Progress in VECC Cryogenic Penning Ion Trap Development

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Introduction

The development of VECC Cryogenic Penning Ion trap has reached an advanced stage and the system would soon be commissioned. We shall present the development of several crucial cryogenic components such as cryogenic feedthrough and cryoelectronic components. Both the cryogenic feedthrough and cryoelectronic components like RC filter, switching circuit and low-noise amplifier are essential items for the successful commissioning of the cryogenic Penning trap system and their developments have been described here.

Cryogenic Feedthrough

A special cryogenic, non-magnetic, multi-pin, vacuum feedthroughs is required for applying voltages to Penning trap electrodes that would be in a high vacuum environment surrounded by liquid helium in the bore of a 5T superconducting magnet [1]. The feedthrough system must be made of non-magnetic materials so that the high level of spatial uniformity (1 ppm level uniformity over 1 cm DSV) of the magnetic field is not compromised in any way. The development and installation of such special feedthroughs has always been a challenge. We have developed such a cryogenic feedthrough system (19 pin feedthrough) and tested it down to 77° K. The pins were made of copper wires of diameter 1 mm. An aluminum flange and Stycast 2850 Ft (blue) were used as sealant [2]. Many designs of the flanges and placements of the copper wires were tried. Finally, an optimum design using a wedged-shaped cylindrical aluminum flange filled with Stycast 2850 (blue) was developed and it remained leak-tight down to 77° K under many thermal cycling from room temperature to liquid nitrogen temperature. Fig. 1 shows the fabricated feedthrough connected to the Penning Trap vacuum chamber.

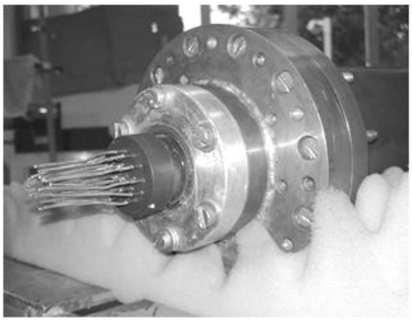

Fig. 1 Fabricated feedthrough connected to vacuum chamber

Cryoelectronics

In a cryogenic Penning Trap, it is required to measure very weak image signal (~few microvolt) produced by a cloud of electrons. So, it is essential to eliminate all sources of noise and fake signals that might mimic our signal of interest. In order to improve the signal to noise ratio, the electron cloud is resonantly excited by a radiofrequency wave. However, the applied RF should not be on all the time. The image signal of the electron cloud should be measured when the RF is off. So, a cryogenic switching circuit and proper RF grounding are required. In order to reduce noise, applied dc trap voltages should also be filtered by RC filters and hence the development of cryogenic RC filters was required. In Fig. 2, we show a picture of a board containing RC filters and switching circuits. The board has been tested down to 77° K using indigenously developed copper wire feedthrough system. Unfortunately, it was found that the copper wires of feedthrough act like antenna for Rf signal and induce signals among one another. We used RF shielding on feedthrough pins and could reduce the RF interference effect to an acceptable level.

Fig. 2 RC filter board along with cryogenic switches fabricated at VECC.

Another developmental activity is the development of cryogenic low noise amplifier. Cryogenic low noise amplifier is required for the detection of feeble voltage signals of trapped electrons. The amplifier should have high input impedance, low input voltage noise density, low power consumption and capable of operating in the frequency range between 55 MHz - 70 MHz in the environment of high magnetic field of 5T . As the amplifier has to operate at cryogenic temperature and higher magnetic field, a GaAs devices has been selected for amplifier design. A cascode topology [3] has been implemented in our design to achieve our requirements [4]. In Fig. 3(a), we have shown a picture of an indigenously developed and built low noise amplifier. The voltage gain and input voltage noise density of the amplifier at 63 MHz (which would be the frequency of the trapped electron cloud) for different operating drain currents are shown in Fig. 3 (b). The initial result is satisfactory but it is required to further reduce the input noise voltage in order to be comparable with the best available ones in the world.

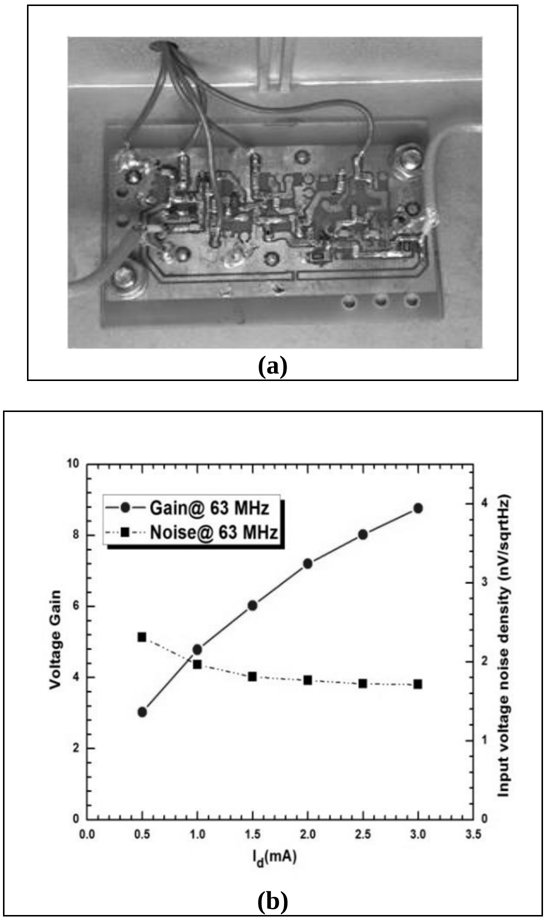

Fig. 3 (a) Low noise amplifier fabricated at VECC and **(b)** Measured voltage gain and input noise voltage density of the fabricated amplifier at 63 MHz for different operating drain current

References

[1] A. K. Sikdar et al. , Proc. DAE Symp. **57** (2012) 884.

[2] C.D.Bass , Rev. Sci. Instrum **79** (2008) 05501.

[3] S. Ulmer et al., Nucl. Inst. and Meth. A **705** (2013) 55.

[4] A.S. Sedra and K. C. Smith, Microelectronic Circuits, Oxford International student edition (2011) 638.