Mammodos – In-Vivo Dosimetry in Mammography

J.U. Wuerfel[1], C. Pychlau[1], C. Cappellini[2], A. Bulgheroni[3], F. Risigo[2], V. Chmill[2], M. Caccia[2], and A. Martemiyanov[4]

[1] PTW-Freiburg, Freiburg, Germany
[2] Department of Physics and Mathematics, University of Insubria, Como, Italy
[3] Istituto Nazionale di Fisica Nucleare – Sez. di Milano, Milano, Italy
[4] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia

Abstract— **In the scope of the RAPSODI EU research project, a prototype detector for in-vivo dose measurements in Mammography was developed. We present and discuss first results on the system qualification, in particular on the linear dynamic range, the energy response and the radiological as well as optical transparency of the detector.**

Keywords— **In-vivo dosimetry, Mammography, Diagnostic instrumentation, Average glandular dose**

I. INTRODUCTION

An increasing number of countries in Europe are starting to introduce Mammography screening programs for the early detection of Breast Cancer [1]. To evaluate the radiation hazard these patients are exposed to, it is essential that the dose for each examination is well documented. For most modalities of classical diagnostic imaging in Germany, the dose of each examination has to be measured and recorded [2]. Dose measurements are also requested by the EC for any new radiological equipment [3]. Currently, there exists no device on the market that is able to measure the dose during a mammographic examination. In the scope of the RAPSODI EU-project a prototype, "Mammodos", to measure in-vivo dose in Mammography has been developed. Mammodos is designed to measure the surface dose on top of the breast during the examination. It consists of a flat sheet of transparent plastic and will be placed between breast and compression plate, see Fig. 1.

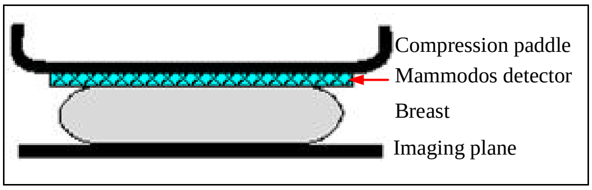

Fig. 1 In order to measure the surface dose on the breast, the Mammodos detector will be placed between compression paddle and the breast.

II. MATERIALS AND METHODS

The X-ray dose is measured by an organic scintillator. Via a polymeroptical cable, the scintillated light is transported to a very sensitive semiconductor based light detector, called "Silicon Photo Multiplier" (SiPM). In order not to disturb the mammography image, the scintillator is embedded into a plastic sheet of X-ray equivalent material. This embedded detector is almost invisible on a mammogram. In addition, the embedding material is optically transparent to facilitate the handling of the detector in every day use.

SiPMs from Hamamatsu [4] and from SensL [5] have been used. In addition to the SiPMs, an Optidos dosemeter (type T10013, PTW-Freiburg, Germany [6]) employing a classical Hamamatsu photo multiplier tube, was used to measure the optical signals. The scintillation detectors were produced by ITEP and the light coupling to the SiPMs or the Optidos was done via FC optical connectors. The SiPM signals were read out using a transimpedence amplifier developed at SensL, effective gain 470 mV/mA, and digitized by a CAEN V792 Charge to Digital Converter. The resulting signal was typically sampled at a frequency of 30 kHz with integration times ranging between 500 and 5000 ns.

The radiological performance of the detectors was evaluated in the calibration lab of PTW.

III. RESULTS

The linearity with dose rate of the detector was measured using a Pandoros X-ray (Siemens, Germany [7]) at 35 kV tube voltage with a Tungsten anode and 1.2 mm Aluminum equivalent self-filtering. In Fig. 2, the response of a non-embedded prototype to dose rates in the range of 5 to 200 mGy/s is shown. The signal was recorded using a Hamamatsu SiPM.

The energy response of the same Mammodos prototype was evaluated for five standard radiation qualities stated in Table 1. The measurements were performed on a Mammomat (Siemens) using the Optidos as optical detector. The scintillator was placed on a plate of polyvinyl chloride (PVC). For each radiation quality, the response of the prototype was measured. The deviation of the response to each radiation quality from the mean response is depicted in Fig. 3.

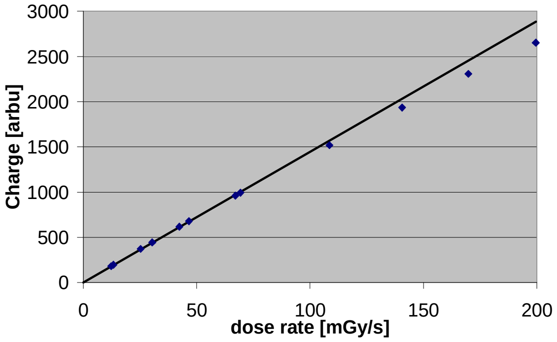

Fig. 2 Detector signal versus dose rate of the Mammodos prototype. The deviation from a linear dependence above 100 mGy/s is clearly visible. The dose rate of most Mammography machines is below 100 mGy/s, hence the linear dynamic range can be considered as very good.

Table 1 Radiation qualities used in this work

Radiation quality	Anode / Filter	Tube voltage range [kV]
MMV	Mo / 32 µm Mo	25–35
WRV	W / 54 µm Rh	25–35
MRV	Mo / 25 µm Rh	25–35
WMV	W / 60 µm Mo	25–35
WAV	W / 0.5 mm Al	25–35

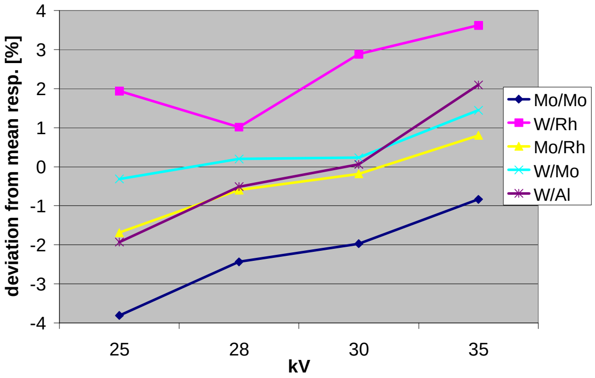

Fig. 3 Energy response of the Mammodos prototype using the Optidos as optical detector. For each radiation quality the deviation of the response to the mean response of all measurements is indicated.

The latest prototype consists of a scintillating fiber fully embedded in an organic matrix as depicted in Fig. 4.

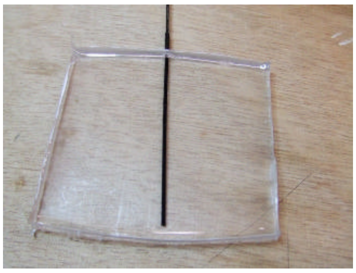

Fig. 4 Prototype of a fully embedded scintillating fiber detector. It is optically transparent, the grain of the wood is well visible.

Mammography images of this prototype were taken on top of an anthropomorphic breast phantom Rachel (Gammex, USA [8], 5 cm equivalent thickness) in the Radiology department of S. Anna hospital in Como, Italy. The resulting Mammogram is displayed in Fig. 5.

Fig. 5 Mammogram of the prototype depicted in Fig. 4 on an anthropomorphic breast phantom. The image was taken with an Essential Senographe (GE Healthcare, USA [9]) in maximum contrast mode. The exit of the fiber (see arrow) can be identified while the embedded part of the fiber is not visible in this Mammogram.

IV. DISCUSSION

The dose rates of most Mammography machines are below 100 mGy/s. Hence the linear dynamic range of the prototype as shown in Fig. 2 can be considered as very good. The same is true for the energy response of the prototype. For comparison: an SFD-chamber (type 34069, PTW-Freiburg) having an excellent energy response exhibits deviations of ±3 % over the full range of the radiation qualities listed in Table 1. It must be noted, however, that the energy response was measured on a non-embedded prototype. The final energy response will depend on the exact surrounding material of the detector.

The embedding procedure, as shown in Fig. 5, seems to work very well. Further research is necessary to thoroughly check whether the prototype might nevertheless degrade the image quality. The final prototype will be of the same size as the compression paddle, hence no naked fiber (as on the right hand side in Fig. 5) or edge will be visible.

V. CONCLUSIONS

In the presented work, we have shown that in-vivo dosimetry is conceivable in mammography. A detector was developed that has a very good linear dynamic range and energy response. In addition, it is almost invisible on a mammography image. The next step will be to perform a detailed analysis whether the detector might influence the image quality.

ACKNOWLEDGMENT

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