What Life Scientists Should Know About Molecular Imaging

Nuclear Imaging: Physical Principles and Instrumentation

SPECT and PET Detector Technologies

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Learning Objectives:

- To obtain a basic understanding of the physical principles of radiation detection
- To learn the essential principles of inorganic scintillators and their most important properties
- To acquire basic knowledge of photosensors and readout electronics relevant to radiation detection

This lecture provides a basic introduction into the physical principles of the detection of gamma radiation in nuclear medicine imaging (preclinical PET and SPECT in particular). The emphasis lies on scintillation detectors, which are the most commonly applied type of detector. The interaction of the gamma quanta with the scintillation material forms the basis for the signal formation. Therefore, a basic understanding of the different types of interaction that may occur is required to understand the operation and performance of a scintillation detector. Furthermore, the physics underlying the conversion of the energy of a gamma quantum into scintillation photons will be briefly discussed. The next step in the detection chain is the conversion of the relatively weak light signal emitted by the scintillator into an electronic signal by means of a photosensor. An important aspect of detector design is the optimization of the crystal-photosensor geometry in order to achieve a good balance between multiple and often conflicting requirements on the detector performance at reasonable costs. The classical and still most widely used photosensor is the photomultiplier tube (PMT). For a long time, the relatively large internal gain and low noise of these devices made them the first, if not only, choice for the detection of very small amounts of light, down to the single photon level. However, advances in semiconductor technology have recently given birth to several new types of low-level light sensor, some of which have distinct advantages compared to PMTs for certain applications. Examples include avalanche photodiodes (APDs) and silicon photomultipliers (SiPMs). These solid state devices enable new crystal-sensor geometries, as well as new combinations of imaging modalities such as PET and MRI in highly integrated multimodality systems. For optimum detector performance, the use of dedicated front-end electronics, adapted to the specific properties of the scintillator-photosensor combination, is paramount. The readout electronics and data acquisition (DAQ) architecture furthermore need to be tailored to the imaging modality and application, as the corresponding requirements may vary greatly. The overall detector performance, expressed in terms of parameters such as spatial resolution, energy resolution, timing resolution, and detection efficiency, is the result of the design choices made with respect to each of the above components making up the detection chain (scintillation material, photosensor, detector geometry, electronics). Since the performance of the detectors impose ultimate limits on the image quality achievable with any scanner, it is not surprising that many research groups work on new and better detectors. Some of these recent developments will be briefly highlighted in this lecture.

Relevant Publications:

1. van Eijk, CWE. Inorganic scintillators in medical imaging. Phys Med Biol. 47:R85-R106, 2002
2. Lewellen, TK. Recent developments in PET Detector technology. Phys Med Biol. 53:R287-R317, 2008

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