A NEW METHOD FOR HIGH PRECISION DEE VOLTAGE STABILIZATION

P. v. Rossen[+], K. Euler[++] and F. Hinterberger[++]

[+] Institut für Kernphysik, KFA Jülich, Jülich, W. Germany

[++] Institut für Strahlen- und Kernphysik, Universität Bonn, Bonn, W. Germany

Abstract

A new method has been successfully tested at the Bonn Isochronous Cyclotron that gives superior dee voltage stability. This new principle is especially of interest for larger cyclotrons. Measurements are presented and their implications discussed.

Introduction

Many experiments depend strongly on the quality of the extracted cyclotron beam. From the various parameters which have to be stabilized like main field, trim coils, RF-frequency, the dee voltage is especially difficult, because it is not easy to construct a reliable voltage probe that allows to obtain the correct error signal for the stabilizing circuit. Very often beam property fluctuations that impair precision experiments are mainly due to dee voltage variations. Therefore, numerous attempts have been made to improve the stability of that important parameter.

Standard Regulation Schemes

The method widely applied to obtain a stable dee-voltage is the use of a capacitive or inductive pick-up probe and the comparison of this signal with a preset value. The error signal obtained is fed to a regulation circuit that varies the power of the RF generator accordingly. With a scheme like this the precision in dee voltage stability is virtually limited only by the accuracy of the probe. Unfortunately these probes are very sensitive to mechanical changes due to temperature variations or vibrations. By this way dee voltage fluctuations are actually introduced through the servo loop.

Energy Feedback Systems

To overcome the limitations set by these conventional regulation schemes the Bonn Isochronous Cyclotron is using a modified regulation system which is an overlay of two servo loops[1] (cf. figure 1). The conventional one where the signal is obtained with a capacitive probe to give a coarse regulation. For the 10^{-4} level of $\Delta V/V$ an additional signal is derived from the current asymmetry of a slit that is located behind the first analysing magnet. Thus the energy of the extracted beam is used to stabilize the dee voltage. With that scheme even small drifts of the main field and/or RF-frequency are compensated by readjusting the dee voltage.

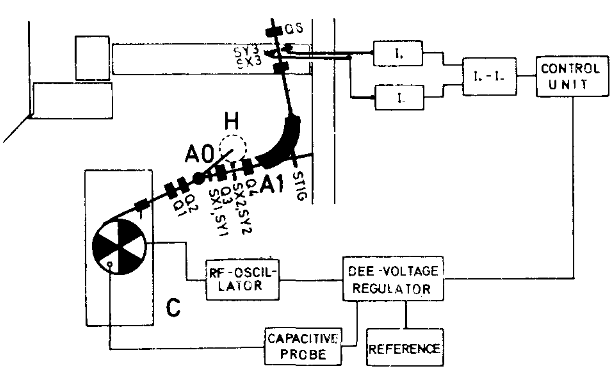

Figure 1: Dee voltage stabilization by using the analysing slit.

The limitation of this method, which is similar to the ones of terminal voltage stabilization in tandem accelerators, is the necessity of nearly single turn extraction. Larger cyclotrons, where many orbits are mixed in the extracted beam, are therefore not able to take advantage of this technique. To obtain an improved dee voltage stability for this kind of machines, too, we have tested a new method for obtaining a high precision error signal.

Instead of using external slits an internal slit is installed.

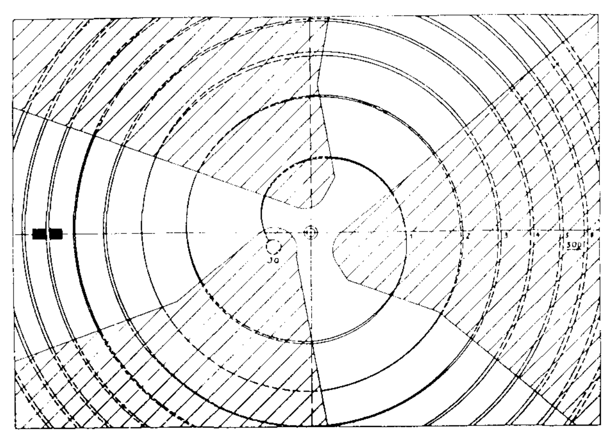

Figure 2: Inner orbits of the cyclotron with the slit at the fifth orbit on the left side.

Fig. 2 shows schematically the inner orbits of the cyclotron with the slit positioned at the fifth orbit. Under the asumption that all other parameters are constant the radius is given by:

$$r = \text{const.} \cdot \sqrt{V}$$

and thus

$$\Delta r = 1/2 \cdot \frac{\Delta V}{V} \cdot r$$

This shows that for obtaining a large displacement of the orbit for a given variation of the dee voltage one has to choose a radius as large as possible. In addition the radial phase space shrinks with increasing radius and a variation of the orbit position leads to an increased asymmetry signal. In figure 3 the radial position of the slit is varied and the vertical axis shows the measured asymmetry voltage V_a. It is easy to see that dV_a/dr gets bigger for large radii increasing the sensitivity of the probe. To obtain the best position

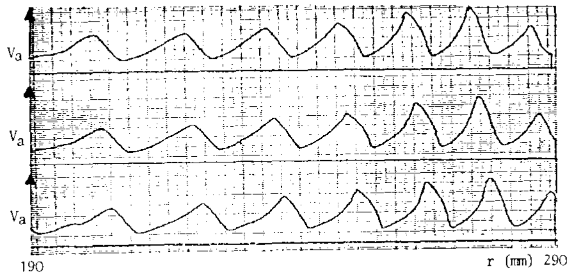

Figure 3: Asymmetry signal (left current - right current) versus radial position of the slit for different settings of the dee voltage in rel. units: top 660 middle 670 bottom 680.

one moves the slit while observing the beam at an outer radius to find the optimum for sensitivity and transmission.

In our test the slit jaws had a width of 5 mm each with a 5 mm gap in between. In the optimum position for regulation the beam intensity had dropped to ca.50%. No attempts were made to improve this value as the main objective was to study the behavior of such a system. The current signals of those slits were after careful filtering of the residual cyclotron RF fed to the current amplifiers of the external slit system.

This method needs again the double servo loop technique as the asymmetry signal can only be used in a narrow regulation range. After matching the PID characteristic of the regulation circuit a performance was obtained comparable to the old system which stabilizes $\Delta V/V$ to 10^{-4}.

Conclusion

The tests of a new method for a dee voltage stabilization have shown that it results in a much improved stability compared to a capacitive or inductive regulation circuit. The necessary requirement of stabilizing main field and RF frequency sufficiently can be fullfilled without difficulties. As shown in ref. 1 the method has the additional advantage that beam energy fluctuations due to small instabilities of the RF-frequency are essentially smoothed by the compensating effect of the dee voltage regulation. The method is applicable also to cyclotrons which have no separated orbits at the extraction radius. It can be either used for regulation or for checking existing stabilization systems.

Reference

1) F. Hinterberger, P. v. Rossen, and K. Euler, Nucl. Instr. and Meth. 133 (1976) 1