PULSE SHAPING SYSTEM FOR INR PROTON LINAC

V.V. Kouznetsov, A.N. Mirzojan, A.N. Naboka, A.V. Novikov-Borodin, V.L. Serov, A.V. Feschenko
INR RAS, Moscow, Russia

The system for proton beam pulse shaping in the 400 keV injection line of the INR linac is developed, built and implemented. The use of a traveling wave fast deflector and the Behlke Electronic fast HV transistor switch with operation voltage up to 6 kV enables formation and adjustment of different macro- and micro-pulses of the accelerated beam thus expanding considerably accelerator possibilities. It is important for many accelerator applications, especially for time-of-flight neutron studies.

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1. INTRODUCTION

Normally all the accelerator pulse systems of INR RAS linac, including injector and RF system, operate at 100 Hz (or 50 Hz) and provide beam pulses with a duration up to 200 µs. To satisfy both fundamental and applied research requirements it is necessary to realize a frequency adjustment of beam macro-pulses from 1 Hz to 100 Hz as well as to create within one macro-pulse one or two 20…50 µs micro-pulses with edge times less than 10 µs or 0.3…5 µs micro-pulses with edge times less than 100 ns. Short micro-pulses are important for time-of-flight neutron studies. The delay time between the two micro-pulses must be varied within the range of 20…100 µs. Beam pulse formation is done by deflecting and completely absorbing appropriate beam macro-pulses (or parts of the macro-pulses) in the 400 keV injection line. Special high voltage fast deflector is used to deflect the beam. HV deflecting pulses are produced with a high voltage pulse generator along with a fast transistor switch. The system is also used to lock out the accelerated beam in case of any accelerator breakdown or fast protection system actuation.

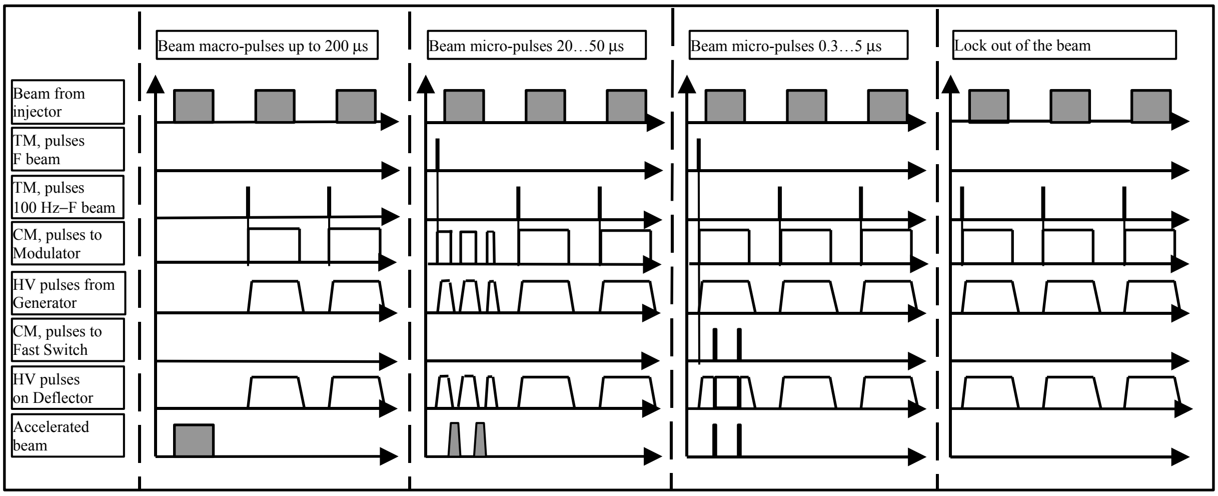
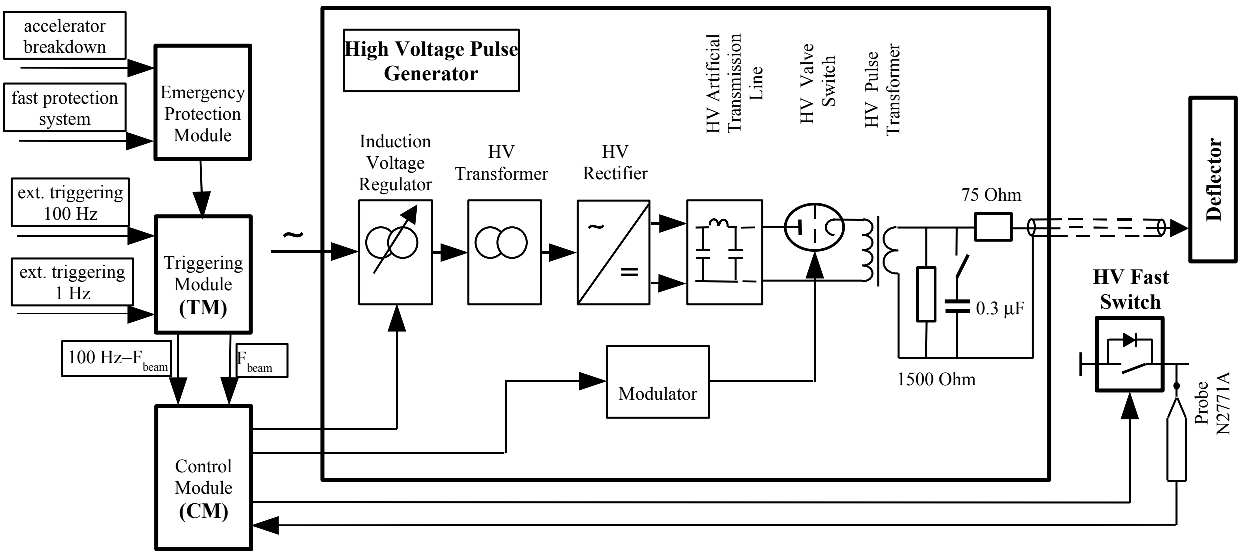


Fig.1. Time diagrams for different modes of pulse shaping system operation



2. PULSE SHAPING SYSTEM

The time diagrams for different modes of pulse shaping system operation are shown in Fig.1. Block diagram of the system is presented in Fig.2. The deflector installed in the injection line represents a 75 Ohm spiral retarding system, each period consisting of a strip line and coaxial line elements. The deflecting field is formed between the strips and an additional grounded plate [1-2]. The velocity of high voltage traveling wave is selected to be equal to that of a 400 keV proton beam. The edge times of the beam pulses for this configuration are estimated to be less than 10 ns. The deflector is foreseen to operate with the voltages up to 6 kV. The picture of the spiral system is shown in Fig.3.

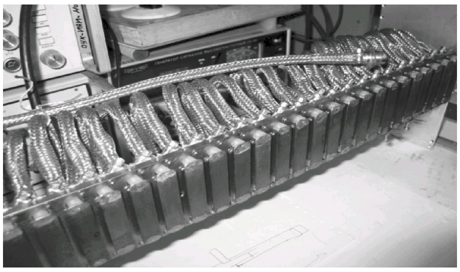


Fig.3. Deflector spiral retarding system

The triggering module (TM) generates a short pulse sequences F_{beam} and 100Hz–F_{beam}, where F_{beam} is an adjustable beam pulse repetition frequency, and triggers the Control Module (CM). The CM generates pulses applied to the High Voltage Generator (HVPG) and the HV Fast Switch. The generator along with the switch provides high voltage pulses of different frequency, duration, and edge times on the deflector. The capacitor 0.3 μF installed at the output of the generator is connected to the circuit only for the mode of 0.3…5 μs micro-pulses generation. In case of accelerator breakdown or accelerator fast protection system actuation the Emergency Protection Module (EPM) is activated resulting in generation of 100 Hz 320 μs pulses by TM and CM. In this case all the beam pulses are deflected and absorbed in the injection line. As a result no beam is accelerated.

The control modules are installed in an accelerator control room, the HVPG is located in an accelerator RF gallery, the deflector is installed in an accelerator tunnel about 50 m away from the HVPG and the HV Fast Switch is installed in the vicinity of the deflector.

3. EXPERIMENTAL RESULTS

To provide accelerated beam macro-pulse repetition frequency F_{beam}, the CM generates 320 μs pulses with a frequency of 100Hz–F_{beam}. The corresponding beam pulses are deflected and absorbed, the rest of the pulses are accelerated. The value of F_{beam} is foreseen to be equal to 1, 5, 10, 25, 50, and 100 Hz with a uniform spacing as well as 40 and 80 pulses per second as a 100 Hz pulse packet. Fig.4 shows the signal at the CM output and the deflecting voltage for beam macro-pulses frequency adjustment mode of operation. The deflecting voltage of 2.5 kV is sufficient to absorb the deflected beam in the injection line.

To provide 20…50 μs beam micro-pulses, the corresponding deflecting pulses are generated with the HVPG only. The HV Fast Switch in this mode is always off. Fig.5 shows the signal at the CM output and the deflecting voltage for 20…50 μs mode of operation. The corresponding beam micro-pulses are shown in Fig.6 (lower line). The rising and the falling edges are equal to 12 μs and 20 μs, correspondingly. The falling edge is additionally increased due to a 4.2 nF deflector line capacitance discharge through 1575 Ohm resistance. The edges of the beam pulses can be decreased by increasing the deflecting voltage. As an example, Fig.7 demonstrates the beam pulse with the edges better than 10 μs for 3.5 kV deflecting voltage.

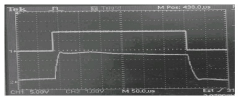


Fig.4. Above–control pulse to generator, below–high voltage pulse 320 μs on deflector

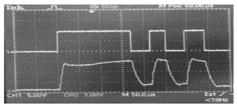


Fig.5. Beam micro-pulses for 20…50 μs mode of operation (upper line–CM output, lower line-deflecting voltage)

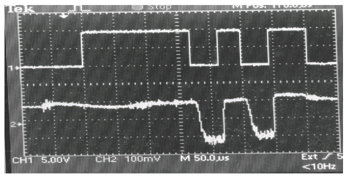


Fig.6. Beam micro-pulses for 20…50 μs mode of operation (upper line–CM output, lower line-two beam micro-pulses)

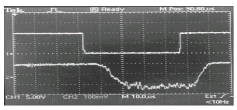


Fig.7. Beam micro-pulse for 20…50 μs mode of operation (upper line–CM output, lower line–beam micro-pulse with duration 42 μs and edges better than 10 μs)

To obtain 0.3…5 μs beam micro-pulses, the HV Fast Switch is additionally incorporated. A Behlke Electronic HTS 61-12-B fast HV transistor switch with 6 kV maximum voltage and 125 A maximum peak current is used. Typical turn-on and turn-off times of the switch are about 30…50 ns, minimum on-time equals 180 ns. An important feature of this mode of operation is the use of the additional 0.3 μF capacitor shunting the HVPG output. This capacitance is used to match the deflector and the corresponding cable for short pulses and to decrease droop of these pulses. The basic oscillograms are presented in Fig.8 and Fig.9.

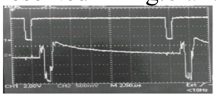


Fig.8. Beam micro-pulses for 0.3…5 μs mode of operation (upper line–CM output, lower line–two beam micro-pulses with duration 1 μs, edges about 100 ns and 18 μs spacing)

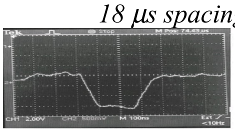


Fig.9. Beam micro-pulse for 0.3…5 μs mode of operation (duration 0.280 μs, edges about 100 ns)

4. CONCLUSION

The new pulse shaping system is realized in the INR RAS proton linac. The system provides the following modes of operation: 1) beam macro-pulses with duration up to 200 μs and frequency adjustment from 1 to 100 Hz, 2) one or two micro-pulses with duration 20…50 μs, edge times less than 10 μs, delay time between pulses 20…100 μs, frequency adjustment from 1 to 100 Hz, 3) one or two micro-pulses with duration 0.3…5 μs, edge times less than 100 ns, delay time between pulses 20…100 μs, frequency adjustment from 1 to 100 Hz. The lock out of an accelerated beam is also provided in case of any accelerator breakdown or fast protection system actuation.

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СИСТЕМА ФОРМИРОВАНИЯ ИМПУЛЬСОВ ПУЧКА НА ПРОТОННОМ УСКОРИТЕЛЕ ИЯИ РАН

В.В. Кузнецов, А.Н. Мирзоян, А.Н. Набока, А.В. Новиков-Бородин, В.Л. Серов, А.В. Фещенко

Реализована система формирования импульсов протонного пучка с энергией 400 кэВ на канале инжекции ускорителя ИЯИ РАН. Эта система с использованием быстрого дефлектора на бегущей волне и быстрого высоковольтного полупроводникового ключа фирмы Behlke Electronic с рабочим напряжением до 6 кВ существенно расширяет возможности ускорителя, так как обеспечивает регулирование частоты следования макроимпульсов, а также формирование различных микроимпульсов пучка. Реализация этих режимов необходима для проведения различных физических экспериментов, в том числе для времяпролетных исследований на нейтронных источниках.

СИСТЕМА ФОРМУВАННЯ ІМПУЛЬСІВ ПУЧКА НА ПРОТОННОМУ ПРИСКОРЮВАЧІ ІЯД РАН

В.В. Кузнецов, А.Н. Мірзоян, А.Н. Набока, А.В. Новіков-Бородін, В.Л. Серов, А.В. Фещенко

Реалізовано систему формування імпульсів протонного пучку з енергією 400 кеВ на каналі інжекції прискорювача ІЯД РАН. Ця система з використанням швидкого дефлектора на хвилі, що біжить, і швидкого високовольтного напівпровідникового ключа фірми Behlke Electronic з робочою напругою до 6 кВ істотно розширює можливості прискорювача, тому що забезпечує регулювання частоти проходження макроімпульсів, а також формування різних мікроімпульсів пучка. Реалізація цих режимів необхідна для проведення різних фізичних експериментів, у тому числі для часопролітних досліджень на нейтронних джерелах.