Investigating the optimal scanning resolution for radiochromic EBT-2 films using an Epson 10000XL flatbed scanner

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Purpose

It has been shown that a lower scanning resolution leads to reduced signal noise[1] on EBT2 film scans. Since a precise digitization process is vital for reliable quality assurance, the purpose of this work is to determine the optimal scanning resolution for an Epson 10000XL scanner and the analysis of radiochromic EBT-2 films. While the manufacturer suggests 75dpi as scanning resolution[2], in this work we will investigate the necessary sampling distance for very steep dose gradients close to the theoretical limit of minimized lateral scattering influence as may occur in shallow depths or stereotactical treatments with cone collimators.

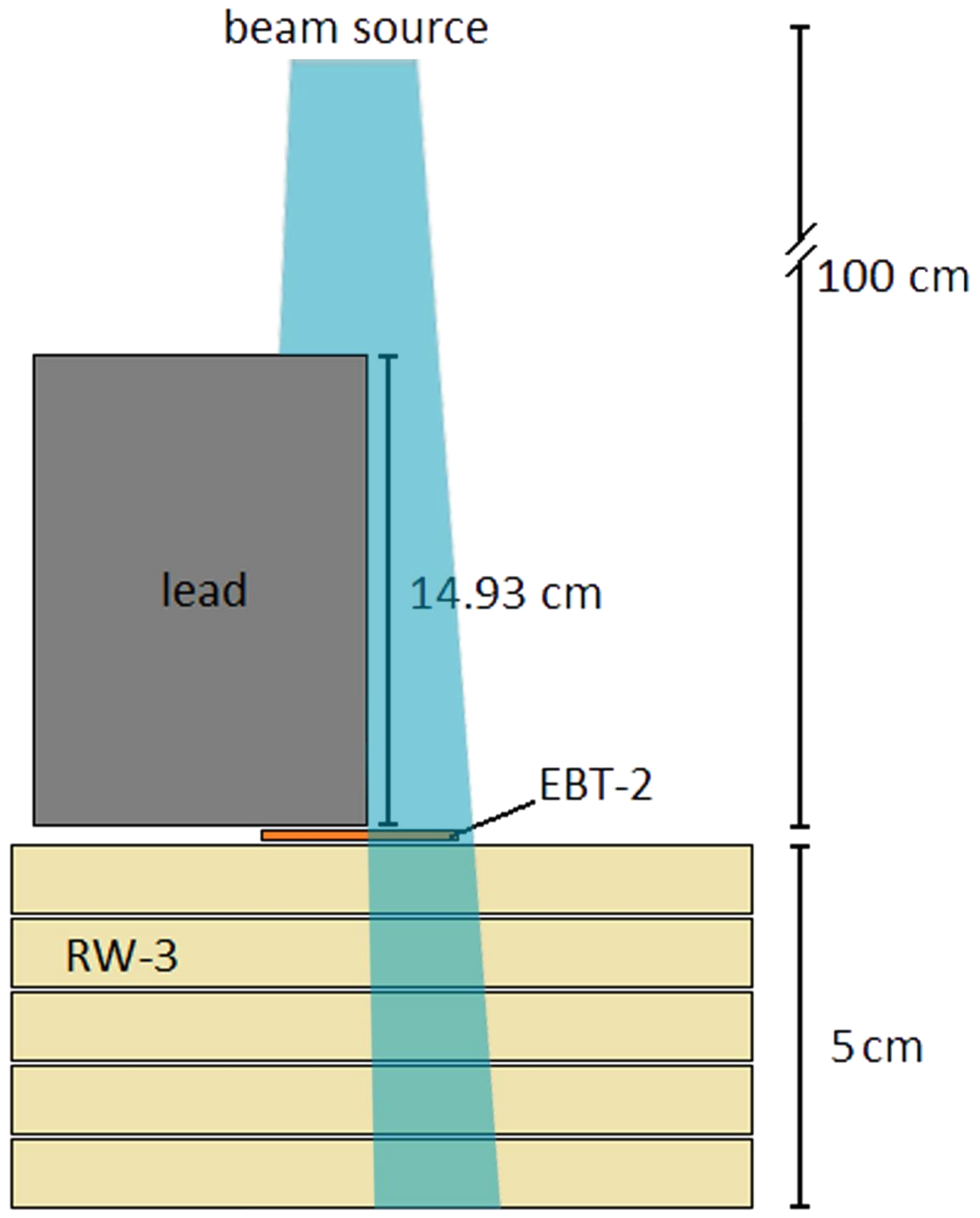

Figure 1: The setup used to create a sharp step dose profile

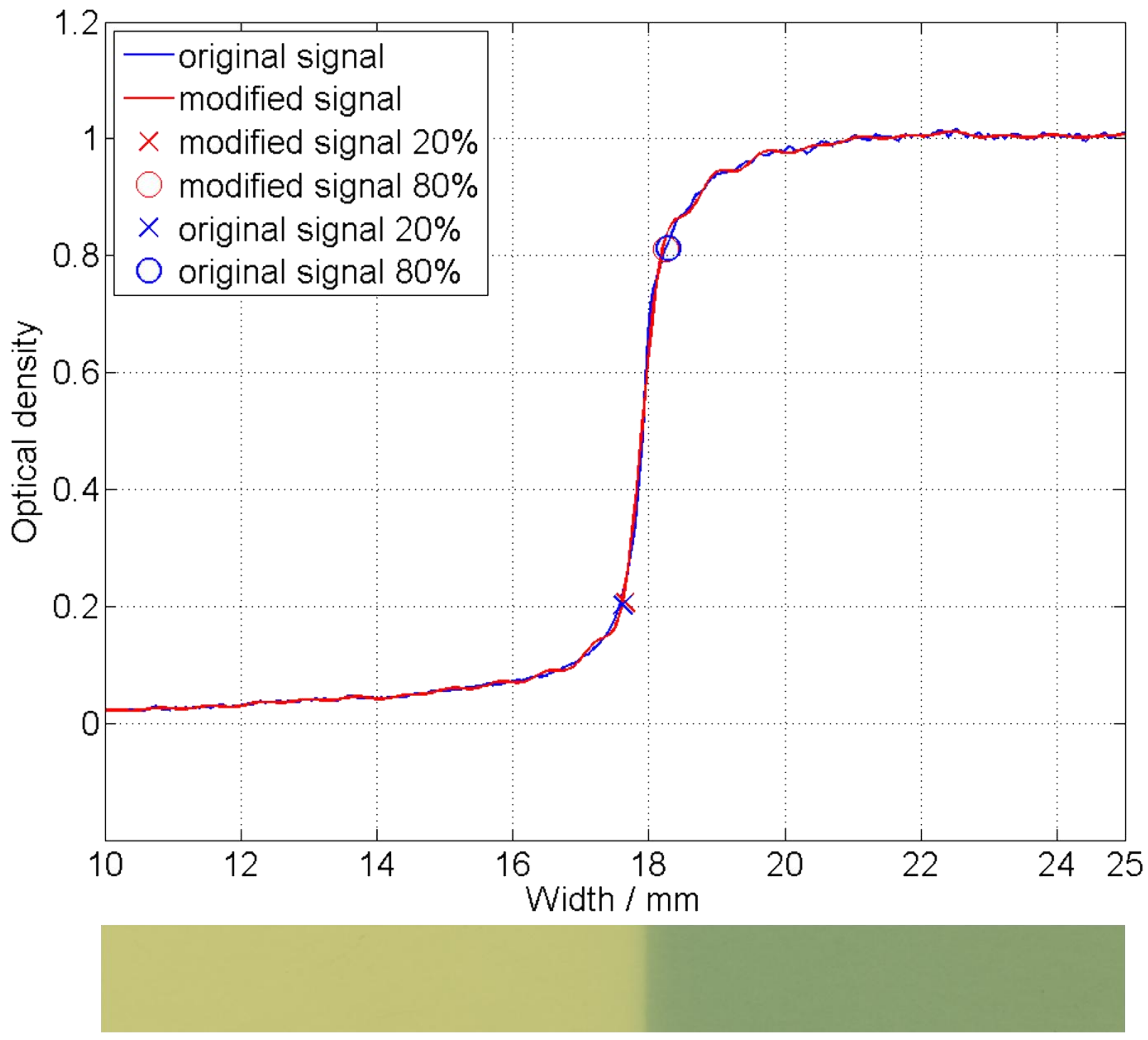

Figure 2: The blue line profile stems from the EBT2 scan shown below. The red line profile was reduced of all frequency components above 36dpi. The required scanning resolution is twice the cut-off frequency.

Setup: A setup was created, in which one half of a 6×6cm² EBT-2 film was shielded to exposure using a 15×5×10cm³ lead block to obtain a sharp step dose profile. The film itself was placed on top of a 5cm RW3 stack. The setup is shown in figure 1. Preliminary investigations were performed with a second RW3 stack between the lead and film acting as build-up material.

Irradiation: Using a Siemens Primus linear accelerator operating at 6/15MV nominal energies, the setup shown above was exposed to 600MUs at 6MV and 800MUs at 15MV respectively. The setup with build-up material was exposed to 400MUs at 6MV and 500MUs at 15MV.

Digitization: Initial image acquisition was performed at 600dpi to minimize information loss. The films were fixed with a frame to prevent interference patterns[4] (Newton rings) on scanned images and ensure reproducible positioning of the films on the scanning bed.

Results

The sharpest step dose profile with a penumbra width of 0.64mm was created by the 6MV photon beam and no build-up material. The step dose profile was reproduced with good quality after its spectrum had been cut at 36±1dpi. Therefore, a scanning resolution of 72±2dpi is necessary. The remaining oszillation of the reproduced profile (figure 2) is a residue of the hard cut-off in the frequency domain.

Analysis: Prior to evaluation, a film uniformity error correction algorithm[3] was applied to the scanned images. The average of five neighbouring line profiles was Fourier-transformed using the Fast Fourier Transformation (FFT) algorithm in Matlab (*The MathWorks* Inc, Natick, MA). The frequency domain was then reduced of all frequency components above a cut-off frequency ω_{cut} and the original image was reconstructed with the inverse FFT operation. An example of a high resolution step dose profile and its reconstruction is shown in figure 2. In order to find the minimal cut-off frequency, which allows the reconstruction of the high resolution step profile, the cut-off frequency was increased stepwise until the penumbra width difference was less than two pixel at 600dpi (84.7µm). According to the Nyquist-Shannon sampling theorem, the required sampling frequency (scanning resolution) is twice the highest frequency component of the sample (cut-off frequency).

Conclusion

A scanning resolution of 72±2dpi is sufficient even for steep dose gradients. Signal noise reduction without loss of significant information can be achieved by reducing the scanning resolution to this level. The investigation of step dose profiles created by a cyber knife is planned.

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Literature:

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4. Kairn T, Aland T, Kenny J 2010 Some EBT2 problems solved *Phys. Med. Biol.* 55(15): L37-L42