Dynamic Modulated Brachytherapy (DMBT): Robotic Applicator Design

We have designed a novel system for intracavitary brachytherapy we call Dynamic Modulated Brachytherapy (DMBT). DMBT uses spatial modulation of a well-directed radiation source to achieve previously unmatched treatment plans for rectal cancer patients. Here, we will discuss the hardware necessary for implementing this revolutionary device.

The DMBT system consists of three major components: 1) shield and shield delivery module, 2) controlling module, and 3) DMBT controlling and monitoring software. See Figure 1. The shield is made of 95% Tungsten 3.5% nickel, and 1.5% copper iron alloy. The shield is a 1.9-cm diameter and 4.5-cm long cylinder with a 5.5-mm rectangular shape opening. An Ir-192 radiation source will be placed in the center of the shield through the aluminum pipe. The shield is rotated and translated with gear set (1:3) and linear actuator (2mm/turn). Two Nema-17 stepping motors are used for operating the gears and linear actuator. Both motors are controlled by a servo system, EvoDrive ST-17 (EVA Robotics, Queensland, Australia). Both EvoDrive ST-17s are triggered with four signals that are generated by USB-6009 DAQ (National Instrument, Austin, TX). The operating program using LabView (National Instrument, Austin, TX) controls input and output signals through the DAQ (Figure 1). With our in-house operating program, we can make and load plans for treatment. Checking the shield position is also possible through the operating program. For safety, a lexan sheath tube and emergency buttons (programmatic and hardware) are used.

The DMBT robot has 2 degrees of freedom, which are linear translation and rotation. With the servo motor system (2.5% error, 1.8° step size), the spatial resolutions are 0.0125mm (linear stage) and 0.012° (rotating). Both motors are set with 0.5s for each command. The maximum speeds are 450step/s (1°), 7500step/s (30°), and 12000step/s (5mm). EvoDrive ST-17 has 8 registers that are triggered with rising/falling edge and we use 4 registers with rising edge. The safety button is directly connected to the servo driver register, ‘initial position’ command so that any emergency stops will retract the applicator back to its starting position.

For treatment, the system needs more elements to support the DMBT robot; lexan sheath tube holder, DMBT robot security joint, and a system for reducing friction between the tube and shield (see Figure 2). The first three pieces should be securely attached, but easy to disassemble for safety reasons. The friction reducing module can increase security of the shield’s position and can reduce treatment. We will also refine our system to be more compact by using DC servomotors instead of the larger Nema-17 stepping motors.

In all, we have designed the hardware components of the DMBT system for rectal cancer. The system consists of two stepper motors for translational and rotational motion, which are controlled by in-house built LabView software. The system is accurate enough for the DMBT treatment delivery.

Figure 1. DMBT robot (left) and user interface of operating program (right).

Figure 2. Lexan sheath tube holder, DMBT robot security joint, friction-reduce system between tube and shield, and another design.