IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

WIDE BAND FERRITE BEAM CURRENT MONITORS

J. B. Broberg
National Bureau of Standards
Washington, D. C. 20234

Abstract

A ferrite electron beam current monitor has been developed for use with the NBS Linac. This monitor is useful at the fast rise times (< 5 ns) needed for the short pulsing of the linac and also gives good flat top response for the long pulse (up to 5 μs) work. The low frequency response is achieved by using ferrite with a large μ (= 5000) and a large number of turns (100). At the higher frequencies the core plays a very small role and the structure acts as an air core transformer. The main difficulty observed with other types of ferrite transformer monitors has been ringing due to coil resonances, making these transformers unsuitable for use with fast rise times. This ringing has been eliminated by the placement of damping resistors around the coil and tying them to a common but independent annular ring adjacent to the coil.

Introduction

Beam current monitors using ferrite cores in a pulse transformer configuration are not new, and have been used with many accelerators[1] including the linac at the National Bureau of Standards.[2] This type of device is of a necessity quite large. (The monitors used in the beam handling system of the NBS linac use seven ferrites 14.3 cm O.D., 9.5 cm I.D., and 1.5 cm thick cemented together.) Also, a large number of turns are needed (we use 100) to reduce pulse droop and to keep the sensitivity high.

While the low frequency cutoff of such a device is predictable, it is not true of its high frequency cutoff. Resonances in the secondary winding, due to capacity between turns and the core and/or shield, lead to shock excited oscillations when the rise time of the primary (or beam) current pulse is fast enough to require frequency response higher than these internal resonances.

A solution to this problem is suggested in an article on wide band, single wire primary coaxial pulse transformers.[3] The author found that a simple solution to the same problem in coaxial pulse transformers, was to place a series of resistances uniformly tapped along the secondary winding and all terminating in a common connection. This attenuates propagating modes on the winding without influencing the desired response. No signal current flows in the damping resistors when the core is uniformly excited.

Description

The monitor is shown schematically in Fig. 1. Symmetrical disposition of the secondary about the primary beam current in the form of a toroidal winding, assures uniform excitation of secondary current. The windings should have constant turns density to prevent gradients of induced currents around the torroid. We had already been using 100 turns and have stayed with that number.

The damping resistors shown in Fig. 1 are tapped to the secondary at equal turn intervals, so that no net signal current flows in this network. A low inductance common tie terminates the resistors. This limits us to the use of 100, 50, 25, 20, 10, or 5 resistors and only experience shows how many will be needed to push coil resonances above the frequencies desired. We found that 25 one kΩ resistors placed four turns apart, did our job.

The type of ferrite material used was Indiana General Q2, which had already been used in the earlier monitors. Q2 material has a low μ and we do have some pulse droop in long pulse operation.

Results

Figure 2 shows the output from an undamped ferrite monitor with ringing at the fast transitions at the rise and fall of the pulse. Figure 3 shows the output from a monitor using damping resistors with a calibration current through a wire at the center of the monitor. Figure 4 is the output of one of the new monitors with a beam pulse from the linac. The rise time of the pulse in Fig. 4 is limited by the electronics used with the monitors. In test setups we have measured rise times below 10 ns with ringing reduced to no more than a single overshoot. Fig. 5.

References

1. D. A. L. Paul, E. W. Harrigan, M. Kisly, D. K. Lam and J. Maksimon, "Instrumentation for Monitoring Current for a 30 MeV Electron Linac, IEEE Trans. Nucl. Sci., Vol. NS-16, No. 1, pp. 96-102, (February 1969).

2. J. L. Menke, "Beam Monitoring at the NBS Linac," IEEE Trans. Nucl. Sci. Partical Accelerator Conference, 1969, Vol. NS-16, No. 3, p. 92.

3. J. M. Andersen, "Wide Frequency Range Current Transformers," The Review of Scientific Instruments, Vol. 42, No. 1, July 1971, p. 915.

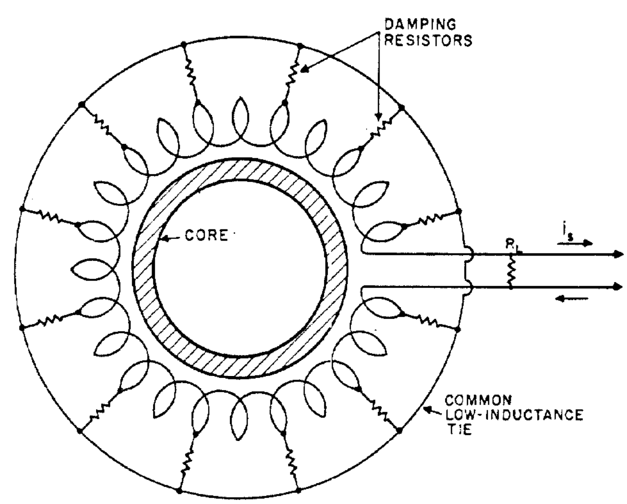

Figure 1. Schematic of a ferrite monitor typical of those constructed for use with the NBS Linac. Damping resistors are placed symmetrically about the windings all tied to a common but indendent ring adjacent to the windings.

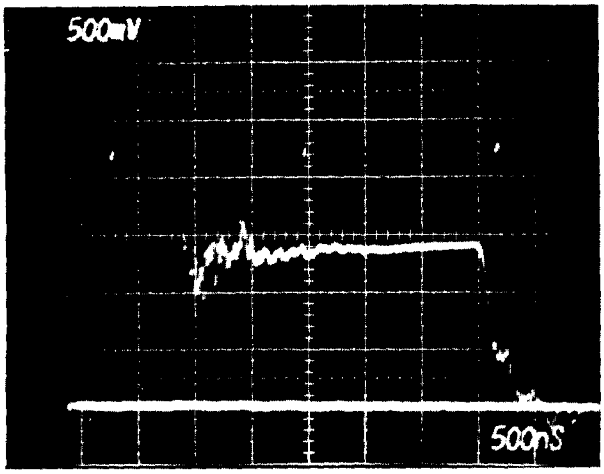

Figure 2. This is a typical output from an undamped monitor. Note the ringing at the rise and fall of the pulse. (500 ns/cm)

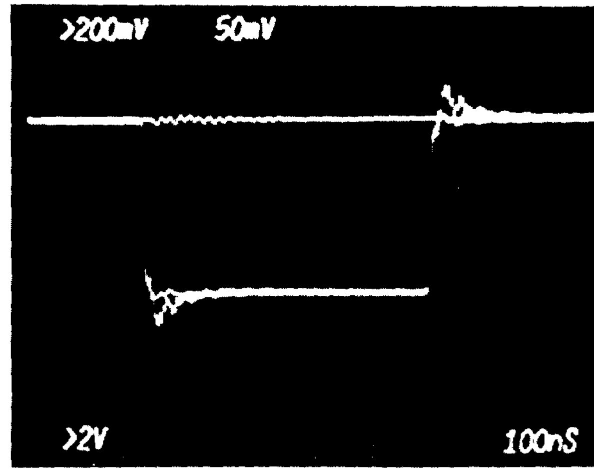

Figure 3. The output from a damped monitor using a test wire as a primary current. (100 ns/cm)

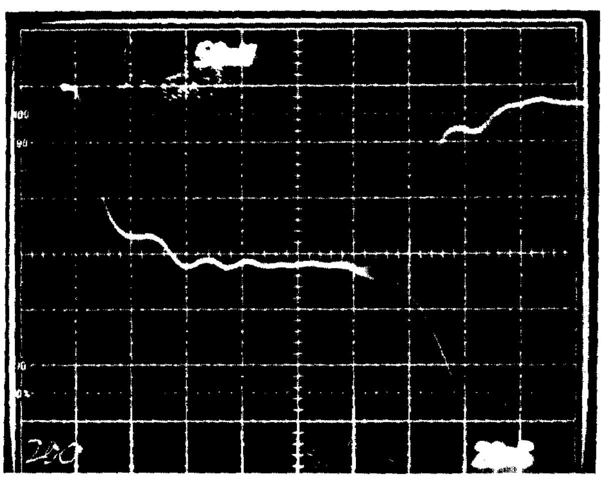

Figure 4. The output from a damped monitor looking at a linac beam pulse. The rise time is limited by the electronics used. (20 ns/cm)

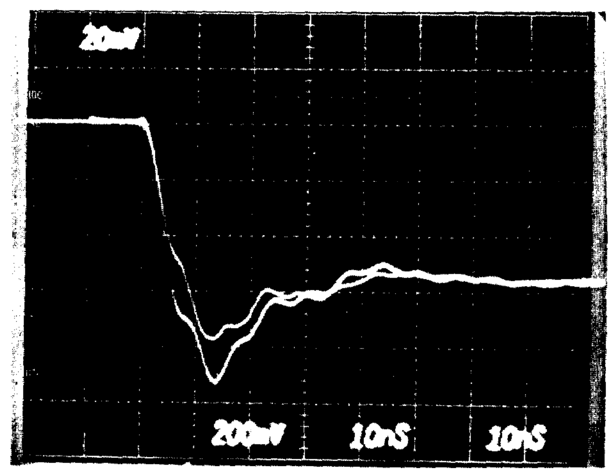

Figure 5. Test pulses used with damped monitors. (10 ns/cm)