A Digital Approach of Beam Phase Measurement and Regulation System

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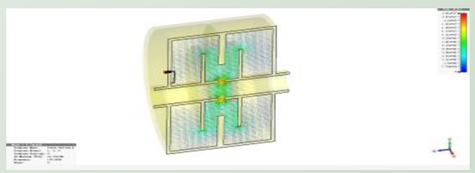
Abstract

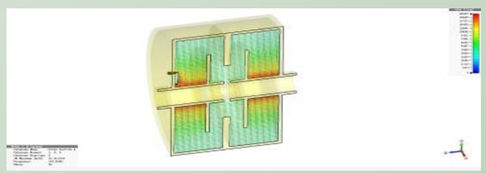
A superconducting cyclotron, namely CYCIAE-230, is developed by the China Institute of Atomic Energy (CIAE) as a proton source for cancer therapy. Proton therapy is a very demanding application for beam stability, it is very important to control the isochronism for the cyclotron. A digital approach of beam phase measurement and regulation system is designed and tested, faced with the phenomenon that the phase slip during the operation of the acclerator. The experiment results show that the beam phase measurement and regulation system could limit the accumulation of the phase slip and control the isochronism of the cyclotron. In the meantime, the relationships between beam phase and the cyclotron magnet exciting current are measured by the experiments.

Introductions

The digital approach of beam phase measurement and regulation system is consist of hardware and software. The hardware realizes the function of phase discrimination between beam phase and RF reference signal. The software realizes the functions of communication with CPCI bus and PID core algorithm. The whole system is able to control the isochronism for the accelerator

Design of the beam phase probe cavity





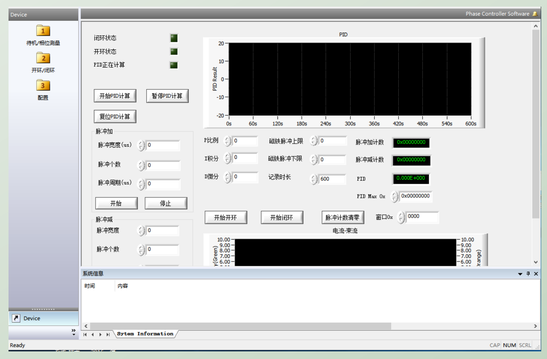
Frequency	**142.28MHz**
Tuning Range	**±200KHz**
Unload Q	**7300**
R_p	**1.0MΩ**
Cavity Thickness	**0.4m**

The beam phase probe cavity is maed up pure aluminum.The resonant frequency of the beam phase probe is determined to be the second harmonic. The resonato adopts a high Q design, the bandwidth is limited to be about 39KHz. Two aluminum tuning rods are added to provide the ability to adjust frequency online.A coupler is also added to the cavity to fetch the beam generated RF signal.

PCB Board

The beam phase control PCB board is complemented as a 6U CompactPCI card using 8 layers layout design. It provides a relatively small footprint. It locates in the second slot of the CPCI crate. In the meantime, it can meet the demands of electromagnetic compatibility.

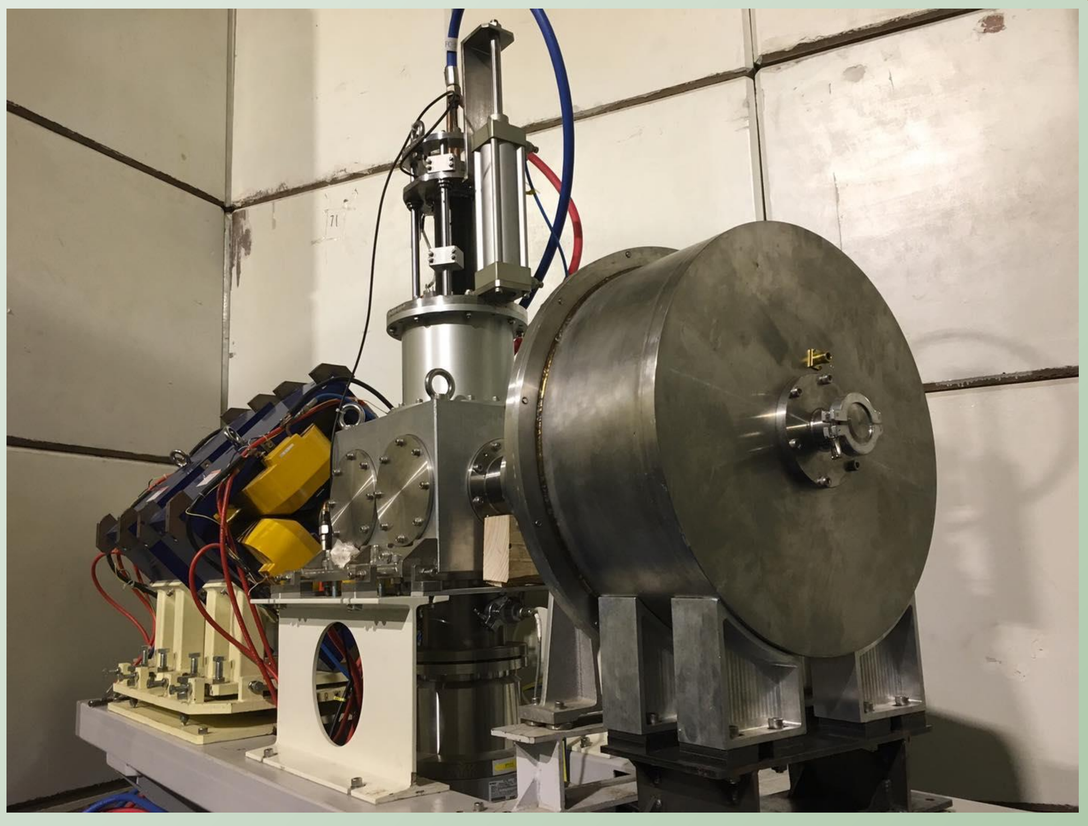
The GUI of the beam phase control system



The environment for the user interface is determined to be Microsoft Windows. It can switch to different dialog views as needed by the user. The user can set the pulse width, the pulse numbers, the PID gain,etc .

The history diagrams of the beam phase, PID output voltage, and the frequency of the pulse train can be showed on the interface. There is a message output bar located in the bottom part of the GUI. In which, a timestamp, as well as each Modbus TCP traffic, can be displayed for diagnostics purposes for the data engine. In operational mode, this output bar is used to promote important messages from the control hardware, including network disconnection, etc.

The experiment on the CYCIAE-100 cyclotron



The beam phase control PCB board is tested on the beamline of CYCIAE-100 cyclotron. Preliminary results in the experiment with the proton beam of 44.8125MHz repetition rate show there is a quasi-linear monotonic relation between the cyclotron magnet exciting current and beam phase. The experiment results prove the feasibility of the system.

Summary

The experiment results verify the feasibility of the beam phase control system, also show a proportional relationship between the beam current and probe signal strength. This effect is used to yield a non-destructive beam diagnostic method for the vertical deflector control, as one of the feedback. The whole system was designed at the end of 2019 and is expected to be applied to the CYCIAE-230 cyclotron at the end of 2020.