Dosimetric Challenges of Preclinical FLASH Orthovoltage X-Ray System

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A new generation of preclinical orthovoltage x-ray system, the FLASH-SARRP, has been invented at the Radiation Physics Research Group in Johns Hopkins Medicine. This system supports the capability of producing kV x-rays at both ultrahigh (~100Gy/s) and conventional (~1.0Gy/s) dose-rate for irradiation of small animals. This study aims to investigate dosimetric challenges of FLASH-SARRP for its standard operation and provide recommendations for quality assurance.

Parallel-opposed (PO) rotating anode x-ray sources (150kVp) with 2.0mm nominal focal-spot powered at 100kW were utilized in the FLASH-SARRP. 30-mm separation distance between x-ray tubes was set to accommodate a 20-mm thick phantom, representing a mouse thickness. PO source geometry with mirrored beams compensates rapid depth-dose drop off and non-uniformity dose distribution due to heel effect. This design poses several dosimetric challenges of (1) alignment of PO x-ray beams, (2) coincidence of beams turning-on, and (3) consistent beam output between two sources. At short SSD, focal spot cannot be considered as a point source, thus source structure may affect the dosimetry. To address these challenges, several in-house equipment has been designed (Figure1) such as a high-precision alignment toolkit for mechanical alignment of PO tubes, and a dedicated jig to determine radiation center versus mechanical center and investigate the effect of source structure on small fields, e.g., mini-beams (<2mm). Solid water-equivalent phantom, parallel-plane and pinpoint chambers, and calibrated Gafchromic (EBT3/XD) films were used for dosimetric measurements.

Our results showed that radiation center is within 1-mm distance from mechanical center and two x-ray tubes can be aligned within 0.5 mm accuracy. These results support the use of mechanical center for sample positioning. Mini-beams (0.5–2mm) irradiation at ultrahigh dose-rates (>40Gy/s) for SFRT study can be achieved. The PO source setup allows ±5% uniformity in dose-rate distribution within the volume of 25mmx25mmx10mm in central region of the 20-mm thick phantom. Coincidence of beam firing and output consistency are within 1-ms and 5% between two x-ray sources, respectively.

Dosimetric and mechanical properties of FLASH-SARRP can be appropriately characterized utilizing special tools designed for this system. QA program requires daily, monthly, and annual tests for the optimal operation of the system.

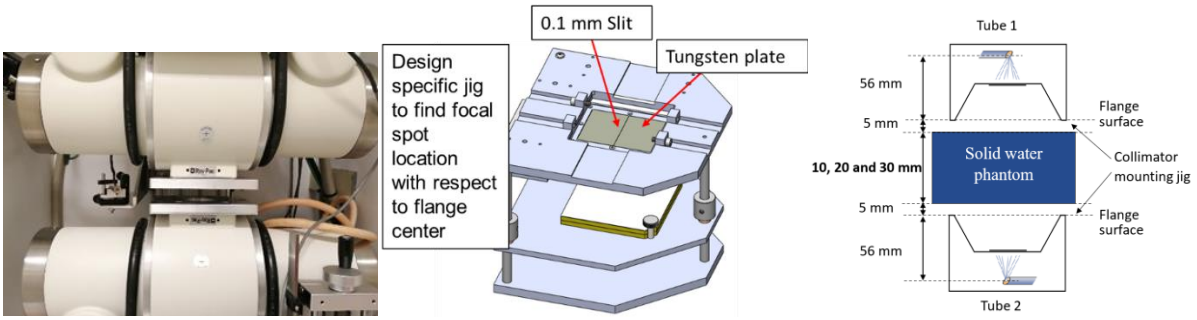

Figure 1 A- High-precision tube alignment toolkit, B- Focal spot positioning toolkit with 0.001 mm translation precision, C- Experimental setup for depth dose and profiles