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On the use of chaotic billiard geometry to improve the light output of a scintillator

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Detector geometry providing a chaotic dynamics of light rays has been confirmed experimentally to be among ways to improved light output of scintillators. For rectangular and cylindrical shapes, this can be attained by rounding their vertices and edges. Experiments with such detectors revealed a light output improvement in chaotic dynamics detectors up to 20 % as compared to samples with regular light ray dynamics.

Экспериментально подтверждено, что одним из способов улучшения светового выхода сцинтилляторов является переход к геометрии детектора с хаотической динамикой световых лучей. Для детекторов прямоугольного и цилиндрического типов это может достигать скруглением их вершин и ребер. В эксперименте с детекторами такого типа обнаружено повышение светового выхода до 20 % для образцов с хаотической динамикой по сравнению с образцами с регулярной динамикой световых лучей.

Development of scintillator-photodiode detectors (SD) with alkali halide, semiconductor, and oxide scintillator types is among urgent tasks in the modern materials science [1, 2]. A factor restricting the use of SD consists in a relatively low sensitivity to β and γ radiation as well as spectrometric characteristics that do not answer to modern requirements. On the other hand, considerable technical problems are to be get over in development of novel scintillators with a high conversion efficiency. The SD parameters can be improved by increasing sensitive volume of available scintillators and using photodiodes (PD) of corresponding size. The use of detectors with large sensitive areas results in the scintillator "overhanging" over the PD input window causing an appreciable deterioration of the detector output signal [3].

Another way to improved SD sensitivity consists in the use of such shapes of the scintillating crystal that provide optimum light collection condition therein and thus an increased light output. It is just the use of stochastic approach where the improved light output can be attained by finding the scintillator geometry providing chaotic mixing of light rays that offers certain progress in this way.

To solve the problem of chaotic light collection in scintillators of arbitrary geometry, a novel theoretical approach has been proposed where a mathematical billiard is considered to be an adequate model of physical detector. Under this approach, the light ray pattern is considered within the phase space of a dynamic system corresponding to the detector (billiard). Therewith, the phase image of light collection reveals changes and singularities of the ray pattern that are not observable in the usual geometric space. This assists in establishment of more deep physical reasons for light trapping that accompanies the light collection and to propose novel methods to overcome it. The light trapping is associated with the presence of a regular (inte-