# Development of a prototype of intraoperative PET-laparoscope system for surgical navigation in cancer surgery

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## Background

- Locating lymph node metastasis during a surgery is difficult and this leads to unnecessary tissue removal.
- PET-laparoscope system has been proposed for identification of lymph node metastasis during gastric cancer surgery [1].
- This study presents the development of detectors for the PET-laparoscope system which consists of two detector systems; a fixed external detector and a movable detector probe.

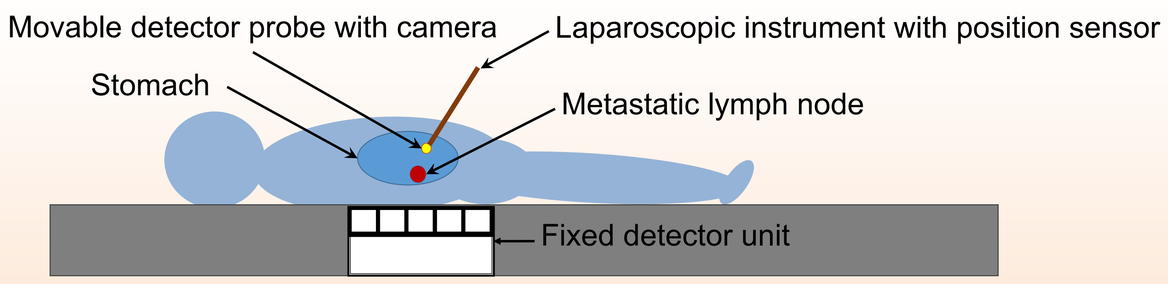



Fig. 1. Conceptual diagram of the PET-laparoscope system

## System components and methods

### A. Detector system overview

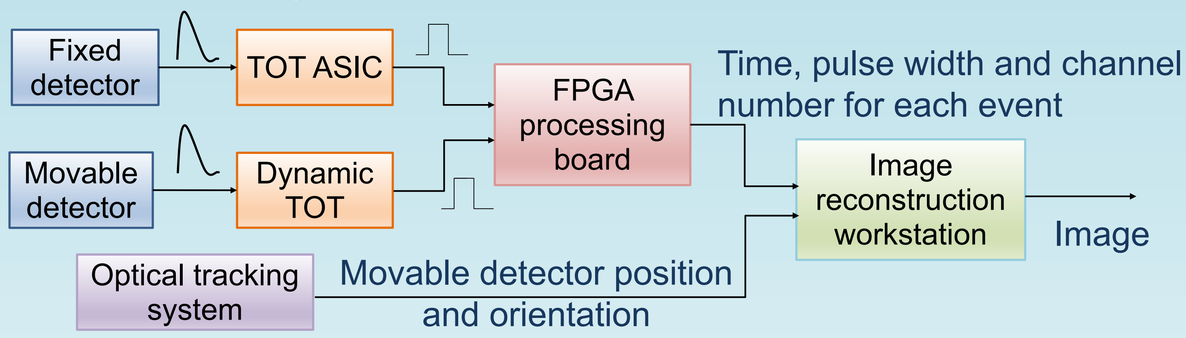



Fig. 2. Block diagram of the detector system

### B. Fixed detector and movable detector

- Fixed detector is a 7 × 7 array of 10 × 10 × 20 $mm^3$ Ce:GAGG ($Gd_3Al_2Ga_3O_{12}$) crystals coupled to SiPMs.
- As the movable detector, the probe developed by Dr. Y Nakamura was used [2]. It consists of GFAG (gadolinium fine aluminum gallate) crystals with 2 × 2 × 3 $mm^3$ size coupled to MPPCs. It has 4 layers of 12-pixel arrays.

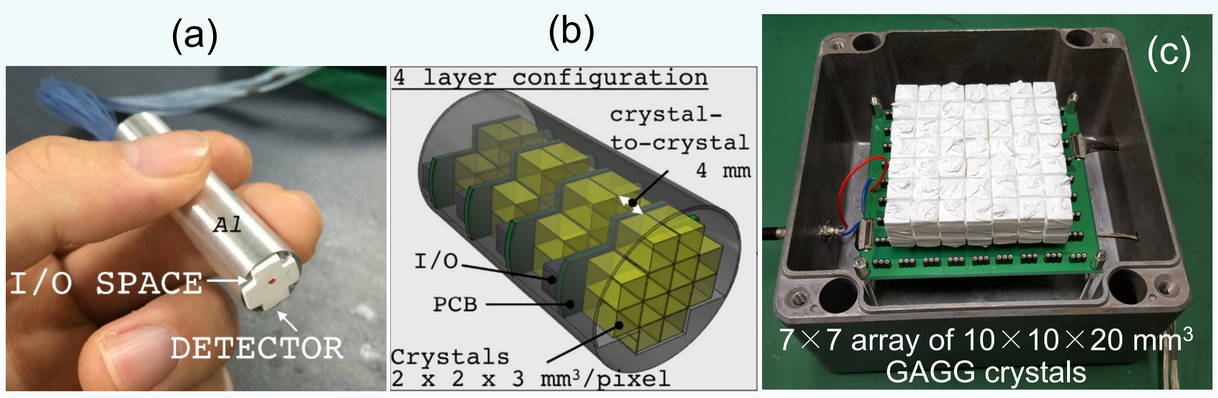



Fig. 3. (a) Movable detector probe, (b) Crystal structure of the movable detector probe, (c) Fixed detector array

### C. Readout system

- Photodetector outputs were digitized using TOT (time over threshold) method. Outputs from the fixed detector were connected to single threshold TOT ASICs [3] and the outputs from the movable detector were connected to a dynamic TOT board [4].
- An FPGA based DAQ system was developed to determine the arrival time, pulse width and channel numbers of each TOT output using a CX-Card4 board (Prime Systems Inc., Nagano, Japan).

### D. Position tracking

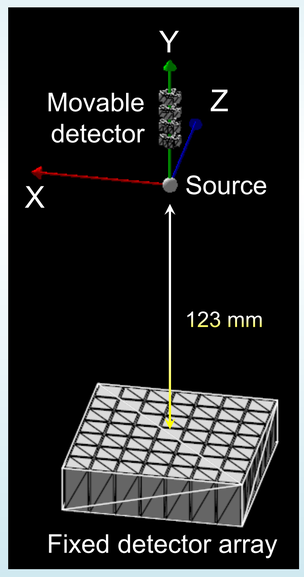
- Polaris optical tracking system (Northern Digital Inc., Ontario, Canada) was used to track the position and orientation of the movable detector probe.
- Synchronization of position data of the probe and photon events was achieved by starting the time counters of FPGA and the position tracking system at the same time.

### E. Image reconstruction

- Image is first acquired by FBP (filtered back projection) algorithm.
- Next performance of an MLEM algorithm will be investigated.

### F. Image reconstruction experiments

- Source: 330 kBq $^{22}Na$ source with less than 0.71 mm diameter
- Distance from the source to the fixed detector: 123 mm
- Distance from the source to the movable detector: about 20 mm
- Scan duration: 2 minutes
- A simulation study was also conducted in Geant4 platform
  - Detector sizes same with the prototype
  - Source: $^{18}F$ point source



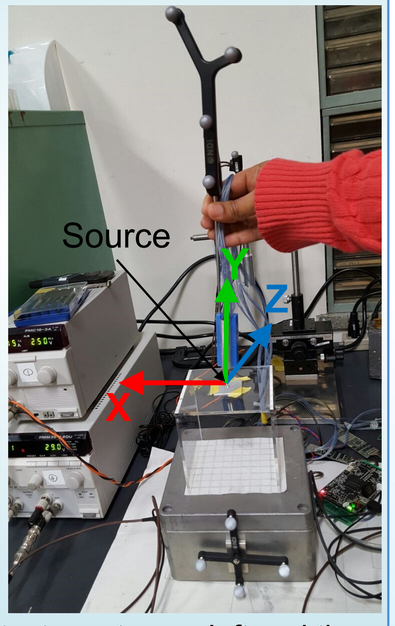
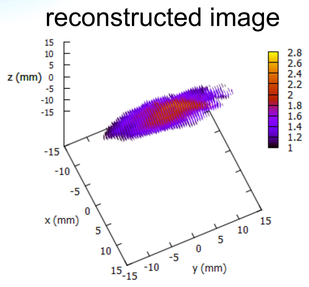




Fig. 4. Simulated detector setup on left and the experimental setup for the prototype on right

## Results and discussion

3D view of the reconstructed image



An image slice through XZ plane

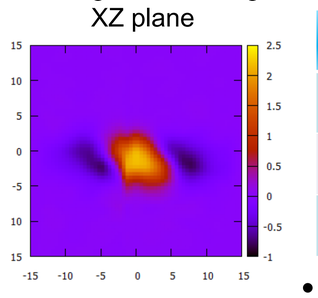
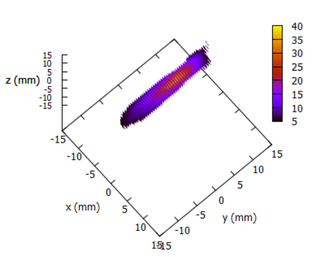


Fig. 5. Image from the prototype



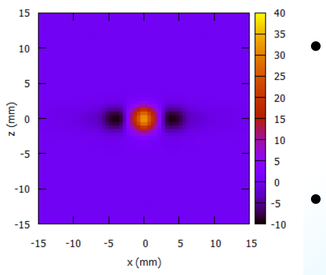


Fig. 6. Image from simulation

FWHM spatial resolution (mm)

| | Prototype | Simulation |
|---|---|---|
| X | 4.4 | 2.6 |
| Y | 21.7 | 12.3 |
| Z | 5.4 | 2.8 |

- Spatial resolution in X and Z directions were satisfactory.
- Resolution in Y (depth) direction was limited due to low angular coverage.
- Difference between prototype and simulation images may be due to measurement errors.

## Conclusion

- A prototype for the PET-laparoscope system is presented for intraoperative identification of lymph node metastasis.
- Detector prototype reconstructed images with better than 6 mm spatial resolution in X and Z directions.

## Future work

- Designing a better probe holder for improving position accuracy
- Obtaining a Compton image from the movable detector probe and combining it with the PET image
- Investigating performance of an MLEM image reconstruction algorithm

References

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[2] Y Nakamura *et al*. 2016 “Development of a novel handheld intra-operative laparoscopic Compton camera for $^{18}F$-Fluoro-2-deoxy-2-D-glucose-guided surgery” *Phys. Med. Biol.* 61 5837–50

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