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Efficiency of SEM/STEM Scintillation Electron Detectors with Edge Guided Signal

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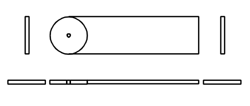
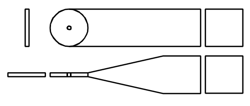
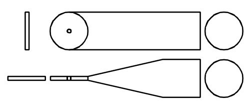
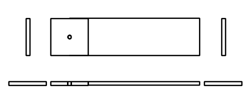
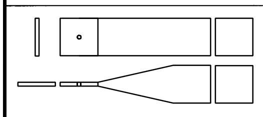
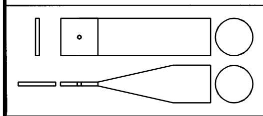
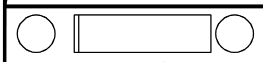
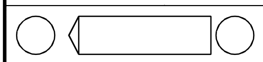
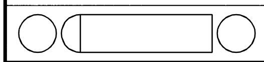
Some Image modes of SEM or STEM require that the electron impact active surface of the detector of signal electrons should be fitted into a very small space, mostly symmetrically around the primary electron beam. This demand is easily fulfilled for semiconductor or channel plate detectors. However, they possess a low detective quantum efficiency and/or a high decay time, so that they are often unusable. Therefore, scintillation detectors in non-classical arrangements are applied. Here the signal must be guided through an edge of a plate scintillator[1]. The input end of the light guide must be narrow, to match to the edge of the scintillator, and the output end may be enlarged, according to the input window of the photomultiplier. The design of such a scintillator - light guide system with a high efficiency of the light transport is the key problem of the detector design.

Generally, the efficiency of these edge guided signal (EGS) scintillation detectors is very hard to estimate. Owing to the low symmetry of EGS detection systems, the efficiency can hardly be calculated analytically. For this reason, the Monte Carlo (MC) simulation method has been created. The first results obtained by this method are presented in this paper. The new MC model includes the same physical processes as the previous one[2] which is intended for a base guided signal (BGS) rotationally symmetric Everhart-Thornley detector. However, a quite new algorithm has been written for the interaction of a photon with a surface, so that now the detector system may include all surfaces (or their parts) which satisfy the following demands: (1) Surfaces are given by a rotationally symmetric body or by a plane, (2) the axis of a body of each non-plane surface must be parallel with any axis of the coordinate system and (3) the normal of each plane must be parallel with any plane of the coordinate system. This means that the new program enables the calculation of the efficiency of light transport for nearly any configuration of the scintillation detector. The source code of the program has been written in Fortran 77 and can be, therefore, run on computers of different classes.

An example of the MC simulation method, i.e. the results of modelling very simple EGS scintillation detector configurations, is shown in Tab. I. The YAG:Ce single crystal and PMMA were materials used for scintillators and light guides, respectively. Two shapes of scintillators with Al deposited electron impact surfaces, in combination with three shapes of light guides, were tested. The output edge of the scintillator (alternately polished and matted) was connected to the input end of the light guide by using optical cement. Two longitudinal sections (perpendicular to each other) and the front and back views of the configuration geometry are shown. The circular and the square profiles of scintillators were 20 mm in diameter and side length, respectively. All light guides were 60 mm long. To estimate the influence of the hole in the scintillator, simulation of each configuration with and without the hole was carried out. For comparison, efficiencies of light transport through classical BGS rotationally symmetric detectors with a disc, conical and hemispherical scintillator, respectively, are also shown in Tab. I. Results of mean, minimum and

Table I. Efficiency of light transport through EGS and BGS scintillation detectors.

front view / longitudinal sections of the detector / back view	description	matted scintil. output	hole	EFFICIENCY OF LIGHT TRANSPORT mean	min.	max.
	Circular plate scintil-	yes	no	0.0052	1.2E-04	0.0316
	lator with strip light	yes	yes	0.0065	8.3E-04	0.0318
	guide	no	no	0.0046	2.0E-04	0.0341
		no	yes	0.0066	5.7E-04	0.0341
	Circular plate scintil-	yes	no	0.0526	0.0187	0.1629
	lator with light guide	yes	yes	0.0531	0.0156	0.1638
	widening to square	no	no	0.0698	0.0083	0.1810
	profile	no	yes	0.0696	0.0086	0.1814
	Circular plate scintil-	yes	no	0.0521	0.0204	0.1440
	lator with light guide	yes	yes	0.0526	0.0144	0.1606
	widening to circular	no	no	0.0688	0.0100	0.1740
	profile	no	yes	0.0685	0.0102	0.1745
	Square plate scintil-	yes	no	6.6E-04	4.5E-05	0.0034
	lator with strip light	yes	yes	0.0017	1.7E-04	0.0089
	guide	no	no	1.2E-04	9.7E-06	0.0017
		no	yes	0.0014	1.1E-04	0.0070
	Square plate scintil-	yes	no	0.0561	0.0119	0.1674
	lator with light guide	yes	yes	0.0562	0.0101	0.1702
	widening to square	no	no	0.0649	0.0145	0.1796
	profile	no	yes	0.0657	0.0084	0.1850
	Square plate scintil-	yes	no	0.0556	0.0122	0.1604
	lator with light guide	yes	yes	0.0564	0.0103	0.1681
	widening to circular	no	no	0.0644	0.0140	0.2021
	profile	no	yes	0.0651	0.0081	0.2073
	Disc scintil. with	yes **	no	0.186	0.174	0.196
	cylindr. light guide *	yes	no	0.025	0.011	0.035
	Conical scintil. with	yes	no	0.138	0.091	0.155
	cylindr. light guide *	no	no	0.179	0.126	0.352
	Hemisph. scintil. with	yes	no	0.0507	0.0406	0.0838
	cylindr. light guide *	no	no	0.0680	0.0082	0.1305

* BGS rotationally symmetric system

** no optical cement was used

maximum efficiencies over the electron impact surface of the scintillator are given for each configuration.

It can be seen, that EGS configurations are less efficient than classical BGS ones. All EGS configurations with widening light guides are approximately as efficient as the BGS rotationally symmetric detector involving a hemispherical scintillator, with the hole having a negligible effect. The matted scintillator output decreases the efficiency by about 15 and 25 %, and therefore it is disadvantageous. Of the examined set of EGS detectors, the most convenient is that one with the circular scintillator and light guide widening to a circular profile. It possesses nearly the highest mean efficiency and the highest homogeneity of efficiency over the electron impact surface of the scintillator. Furthermore, it is, as well as its flange, easy to fabricate. Detectors with strip light guides are inefficient.

References

1. B. Bauer and B. Egg: An Optimised Back Scattered Electron Detector for the Scanning Electron Microscope. *Pract. Met.* **21** (1984), 460-471.
2. P. Schauer and R. Autrata: Light Transport in Single-Crystal Scintillation Detectors in SEM. *Scanning* **14** (1992), 325-333.