

# Modifying a Clinical Linac for Flash-RT Use

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**OBJECTIVES:** The purpose of our study was to modify a clinical linear accelerator (linac), in order to make it capable of producing ultra-high dose rate irradiation, with dose rates high enough ( $\geq 40$  Gy/s) for Flash radiotherapy (Flash-RT). Since our linac is used clinically, all modifications and the change to “Flash-mode” had to be quick, reversible, and possible without compromising clinical treatments.

**METHODS:** As a starting point, the electron gun and bending magnet current values usually used for 10 MV photon beams, were applied to the 10 MeV electron beam settings. Subsequently, the gun current had to be changed slightly to optimize for a sufficiently high and stable output. In order to control the machines output on electron pulse level, an Arduino Uno board using an Atmega microcontroller unit (MCU) was connected to an optocoupler circuit, controlling the pulses to the accelerators thyatron, preventing any discharge of the pulse forming network (PFN). To be able to operate the linac using the external electrical circuit, some of the machines dose and gun interlocks had to be overridden.

**RESULTS:** We were able to reach a dose rate high enough for Flash-RT just downstream of the MLC and at the motorized wedge position (inside the treatment head), with  $>60$  and  $>400$  Gy/s, respectively. Further downstream at the cross-hair level (outside of the treatment head), the dose rate was  $>25$  Gy/s. The output variation was 3-4% (standard deviation), with our current beam control system. The beam flatness was 5% at the cross-hair position. At the wedge position, the beam was circular of Gaussian shape with a ring pattern, resulting in a useable irradiation area (flatness  $< 10\%$ ) of 4.5 cm in diameter. (See Figure.)

**CONCLUSIONS:** We have shown how to modify a clinical linac to be able to produce dose rates high enough for Flash-RT. It is possible to control the delivery of radiation on an electron pulse level with a useable variation in output. We now aim fine-tune the dose delivery by using the on-board transmission chamber signal and manipulating the pulse amplitude.

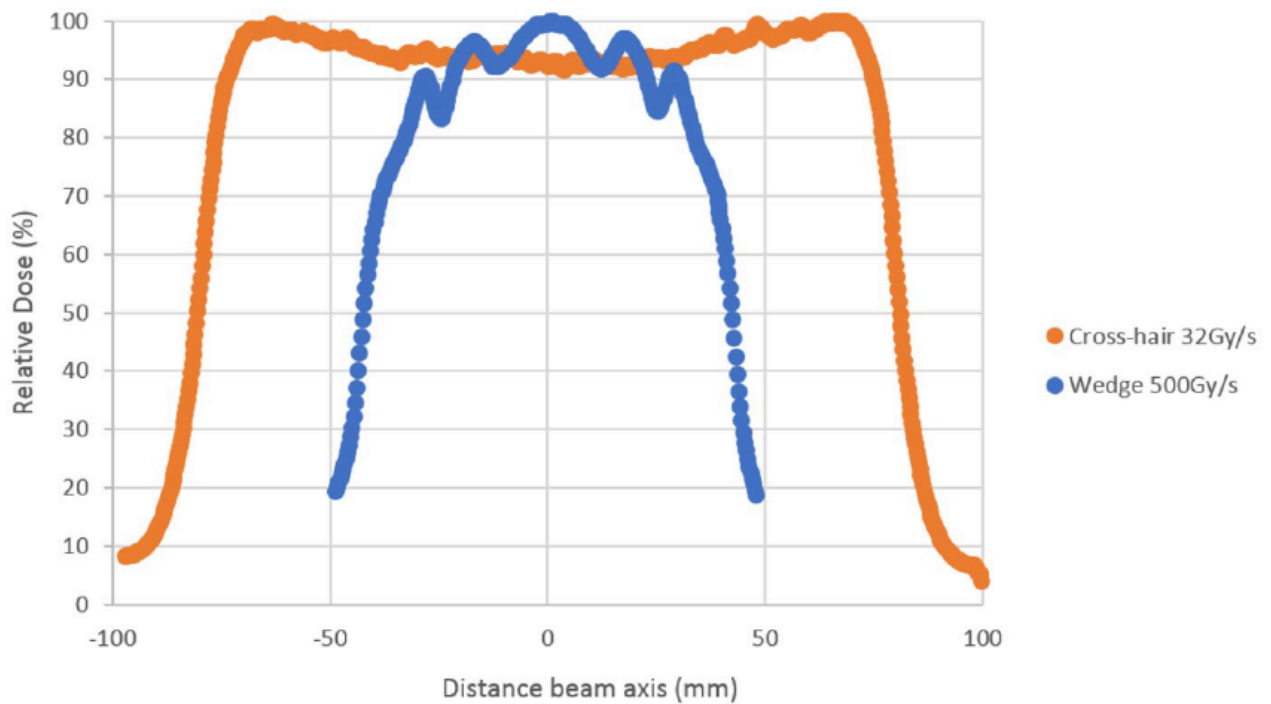
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## Beam Profiles at different irradiation positions



**Figure:** Field profile at the cross-hair level and at the position of the motorized wedge, with the dose rates at the normalization points specified.

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