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Authors
Jacob, ft.
son, G. R. Lambert

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A. Jacob and G.R. Lambertson

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IMPEDANCE MEASUREMENTS ON BUTTON ELECTRODES*

A. Jacob and G. R. Lambertson

Accelerator & Fusion Research Division
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720

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IMPEDE MEASUREMENTS ON BUTTON ELECTRODES

Arne Jacob and Glen R. Lamberton
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720 USA

Abstract

In the Advanced Light Source, there will be about 400 capacitive button electrodes in the beam position monitor (BPM) system, hence the contribution of each button to the machine beam impedance must be very small. We have measured the impedance of a single button as sensed by a coax connected directly to the button surface. This method is very sensitive and did not require a model of the total beam chamber as would the usual wire method. The measurements covered the range 0.1-to-20 GHz. The proportionality factor between the button impedance and the beam impedance depends upon geometry and frequency and was obtained from the measured sensitivity of a developmental BPM at low frequency. Discontinuities in the connection of the coax to the face of the button introduce parasitic effects that must be accounted for in interpreting the data. Below 5 GHz the results compare very well with responses computed from mechanical dimensions of the electrode. Above 15 GHz corrections for the parasitic elements become more uncertain but the accuracy of the method is still adequate. The results show multiple resonances, a prominent example being for one button a beam impedance peak of -1 ohm with a Q of 50 at 16 GHz.

Introduction

It is desired that the position-monitoring electrodes, as designed for the Advanced Light Source (ALS), present an acceptably low impedance to the electron beam in order to avoid exciting coupled-bunch instabilities or heating of the electrodes from induced currents. These concerns require that resonant responses of any one of the 400 assumed identical electrodes have peak beam impedances that are less than 2.5 ohm within the frequency range from 0.5-to-20 GHz.

Description of electrodes

Each pickup is a coaxial structure as sketched in Fig. 1 having a 7.6 mm diameter exposed surface flush with the wall of the beam tube and connected to a 50 ohm cable. Further details of the electrode are found in reference [1]. Measurements with a wire excited at 500 MHz have shown the coupling impedance of a single button to the beam to be $Z_p = 0.05$ ohm as a pickup driving a $R_o = 50$ ohm load. At low frequency the button has capacitance $C = 20$ pF.

From the longitudinal beam impedance $Z_B$, a voltage

$$V_B = I_B Z_B$$  \hspace{1cm} (1)

is imposed upon the beam current $I_B$. Applying reciprocity relations to the circuit in Fig. (2), we have

$$V_B I_B = -(I_e Z_e) I_e$$  \hspace{1cm} (2)

where $I_e$ is the current induced in the button by the beam. Combining eqs. (1) and (2) we find

$$Z_B = Z_e (I_e / I_B)^2$$  \hspace{1cm} (3)

The ratio $I_e / I_B$ is proportional to frequency $f$ and from the values of $R_o$, $C$, and $Z_p$ at 500 MHz we obtain

$$I_e / I_B = j \left(3.3 \times 10^{-3} \frac{f}{5 \times 10^8}\right)$$  \hspace{1cm} (4)

At the highest frequencies this ratio becomes smaller than the above value, being about 30% lower at 20 GHz. We have not applied this correction to the results. If in using this method to find $Z_B$ coupling data at one frequency were not available, one could calculate the ratio $I_e / I_B$ for a reasonably simple geometry.

Fig. 1 Schematic cross-section of ALS beam chamber with four button electrodes.

Method

For measuring the beam impedance, we chose to avoid the complexities of the wire method extended to 20 GHz, which is well above the beam-tube cutoff frequency of 5 GHz. Instead, we measured the impedance $Z_e$ presented at the face of a single button and from that calculated the beam impedance.

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