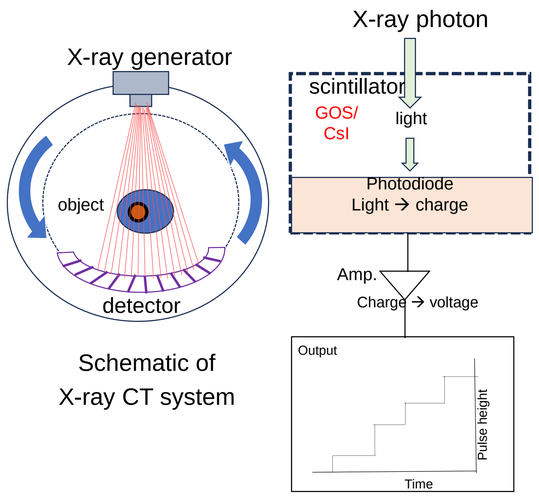
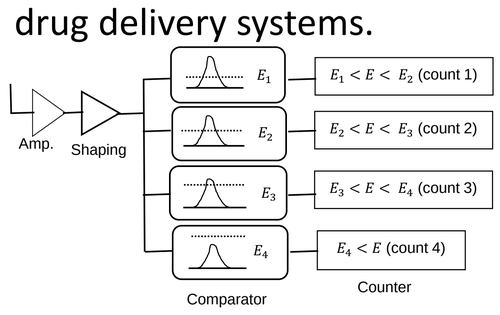
Research Background



Schematic of X-ray CT system

Energy-integrating detector for Conventional CT

- Conventional CT limitation: **Monochromatic:** Loss of energy information → Unable to distinguish different material components.
- **Distinguishability of material** → Effective for medical diagnosis and drug delivery systems.

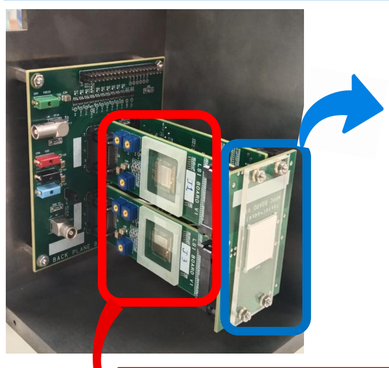


Photon Counting Detection System

- **Photon Counting CT can overcome conventional CT limitation.**

Expanded Photon Counting (PC) Detector

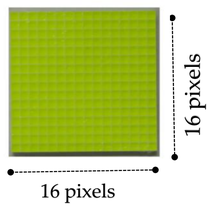
2-dimensional PC CT Detector



Coupled of 16 × 16-channel MPPC and scintillator array

2D Multi Pixel Photon Counter (MPPC) Array

Signal amplification → ~10^6
Time response → ~ 1 ns



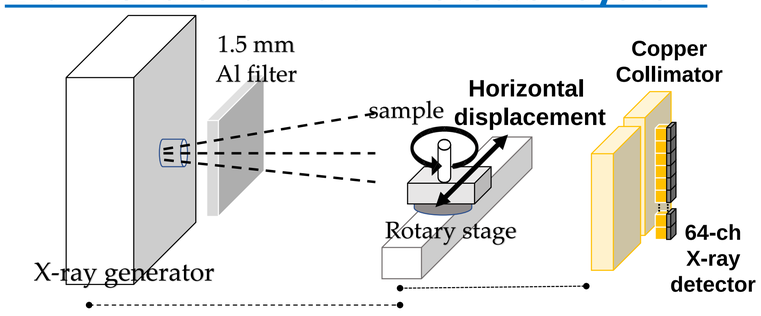
2D YGAG Scintillator Array

$1 \times 1 \times 1$ mm^3

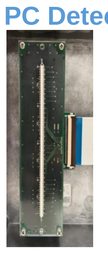
Decay time → ~70 ns
Light yield → 5 × 10^4 photons/MeV

4 × LSI Boards → Each LSI (large-scale integrated) circuit processing 64-channel detector which each channel has six voltage (i.e. X-ray energy) thresholds.

1-dimensional PC CT Detector System

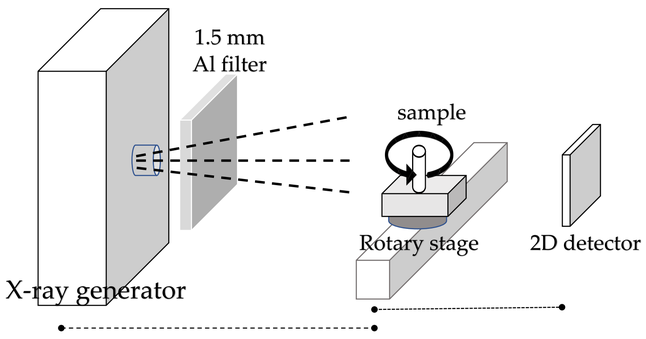


1D PC Detector



- **Successfully performed contrast agent estimation** both in static and mouse imaging experiments [1-4].

2-dimensional PC CT Detector System

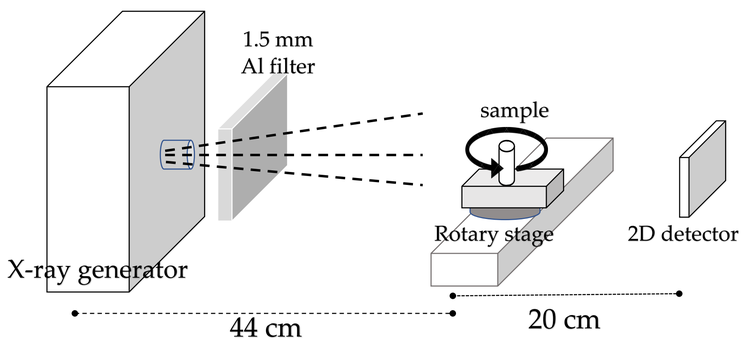


2D PC Detector

Reduce the imaging time → **Temporal resolution improvement in dynamic imaging**

- **Evaluate the concentration estimation of the contrast agent samples.**

Experimental Setup



	Non Mixture sample	Mixture sample
Sample tube		
Size	Ø = 11.6 mm h = 32 mm	Ø = 6 mm h = 21.5 mm

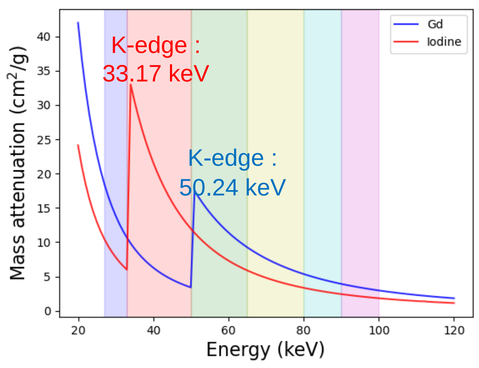
	Non Mixture sample	Mixture sample
Sample	Iodine : 1mg/mL, 3 mg/mL, 5 mg/mL, 10 mg/mL Gadolinium : 5 mg/mL, 10mg/mL Water	Mixture of Iodine and Gadolinium, Water
X-ray tube voltage (keV) / Tube current (mA)	100 / 0.1	120 / 0.1
Energy Threshold (keV)	27, 33, 50, 65, 80, 90	23, 33, 50, 65, 80, 100

Analysis Methods

Image Reconstruction Algorithm

- Filtered Back Projection (FBP) Algorithm

Concentration Estimation



CT Value

$$CT = \left(\frac{(\mu_s + \mu_w) - \mu_w}{\mu_w}\right) x\ 1000$$ → **Each pixel of CT Image data**

$$CT = \left(\frac{\rho_s \left(\frac{\mu}{\rho}\right)_s}{\rho_w \left(\frac{\mu}{\rho}\right)_w}\right) x\ 1000$$

NIST data

→ **Ideal CT value**

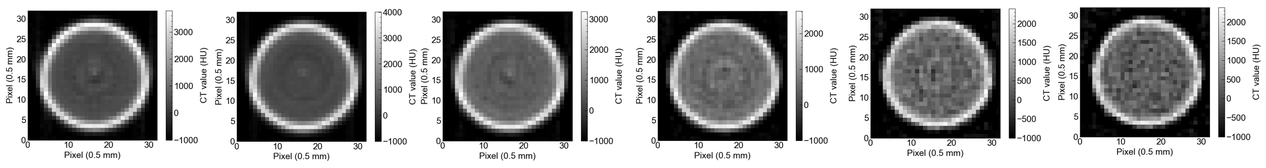
μ_s = sample linear attenuation
μ_w = water linear attenuation
ρ_s = sample concentration
ρ_w = water concentration
$\frac{\mu}{\rho}$ = mass attenuation (μ')

Least Square Method for Concentration Estimation →

$$\sum_E (CT_{measured_E} - \rho_s \frac{\mu'_{s_E}}{\mu'_{w_E}})^2$$

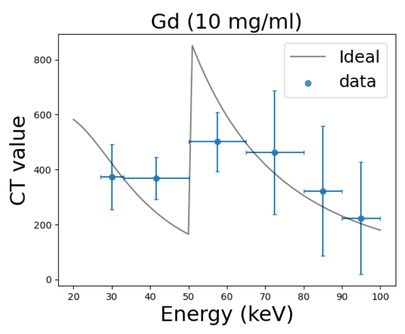
Result

CT Image of Gd 10 mg/mL Sample

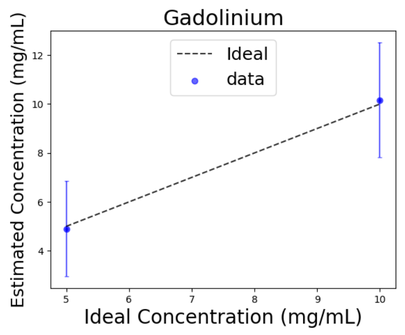


27 – 33 keV | **33 – 50 keV** | **50 – 65 keV** | **65 – 80 keV** | **80 – 90 keV** | **90 – 100 keV**

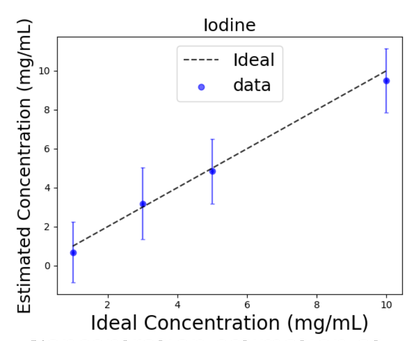
Concentration Estimation



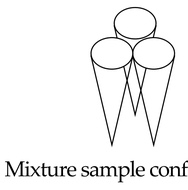
CT value graph of Gd 10 mg/mL



Concentration estimation of Gadolinium sample

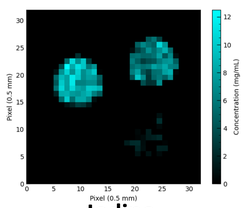


Concentration estimation of Iodine sample

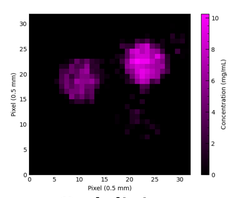


Mixture sample configuration

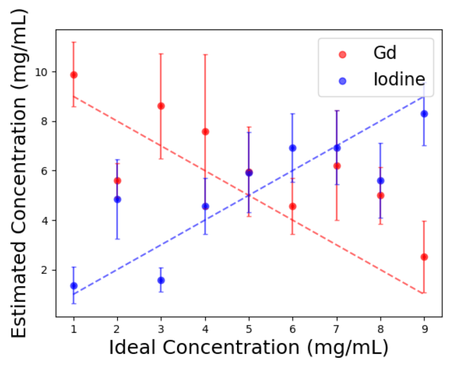
2 — Iodine 4 mg/mL + Gd 6 mg/mL
1 — 3 — water
Iodine 6 mg/mL + Gd 4 mg/mL



Iodine Concentration map

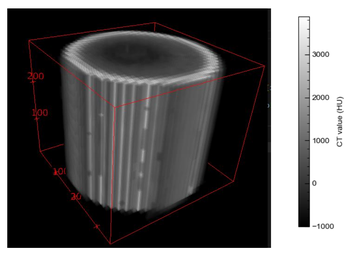


Gadolinium Concentration map

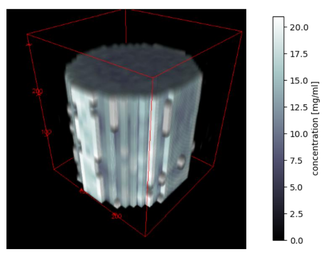


Concentration estimation of the mixture sample considering energy resolution

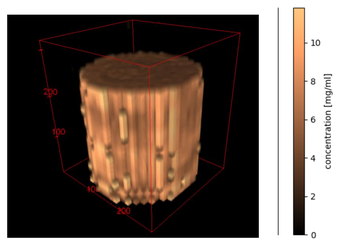
3D image



Gd 10 mg/mL (27 – 33 keV)



Concentration of Gd 10 mg/mL



Concentration of Iodine 5 mg/mL

Conclusion and Future Work

- The 2D PC CT System combining YGAG Scintillator and MPPC Array has been developed.
- Successfully estimate the concentration of the contrast agent samples.
- Reanalyze the mixture samples to get more accurate estimation of the concentration.
- Perform the artifact correction (i.e. ring artifact) to get a more homogeneous CT image.

References

[1] H. Kiji et all., NIM-A, **984** (2020), 164610
[2] T. Maruhashi et all., NIM-A, **958** (2020), 162801
[3] D. Sato et al., NIM-A, **1048** (2023), 167960
[4] M. Sagisaka et all., NIM-A, **1045** (2023), 167580
[5] M. Arimoto et all., NIM-A, **1047** (2023), 167721
[6] H. Morita et al., NIM-A, 857:58-65, 2017.