DC TO 100 KHZ BEAM CURRENT TRANSFORMER FOR CELSIUS

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Abstract

A new DC to 100 KHz beam current has been developed recently for the CELSIUS ring at Uppsala. Special shielding has been designed to suppress the strong magnetic stray fields.

1 INTRODUCTION

CELSIUS is presently equipped with a DC current transformer, which was taken over from the decommissioned ISR [1]. The space occupied by this transformer is claimed by new experimental equipment to be installed in the ring [2], therefore a more compact transformer had to be built. At the same time, we wanted to get better resolution and dynamic range and faster response than what is available from the old DCCT.

2 PRINCIPLES OF OPERATION

The operation of the new DC to 100 kHz beam current transformer is based on the principle of magnetic modulator [3].

The transformer consists of seven cores wound with NiFe alloy tape Ultraperm 10 [4], 0.3 mm thick, 5×5 mm^2 cross section, produced by Vacuumschmelze GmbH, Hanau, Germany. Two cores, which have been selected to give the best permeability match, work as magnetic modulator. Another one works as a buffer. The others are for AC signals. The DC and AC channels are joined together smoothly to obtain frequency response from DC to 100 kHz.

The circuit consists of a modulator, a demodulator, an AC channel, a feedback loop, and a calibration circuit. The drive signal is a square wave current source working at a frequency of 2.3 kHz.

Because the square wave signal does not contain even harmonics, so when there is no DC current to bias the cores, the output signal contains only odd harmonics. But when there is DC current going through, the second harmonic of the exciting frequency appears. Both its phase and amplitude are related to the DC current [5].

A capacitor is used in parallel with the drive cores to provide a large current to drive the modulator cores into deep saturation (see fig. 1). When the driving current starts driving the core into saturation, at the same time a part of the current is charging the capacitor. When the core is saturated, the inductance of the driving coils reduces to zero, the charge accumulated on the capacitor will then be released into the drive coil to drive the cores into deep saturation. Therefore, the value of the capacitor is very important. If it is too large, the time constant will be too large, it will not be charged enough, if it is too small, enough charge will not be accumulated. The value of the capacitor is determined by testing. The drive frequency has to be optimised to obtain the largest possible drive current with the least power drawn from the power supply. In our case, the total driving current drawn from the +18V DC power supply is 120 mA, 2.2 W.

The DCCT of the old style is a simple modulator and demodulator, this new PCT employs many techniques to improve the stability and resolution. There is a phase adjustment circuit after the crystal square wave signal generator to optimise the phase for the synchronised demodulator. There is a filter before the demodulator to filter out the main, third, fourth harmonics.

A demagnetisation circuit is used to demagnetise the cores each time the power is turned on in order to reset the cores by clearing their residual magnetic field. The circuit generates a 45 Hz sine wave current with peak current >10 A. This is sent to the feedback coil for demagnetisation The current decays exponentially with a time constant of 10 s. After demagnetisation, the feedback coil is switched back to the feedback loop. The whole transformer works in a very stable way, the resolution is better than 1 μA.

The output of the PCT has different options. Pure DC output , full bandwidth output, and *dI/dt* output, which shows the current change. The main circuit will be placed close to the transformer in order to reduce the loss due to the cable, so the drive and the demagnetisation circuit can still provide enough current to drive or demagnetise the cores. In the control room, there is a module to give the various output options.

Instead of choosing the material Vitrovac 6025 to wind the cores, we have chosen Ultraperm 10, which has better temperature stability. We considered this more suitable for us because the CELSIUS ring has to be baked out frequently. The material we use is thicker, and the permeability is not as high as for Vitrovac, therefore our drive frequency can not be very high, only 2.3 kHz; this mainly affects the transition frequency from the DC to the AC channel. With a lower transition frequency, the AC core section has to be larger to have a low enough frequency response. We use four cores for the AC channel.

3 MAGNETIC SHIELDING

The current transformer detects the magnetic field produced by the beam. For a 1 μA beam, the magnetic field

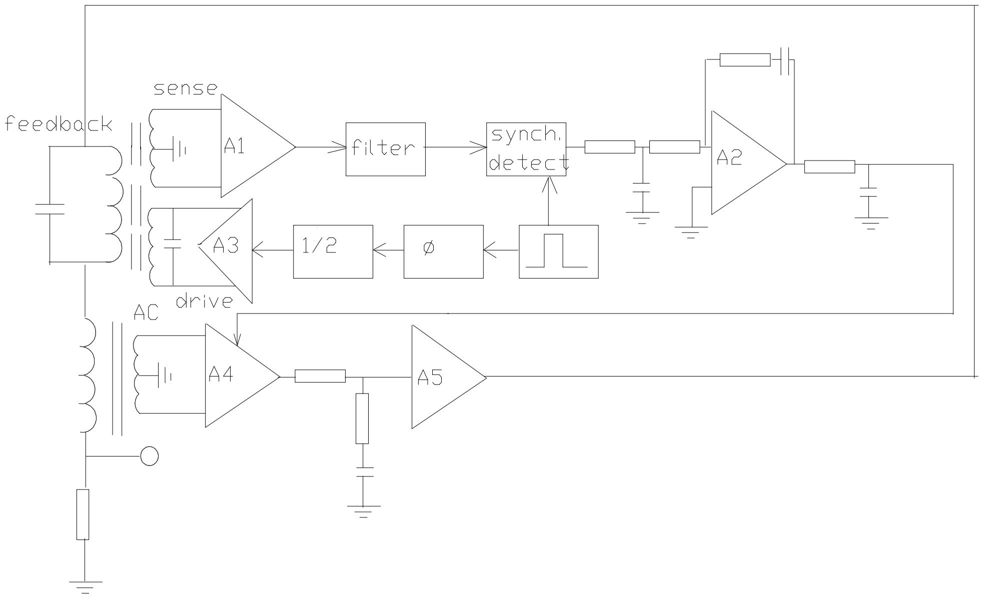

Fig. 1 Circuit diagram

produced in vacuum at a distance of 10 cm is 2×10^{-12} T, in the Ultraperm cores, with $\mu = 5000$, it is 1×10^{-8} T. At the same location, the stray field from the CELSIUS ring magnets can be as high as about 2×10^{-4} T, a very good magnetic shielding is therefore needed.

The shielding has 7 layers, wound with Vitrovac 6025 tape, both inside and outside of the cores. There is a gap of 1 mm between each layer. The total length of the shielding cylinder is 300 mm, which is three times longer than the transformer, so the magnetic stray field coming from both ends is greatly reduced at the location of the transformer. We calculate the shielding factor to be about 5000. Outside the Vitrovac shielding, there are two layers (1 mm thick) soft ion shielding to greatly reduce the stray field to prevent that the high-μ Vitrovac shielding gets into saturation. There are water cooling pipes brazed to a heat screen to prevent the Vitrovac tape from getting hot during the baking process.

4 BENCH TEST RESULTS

Bench tests have been done to calibrate the sensitivity, linearity, frequency response and long term drift of the transformer. A computer program has been written to record data of the transformer to a computer via a HP34401A multimeter. The calibration curves shows the linearity (fig. 2) and the resolution (fig. 3). In the measurement, the transformer was not set to zero. The zero drift has been recorded. In a period of 12 hours the PCT had about 1.6 μA drift, basically due to room temperature changes.

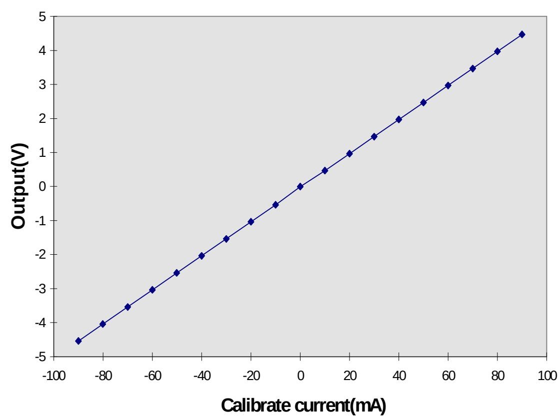

Fig. 2. Linearity calibration curve

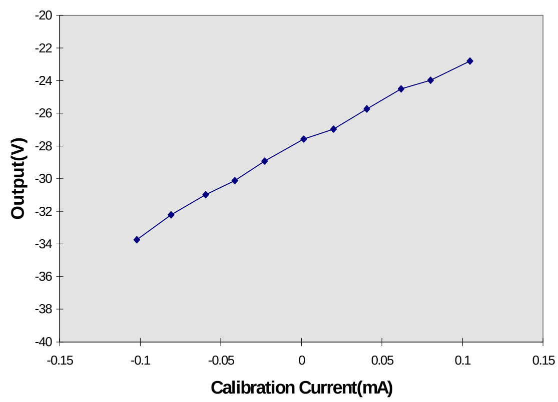

Fig. 3. Resolution calibration curve

The frequency response has also been measured (see fig.4). The AC channel has greatly improved the performance of the PCT with its fast response and stability.

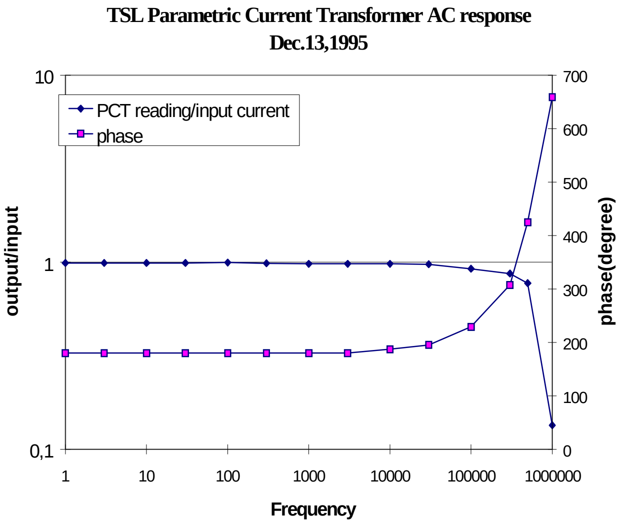

Fig. 4. PCT frequency response.

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