FAST AND HIGH REPETITION BEAM KICKER WITH MA CORES

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Abstract

New kicker magnet systems for the injection and the fast extraction of the 50 GeV proton synchrotron, as well as for the PRISM/FFAG ring are being developed. In order to obtain a sufficient kick on the high intensity beam, the kicker systems must have both a large aperture and a high field. The PRISM project also demands 1 kHz repetition kickers.

In order to fulfill those demands, new technologies are introduced and now being tested. Among them are high-power IGBT modules, a subordinated-gating systems, 1 kHz repetition pulsed power supply, and kickers with MA cores used as return yokes.

1 INTRODUCTION

Today's front-end accelerator projects demand the kicker magnets to have both higher fields and larger apertures. For example, in the 'Joint Project', the high-power proton accelerator project promoted by JAERI and KEK[1], the 50 GeV main-ring requires the injection and the fast extraction kickers to have the field strength of 1 kGauss and the gap height of 130mm. The injection and the extraction schemes are illustrated in Figure 1.

In some applications, in addition to the above issues, higher repetition rates in the range of kHz are strongly requested. In the recent 'PRISM/FFAG' project, the phase rotation ring project for the production of high quality muon beams[2], the kickers need to produce 1 kHz repetition fields on the aperture of ~200mm x ~500mm.

In order to fulfill all those demands, new kicker technologies are now being developed and tested at KEK. Some of the items included are; use of high-power IGBT modules, subordinated-gating switching technology, 1 kHz repetition pulse power supply, and magnetic-alloy (MA) cores as kicker return yokes.

2 IGBT POWER SUPPLY

Thanks to the recent progress in semiconductor technologies, a single IGBT switchng module that can be operated at more than 1 kV and at hundreds of amperes has been available. A kicker magnet with a high field and a large aperture demands a high-current, high-voltage power supply. Massive connections of high-power IGBT modules both in parallel and in series open the opportunity of realizing a power supply with the output current and voltage that has been impossible to obtain by traditional thyratron tubes. The use of this kind of semiconductor modules is one of the crucial issues to satisfy the recent demands on kickers.

The difficult problems in such massive connections of IGBT modules are, first, a simultaneous turning-on of all the switches and, second, avoidance of possible insulation break-downs which may occur at all the gating-signal lines and the power lines connected to all the modules.

The key technology to solve the above-mentioned difficulty is the subordinated-driving method that is applied to the multi-stage gating circuit[3]. Figure 2 shows the principle function of the subordinated gating. In the figure, numbers of IGBT modules are connected in series. The gating signal is supplied only on the module nearest to the ground, which is called the master-stage. The other modules are called the subordinated stages.

Before the gating signal is put in, all the IGBTs are open and the equal voltage distribution of +HV/n is applied on all the stages, where n is the number of the stages. When the gating signal is applied to the master-stage, the potential difference of the master stage disappears, and the voltage applied on all the subordinate stages increases from +HV/n to +HV/(n-1). This increase of the voltage leads to the flow of the 'displacement current' (Figure 2). The current is picked-up by the

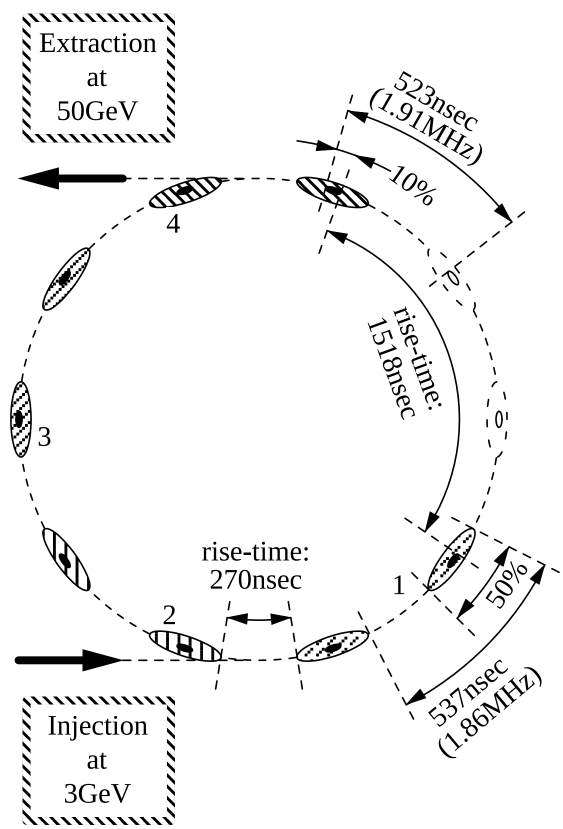

Figure 1: Injection and fast extraction scheme of the 50 GeV ring. Two successive bunches are injected into the ring at one injection cycle. After four injection cycles, numbered 1 to 4 in the figure, the ring is filled with eight bunches and starts acceleration. Since the harmonic number of the ring is ten, two buckets are left empty, which allows a longer rise-time for the extraction kicker.

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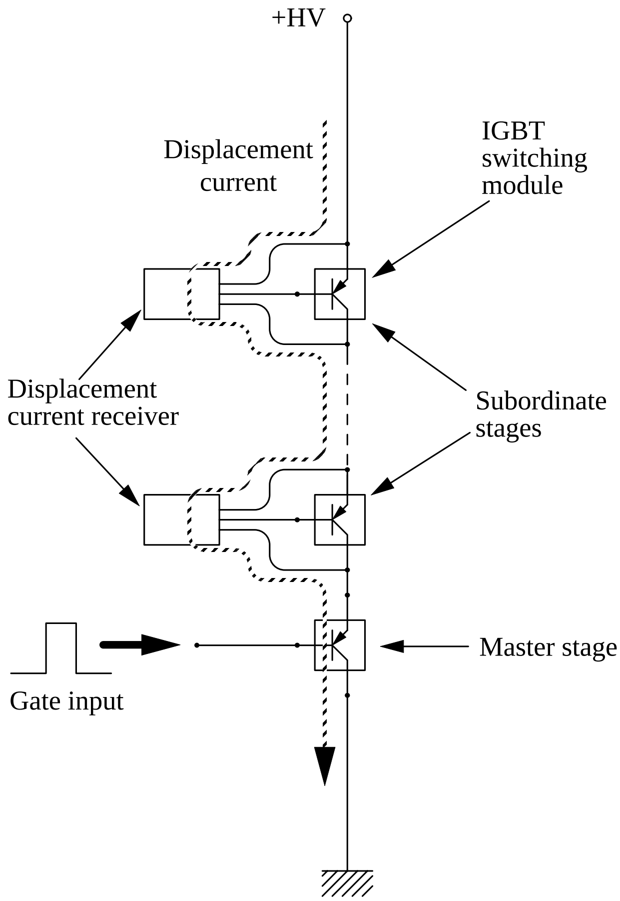

Figure 2: Principle of the subordinated gating system. Numbers of switching modules (in the figure, IGBTs) are connected in series. The gating signal is supplied only on the module closest to the earth potential, called the master-stage. The other stages are turned on subordinately to the master-stage.

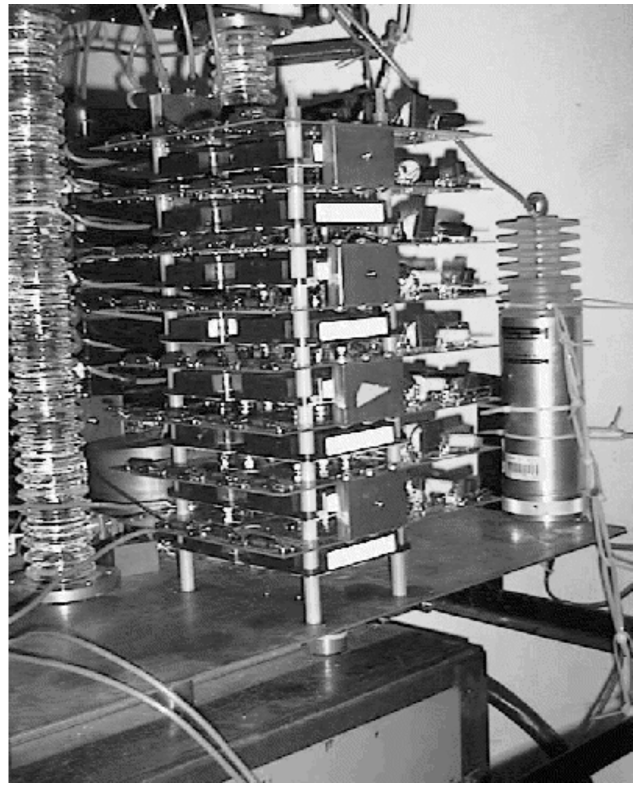

Figure 3: An example of subordinated-driving switching circuit on construction. The circuit consists of eighteen stages connected in series. Each stage contains IGBT modules and a displacement current receiver unit. No connections are made to feed power and gating signals on each subordinate stage. (Photograph by courtesy of Dr. A. Iwata, Mitsubishi Elec. Co.[4])

displacement current receivers on all the subordinate-stages, which gives the gating-signals onto all the subordinate-stages. Thus the simultaneous turning-on is assured without any complicated line connections.

Figure 3 shows an example of the IGBT switching system with the subordinated-driving gating circuit. Additional piling-up of the stages allows the higher voltage output. Using this principle, the 1 kHz pulsed

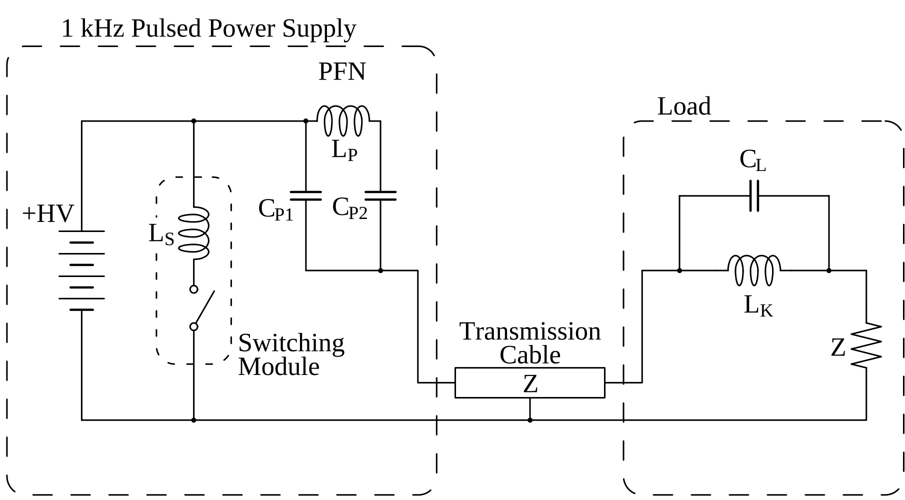

Figure 4: Simplified circuit diagram of the kicker power supply now on construction with a 1 kHz repetition rate pulsing. The use of a high-power semiconductor device as a switching module enables a high repetition rate switching in the order of 1 kHz or higher.

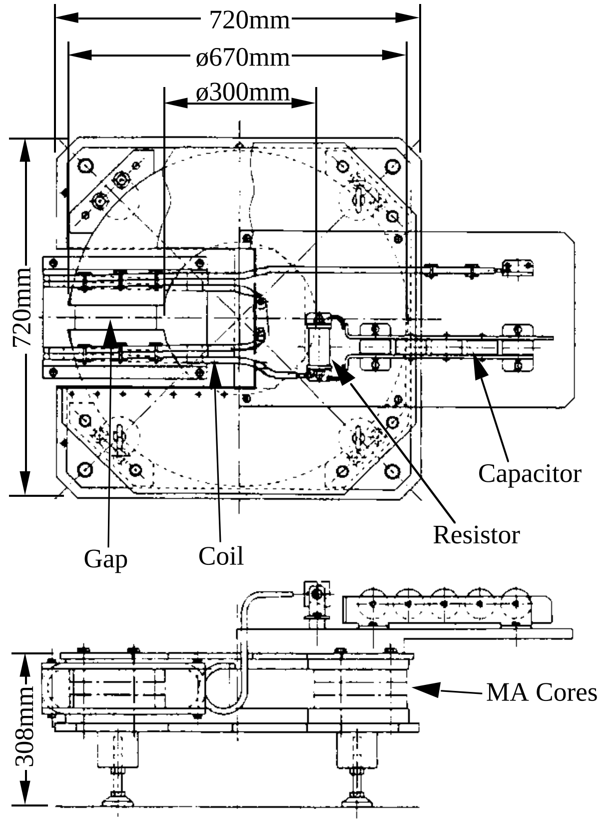

Figure 5: Mechanical drawings of the MA kicker test-bench. Three MA cores with 1 inch thick are laid horizontally. The gap height is 50mm. The total weight of the test-bench is ~280 kg.

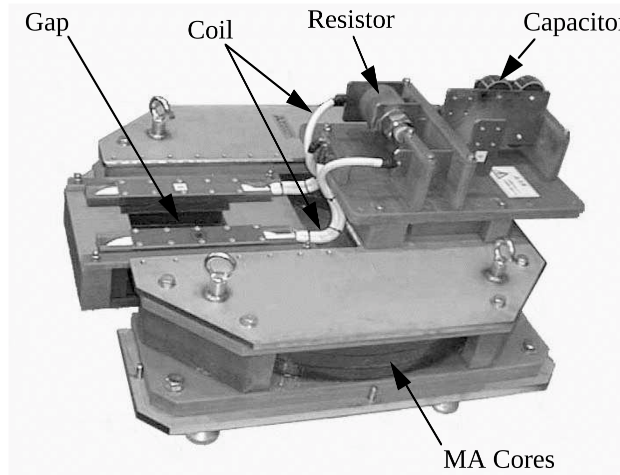

Figure 6: A test-bench photograph. Load circuit modules like resistors, capacitors, and coils are placed adjacent to the MA cores. They are made so that the circuit modules can be exchanged their configuration according to the experimental conditions of the kicker test operations.

power supply is now being constructed (Figure 4). The test operations will start soon.

3 MA KICKER TESTBENCH

Magnetic-alloy (MA) cores can be advantageous when the kicker field is 1 kGauss or higher. In order to prove this, the kicker testbench with the MA cores used as the return yokes is constructed. Figure 5 shows the mechanical drawing of the testbench. Three MA cores with a 670mm outer-diameter and an 300mm inner-diameter are placed horizontally in a pile. A 50mm gap is made on the cores, by a highly-pressurized water-jet cutting method. Figure 6 shows its photograph. The testbench will be used in connection with the above-mentioned 1 kHz pulsed power supply. The power supply is close to completion. It will be delivered and the test operations are planned to start in summer.

4 SUMMARY

New kicker magnet technologies are being developed to fulfill the demand of new generation of high-power accelerators. Both the high field strength and the large aperture are demanded.

In order to satisfy those demand, recent technologies are used and now being tested. Among them are, use of high-power IGBT modules in connection with the subordinated-gating technology, 1 kHz repetition rate pulsed power supply, and MA cores applied to the kicker return yokes. New power supply system is now on construction, and the test operations will start soon.

5 ACKNOWLEDGMENTS

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