EXPERIMENTAL AND SIMULATIVE METHODS FOR SCINTILLATION DETECTOR OPTIMIZATION

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In S(T)EM an image is formed using a focused electron beam, which is scanning across a very small part of the specimen surface. A scintillation detection system consisting of a scintillator, light-guide and photomultiplier (PMT) processes only one pixel of the image at any given moment. Not only efficiency, but also kinetic properties of such a system are of great importance. Scintillation detectors can show a noticeable difference in detective quantum efficiency (DQE) due to the bad electron-photon energy conversion and/or light losses in the optical part of the detector. Up to now, some studies were engaged in measurement of S(T)EM detectors performance ascertaining very low DQE for some detectors, but no suggestion has been made to optimize the detector set-up. To find the neck of a detection system, one must examine the whole detection path (Figure 1) step by step.

Electron-photon conversion optimization

The main component of a scintillation detector is the scintillator. The scintillator provides energy conversion from electrons to photons. It has to be very fast, possess high efficiency of electron-photon conversion, and it has to emit the light in the spectral region of high PMT sensitivity. To optimize the scintillator one must use a direct excitation method and measure its cathodoluminescent (CL) properties, i.e. its energy conversion efficiency, decay time and spectral emission characteristics. These CL properties can be measured using the equipment built in our laboratory [1]. The excitation unit of this equipment is formed by a column of an electron microscope with an electrostatic deflection system and a blanking diaphragm, so the continuous properties (CL efficiency) as well as kinetic properties (rise and decay times) can be measured. The equipment is controlled and the data are processed by a personal computer using IEEE-488 (GPIB) interface bus. Some tens of different single crystal materials were measured at our laboratory [2]. Of these, single crystals of YAG:Ce, YAP:Ce and P47 were chosen as the most interesting ones for S(T)EM applications. Alternatively, the transparent sintered YAG:Ce ceramics with optically good isotropy and pore-free structure (as presented by Ikesue [3]) seem to be interesting.

Optical properties optimization and PMT choice

In the separate step of optimization the materials of the light-guide, photocathode, conductive and reflective films and of the optical cement have to be evaluated. Optical characteristics (such as optical transmittance, position and width of the emission band, spectral response of and matching to PMT photocathode sensitivity) have to be utilized at this step of optimization. In fact, the PMT choice, including its photocathode matching, is a relatively simple task, because PMTs are well developed commercial components with precise data sheets.

Photon collection and system geometry optimization

Design of the system including geometry is the most demanding step of optimization. The efficient geometry is dependent on a lot of optical quantities of all components used, and no simple method is available for this step. To determine the photon transport efficiency, the Monte Carlo simulation method has been developed [4]. In Figure 2, the significance of this step of optimization is demonstrated by presenting the efficiency of the bad and good geometry of the BSE scintillation detector for the S 4000 Hitachi SEM. The good system possesses transport efficiency of about 400 % compared with the bad one.

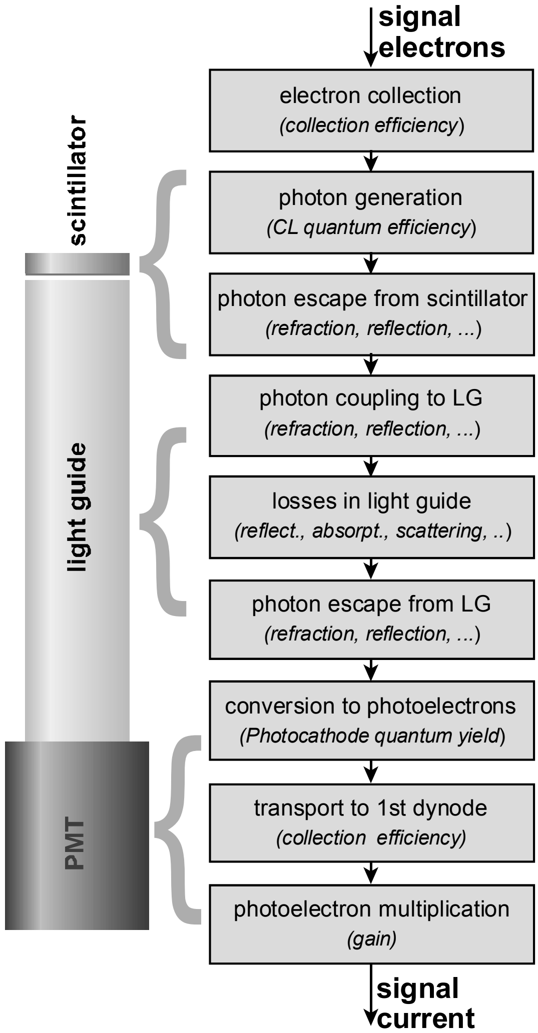

Fig. 1. Outline of detection path in a S(T)EM scintillation detector. To find the neck of a detection system, one must examine the whole detection path step by step using experimental and simulative methods for individual parts and/or assemblies of the detector.

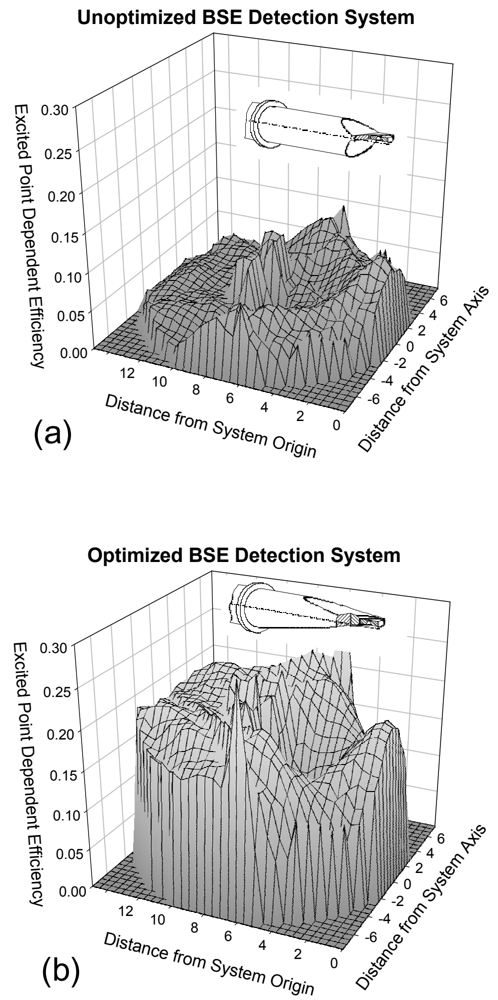

Fig. 2. Monte Carlo simulation of the efficiencies of the photon transport through scintillation detection systems possessing (a) the bad (b) the good geometry. 3D graph presents the dependence of the photon transport efficiency on the coordinates of the excitation point at the surface of the scintillator.

Detector configuration, position, and electron collection optimization

The previous steps of optimization are not related to the detector surrounding, which substantially influences collection of signal electrons. Interesting results of collection efficiencies of scintillation detection systems have been published using simulation of secondary electron trajectories [5].

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