DARK CURRENT REDUCTION SYSTEM FOR SPRING-8 LINAC

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Abstract

The SPring-8 linac accelerates dark currents generated by its injector part up to 1GeV. These dark currents are injected with main beam into the SPring-8 storage ring and then spoil the purity of the stored beam. The dark currents are mainly composed of a grid emission current from a thermionic gun and field emission currents from rf accelerating structures. A beam deflector for kicking only the grid emission by a pulsed electric field was developed and installed just downstream of the gun.

We observed that the beam deflector greatly reduced the grid emission current accelerated up to 1GeV. The measured impurity of the stored single-bunched beam was almost 1/10 of the impurity without filtering by the deflector. The field emission currents from the acccelerating structures cannot be reduced by the deflector located upstream of a prebuncher. These currents, however, decay and will be negligible after RF operations of a couple of months.

INTRODUCTION

The 3rd generation synchrotron radiation (SR) facilities are in advance to provide high quality SR lights to power users for their precise experiments: The SR lights of constant intensity, which was realized by top-up operations of storage rings, maximize performance of high precision experimental devices[1]. The top-up operation also enables some filling patterns which have the short Touschek lifetimes such as the single bunch operation. The highly purified (i.e. no satellite) single bunch beam enhances the detection sensitivity of measurement systems.

The SPring-8 booster synchrotron installed an RF-KO system[2] which kicks out the satellite bunches around the main bunch. The storage ring recently achieved the very low impurity of the stored beam; the latest measured value of the impurity is about 10^-9 after accumulating the satellites for one week, which is 10 times the detection limit.

An origin of the satellites is the dark current injected by a linac. The dark currents are generally composed of two components; the grid emission currents from a themionic cathode assembly of a gun and the field emission currents generated in accelerating structures. The grid emission dominates the dark current if the cathode is not new and accelerating structures in an injector section is well RF-conditioned as mensioned in the later section.

We installed a beam deflector just downstream of the gun. The beam deflector kicks out the grid emission current by a pulsed electric field, the main beam pulse, however, is transmitted without deflection. We confirmed that the deflector gated the 1 ns beam pulse and filtered out most of the grid emission[3].

MEASUREMENT OF DARK CURRENT

The measurement of the dark current was done by the following two methods: One is observation of bremsstrahlung induced by the accelerated dark currents. The other is observation of photons radiated by the circulating satellite electrons which originate from the dark currents and are finally captured in the RF buckets of the storage ring.

The former is gamma ray detection by using a photomultiplier with a plastic scintillator at a 1GeV chicane section of the linac as shown in Fig.1. In order to produce the gamma ray, a fluorescent screen or an OTR foil[4] was inserted in a beam transport line. The photomultiplier is covered over all with a radiation shield made of lead.

The latter is a gated photon counting method which utilizes fast pockels cells for switching light pulses at the SPring-8 storage ring photon beam line. The visible synchrotron radiation light is measured at a photon beam line of the storage ring for beam diagnostics of the stored electron beam, such as bunch length and single bunch impurity. To improve the extinction ratio or isolation of the light shutter, the optical system was improved so that two pockels cells are arranged in tandem. Recently, we have been achieved a sensitivity to satellite bunches in order of 10^-10[5,6]

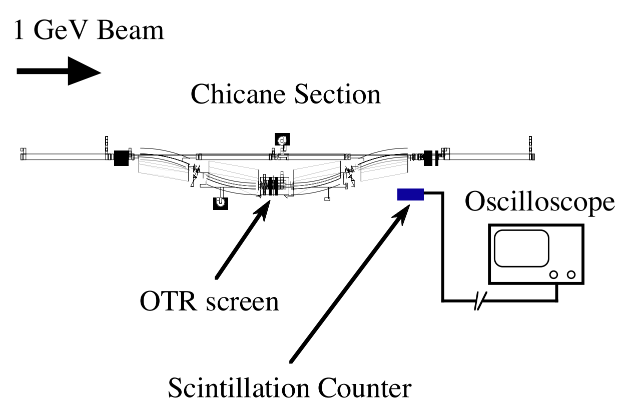

Fig.1. Measurement system of gamma ray by using a photomultiplier with scintillator at linac 1-GeV chicane section

REDUCTION OF GRID EMISSION

After long time operation of the electron gun, barium atoms evaporated from a heated cathode of the gun and accumulate on a grid of the cathode assembly. This phenomenon causes electron emission from the grid when a high voltage is applied to the cathode. The grid emission current depends on the cathode high voltage. Therefore it cannot be controlled by a grid control voltage.

In order to reduce the grid emission, a beam deflector was developed and installed between the gun and a prebuncher of the SPring-8 linac in Dec, 2001.

The schematic drawing of the beam deflector system is given in Fig.2. The deflector system consists of a deflector chamber, two solenoid coils, a steering coil, an iris chamber, a beam profile monitor and two ion pumps. The deflector chamber is placed just after the gun anode. The deflector itself is composed of a rectangular chamber and two parallel-plate electrodes in it.

The 180-keV electron beam is horizontally deflected with an angle of 110mrad when an electric field of 7-kV is applied between both the electrodes, then it is blocked by an iris plate placed 150-mm downstream.

Two 7kV pulses are fed to both electrodes and each timing of them is adjusted so that the true 1-ns beam is not deflected, and so that most of the grid emission currents are kicked out of a straight beam orbit. The timing chart is shown in Fig.3.

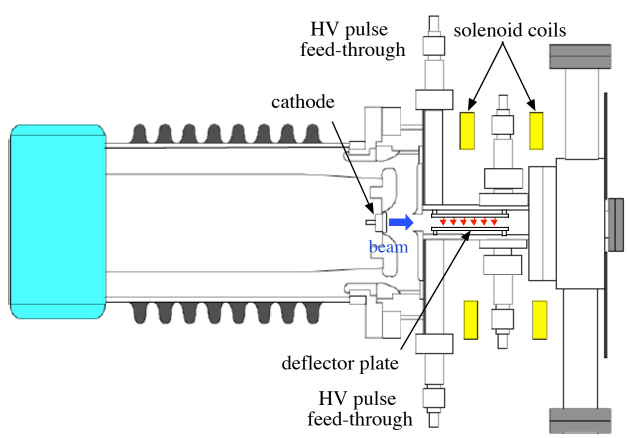

Fig.2 Schematic of the beam deflector

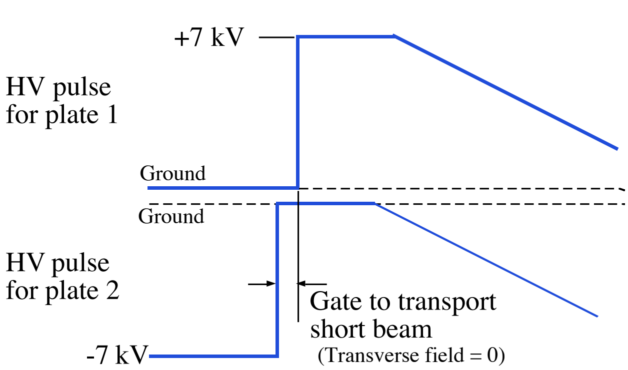

Fig.3 Timing chart of the deflector pulses

We measured the gamma rays induced by the dark currents. During these measurements, the RF powers fed to the injector section were attenuated not to generate the field emission currents in the accelerating structures. Figure 4 presents screens of an oscilloscope which observed pulse signals generated by the photomultiplier. The right picture clearly shows that the deflector greatly reduced the grid emission currents observed in the left case.

We also measured the satellite SR lights at the beam line. Figure 5 shows distributions of the accumulated photons radiated from the satellite RF buckets. The RF-KO system of the booster synchrotron did not work during this experiment. Comparison of the distributions results that the grid emission currents are 10 times or more larger than the field emission currents in this case. Another experiment verified that the field emission in the first accelerating structure dominated the dark currents represented in the right picture.

Note that the distribution patterns in the figure are determined by pulsed magnetic fields of the synchrotron's kicker.

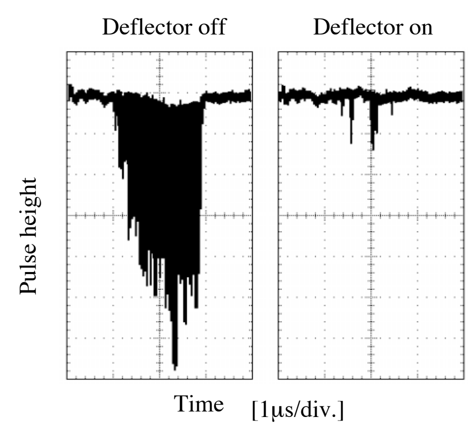

Fig. 4 Observation of gamma rays generated by dark currents

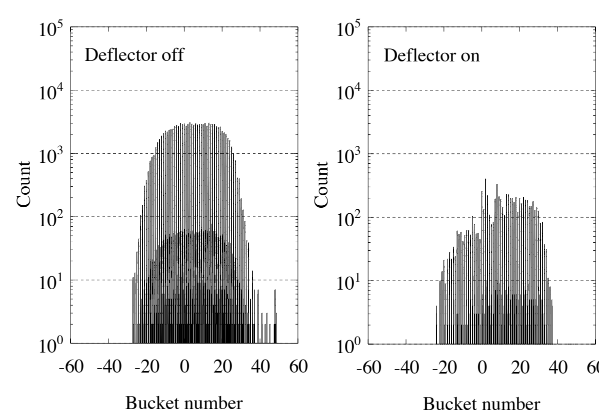

Fig.5 Stored dark currents observed by photon counting method

FIELD EMISSION

The field emission phenomena may occur in every accelerating structure holding the high field gradient. The energies of the field emission currents observed at the end of the linac have wide spectrum from 0 to 1GeV. The electrons emitted from the injector section, which includes a buncher section and the first accelerating structure, can only be accelerated up to 1GeV and injected into the synchrotron holding the energy acceptance of 2%. Therefore we have to consider the field emission currents generated in the injector section only. The first accelerating structure actually dominates the field emission currents as mentioned in the previous section.

The RF conditioning of the accelerating structures evidently decreased the field emission: Figure 6 compares the charge distributions of the stored single bunch beam, which were obtained with an interval of about 50 days. The later distribution in the right shows that the satellite intensity was attenuated by 1/10 after the RF conditioning.

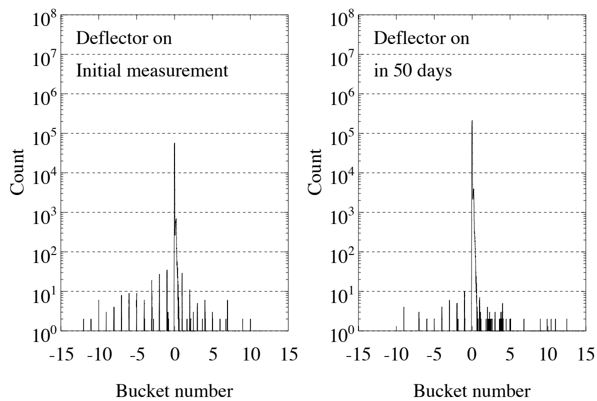

Fig.6 Satellite distributions of stored single bunch beam obtained with an interval

CONCLUSION

We accelerated electron beams under the tentative condition where the RF powers for the injector section was attenuated to be as low as possible in order to minimize the field emission. Figure 7 presents the charge distributions of the stored single bunch beams when the deflector being in or out of operation. These experimental results clearly prove that the deflector has filtered out the faint charges around the main bunch that were observed when the deflector was not in operation.

We conclude that the deflector reduces the dark current originating from the grid emission and consequently improves the purity of single bunched beam.

The field emission currents may dominate the total dark currents during a period after evacuation of the injector section. In this period, the deflector is not useful to reduce the dark currents. The field emission currents decay and will be negligible after an interval of a couple of a months. Now we are tying to control the dark currents generated in the first accelerating structure.

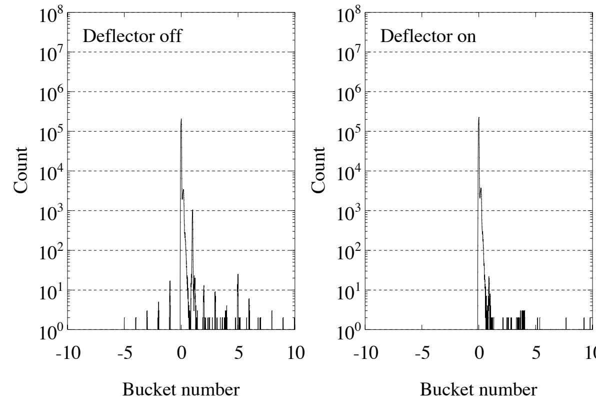

Fig. 7 Satellite distributions of stored single bunch beam, beam deflector being in/out of operation

ACKNOWLEDGEMENT

We would like to express gratitude to Dr. N. Kumagai, Dr. H. Ohkuma and Dr. H. Tanaka for their helpful suggestion to this study. We also were grateful to Mr. K. Yanagida and Mr. A. Mizuno for their contribution in the experiment of the beam deflector.

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