DEE VOLTAGE STABILIZER USING A SERIES TUBE FOR THE INS SF CYCLOTRON

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The rf resonator of the INS 176 cm Sector Focusing Cyclotron has been designed to operate in a frequency range of 7.5 ~ 22.5 MHz, and now is used in a range of 7.3 ~ 18 MHz. A self-exciting triode (9T71A) oscillator generates the rf power for the resonator. A 7F25B tetrode is used as a boosting oscillator to overcome the multipactoring. The rf system is equipped with a dee-voltage stabilizer, which is described in this report (see fig. 1).

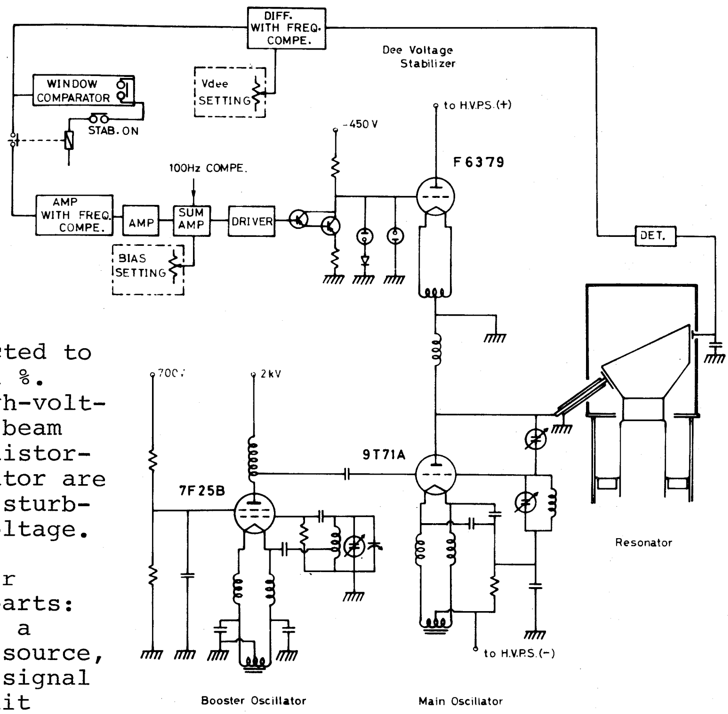

Fig. 1 Block diagram of the rf system

High stability for the dee voltage is required primarily because of the requirement to get high intensity beams on the target, which are momentum-analyzed for use in the high-resolution experiments. The stability is expected to be better than 0.1 %. Ripples of the high-voltage power supply, beam load and thermal distortion of the resonator are main sources of disturbance to the dee voltage.

The stabilizer consists of four parts: a regulating tube, a reference voltage source, a high-gain error-signal amplifier and a unit named "de-rippler". A low-μ triode (ITT, F-6379) is used as the regulating tube, which is cooled by forced water and air, heated by a.c. current. It is operated with a negative grid bias. The typical operating conditions are: plate voltage 3.0 kV, plate current 5.2 A, and grid bias -200 V. These conditions result in a 30 % plate dissipation of the maximum rating. The error-signal amplifier is composed of low-level drivers, a window comparator and a power-transistor stage. The dee voltage is picked up by a capasitor to obtain the image voltage, which is fed into the first operational amplifier (119K) together with the reference voltage controlled by a potentiometer at the control desk. The window comparator closes the feedback loop when the error signal falls in a predetermined range. The error signal is amplified and a voltage in the range of -50 ∿ -400 V is applied on the grid leak (1kΩ) of the regulating tube. The grid leak is in series with the power transistors. The negative bias is preferred, because little current flows through the grid of the regulating tube.

Since the feedback loop has a high Q-value, the phase shift of the error signal is appreciable and limits the open loop gain of the system. Taking this effect into account, we chose an open loop gain of about 55 db at d.c. including the efficiency of the dee-voltage pickup (-80db). This gain should be enough for suppressing the ripple of 600 Hz with an amplitude of 0.5 % rms, which comes from the high-voltage power supply employing a six-phase full-wave rectifier, if the phase and amplitude of the line voltage are properly balanced. However, an appreciable amount of 100 Hz ripple appeared, indicating that the balance was probably not complete and the filter of the power supply was not enough. Furthermore, when the regulating tube was used as a voltage controller by opening the feedback loop, the ripple voltage of 100 Hz increased in comparison with the case when the regulating tube was by-passed. This effect is supposedly due to floating the power supply (see fig. 1) and a.c. heating of the regulating tube. Thus the "de-rippler" was inserted, which generated a 100 Hz signal with an anti-phase to the ripple.

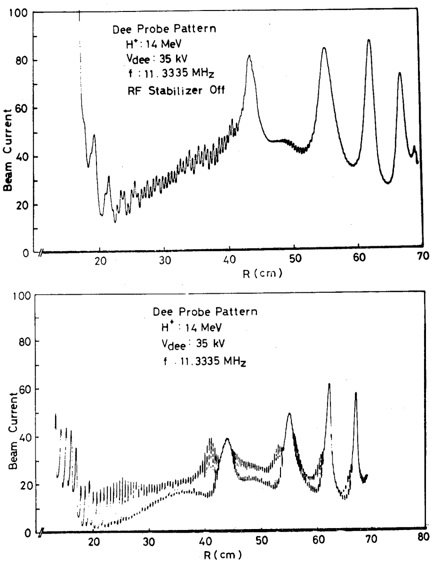

Fig. 2 Differential probe patterns of the internal beam observed with (bottom) and without (top) the dee voltage stabilizer

Stability of the dee voltage, after warming up for 30 min., is better than 5×10^{-5}/hr (3×10^{-2} when unregulated) without the beam load, and 1×10^{-4}/hr (3.7×10^{-2} when unregulated) with a 30 μA internal beam of 14 MeV protons. The internal-beam structure observed by a differential probe was improved greatly, as shown in fig. 2, when this stabilizer was used. At the same time the intensity on the target of the high-resolution cources increased. When the cyclotron accelerated heavy ions, a considerable drop of the dee voltage was observed in the period when the pulsed heavy-ion arc was switched on. However, the use of the stabilizer increased the beam intensity, although the stabilizer could not regulate the dee voltage completely and the variation of the dee voltage was observed.