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A digital approach of beam phase measurement and regulation system

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A superconducting cyclotron, namely CYCIAE-230, is developed by China Institute of Atomic Energy (CIAE) as a proton source for cancer therapy. As proton therapy is a very demanding application for beam stability, it is very important to control the isochronism for the cyclotron. In the daily operation of the accelerator, the accumulation of phase slip should be limited. In general, there are several ways to regulate the magnet field for a fix frequency cyclotron. One of them is to measure the beam phase with respect to the RF cavity. This phase result can be used to increase or decrease the field accordingly, so that the total acceleration time for different particles can be constant. The beam phase stability control system of CYCIAE-230 superconducting cyclotron is designed to measure the beam phase and using it to adjust the current setting of main magnet power supply. The reported system includes a high-resolution resonator type beam phase probe, a digital frequency down conversion and phase detector module, a digital PID controller and a digital power supply adjustment interface. This paper summarizes the numerical analysis of high-resolution phase probe, and will give the design of digital frequency reduction phase discriminator, the core algorithm of digital controller, and the digital power control interface. A prototype has been manufactured and tested with CYCIAE-100 cyclotron, the results will also be evaluated in this paper.

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