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Single Fiber Beta Detector for Stereotactic Biopsy and Intraoperative Lumpectomy of Breast Cancer¹

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Abstract

We have developed an intraoperative probe for use in early detection of breast Cancer and aiding lumpectomy. The probe consists of a small plastic scintillator, 0.8mm diameter and 3mm length, coupled to a single clear optical-fiber strand, and solid state photomultiplier. Due to the small size of the probe, it can be placed inside of a small gauge biopsy needle. The scintillator is very efficient in detecting betas and positrons while being very inefficient to energetic gammas due to its small size and low density. High quantum efficiency, 80%, and high gain obtainable, solid state photomultiplier makes the probe very low noise device in detecting beta particles. Intrinsic resolution of the probe is expected to be around 1 millimeter. Preliminary results using beta sources and a rat bearing R320 adenocarcinoma tumor were very successful.

I. INTRODUCTION

With an estimated 211,000 new cases of breast cancer in 1994[1], it is the second leading cause of death in American women of child bearing age[2]. Early detection has allowed for less extensive surgical procedures and/or decreased need for radiation therapy. Since a substantial majority of questionable lesions detected by mammography are benign, there is a growing interest among the health care professionals and patients in finding alternatives to surgical biopsy for diagnosing these lesions. Fine-needle aspiration (FNA)[3] and stereotactic needle core biopsy (SNCB) are techniques used in the work up of breast lesions suggestive of breast cancer. State-of-the-art stereotactic breast biopsy is comparable in sensitivity to surgical biopsy, and the procedure is quicker, cheaper, and easier than the standard practice of preoperative, mammographically guided localization followed by surgical biopsy.

In spite of all the recent developments in the field, several problems remain unsolved in the detection and excision of small occult breast cancers, particularly those manifesting with micro calcifications alone. In many instances, the ductal system containing the malignancy, ductal carcinoma in situ (DCIS), may also be involved but

cannot be determined without at least core biopsy, and the positive predicted value for clustered calcifications remains at 20 to 25%, although for solid masses it approaches 40%. These problems could be ameliorated by a nuclear medicine procedure using a beta detector on the end of a 0.8 millimeter diameter fiber optic cable. By positioning the detector within a few millimeters of the suspected area, small lesions, usually not detectable using gamma radiation detectors, can be identified and quantified for activity. The fiber optic plastic cable with a small scintillating plastic fiber attached (fused) to the tip can either be inserted into a core biopsy needle before stereotactic core biopsy, or can be used during ductogram to identify the duct system containing microcalcified clusters. When inserted into a surgical wand, it could be used to ensure that all residual tumor was removed during lumpectomy. This diagnostics alone is very much needed to prevent recurrence and spread of malignant tissues.

II. MATERIALS AND METHODS

We have developed a prototype suitable probe that uses a rather small diameter biopsy needle (in the current study an 18 gauge needle with an external diameter of 1.25 mm) containing a 0.8mm diameter and 3mm length 3HF (3-Hydroxyflavone) multiclad scintillating fiber [4], which is fused to the same diameter multiclad clear optical fiber of 200 cm length.

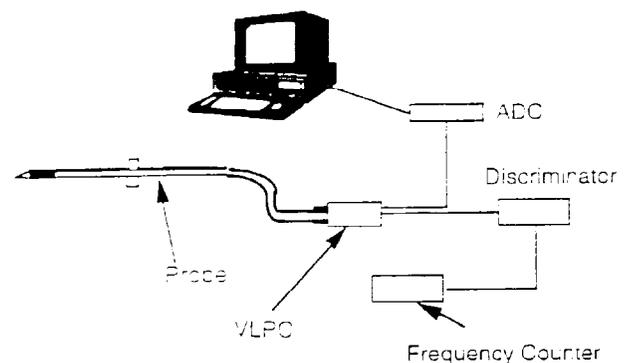


Fig. 1 A schematic view of the biopsy needle probe together with a simple data acquisition system.

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Photons, emitted from the scintillating fiber by the passage of betas or positrons, are transmitted through the optical fiber, and are detected by the VLPCs (Visible Light Photon Counter) [5]. The VLPC is a solid state photomultiplier having quantum efficiency of above 80% for the photons (around 530nm wave length) emitted by the 3HF scintillator. The probe assembly and the rather inexpensive data acquisition system are shown in Fig. 1.

The signals from the VLPC were amplified by a TIA (transimpedance amplifier), fed into a discriminator, and counted by a commercial scaler. The VLPC produces avalanche gains of about 30,000 per photoelectron. When the threshold is set above 3 photoelectrons, we obtain less than 2 counts per minute as background rate. We measured experimentally that the average detectable photons is more than 40, by the passage of betas through the thin scintillator. The pulse height spectrum obtained using a Bi²⁰⁷ beta source is shown in Fig. 2. Only a small fraction of the 1 MeV energy is left in the thin scintillator, giving rise to the pulse height spectrum.

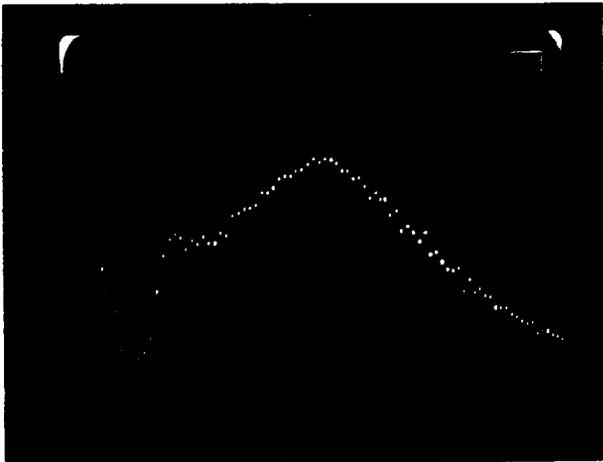


Fig. 2 Pulse height spectrum obtained using Bi²⁰⁷ beta source. The average energy released in the scintillating fiber is about 60 KeV. The peak value corresponds to 40 photoelectrons detected by the VLPC.

III. EXPERIMENTAL RESULTS

In order to determine the point spread function, we moved the probe linearly relative to 1 microcurie Bi²⁰⁷ source without and with 1.5mm thick Lucite sheets in between (mimicking tissue equivalent density), and recorded the counts per second. The source diameter was approximately 4mm and it was not collimated. The results, plotted in Fig. 3. show that the 1 MeV betas from the source are very much attenuated after one sheet of Lucite, but we can still resolve the source position after

4.5mm thickness. We expect that the intrinsic resolution of the probe be 1mm.

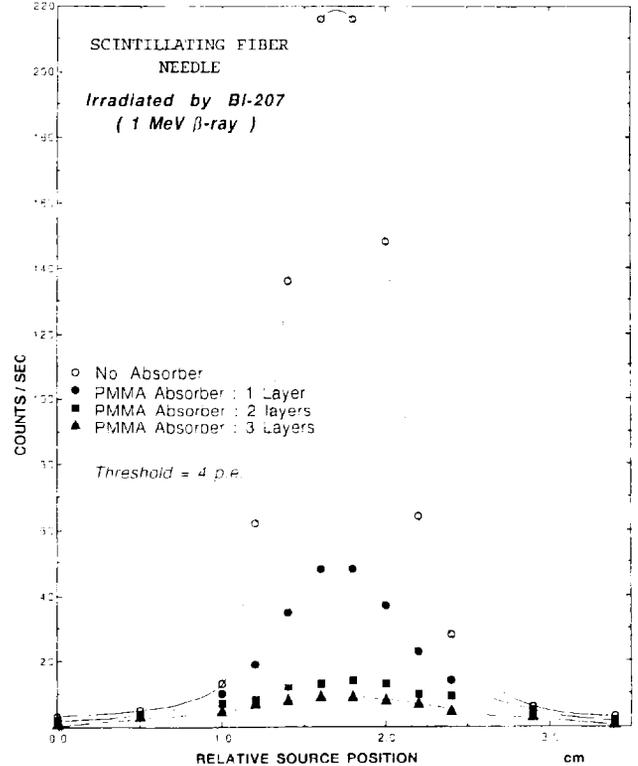


Fig. 3 Results from the Bi²⁰⁷ source test. The curves clearly indicate that the 1 MeV betas are very rapidly absorbed by the 1.5mm thick Lucite sheets, and there are not many counts from gamma conversions in the scintillator, although 90% of the decays from the source are gamma rays in this case.

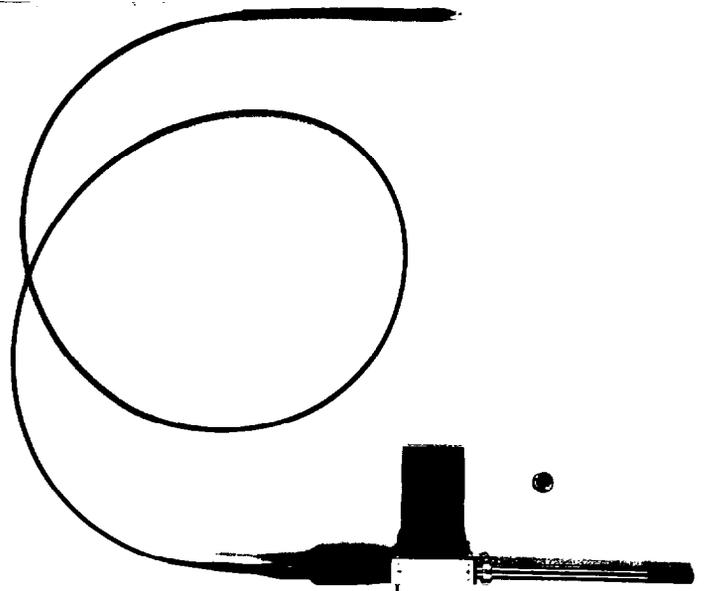


Fig. 4 Photograph of the probe with the 2 meter long optical fiber between the biopsy needle and the VLPC unit.

The curves also show that the probe is sensitive to betas and not to the gammas, although only 8% of the decays produce betas and the rest being the gamma activity. This feature is important due to the fact that the probe will not be sensitive to 511 KeV gammas when a positron source is traced. Similar work, using the VLPCs having many fiber channels and a collimator was reported earlier [6]. In this case, the probe size was about 1cm diameter which was developed for a different application. A photograph of the probe is shown in Fig. 4. The 18 gauge biopsy needle with 2 meter optical fiber connection to the VLPC unit are seen in the picture. The VLPC having high avalanche gain (about 30,000) at 80% quantum efficiency needs to be operated around 7 K. For a unit like this, such a temperature can easily be achieved and kept by cooling the unit using liquid helium vapor.



Fig. 5 Test done with a rat having an R3230 AC in the hind leg. The rat was administered 432 microcurie FDG i.v.

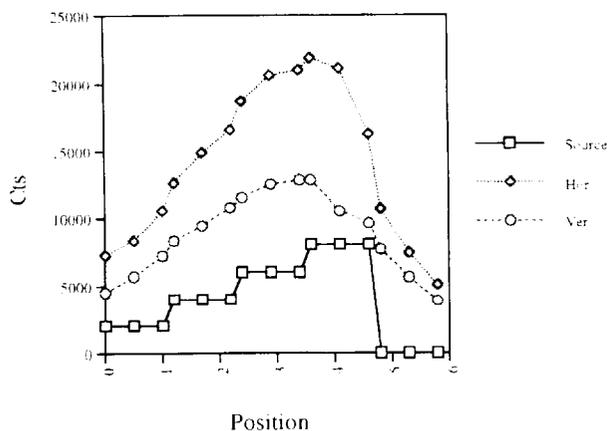


Fig. 6 Two dimensional scan, even from outside of the skin indicates where the radionuclide concentration is.

As a first experiment, a preliminary test was done using a rat bearing R3230 adenocarcinoma. As the radioactivity profile shows, the tumor had grown rather large. The experimental arrangement is shown in Fig. 5.

As shown in Fig. 6, the biopsy needle was moved in an x,y matrix points and the count rates were recorded. To see the tumor together with the biopsy needle, an X-ray picture was taken Fig. 7. This is actually not necessary to find out where the activities are. The probe itself will be sufficient.



Fig. 7 An X-ray image of the probe together with the region of the tumor. This was to show that the probe was in the vicinity of the malignant tissue. In actual case, this is not needed.

IV. CONCLUSIONS

We believe that such a small scintillator could be very useful in early detection of breast cancer and save many lives. It is a low cost system that can easily be purchased and used by even small clinics. It would also be a low cost diagnostics system for screening. We intend to do further tests to understand the full capabilities of such a probe.

V. REFERENCES

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