QUALITY ASSESSMENT OF SCINTILLATION DETECTOR IN SEM USING MTF

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One of the recent trends in S(T)EM is increasing of the e-beam scanning speed. In general, higher speeds decrease object degradation and prevent image artifacts caused by slow electrical discharging. However, the increase of the scanning speed is limited by the time response of the signal-electron detector [1]. When the detector response is slower than the scanning speed, it can have negative influence to the quality of the scanned image, such as contrast reduction and image blurring. Usually, the rise and fall edges of the time response curve to a square electron pulse have more complex form, such as a multi-exponential function of time. Evaluate and compare the time-dependent edges in context of their influence on the image quality is rather complicated. Therefore, we propose to express the detector time response by the modulation transfer function (MTF), which contains all relevant information. It can give the answer to the important question, what maximum scanning speed can be used not to significantly decrease the image quality.

MTF represents relative image contrast as a function of spatial frequency [2]. The spatial frequency is expression of the image detail; higher spatial frequencies generally correspond to fine details, low frequencies represent global information about the shape. The spatial frequency can be expressed in units of cycles per pixel ($pixel^{-1}$), which means how many image alternations from a black point to a white point in the distance of one pixel are presented. Thus, the spatial frequency in the units $pixel^{-1}$ is always lower than 1, because a meaningful black-to-white alternation occupies distance above one pixel.

MTF can be calculated as the magnitude of the Fourier transform of the point spread function (PSF). PSF represents a line-scan of one pixel point broadened by the detector time response. In this work, PSF of the detector was acquired using the CL device [3] in which the detector can be irradiated by electrons for a variable time. Thus, one pixel line-scan can be simulated by irradiation for period arising from defined scanning speed. We aimed to measure PSF and calculate MTF of a scintillation detector, which is the most used type of electron detector in S(T)EM. The scintillation detector used consisted of single crystal scintillator produced by CRYTUR, photomultiplier tube Tesla 65-PK-415 and preamplifier Hamamatsu C9663. The scintillation detector was alternated using three samples of scintillators: YAG:Ce #1 with high concentration of the defect centers, standard YAG:Ce #2, and standard YAP:Ce.

The fall edges of the time response for the three alternative of the scintillation detector are shown in Fig. 1. One can conclude that the curve with the shorter decay (YAP:Ce) is better for fast scanning. However, these curves don't contain any explicit information about the resulting image. MTFs for a specific scanning speed are drawn in Fig. 2. The MTF curve with bigger area under the curve represents higher image contrast for higher spatial frequencies. In addition, the spatial frequency 0.5 $pixel^{-1}$ corresponds to difference between two image pixels, so MTF at this spatial frequency is particularly important.

In Fig 3 is shown that the contrast between the adjacent pixels increases with the decreasing scanning speed. The influence of the speed increase on contrast between two pixels is depicted in Fig. 4. This graph answers the question what maximum scanning speed can be used, if one requires contrast between two pixels at least, let say, 50 %. To conclude, MTF seems to be very useful to express the influence of the detector time response on the resulting image quality. For complete detector evaluation, MTF should be extended by the DQE function, which quantifies the noise performance of the detector.

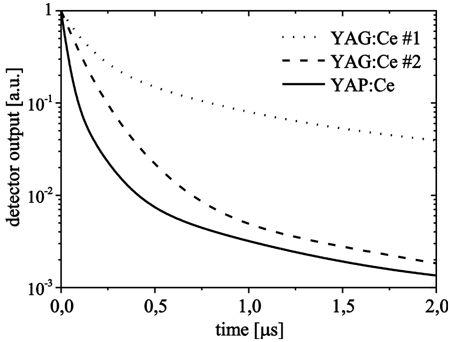

Figure 1 The fall edges of the time response to 100 ns square electron pulse of the three scintillation detector alternatives.

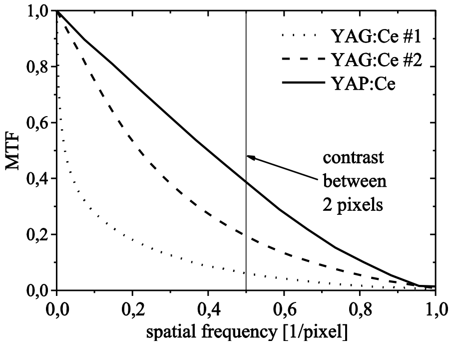

Figure 2 MTF of the three scintillation detector alternatives. The scanning speed is 100 ns/pixel.

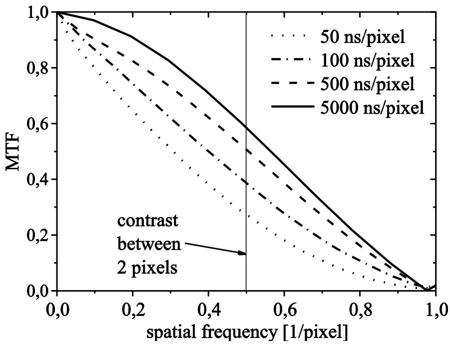

Figure 3 MTF of the scintillation detector using YAP:Ce for various scanning speeds.

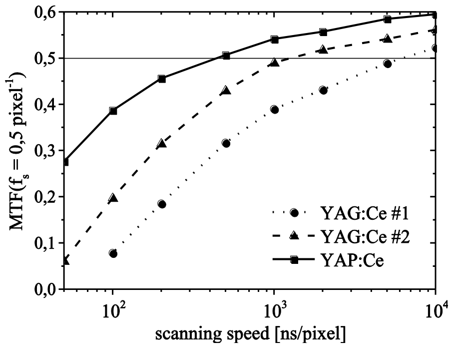

Figure 4 MTF at spatial frequency 0.5 $pixel^{-1}$ as a function of the scanning speed. MTFs are drawn for the three scint. detectors alternatives.

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