BEAM CURRENT MEASUREMENT SYSTEM IN CSNS LINAC

Peng Li#, Taoguang Xu, Ming Meng, Fang Li
Institute of High Energy Physics, Beijng, China

Abstract

The China Spallation Neutron Source (CSNS) is under construction now at Dongguan, Guangdong province. Beam Current Transformers (BCTs) have been designed to measure the H-minus beam current in CSNS Linac. The macro-pulse width is about 500µs which repeat period is 40ms and the current will be 5~50mA in CSNS Linac[1]. Besides, a FCT is planned to measure the macro-pulse current also because there is no enough space to install a BCT after DTL1.

INTRODUCTION

The CSNS accelerator consists of an 80MeV H- linac, an 1.6 GeV Rapid Cycling Synchrotron (RCS) and related beam transport line. There are Low Energy Beam Transport line (LEBT) after the 50KeV H- Ion Source, Medium Energy Beam Transport line (MEBT) after the 3MeV Radio Frequency Quadrupole (RFQ), Lianc to Ring Beam Transport line (LRBT) after Drift Tube Linac (DTL).[2] The layout of the CSNS linac is shown in Fig. 1.

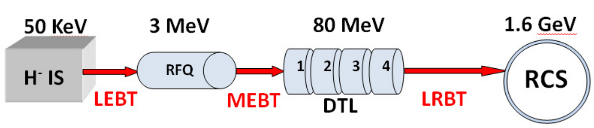

Figure 1: Layout of CSNS Linac.

The repeat period of H- beam macro-pulse is 40ms and pulse width is about 500µs. And the beam current will be 5mA to 50mA in CSNS. BCT can be used to measure beam current and pulse width. We plan to install BCTs in front and rear of each transport line and space between DTL tanks. So we can got the beam's pass through ratio and evaluate the beam loss of each part.

BCTs

The BCT measurement system contains a toroid monitor and related electronic module. We do our best to increase the toroid's inductance L and decrease the input resistance R of electronic module. So that we can got the longer droop time constant τ=L/R. The waveform we got more close to real beam pulse. The amplitude decay at 500µs is lower than 1%.

The main parameters on which toroid's inductance dependent are the coil turns N, the relative permeability μ_r, and the size of toroid h, r_o, r_i [3]. the equation is:

$$L = \frac{\mu_0 \mu_r}{2\pi} N^2 h \ln \frac{r_o}{r_i} \quad (1)$$

The relative permeability μ_r larger, the inductance L larger. We have been looking for soft magnetic materials which have good performance in low magnetic loss, low remanence, fast flux reversal, lineal hysteresis loop curve etc. At last we choose a kind of Co-based alloy material called CAL, whose main component are Co, Fe, Si etc. It's relative permeability μ_r is larger than 20000 in the condition of 25Hz, magnetic flux density not more than 0.5A/m. Another need to be noticed is that the relative permeability will decrease in the growth of frequency.

We can wind more coil turns properly to increase the toroid inductance. However the turn number can not be too large. The equivalent signal amplitude which input the electronic module is I/N. The more turns, the smaller amplitude, and the lower SNR. We choose 150 turns to ensure the good SNR.

About toroid size, we are not so free to design each dimension. There are so much various monitors would be installed and the space along beam's movement is limited strictly. The inner diameter of toroid is main dependent on outer size of vacuum pipe. The only free dimension is toroid's outer diameter.

Besides we plan to use the same electronic module, so we designed the same toroid inductance although these transport lines have different vacuum pipe outer size. We designed different sizes of BCTs for each beam transport line. The detail sizes are listed in Table 1. The inductance is about 0.5H.

Table 1: Toroid Sizes

section	quantity	length	Inner	Outer
LEBT	2	17mm	110mm	157mm
MEBT	2	17mm	60mm	85mm
DTL	3	17mm	60mm	85mm
LRBT	4	17mm	105mm	150mm

After winding 150 turn on the magnetic core of toroid, we poured epoxy on it to be a regular whole. And each side size will increase about 2mm.

The BCTs which will be installed in LEBT, MEBT, DTL have been produced completely and so do their vacuum pipes which be disconnected by ceramic on the location of BCT. And we are about to make BCTs for LRBT.

#lipeng@ihep.ac.cn

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MEASURER MACRO-PULSE USING A FCT

Between DTL1 tank and DTL2 tank, the space is too narrow to install both a BCT and a FCT. The FCT is planned to measure beam phase and the BCT will be not installed. We try to measure macro-pulse using the FCT.

FCT is well known for fast response. It's rise time lower than 1ns [4]. So it usually be used to measure each bunch, which is called micro-pulse sometimes. And it can be used to measure beam's phase and energy etc. Due to it's powerful performance in high frequency, it's low frequency response is not so good, just like every coin has two sides. It's inductance is far smaller than CT and it's droop time constant τ is about 10~100μs normally. The waveform we get decay apparently when you using a FCT to measure a pulse long than 10μs. To solve this problem, improving the electronic module is an effective method but a difficult way. We introduce another idea to measure long pulse using FCT [5].

When testing a ideal pulse signal, the shown waveform we got using a BCT system is also a regular pulse shape. The amplitude is same during the pulse continuance, it is a straight line and we can get the current data easily. But the shown waveform is a exponential decay curve when using a FCT to measure a ideal long pulse signal. It's not so easy to get the current data because the amplitude is different at every time point during the pulse continuance. However we need noticed that the whole exponential decay curve could deliver the tested signal's information alike. As long as the test signal is unchanged, the curve got from FCT is unchanged also. The transform relationship is fixed in other words. And we could find the response formula easily. Once we got the curve data, we compute in PC using the formula and we could display the original appearance of test signal. Furthermore we can revert to the real waveform no matter what type of signal is.

It's not hard to write the corresponding formula between input signal and output signal of our FCT measurement system if we have known all details of FCT, the electronic module, and other parts else such as the connected wire. Besides, analysing output signal of known input signal is a more precise method. It's also called Impulse Response in many books. Computing in frequency domain would be easier. However, FFT and IFFT are unavoidable.

We have done some test in laboratory and revert to original input signal offline successfully. Apparently it need time to compute data when measuring macro pulse using FCT. And we need high speed sample technology.

So this FCT installed after DTL1 has two functions. We connect it to an oscillation directly when measuring beam phase, and connect it to the normal BCT's electronic module when measuring beam macro-pulse.

CONCLUSION

Though different vacuum pipe sizes in CSNS Linac the BCT monitors have been designing step by step. They all have a good performance in laboratory. And the electronic module is developing. So do related works such as data acquirement and programming. The whole system error will be controlled lower than 1%.

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