Development of Gamma and Beta probes for radioguided surgery

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The proposal of this document is lay down some general guidelines for the study. Discussion on this topic can be found in https://indico.cern.ch/category/9126/

1) Introduction

The use of radiation probes in radioguided surgery has been demonstrated as an effective and well established procedure to track and remove tumoral tissue [1,2] for many decades. The recently development in detectors [3] and commercial electronics devices (suitable for front end signal processing like amplifiers, digitizers and programmable logic) presents an opportunity to push the methods in this area beyond the state of the art. Moreover, new procedures for non-tumoral treatments [4] represents an opportunity to investigate the use of the technique with more specific probes. While most of the probes and application relates to detection of gamma radiation (produced by some common isotopes like X,Y,Z etc.) recent developments on detection of beta radiation may bring some advantages on some specific location and tissue investigation, as the electrons have a very short range (few mm) and do not produce a background that may hinder low activity tissue areas, which may be left without removal. Hence, the investigation of new detector geometries and probe configurations, as well as new ideas on signal processing and acquisition is an area well worth investigation that can bring immediate applicability on medical procedures .

2) Motivation

As we already noted in the introduction, the exploration of new detectors and scintillator materials and geometries, signal processing and acquisition techniques that are now commonly applied in the area of radiation detection (homeland security, high energy physics, nuclear physics etc.) can improve the performance of the current available probes. We propose to study this using the state of the art detector and scintillator materials, first using simulations [5,6] to evaluate the performance gains and then develop a small prototype where the front end processing electronics can be developed and tested. We envisage the involvement of the medical community since the early stages of this project, so it can be targeted towards the real needs of the users.

3) Initial Implementation

One of the main problems related to the use of probes in radioguided surgery are related to the probe sensitivity and directivity [7]. We propose to investigate how new high sensitivity detectors [8] coupled with high yield scintillator materials can improve the probe sensitivity. The background caused by Compton scattering in the tissue is irreducible, but can be treated by further signal processing with the aid of extra detectors (or by segmentation of the main detector). Furthermore, this also can provide some directivity information, and it is left to the simulation and tests to answer if this information can be useful to better guide the probe in a surgical procedure.

The simulation framework will be developed using GEANT4 and/or GATE and we will start with a common monolithic detector and scintillator surrounded by tissue to understand how the background affects the probe sensitivity and directivity. Based on that, new scintillator materials and geometries (including more than a single detector) can be tested in simulation. We call this a *baseline device*.

3.1) Baseline simulation

Bearing this, the first geometry for the baseline device will be :

- A cylindrical scintillator of (define the scintillator material) attached to a silicon photomultiplier . For the moment we will not choose a commercial available size but will try to stay close to what is available.
- A surrounding uniform tissue medium (choose the tissue)
- One or more localized radiation sources, mimicking the tumor region(s) . This needs some information from the medical community (size, activity, isotope) so we can start with something close to the reality.

3.2) Baseline signal processing

Given the rapid development and availability of electronic devices, we do not foresee the need to start early with the investigation of the electronics. Most of the devices currently available commercially can handle the necessary level of integration and functionality necessary. We can, however, steer the ideas towards some specific method as we gain insights from the simulation.

4) Further developments and ideas

We can profit from our expertise in the area of radiation detection, simulation and signal processing to rapidly investigate if this proposal can provide any useful and significative improvement of the current state of the art . If we succeed, we will investigate the feasibility of using small scale imaging detectors [9] as an advanced location device. All this should first be backed up by simulation, and then tested in a mockup and in-vivo subjects.

5) References

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