Profile Measurements at Low Pulse Repetition Frequencies

1 Introduction

Panel devices like the STARCHECK [1] are commonly used to measure beam profiles from medical linear accelerators. Such data are needed for quality assurance purposes, or for the adjustment of beam parameters such as flatness or symmetry.

It has been reported [2] that at very low pulse repetition frequencies (6 pps) the noise of STARCHECK measurements becomes unacceptable, and averaging multiple measurements to reduce the noise would result in long measuring times. In the following we describe which new features of the STARCHECK^{maxi} [3] device allow accurate and fast measurements of beam profiles at pulse repetition frequencies as low as 6 pps.

2 STARCHECK measurements

STARCHECK features a measuring range of (1 … 20) Gy/min. The typical nominal dose rates of medical linear accelerators vary from 1 Gy/min to 8 Gy/min. A typical profile measurement at a nominal dose rate of 5 Gy/min and a pulse repetition frequency of 400 Hz is presented in Fig. 1.

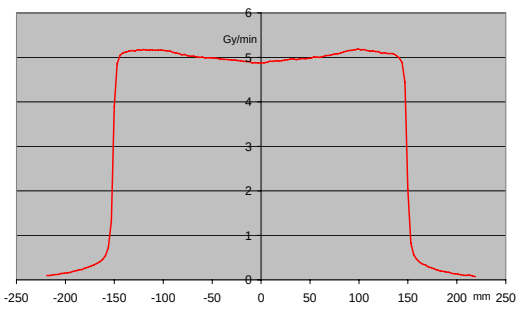

Figure 1: Typical STARCHECK dose rate measurement[1)] at 5 Gy/min and 400 pps. No noise filter was set. Elekta Synergy accelerator, 6 MV Photons, Field 30 x 30 cm².

In special cases the pulse repetition frequency of the linear accelerator can be reduced to 6 pps or less [4], resulting in nominal dose rates as small as 0,06 Gy/min. At such low dose rates, which are far below the measuring range, the STARCHECK device provides noisy profiles as depicted in Fig. 2. Such low dose rates, however, are not clinically used at presence.

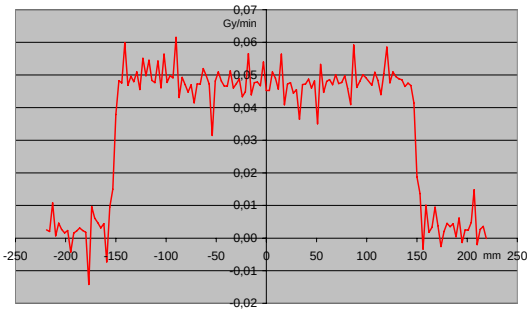

Figure 2: STARCHECK dose rate measurement at 0,06 Gy/min and 6 pps. The Medium noise filter was set. Note that STARCHECK's stated measuring range starts only at 1,0 Gy/min which is approx. 20 times more than the actual dose rate.

3 STARCHECK^{maxi} measurements

a. Low noise measurements

STARCHECK^{maxi} has been designed to cover a full 40 cm x 40 cm. In order to avoid the problems at very low dose rates described in chapter 2 an additional measuring range was implemented:

Low Dose Rate:	(0,05 … 8) Gy/min
High Dose Rate:	(0,5 … 50) Gy/min.

The low dose rate range is optimized for low offset current and noise reduction. In addition, during dose rate measurements further noise reduction is provided by a digital filter while the signal can still rapidly follow significant changes

of dose rate. Fig. 3 shows profile measurements from 6 pps to 400 pps, or from 0,06 Gy/min to 5 Gy/min. It can be seen that after normalization to the central axis value all profiles match perfectly. The standard deviation of the dose differences is approximately 0,4 % at 6 pps.

b. Triggered measurements

At low pulse repetition frequencies (PRFs) the pause time between two subsequent pulses becomes relatively large, e.g. 166 ms for a PRF of 6 pps. When electronics with considerable noise contribution is used, one method to avoid noisy profile measurements is the accumulation of charge only during a radiation pulse. During the pause times between radiation pulses the signal is discarded.

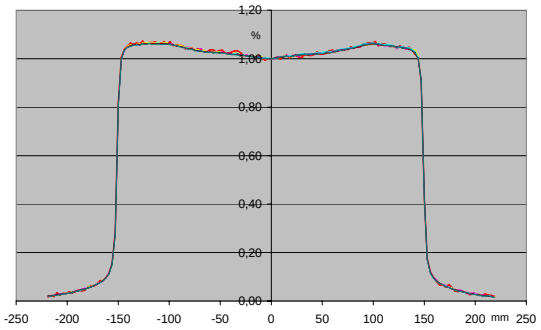

Figure 3: STARCHECK[maxi] *dose rate measurements at dose rates from 0,06 to 5 Gy/min and pulse frequencies of 6, 12, 25, 50, 100, 200 and 400 pps. All measurements were made with a Medium noise filter and the appropriate measuring range Low or High, depending on the dose rate. The worst case profile (6 pps) is printed in red and in bold.*

Such self-triggering circuits recognize the presence of radiation and initiate automatically charge accumulation. PTW has implemented triggering capability in the STARCHECK*maxi* obtaining similar results as shown in Fig. 3 for a PRF of 6 pps. Triggered measurements are very effective in suppressing offset shifts (leakage currents) but they are prone to noise for two reasons:

- An electrometer that is designed to measure individual pulses from an accelerator needs to have a short time constant (high frequency pass filter), resulting in noise components on the signal.

- At a dose per pulse of 0,1 mGy the charge created in a STARCHECK*maxi* ionization chamber is in the order of 200 fC. This charge can only be measured accurately by averaging over several accelerator pulses, or by increasing the time constant of the electronics.

In summary, PTW's investigations revealed no advantage of the triggered measurements over the low noise measurements as described in chapter 3a.

4 Summary

In contrast to the STARCHECK device the large scale model STARCHECK*maix* features a low noise, low dose rate measuring range allowing profiles at a pulse repetition frequency as low as 6 pps to be measured without excessive noise on the signal. An optional trigger technique was tested but not implemented in the final product as the results were comparable to those using the low noise measurement technique.

5 References

[1] PTW-Freiburg, Brochure STARCHECK, 2009

[2] Elekta, Crawley, private communication, 2009

[3] PTW-Freiburg, Brochure STARCHECK*maxi*, 2009

[4] Elekta, Crawley, technical documentation, 2009

[1)] The measurement presented in Fig. 1 was measured with a STARCHECK*maxi* device using the same amplifier and range settings as used by the STARCHECK.

PTW-Freiburg
Lörracher Straße 7 • 79115 Freiburg • Germany
Phone +49 761 49055-0 • Fax +49 761 49055-70
info@ptw.de • www.ptw.de