DEPENDENCE OF THE WALL-CURRENT MONITOR ON THE BEAM POSITION

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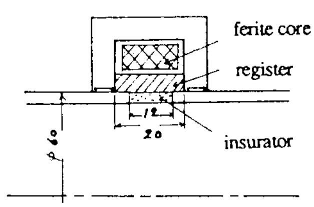
Abstract

The beam position dependence of the wall current monitor used in PF linac is measured on a test bench and analyzed with a simple equivalent circuit. A good agreement between the experiment and caluculation is obtained. This dependence is also measured with an s-band single bunched accelerated beam , which shows that at such high frequencies more complicated circuit is neccesary to get a good quantitative agreement.

Introduction

Wall current monitors have been widely used in accelerators to measure beam intensities, bunch structures and sometimes beam positions, and various types of monitor structures are devised and used[1]~[7].

In the PF 2.5 Gev e+/e- linac at KEK, wall current monitors are used to measure e+/e- beam current with a few nanosecond pulse width. In usual operation of the linac , beam position is adjusted with profile-monitors to pass the center of the accelerator and then the beam current is measured. Therefor, the dependence of the output signal on the beam position was ignored in the wall current monitors. However, in such a case as in positron acceleration, a precise tuning of the accelerator is required to obtain an optimum beam, the beam position dependence of the monitor becomes significant and its investigation was made and presented below.



(b) Cross-section of the monitor

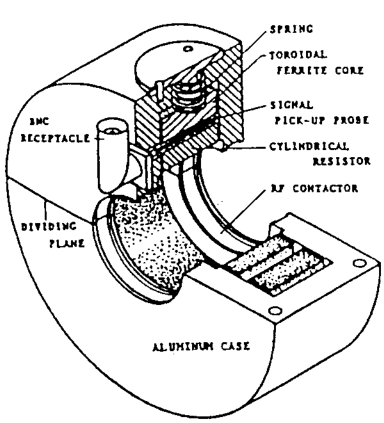


Fig.1 (a) Bird'seye view of the wall current monitor

Wall Current Monitors

A wall current monitor used in the PF linac is described somewhat in detail in Ref.[8], and here described only briefly. It is shown in Fig.1(a), it can be separated into two to enable its installation without breaking vaccuum. A solid register and a ferrite core are both of toroidal shape, and are covered by an aluminium case, which forms an electromagnetic shielding. The ferite core serves to prevent the wall current from flowing the outer cover. The wall current flows mainly from the vacuum duct to the register through the side plate of the case. The electric contact of the duct with the register is made by rf-contactors. The cross-section of the monitor is shown in Fig.1(b).

Test bench and experiment

To measure the dependence of the output signal on the beam position, a simple test bench was constructed, a schematic drawing of which is shown in Fig.2. It consists of a beam-duct, two tapered ducts, a pulse generator, and an oscilloscope. The beam-duct has an insulator in its middle as shown in Fig.1(b). The monitor was installed around the insulator. The beam was simulated by a voltage pulse fed to the wire passing through the duct, and the variation of the beam position was simulated by varying the wire position. The pulse generator (YHP 8082A) has a minimum rise-time of about 1 nsec, and the oscilloscope used is aYHP 54503A whose rise-time is 0.7 nsec.

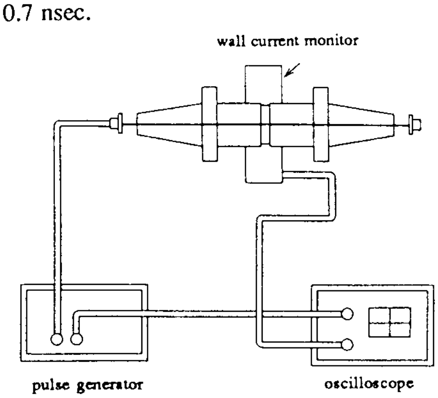


Fig.2 Test bench

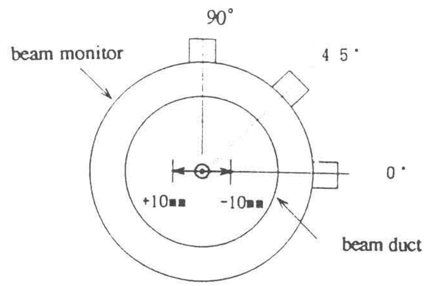


Fig.3 Relation between beam and monitor positions

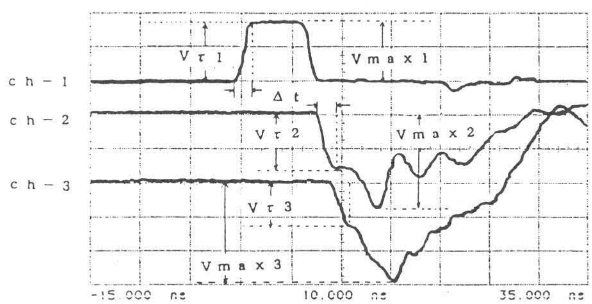


Fig.4 Waveforms of input(ch-1), transmmutted(ch-2),output (ch-3)

Beam position relative to the monitor is, more specifically, the relative position of the beam to the output port of the monitor. To vary the beam position radially the central wire was varied horizontally, and to vary the beam position azimuthally, the monitor was rotated around the central axis as shown in Fig.3. For example, a monitor position 0° means its output port was in horizontal plane, and a minus beam position was the beam moved toward the output port in the same plane.

The horizontal displacement of the beam was made by 2.5 mm step, and for azimuthal variation the measurements were made at three angles ; 0° , 45° and 90° .

A typical output signal is shown in Fig.4 , in which three signals are shown : chanell 1 is the input voltage waveform , chanell 2 the waveform passed through the duct and chanell 3 the output from the monitor. Matching between the cable and the beam duct and that through the beam duct are poor, that the output signals through the duct and from the monitor are appreciably distorted . This is partly because the central wire should have been movable to a large extent. However, the rising part of the output signals ,i.e.the signal of initial ~1nsec duaration seemed to be not affected by the distortion, therefor, the amplitude at the duaration end (indicated by Δt in the figure) was used in the following analysis.

The result of the measurements are summarized in Fig.5. As is expected, the output increases most appreciably with the increase in r at the monitor position 0° and decreases with the decrease in r. While at the monitor position 90° , the output signal stays almost constant in spite of the variation of the beam in the same range as before. This result is analyzed with a simple equivalent circuit.

Analysis of the bench test result

An wall current distribution around the beam duct caused by a beam deviated from the center is well known[1] , and is given by the formula,

$$j(r, \phi, \theta) = (1 - r^2) / \{1 + r^2 - 2 r \cos(\phi - \theta)\} \quad (1)$$

where r, ϕ is the beam coordinate and the current is measured at an angle θ. A simplest equivalent circuit to analyze the experiment is , therefor, to assume the above current flows through the register of the monitor. However, it becomes immediately clear that this model is too simple and results in stronger dependence than the observed. This may be probably because the lengths of the insulator and the register are short and both ends of the beam ducts affect on the current distribution. The registances of the duct around both ends of the register are much less compared with that of the register, that

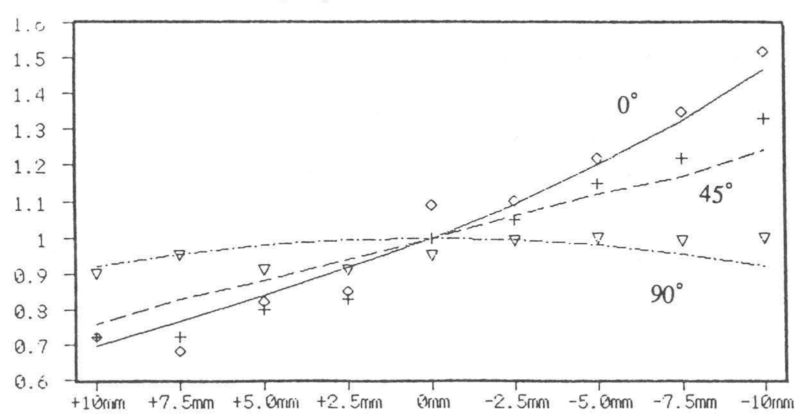


Fig.5 Relative output vs. wire(beam) position

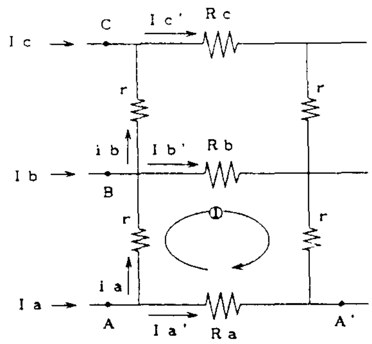


Fig.6 Equivalent circuit. Point D is behind B

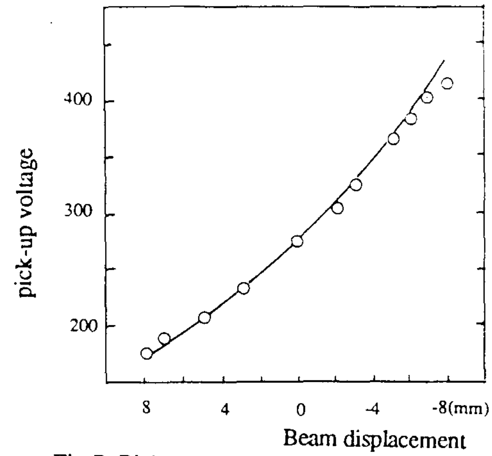


Fig.7 Pick-up voltage vs. beam position

the voltage difference across the register would be appreciably equalized around the duct.

Therefor, next simple equivalent circuit may be the one shown in Fig.6, a similar circuit passing through D is not shown in the figure. Ia, Ib, Ic, and Id are the currents flowing through the duct, and the relative intensities of these currents are given by Eq.(1). When the currents reach the points A to D the distribution is modified: Ia is divided into Ia' and ia, Ib is into Ib' and ib. At C , Ic, ib and id(=ib) are summed to form Ic'. The impedance between two adjacent points is assumed to be the same and represented by r, whereas the solid register is divided into four registers Ra to Rd, each equals to Ro.

From Kirchhoff's 1st law,

$$Ia = Ia' + 2ia$$
$$Ib + ia = Ib' + ib$$
$$Ic + 2ib = Ic'$$

and from the 2nd law,

$$RoIa' = iar + RoIb' + iar$$
$$RoIb' = ibr + RoIc' + ibr$$

Quantities to be calculated are Ia', Ib', Ic', ia, ib, and r, and for these six unknowns only five equations are given, so another equation is neccesary to solve the problem. As for the relation

$$Ia' : Ic' = Va : Vc \ ,$$

measured quantities are used, where Va and Vc are voltages across Ra, and Rc, and the output signals for the displacement of ±10 mm and the monitor position 0° . This gives r= 7.30 Ω, and for analyzing other data this value for r is assumed.

The results of analysis is presented by the curves in Fig.5. There is a good agreement between the experiment and caluculation. Although experimental data had to be used at two points, a good agreement over the whole range of displacement sugests the analysis is based on reasonable assumptions.

Experiment of the monitor with an accelerated beam

The response of the detector was also studied using a high energy electron beam. The accelerator used for this experiment is a 35 Mev electron linac at Nuclear Engineering Research Laboratory of the University of Tokyo.

Single bunched beam passes through a stripline beam position monitor, a wall current monitor, then a screen monitor , and finally a beam current monitor. The beam position monitor and the wall current monitor are both set on a X-Y stage controlled remotely, and instead of varying the beam position that of wall current monitor was varied. The wall current monitor is of the same type as used in the test bench .

A typical example of the measured data is shown in Fig.7. A small fluctuation of a few percent took place in the beam current during the measurement. This fluctuation is corrected in the data shown in Fig.7 .

The analysis of the data is performed in a similar way as described before. The solid curve represents the caluculated values , and the distributed impedance r in azimuthal direction yields the value of 28.4 ohm, which is much higher than the previously obtained value as is expected. The distributed impedance r would be mainly an inductance , its magnitude should approximately be proportional to frequency. The rf frequency of the linac is 2856 MHz and the beam is single bunched , its width being of the order of 10 psec. Thus the obtained value of r is , therefore, sill too low.

At such high frequencies, to improve approximation various components should be taken into account such as distributed inductances and capacitances of the solid register as well as those of the outer cover of aluminium case.

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