# A SIMPLE BEAM CHOPPER FOR T.O.F. EXPERIMENTS

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## Abstract

A beam chopper has been developed for the 60 MeV NIRS Cyclotron facility in Chiba, Japan. The internal beam is stopped on the first turn by a vertical deflector biased by a dc voltage. A 20 nsec wide pulse synchronized with the dee voltage but with 1/8 and 1/16th the repetition rate cancels the dc deflexion voltage allowing single micropulses to be accelerated.

Single turn extraction of various beam were obtained. Further test will give the limit of pulse width and intensity to be obtained by this equipment.

## 1. Introduction

The cyclotron facility of the National Institute for Radiological Science in Chiba, Japan, consists of a cyclotron which is a copy of the Louvain machine with an energy lowered by derating of the power supplies and of a beam transport equipped of 6 targets. One of them is being devoted to neutron production for fast neutrons therapy, the others are used for RI production and for multipurpose irradiation with possibility of neutrons T.O.F. experiments.

Ordered in March 1971 from CGR MeV France, the facility was commissionned in March 1974. The main characteristics are the followings :

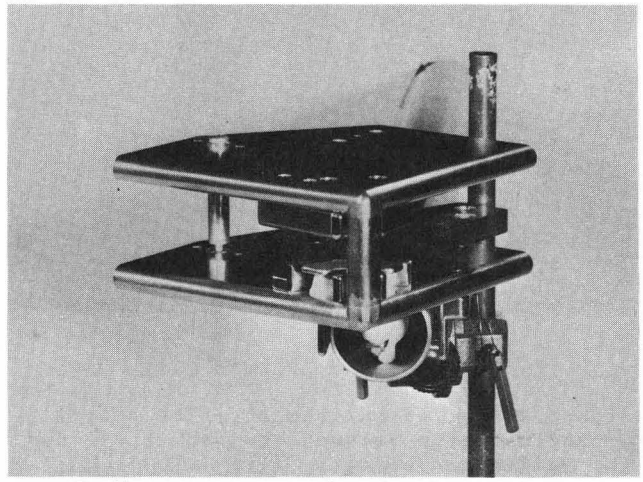
| | Energy range | Beam intensity measured |
|---|---|---|
| Protons | 8 to 70 MeV | 40 µa at 40 MeV |
| Deuterons | 10 to 45 MeV | 40 µa at 35 MeV |
| Alphas | 20 to 90 MeV | 20 µa at 70 MeV |
| Helium 3 | 24 to 120MeV | 10 µa at 93 MeV |

In order to carry out T.O.F. experiment a beam chopper was designed and installed on the cyclotron. Following is a brief description of this apparatus.

## 2. Beam chopper specifications

As in similar equipment, Ref 1,2)the principle to deflect vertically the beam in the center was choosen since in that case a small deflector and a relativity low voltage is required. The cyclotron, with two 90° dees, operates on harmonic 1 and 2 in the frequency range of 11 to 22 MHz and with a RF voltage in the range of 20 to 40 kV. Using the space aera of one dummy dee it was possible to set a deflector of 75° of angular dimension at 5 cm of the center with a gap of 15 mm.

With such dimensions, the deflector could be installed on a fixed position, the beam being deflected at its first turn for harmonic 2 mode and at its second turn for harmonic 1. Then the deflexion voltage needed was between 600 and 3000 Volts.



- Deflector set up in the dummy dee -

In order to have a simple and low power modulator, we decided to use the doubling effect of an open line terminated by the deflector capacitance.

Only a pulse of U/2 Volt is needed to cancel a permanent bias voltage U. Also the pulse rate was choosen to be 1/8 and 1/16 of the RF frequency chich in the worse case gave 450 nsec between two beam pulses.

With such specifications it was possible to determine a fixed pulse shape on the deflector. The amplitude varying between 500 and 4000 Volts, the time rise being less than 20 nsec and the width at 90 % of the amplitude 20 nsec and 50 nsec at 50 % of the amplitude.

## 3. Realisation

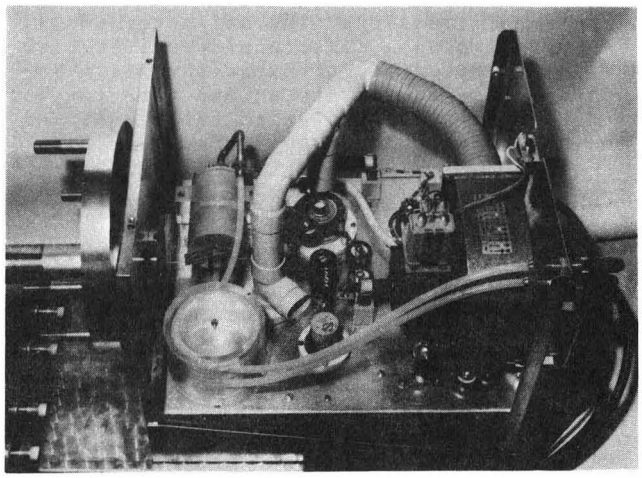
The transmission line between the modulator and the deflector is a coaxial line of 1800 Ω impedance to limit the modulator power at 250 Watts.

The helicoïdal inner conductor being mounted and insulated on pieces made of polypropylene, the attenuation factor obtained was less than 0.5 dB/m.

The pulse is delivered by a 2 stage modulator using a 4CPX250K tetrode driven by a 7211 triode through a coaxial line pulse transformer.

The pulse is generated by taking the dee voltage and detecting the zero crossing of the sinewave. After division by 8 or 16, the pulse is delayed of a quantity adjustable

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 317-319

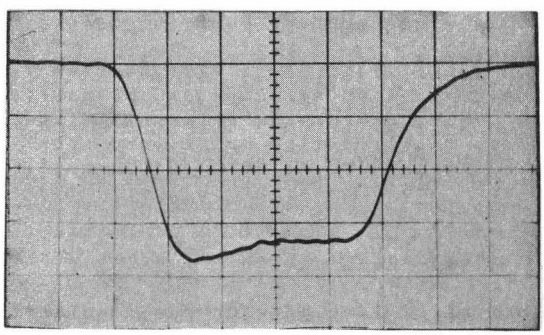


- Modulator unit -

of one RF period maximum to allow proper synchronization between the beam pulse and the deflector pulse.

The pulse properly delayed drives a standard pulse amplifier model 120D6 of E.H. Research Laboratories. The output signal level adjustable between 0 and 50 V drives the modulator stage.

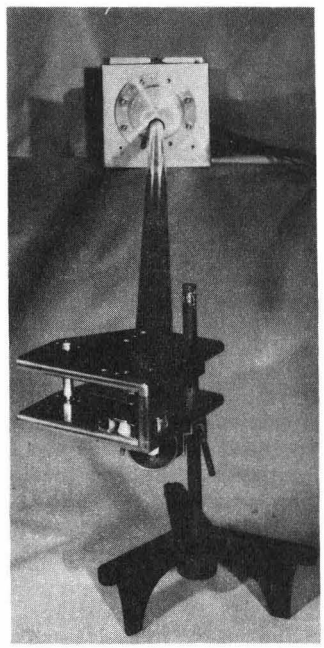
By modulating the screen voltage of the final stage, a circuit allows the possibility of voltage regulation.



- Modulator output signal on resistive load -
700 V/cm 10 nsec/cm

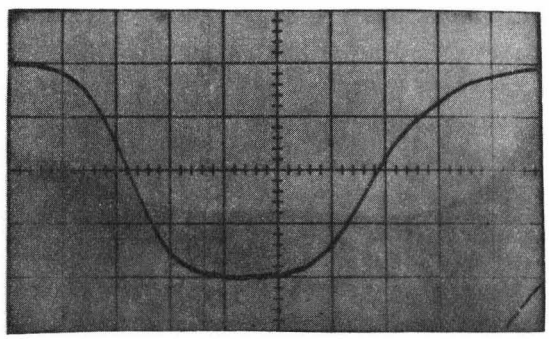
## 4. Result

On a 1 meter model line a pulse of 2300 Volts with a time rise of 10 nsec was obtained at the input. On the deflector the pulse obtained was of 4000 Volts with a time rise of 18 nsec, a width of 46 nsec at half height and 70 nsec at 10 % of the amplitude.

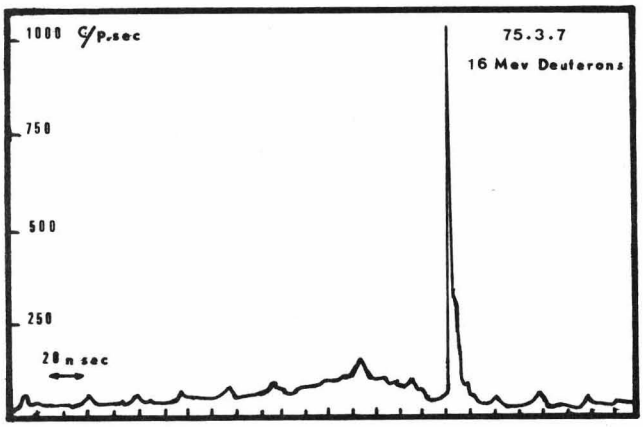


-Deflector and transmission line assembly-

Parasitical pulses generated by reflexion on the line have a maximum amplitude of 25 % and are very short so they cannot disturbed the operation.



1000 V/cm - 100 nsec/cm



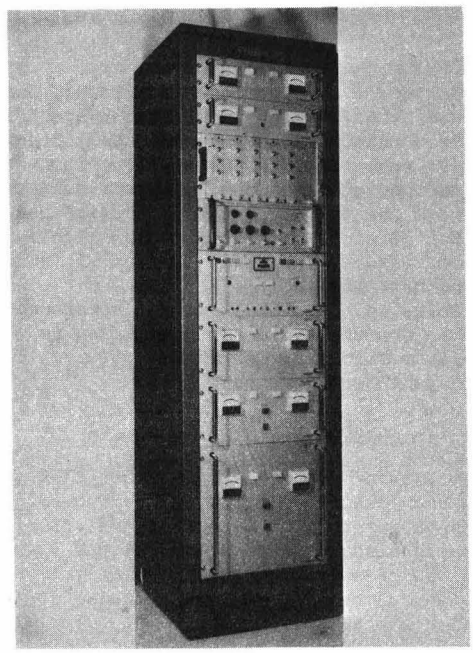

After installation on the cyclotron it was necessary to improve the shielding of the deflector insulators against the metallisation coming from the vicinity of the ion source. Also it was found that if Harmonic 1 mode worked satisfactorly, on Harmonic 2 mode parasitic RF signals pick up by the line was heating the support of the line inner conductor which by dilatation could lead to internal short circuit for some frequencies. Since for this mode much less voltage is requested another line of 200 Ω impedance was realised and will be tested in a few months.

Using a phase slit of 0.5 mmeter pulsed beam were observed with a standard T.O.F. electronic set up by looking at the γ rays produced on the target.

The beam chopper was found a good revelator of the proper tuning of the cyclotron as at first multiturns extraction was shown. After proper tuning single turn extraction was observed on protons beam of 30, 50 and 22 MeV, on deuterons of 16 MeV. A γ peak of less than 10 nsec was observed, the parasitic peak being spaced of 75 nsec and of a maximum amplitude of 8 %. The time resolution of the electronic set up was only 4 nsec per channel, therefore it was not possible to optimize the pulse width with the phase slits since for such beam 1° phase width is about 0.2 nsec.

## 5. Conclusion

This equipment of low power and very simple to use on the machine works satisfactorly. NIRS staff people will carry out T.O.F. measurements in the near future with a new phase slit and a better time resolution apparatus. Already one can say that such an accessory will be very useful for cyclotron facilities where there is a need for neutrons calibration and others T.O.F. experiments. With few modifications, others pulses frequency could be selected with the same modulator as long as the beam energy choosen is compatible with the power dissipated on the final tube.



- Electronics Rack including all necessary equipments -

## Reference

1. W.P. Johnson, M.G. Blosser and P. Siss Fifth International Cyclotron Conference AERE Harwell 1969.

2. A. Svanheden, H.A. Howe, M. Reisser, I.E.E.E. T Nuclear Science Vol NS 12 1965.
Beam pulse selector for a sector focused cyclotron.