# DESIGN, CONSTRUCTION AND CALIBRATION OF A FIRST PROTOTYPE OF BEAM POSITION SYSTEM FOR HADRON THERAPY FACILITIES*

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*Abstract*

Beam Position Monitors (BPM) are essential elements in the instrumentation for the beam control in Hadrontherapy accelerators. The measurement of the beam position becomes more important at the secondary transport lines towards the patient room where this parameter must be completely determined. In this paper we describe the design, construction, read-out electronics and first calibration tests of a 1st prototype of a BPM based on four scintillating fibers coupled to four photodiodes to detect the light produced by the fibers when intercepting the beam tails. The prototype will serve to evaluate the different design options in the mechanical and the read-out electronics implementation as well as to define the best processing method to get the beam position.

## INTRODUCTION

The BPM described in this paper named as "watchdog" is a new type of BPM based on four scintillating fibers [1] coupled to four photodiodes to detect the light produced by the fibers when intercepting the tails of the beam. The first conceptual design for the mechanics and electronic as well as the technology selection and experimental test of the photodiodes chosen is described in detail in [2] and [3]. In this paper we describe the mechanical design, the acquisition electronic and first calibration test of a prototype made with only two fibers to be tested in May 2012 in the PS proton beam area. This first test with proton beam will serve us to evaluate the validity of the technique, the robustness of the mechanics, the final choice of the photodiodes type (MPPC S10362-11-50U or APD S2384 from Hamamatsu [4]) and the sketch for a future dedicated acquisition electronics.

## 1ST WATCHDOG PROTOTYPE MECHANICS

The conceptual mechanical design of the watchdog is described in detail in [3]. The watchdog BPM has four scintillating fibers coupled to four photodiodes to determine the beam position in the horizontal and vertical planes, each of the fiber-photodiode (Figure 1) is moved by means of individuals movers. In the first prototype only two movers will be assembled on the base plate to measure in one of the planes (horizontal or vertical), but the device is ready to set up the whole system with four movers in a future. The 1st watchdog prototype is shown on Figure 2 top.

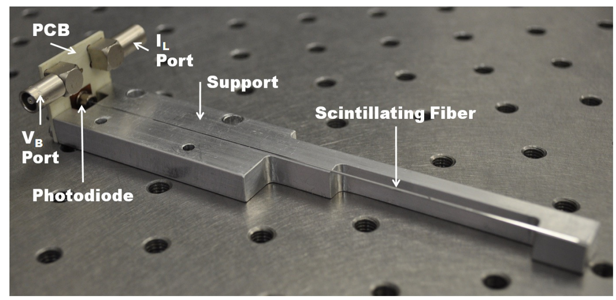


Figure 1: Scintillator fiber support with photodiode for the 1st watchdog prototype.

The movers are driven by a stepper motor of 5 $\mu$m resolution in a range of 50 mm (MICOS LT Linear Stage VT-80 UHV). Furthermore the movers are able to work in Ultra High Vacuum (UHV) conditions (MICOS VT-80 VSS42 HV) [5]. They are placed on the base plate by positioning pins in order to ensure the correct position with a tolerance of around 50 $\mu$m . The fiber support shown in Figure 1 that also host the photodiode and the PCB is fixed to the carriage of these movers and positioned by two pins. The base plate is attached to a rectangular flange. The flange is provided with three O-ring vacuum feedthroughs, two for the movers control and one for the photodiodes power supply and signal. Due to the use of O-ring feedthroughs, no need of welding, the flange could be made in aluminum as well as the rest of components, reducing the weight of the whole device. The flange has a viton O-ring to seal the flange and the case. The matching of the flange and the case is made by means of two positioning pins in order to fix the position of the watchdog inside the case. The case (Figure 2 bottom) was made in aluminum also. The top and bottom faces have been mechanized after welding to make a reference plane. All the components were measured with a Coordinate Measuring Machine (CMM) to know the exact position of each component and the position of each fiber by respect to a external reference. This will be used for alignment purposes in the future beam tests.

## 1ST WATCHDOG PROTOTYPE ELECTRONICS

In Figure 3 it is shown the scheme of the setup used for the read-out and function of the two-channel 1st watchdog

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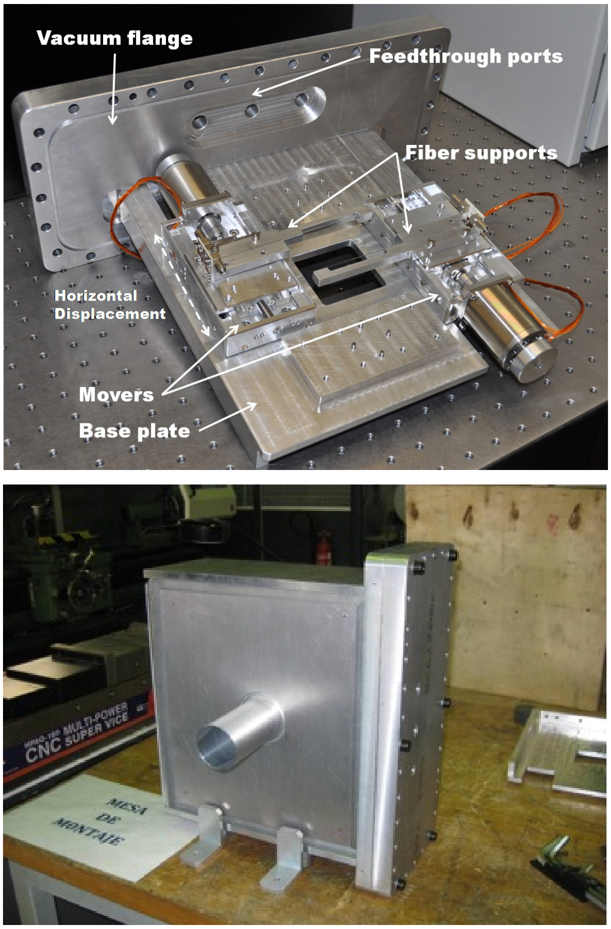


Figure 2: Base with movers and flange (top) and case (bottom) for the 1st watchdog prototype.

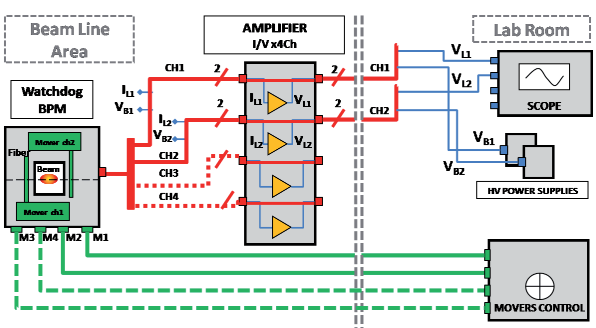


Figure 3: Electronic setup proposed for beam test of the 1st watchdog prototype. The dashed line indicates the next phase with four movers.

prototype. The setup and its elements are chosen to be as configurable as possible being oriented to the study and evaluation with beam of two different photodiodes technology, MPPC S10362-11-50U and APD S2384, already tested with a Sr-90 radioactive source. The results with the Sr-90 could be found in [2] and [3]. It will also serve to get the best suited operation parameters for the final design of the read-out and acquisition electronics for the watchdog. Every channel of the watchdog corresponds to a detecting fiber coupled to a photodiode which has a light signal current output, $I_L$, and a bias voltage input, $V_B$. The PCBs used, shown in Figure 4, are suitable for UHV and they are made without metalizing (Rogers Substrate RO4350B) [6]. The ports of the PCB where the photodiodes are mounted, as shown in Figure 4, are connected to a high-vacuum feed-through connector, Vacom PLUG-MINI-10-A (10 pins), where four pins are used for the two photodiode channels $I_{L1}$ and $I_{L2}$, including their respective ground pins, and only two pins more for $V_B$ and its ground since the two channels share a common bias voltage. In total six pins are used for this prototype, leaving four pins for the extension to the four-channel watchdog. In the amplifier box are implemented two independent transimpedance amplifiers Femto DHPCA-100, one for each watchdog channel. These amplifiers allows a Current-to Voltage strong and variable gain, from $10^2$ to $10^8$ V/A, of the low watchdog current signals. Maximum available bandwidth is 200 MHz, but reduced as the gain increases. Typically the amplifiers must be placed as close as possible to the watchdog, with the necessary radiation protection, due to the low current output signals, under 5 m with low attenuation coax cables were tested successfully.

After the amplifiers the watchdog signals must be carried through coaxial cables to an oscilloscope of 2.5 GHz and 20 GSamp/s for acquiring them. The bias voltages lines coming also from the watchdog are connected to a high voltage power supply in the control room, which are around 71 V and 160 V for the MPPC S10362-11-50U and APD S2384 photodiodes respectively. The cable length used are adapted to the beam SPS test area, lengths are of the order of 40 m long. Concerning the movers controller, the cables length are limited to a 10 m long due to the strong attenuation in the power needed to drive the movers in the watchdog, thus, a long Ethernet cable is used, around 30 m, from a laptop communicating with the controller to send the motion commands. Finally, a data communication link is implemented via USB or Ethernet from the oscilloscope to a laptop in order to get the better process, analyze and store the watchdog waveform signals. A Matlab front-panel application has been developed for this, as well as for the oscilloscope configuration and amplifier remote control.

## FIRST CALIBRATIONS TESTS

The first calibration tests have been carried out at the Valencia Space Consortium (VSC) labs. with a Sr-90 radioactive source of a nominal activity of $37 \times 10^6$ Bq. The goal of the tests are the calibration curve response of the two fibers. The setup as mounted in the VSC labs. is shown on Figure 5. We have measured the electron rate of each of the two fibers individually at different distances (range 50mm - 0mm) with the two movers separately. In Figure 6 it is shown the calibration curve for the two fibers (left/right) for each of the two movers and the relative difference between the two fibers for MPPC S10362-11-50U. The response of the the fibers shown small differences of few percent level.

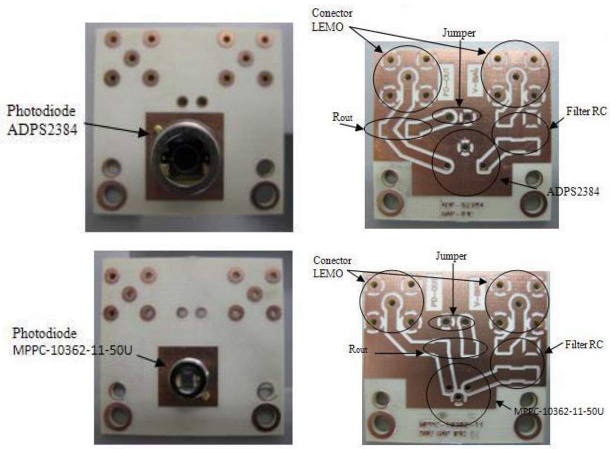


Figure 4: 1st watchdog prototype PCBs (top and bottom) with the photodiodes: APD S2384 and MPPC S10362-11-50U type.

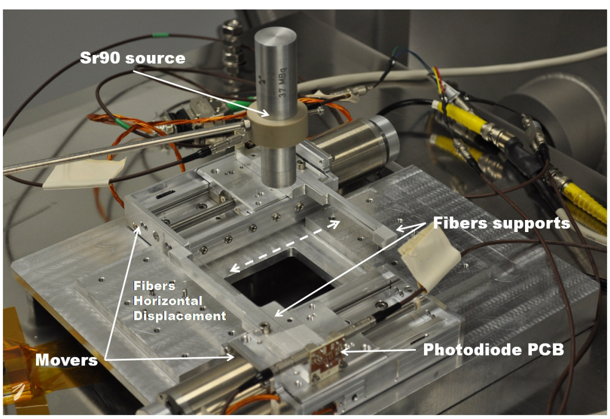


Figure 5: Calibration watchdog setup with Sr-90 radioactive source on top in the VSC labs.

The 1st prototype is ready for beam test. The beam tests will be carried out in the PS beam area with a proton beam from 24-31 May 2012. The proton beam is of T10 type: 6 GeV energy, minimum r.m.s. size of 7 mm in each plane, highest rate of 1 million counts per 0.4 s, 1 spill per supercycle with a debunched beam (no RF structure).

## CONCLUSIONS

The 1st watchdog prototype is constructed and ready to be tested with beam in the PS beam test area during May 2012. This tests will serve us to evaluate the validity of the technique, the robustness of the mechanics, the final choice of the photodiodes type (MPPC S10362-11-50U or APD S2384) and the sketch for a future dedicated acquisition electronics in order to finalize a watchdog BPM totally operational.

## ACKNOWLEDGMENTS

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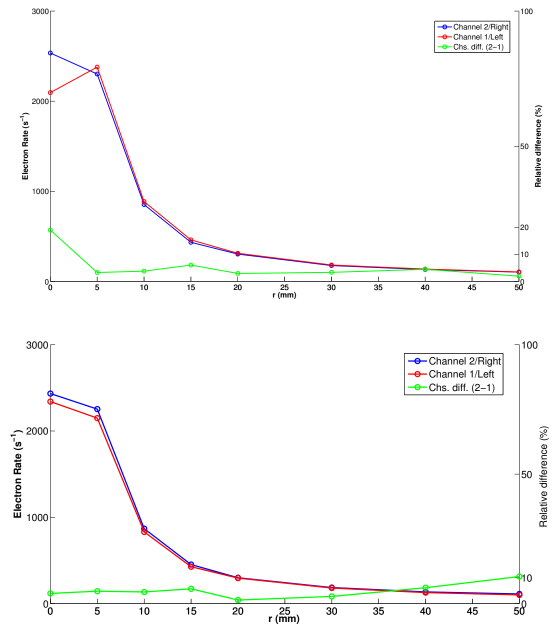


Figure 6: Calibration curve for each of two fibers (left vertical axis) mounted in mover 1 (top) and mover 2 (bottom) and relative difference between the two fibers (right vertical axis) for MPPC S10362-11-50U.

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