Development of Real-Time Dwell Verifier for HDR Brachytherapy Based On 64 Channels of Scintillation Fiber Systeme

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INTRODUCTION

- High-dose-rate (HDR) brachytherapy (BT) : Radiotherapy technique that **treats cancer** by delivering doses **using sealed radioactive sources** inside the human body
- **Necessary to ensure the accuracy of the dwell positions and time**
- Development and Evaluation : A 64-channel **scintillation fiber-based real-time monitoring system (SFRMS)**
- **SFRMS : System for** verify the dwell position and time of the radioactive source in HDR BT

	Diodes	MOSFET	Ionization chambers	TLD	Diamond	Scintillators
Real-time	✓	✓	✓	✗	✓	✓
Low-energy	✗	✓	✓	✗	✗	✓
Small size	✗	✓	✗	✗	✗	✓
In-vivo/in-situ	✗	✗	✗	✗	✗	✓

METHOD

1. **Design & Development of SFRMS**
   - Measurement system : consisted of **64 scintillation fiber sensors** (installed around the tandem)
   - Data read-out system
     - Designed using LabView2012 (National Instruments, Austin, TX, USA)
     - Connected to the measurement system via an **optical fiber**
     - Consisted of a photomultiplier tube(PMT) and NI MAX (National Instruments, Austin, TX)
2. **Accuracy verification of applicators and real-time measurement system**
   - **Radioactive source movement accuracy verification**
     - Source moved in 2.5, 5.0, and 10 mm intervals
     - Dwell time 5 sec, High bias voltage 1300 V, Data sampled every 500 times
     - Fitting the data with Gaussian and inverse square functions
   - **Verification of accuracy and linearity according to irradiation time**
     - Dwell time 10, 20, 30, 40, 50, and 60 sec (Single position)
   - **Phantom study using a human-like silicon phantom**
     - Test with clinical treatment plan and silicon-based human phantom

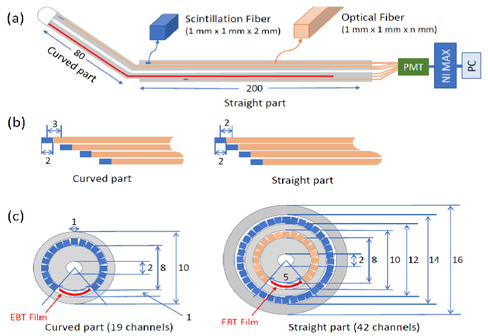
RESULTS

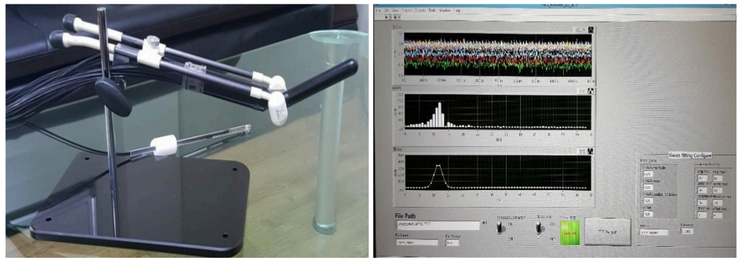
1. Diagram of scintillation fiber-based 64 channel applicator

(a) Side view of applicator

(b) Types of arrangement of curved and straight parts of scintillation fibers and optical fibers

(c) Cross sectional view of curved and straight parts of the applicator

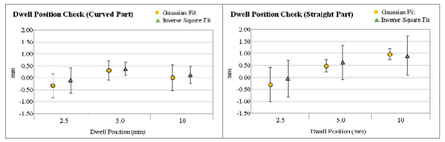




➢ **SFRMS : Scintillation fiber-based 64 channel applicator (Lt) and real-time measurement screen (Rt)**

2. Accuracy verification of applicators and real-time measurement system

- **Radioactive source movement accuracy verification**



- **Check the difference with real source position with measured data**
- Difference of dwell position
  - Gaussian fitting : 0.67 ± 0.23 mm
  - Inverse square fitting : 0.62 ± 0.71 mm
  - For the film measurement, the position difference between the source and film was found to be 0.95 ± 0.96 mm

- **Verification of accuracy and linearity according to irradiation time**
  - Dwell time 10, 20, 30, 40, 50, and 60 sec (Single position)
  - We measured the signal from the scintillation fiber for the radiation dose of the Ir-192 source as the irradiation time was increased in increments of 10 s from 10 s to 60 s.

Dwell time [sec]	Time difference [sec]	Signal Deviation	Signal linearity
10	0.0010	0.19	1.0
20	-0.024	0.23	1.9
30	-0.038	0.21	3.0
40	0.0080	0.21	4.1
50	-0.023	0.21	5.0
60	-0.067	0.21	6.1

- **Phantom study using a human-like silicon phantom**
  - Test with clinical treatment plan and silicon-based human phantom
  - Dwell position difference between plans and estimated data : less than 0.88 ± 0.29 mm (for Gaussian fitting), less than 0.85 ± 0.36 mm (for inverse square fitting)
  - The residence time error : 0.76 ± 1.3 s for patient 1 and 0.44 ± 0.40 s for patient 2.

Patient Case	Patient 1		Patient 2	
	Gaussian	Inverse Square	Gaussian	Inverse Square
mean ± STDV	-0.88 ± 0.29	-0.85 ± 0.36	-0.53 ± 0.46	-0.55 ± 0.30

CONCLUSIONS

- We developed a scintillation fiber-based monitoring system capable of real-time dose verification and evaluated the accuracies of the source movement and irradiation time in various cases.
- The SFRMS can accurately detect source dwell positions and times and provide real-time output time.
- The SFRMS might be clinically applicable for HDR brachytherapy for cervical cancers to monitor treatment accuracy and consistency.

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