Modification of MEA modulator-klystron units enabling short pulse injection into a pulse-stretcher ring

F.B. Kroes, E. Heine, NIKHEF, P.O. Box 4395, 1009 AJ Amsterdam, The Netherlands

Abstract

In order to modify the present 500MeV, 1% duty factor electron accelerator MEA into a 900MeV, 0.1% d.f. injector for a newly to be build pulse-stretching ring, the present modulator-klystron units have to be adapted from 4MW, 2% d.f. mode of operation into the 10MW, 0.2% d.f. mode.

Suitable klystrons are commercially availabe, the matching modulators, however, will be obtained by modifying the present ones, which policy is dictated by economical considerations.

The design principles of these modulators -a proto-type is presently under construction- will be discusssed. Special attention is given to the video-pulse shape requirements, dictated by the future performance of the pulse-stretcher. This device has to deliver low emittance, high duty factor (~90%) beams for nuclear physics experiments.

Some proto-type tests of the video-pulse forming modifications will be presented.

Introduction

At NIKHEF-K elaborate (e,e') and (e,e'X) experiments are carried out with 500 MeV, 1% d.f. electron beams from the Medium Energy Accelerator (MEA). In order to extend this programme especially towards double and triple coincidence experiments, the d.f. and max. energy of the beam have to be increased to 90% resp. 900MeV. The d.f. increase will be obtained by means of a pulse-stretching ring, called UPDATE (ref.1), presently under construction. The accelerator will then serve as an (3-turn) injector for this 200m. long ring. This implies that the beam pulse length has to be decreased from 30μs to 2.15μs and that the r.f. peak power has to increase considerably. Moreover, due to the drastic decrease in d.f. the peak currents to be accelerated should increase from 20mA to 80mA in order to maintain average currents at the target at a reasonable level.

Table 1 presents the main machine parameters in the present and in the future operation mode. Table 2 presents the specifications of the Varian klystrons (VA938D), presently in operation and those of the newly to install Thomson klystrons (TH2129), which have been chosen to provide the lower d.f. (0.2%) and increased r.f. peak power (10MW). In the next paragraph will be described how the present modulators will be modified to accommodate the TH2129 klystrons.

Table 1 Accelerator parameters before and after conversion into an injector for UPDATE

Mode of operation		present	future
Energy (@ mA)	MeV	540	827
Peak current	mA	20	80
Beam loading	MeV/mA	2.8	2.5
Beam pulse length	μs	30	2.15
Repetition rate	Hz	300	400
Average current	μA	>100	70
Klystron R.F. peak	MW	4	10
Number of klystrons		12	12
Energy spread	%	0.3	1.a)

a) For proper injection into the stretcher ring, the energy spread will be decreased to 0.1% by means of an energy-spectrum compressing system (ref. 2)

Table 2 Klystron specifications

		present VA 938D	future TH2129
R.F. peak power	MW	4	10. a)
average power	kW	100	30
pulse width	μs	40	4
rep. rate	Hz	500	500
duty factor	%	2	0.2
drive peak power	W	<100	<100
BW (-0,5 dB)	MHz	20	10
Cathode voltage	kV	120	170
current	A	85	140
duty factor	%	2.5	0.3
Collector diss.	kW	350	100
Efficiency	%	43	43

a) the TH2129 is capable to deliver 15 MW

Modulator modification

Before describing the modification, the main features of the existing modulators, which have been described in detail in ref.3 and 4, will be presented here.

The existing modulator lay-out is shown in fig.1.

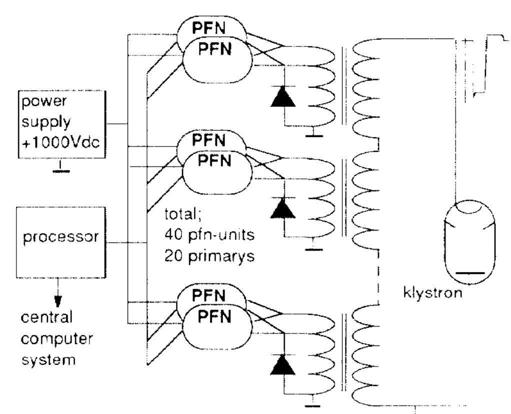


fig.1. Modulator lay out

There are 40 pulse forming network (PFN) units, each of which is a 2kV, 50μs line type modulator (see fig.2). As shown in fig.1 the PFN units are connected in pairs to the primary of a special multi-core pulse addition transformer. This PFN system permits the generation of klystron pulses, the amplitude and repetition rate of which can be changed by chosing (computer controlled) the number of PFN units to discharge.

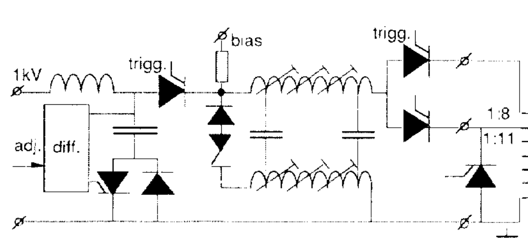


fig.2. PFN-unit

CH2669-0/89/0000-0205$01.00©1989 IEEE

High pulse repetition rate can thus be obtained -at reduced peak power levels- by sequential switching a limited number of units at correspondingly lower repetition rate. The charging and discharging proces of the separate units is controlled by a processor. The transformer primaries not used in the discharging proces are shortened. Fig.3 shows the 3 different discharging schemes presently in use for 1, 2 and 4MW peak power levels.

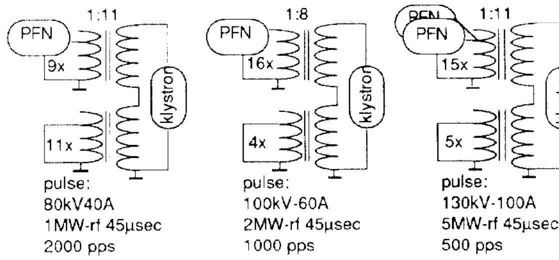
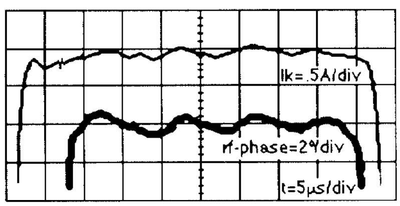


fig.3. Discharging schemes for 1, 2 and 4MW

An example of the flat-top behaviour of the r.f. pulse at the output of the VA 938D klystron is shown in fig. 4. The ripple is in the order of 0.3% for 45µs pulse width.

fig.4
Pulse flatness and phase measurement at 2MW rf level. (109kV-64A)



However, as we will show below, the fall-time of this pulse is about 10µs due to the large leakage inductance of the pulse transformer which, although acceptable for the 45µs pulse width, should be appreciable shortened for the 4µs flat-top pulses required after modification.

Considerable investments have been made in the existing batch of twelve 1% d.f., 4MW modulator-klystron units. Therefore, a design study has been started to investigate how the conversion of the MEA accelerator into a short pulse injector for the pulse stretcher could be carried out economically. As mentioned before, the VA938D klystrons have to be replaced by a new type suitable for the low d.f. (0.2%), high peak power (10MW) requirements. The present modulator, however, can be adapted by relatively small changes in the PFN network as we will discuss now.

Four main points have to be considered when adapting the PFN unit network:

a) Improvement of the short-circuiting behavior
b) Pulse shortening from 45µs to 4µs flat top
c) Matching of the new klystron impedance to the modulator
d) Increase of the input power level to obtain the 10MW r.f. from the new klystron.

The short circuiting behavior can be improved considerably by connecting a "short circuit thyristor" to the primary of the pulse transformer (see fig.5).

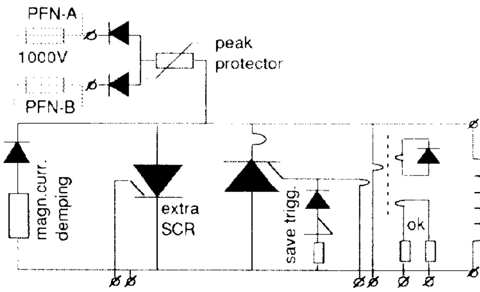
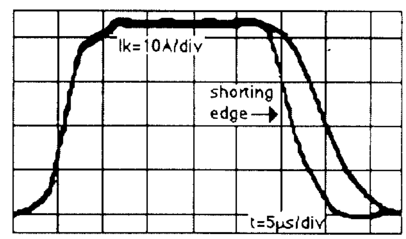


fig.5. Primary shorting circuit

This thyristor can always be triggered during the trailing edge of the pulse and will result (see fig.6) in a steeper trailing edge or shorter falltime. Moreover, positive reflections can be converted into negative reflections so that the PFN is always to be charged from the level dictated by the end of line clipper. Mismatch is allowed within the dissipation limits of the end of line clipper.

The thyristor can also be triggered when the klystron arcs. Then the pulse is short circuited at the primaries and the arcing energy will be limited.Both thyristors are triggered by an external gate pulse to prevent them against damage by the di/dt of the pulse.

fig.6.
Short cicuiting of a primary. (25µsec testpulse)



Pulse shortening and proper matching to the newly to install klystron has been obtained, in the modulator test-facility, by rearranging the PFN network as shown in fig.7.

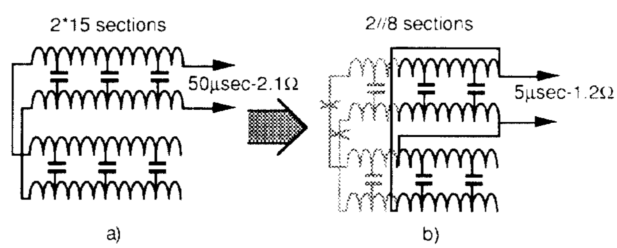


fig.7. Pulse forming network
a) before modification
b) after modification

Using these modified PFN units the 10 MW r.f. peak power can be reached as shown in the discharging schemes presented in fig.8.

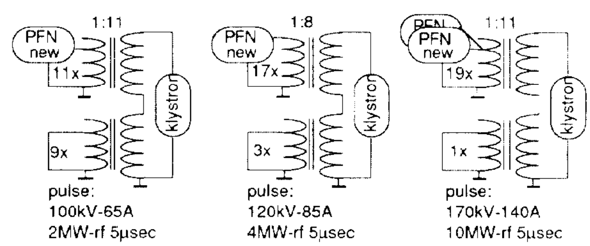


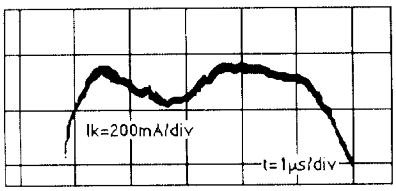
fig.8. Discharging schemes for 2, 4 and 10MW using modified PFN-units

Operation at just the 10MW level (170kV) does not provide enough pulse-level range control for the conditioning of the klystrons and the beam energy of the accelerator. Therefore, as is the case in the present situation, the different switching schemes shown in fig.8 will be essential also for the modified klystron-modulator units. With these schemes an almost smooth input power level range from 90kV-50A to 180kV-150A can be achieved.

Note that the processor must be able to cope with more primary PFN unit choices for discharge then is the case with the present modulator.

Using a limited number of modified PFN units installed in the modulator test facility the 4μs flat-top (≈ 0.3% ripple) behavior is obtained is shown in fig.9.

fig.9
Pulse flatness of modified PFN at 52A klystron current

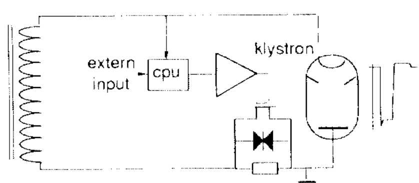


On the basis of these test results it is expected that with the modified modulator-klystron units and considering the considerable increased beam current level requested for the pulse-stretcher, the energy spread of the beam will be in the order of 1%. This spectrum has to be reduced to the 0.1% level for proper injection into the ring, which will be achieved by a so-called energy spectrum compressor system (ref.2) beyond the accelerator. Nevertheless it seems worthwile to consider to what extend the 1% energy spectrum from the accelerator itself can be reduced.

To this purpose we have started a development which involves pulse top level stabilization.

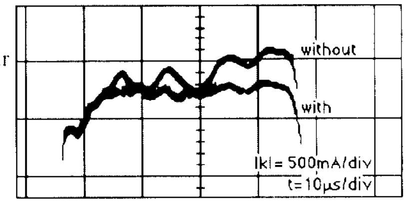
A power FET has been installed in series with the present klystron on the low voltage side of the pulse transformer (fig. 10).

fig.10
Principle of pulse top level stabilization



First test result is givenin fig.11, showing a considerable improvement of the flat-top behavior.

fig.11
Flat top behaviour without and with power FET



Conclusion

At this stage of the development programme it seems likely that the adaption of the present modulators for use of the MEA accelerator as an injector for the pulse-stretching ring can be achieved. This implies that a considerable part of the present batch of 12 modulators will still be usable. Further studies are in progress.

Acknowledgement

We gratefully acknowledge the valuable contributions of the whole NIKHEF-K technical staff in the designing and constructing stage.

The work described in this paper is part of the research program of the National Institute for Nuclear and High Energy Physics (NIKHEF), made possible by financial support from the Foundation for Fundamental Research on Matter (FOM) and the Netherlands Organization for Scientific Research (NWO).

References

1) R. Maas et al., "The Amsterdam Pulse Stretcher", IEEE Trans. on Nucl. Sci. NS-32 (1985) 2706

2) J.G.Noomen et al., "An Energy Compressing System for the Amsterdam Pulse Stretcher", This conference

3) P.J.T. Bruinsma, E.Heine et al., "An all solid state line-type modulator", IEEE Trans on Nucl. Sci, NS-20(1973)

4) P.J.T. Bruinsma, F.B. Kroes et al. "The 500 MeV, 2.5% duty factor linear electron accelerator (MEA)", IEEE Trans. on Nucl. Sci. NS-30 (1983) 3599

5) G.Luijckx, P.J.T.Bruinsma et al. "The Amsterdam Pulse Stretcher Project (APS)", This conference