METHODS OF BEAM PULSING APPLIED AT THE KARLSRUHE ISOCHRONOUS CYCLOTRON

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ABSTRACT

In the last years more and more experiments at the Karlsr. Isochronous Cyclotron were performed using a pulsed particle beam (about 30 % of the whole machine time). The experiments are: neutron time-of-flight experiments, measurements of the magnetic moments of light nuclei, a study of properties of nuclei far from the stability line, charged particle activation analysis and spinrotation experiments in metals to study internal magnetic fields. This spectrum of experiments requires beam pulses with widths and repetition periods in the time range from nanoseconds to seconds. To cover the whole time range two methods have been developed, a radial and axial deflection system on the first two turns inside the cyclotron and an arc current pulsing of the ion source. The design and performance of the two systems and the diagnostic methods for the resulting beam pulses are described.

INTRODUCTION

Until now there have been different attempts to modulate the natural timestructure of isochronous cyclotrons. The methods used are: pulsing the accelerating rf voltage[1], controlling the ion source plasma[2] and various electrostatic deflection systems[3-6]. The latter can be done in principle either for the extracted beam or by stopping the beam on the first turns. The first method has the great disadvantage that the stopped beam activates material and therefore produces background for the experimenters and a health problem for the accelerator operation group. An additional problem in this case is that the power for the pulse-generators to be used at the deflection plates will rise with the increasing energy. On the other hand there exists also a serious problem for the internal deflection systems: A proper selection of a single microstructure pulse on the first few turns will not produce the same time structure in the external beam if the cyclotron works in the mode of multiturn extraction. The main pulse is then followed by some additional pulses depending on the revolution time

Table I Pulsing requirements for the various experiments

type of experiment	neutron time of flight	spinrotation experiments	nuclei far from stability line
time structure	∿ 1.5 nsec width 11 MHz and simultaniously 1-4 μsec width, up to 200 kc/s	∿ 1.5 nsec width 11 MHz or 1-50 μsec width, up to 50 % duty cycle	20 μsec-100 msec, up to 50 % duty cycle
particles	d	α, H_2^+, d	α, H_2^+, d
peak pulse current	100-150 μA	< 1 μA	< 30 μA
removal of unwanted beam	$< 10^{-2}$	$< 10^{-4}$	$< 10^{-4}$
method	radial and axial deflector	radial deflector source pulsing	source pulsing

and the quality of the extraction.

The pulsing modes used for the various experiments at the Karlsruhe Isochronous Cyclotron are listed in Table I.

In principle all the listed conditions can be fullfilled with an internal deflection system. Because ion source pulsing needs no modification of the cyclotron it seems to be a great advantage to use this kind of pulsing whenever possible.

RADIAL AND AXIAL DEFLECTORS

For the neutron time-of-flight spectrometer[3] we need as listed in Table I two different pulse modes simultaneously. In an earlier system this had been achieved by a pair of plates positioned on the 4th orbit deflecting the beam in axial direction. Since the central region of our cyclotron was modified in 1971 for an axial injection system the useful pole gap was reduced from 30 mm to 20 mm. The new system shows Figures 1 and 2 consists of a radial deflector positioned after the first two accelerating gaps between two dummy dees and an axial deflector positioned on the third turn.

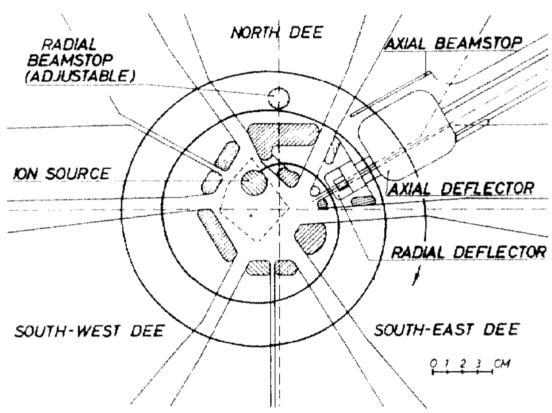

Fig.1 Plan view of the position of the axial and radial deflection system

If one applies a negative dc voltage the beam is stopped in the first case on an adjustable watercooled tantalum block and in the other by a fixed watercooled tantalum bar. The experimental characteristics of beam current vs. controlling potential is shown in Fig. 3. For the radial system the deflection characteristics and the beam losses without an applied dc voltage are strongly dependent on the position of the radial beam

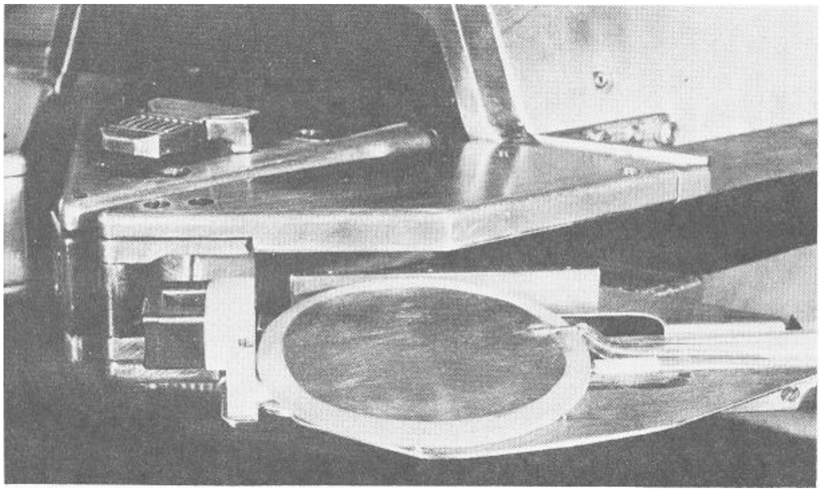

Fig.2 View of the deflection system in working position

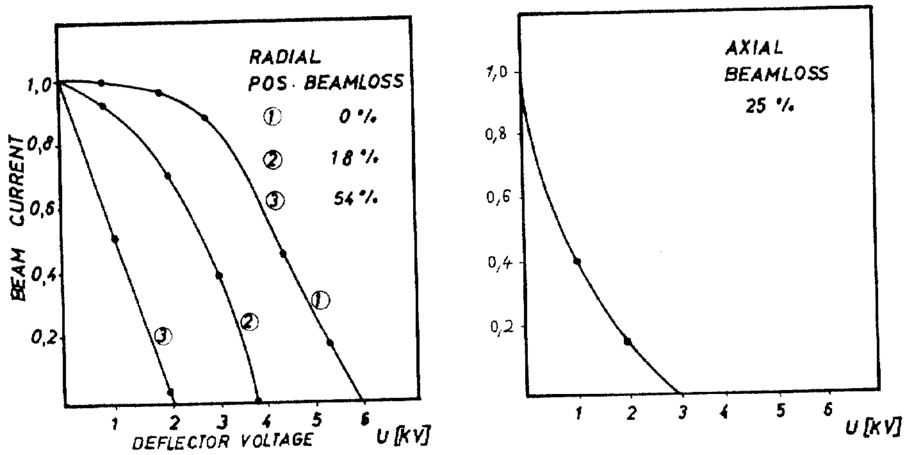

Fig.3 Experimental characteristics of the beam currents vs. controlling potential. For the radial system the curves for different beam stop positions are given

stop. Other parameters influencing the deflection characteristics are the geometry of the ion source slit and the ion source position.

The deflection electrodes are made of tantalum and the insulators of quartz and mycroy. The voltages are applied by two Lecher lines with an impedance of 200 Ω shown in Fig. 4. These lines are 2m long, 10 mm high and are situated below the median plane on the trim coils in a hill section. As the beam cycles just above these

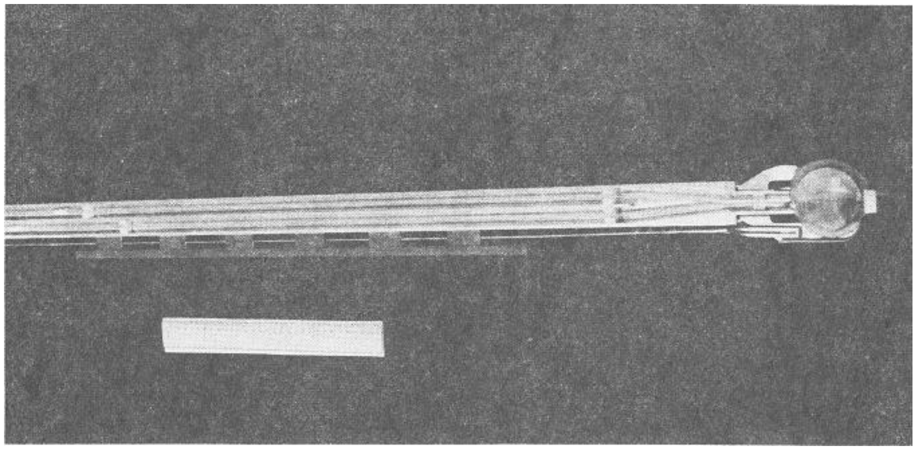

Fig.4 Deflection system with the two Lecher lines and the graphit strip for beam protection

coaxlines a graphit strip is positioned in front of them. The overall capacity of each system is 60 pF. The lines with the deflection plates can be installed or removed within one hour.

ION SOURCE PULSING

We use a conventional hot cathode Livingston type source with a direct heated tungsten or hafnium carbide cathode. The negative discharge potential is applied to the cathode superposed on the heating current. In order to prevent the filament power supply short circuiting the pulse a chocking coil was installed. Due to the complicated structure of the connections to the source inside the machine the pulser is not well matched to the load. Therefore it is very difficult to achieve rise times below several µsec.

DIAGNOSTIC SYSTEM

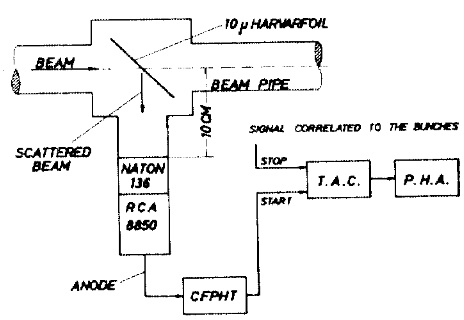

Fig.5 Diagnostic electronic

Proper operation of the system is controlled in the external beam by detecting the particles elastically scattered from a thin target by a standard time-of-flight (TOF) electronic set shown in Fig. 5.

The timing signals are extracted using the method of constant fraction of pulse hight trigger (CFHT). The time resolution of the system is better than 150 psec.

RESULTS

For the suppression of two out of three microstructure bunches a voltage of 11 MHz and a negative bias voltage are applied to the radial deflector. The rf of 33 MHz taken from the cyclotron generator is changed by a frequency divider into 11 MHz and fed over a manually adjustable delay line to a narrow band power amplifier. Fig. 6 shows a TOF-spectrum taken with an external α-beam of 0.5 μA average.

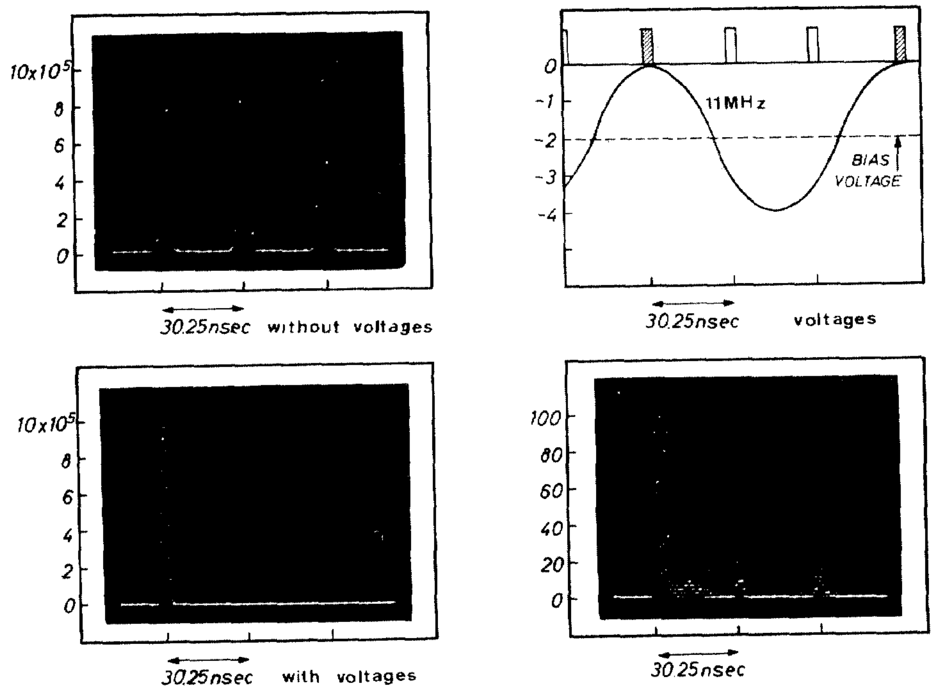

Fig.6 Time structure of the external beam with and without 11 MHz voltage on radial deflector

It is clearly seen that the pulses have been effectively (better than 2×10^{-5}) removed. Operation of this mode has been stable for periods up to one week without any adjustments of amplitudes and delay. When the extremely high currents are used for the neutron time-of-flight experiments (up to 1 mA unsuppressed in time average) some of the insulators are damaged by metal vapour deposition and must be changed in periods of 2 - 3 weeks.

The pulse quality reached with the rectangular pulses applied to the axial deflector is shown in Fig. 7.

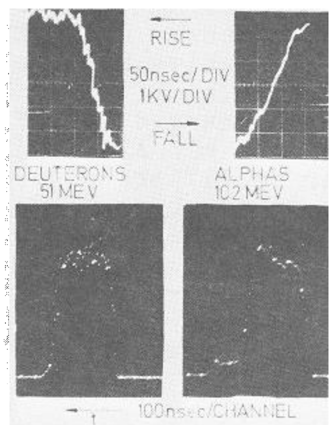

Fig. 7 Time distribution of the particles in the external beam using a 3 μsec deflection pulse. The upper part shows rise and falltime of the negative pulse

A pulse generator with a rise time of 5o nsec and a falltime of 150 nsec is used. The larger falltime and the longer tail of the pulses for the α-particles must be attributed to the larger phase width of 2.4 nsec (29°) f.w.h.m. in this measurement. This results in an energy gain per turn lower by 3.5% for about 10 % of the particles. These particles have to make ten more turns (~1 μsec) to reach the extraction radius.

For the deuterons the phase width was reduced to 1.0 nsec f.w.h.m. with a phase defining slit on the second turn.

To pulse the ion source a capacitor is discharged through the arc of the source. For short pulses a COBER 605 high power pulse generator is applied. Fig. 8 shows a typical result for the ion source pulsing. We have reached several μsec rise and falltimes and not yet found any case where the source showed another time behaviour than the applied pulse.

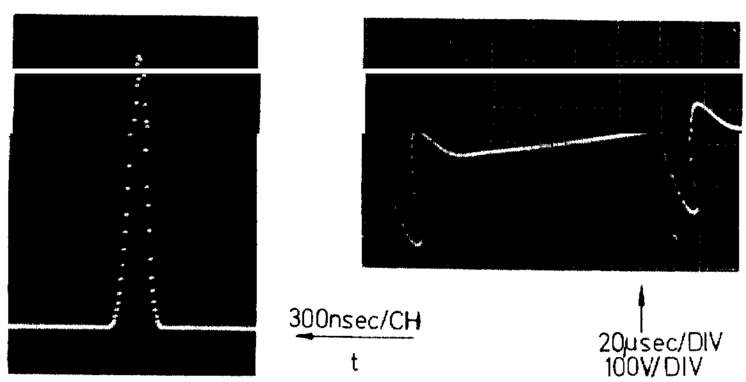

Fig.8 Ion source pulsing. Applied pulses and resulting time structure. The oscilloscope trace is distorted by the cyclotron magnetic field

ACKNOWLEDGEMENT

The authors wish to acknowledge many fruitful discussions with Dr.G.Schatz. The assistance of Mr.H.Müller in producing most of the used electronics, of Mr. H.Bellemann in building the deflection systems and the efficient cooperation of the cyclotron crew under Mr.F.Schulz are gratefully acknowledged.

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