REDUCTION OF DARK CURRNT IN SPRING-8 LINAC

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Abstract

We have investigated the reduction of the dark current emissions in the SPring-8 linac, which are the origin of satellite bunches of the stored beam in the SPring-8 storage ring. The dark currents are generally composed of two component; the grid emission currents from a thermionic cathode assembly of a gun and the field emission currents generated in accelerating structures. The grid emission currents have been successfully reduced by the beam deflector installed just downstream the electron gun.

We examined the following two methods to reduce the field emission currents from the injector section: One is reduction of the rf power in the first accelerating structure and the other is applying the solenoid magnetic fields along the first accelerating structure. We have acquired that the reduction of the rf power efficiently decreases the dark currents, whereas the application of the solenoidal magnetic fields has not yet been effective though beam trajectory simulation predicted its effectiveness.

INTRODUCTION

The SPring-8 facility is composed of the 1GeV S-band linac [1], the 8GeV booster synchrotron, the 8GeV storage ring and the 1.5GeV storage ring NewSUBARU of the University of Hyogo. The linac started the top-up injection of electron beams into the booster synchrotron and the New SUBARU ring.

The booster synchrotron is equipped with the RF-KO system [2] which kicks out the satellite beam around the main bunch. The storage ring recently achieved the very low impurity of the stored beam. The single-bunch impurity is measured by using the visible synchrotron light at the accelerator diagnostics beam-line I (BL38B2). Photon counting method with a fast light pulse shutter system is used. The latest result of the impurity measurement is less than 1E-9.

The origin of the satellites is the dark current injected by the linac. The dark currents are generally composed of two component; the grid emission currents from a thermionic 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 the injector section is well RF-conditioned.

In 2002, a beam deflector was installed just downstream the thermionic gun to kick out the grid emission currents. The beam deflector has consequently reduced the dark currents[3][4].

As the next step, we have investigated applying solenoidal magnetic fields to the first accelerating structure to control the field emission currents. This is because we have expected that the solenoidal fields would provide transverse momentum kicks to the electrons emitted from the disks in the accelerating structure and accordingly make the electrons take the trajectory to strike the disks.

SIMULATION OF DARK CURRENT TRAJECTORY

The field emission phenomena may occur in every accelerating structure holding the high field gradients. We found that the first accelerating structure dominated the dark currents in the latest survey. Therefore we only simulated the trajectory of the electrons generated in the first accelerating structure.

We estimated the effectiveness of solenoid fields by using the self-made electron tracking code [5]. The solenoid fields were generated by the tracking code itself, whereas the RF fields of the disk-loaded accelerating structure of the injector section were calculated by POISSON SUPERFISH and were imported into this code. We assumed the initial condition that electrons were located at the surface of each disk hole of the accelerating structure. The surface of the disk hole forms an arc longitudinally, and the electrons were lined up along the arc surface at even intervals. The electron emission probability was supposed to have no field dependence, that is, all the electrons were immediately accelerated by the RF fields. The tracking calculation was performed for the electrons ejected from every 8th disk of the accelerating structure at various RF phases. The solenoid fields were applied partially, from the entrance to the 60th of 84 disks. Note that the secondary electron emission was not taken into account.

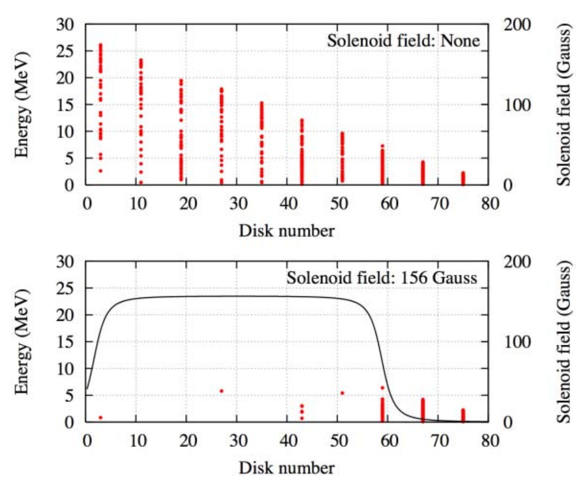

Fig.1: The simulated energies of the electrons which were able to pass through the 3-m long accelerating structure.

Figure 1 shows the energies of the electrons that were able to pass through the accelerating structure. The abscissa is the number of the disk from which the survived electrons were ejected, which are counted from the entrance of the accelerating structure. Almost all electrons holding energies higher than 5 MeV were not able to survive when the central solenoid field was 156 gausses and the RF power was 15 MW.

DARK CURRENT ENERGY MEASUREMENT

In order to measure the energy of the dark currents, we set a photomultiplier with a plastic scintillator downstream the 8-degree bending magnet. The maximum energy of the dark currents is 60MeV. Figure 2 shows the schematic view of the energy currents measurement system at the injector section.

In evaluation of obtained energy spectra, we were mainly interested in the electrons holding higher energies because the electrons of lower energies cannot run through the chicane section where a beam slit defines the energy spread of about 4 %.

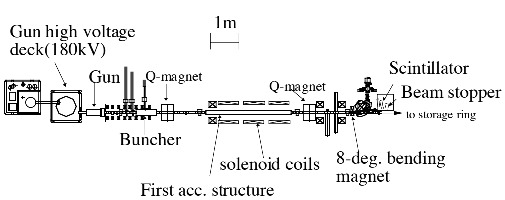

Fig.2: Dark current energy measurement system of SPring-8 injector

Result of beam deflector

Figure 3 compares the energy spectra of the dark currents in the two cases with or without the beam deflector operation. These spectra show that the installed beam deflector evidently decreased the dark currents.

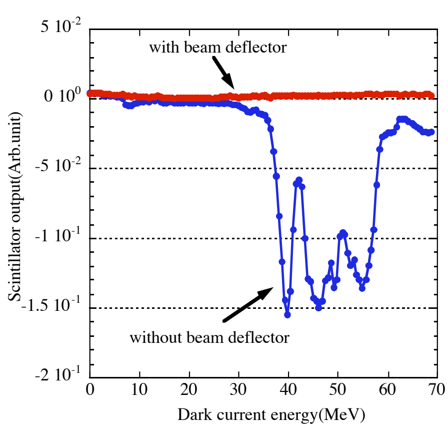

Fig.3: The effect of energy spectra in the cases with or without the beam deflector

Without the beam deflector, a part of the grid emission currents of 5-μs duration may strike the inner walls of the accelerating structure and generate secondary electrons. We expect that the secondary electrons would explain the broad spectra shown in Fig.3. The peaks and dips appearing in the broad spectra have not yet been well explained.

Effect of solenoid field in injector

The injector section of the linac holds seven pancake-like solenoid coils around the bunching cavities as illustrated in Fig. 2. The maximum field strength is about 500gauss. As the first step, we investigated the effect of the solenoidal magnetic fields on the field emission currents generated in the injector section.

The results presented in Fig. 4 clearly shows that the solenoidal fields applied to the injector section reduced the dark currents holding higher energies as we expected. The figure also presents the energy peak around 40 MeV observed in the case without the solenoid fields. The electrons forming this energy peak may be secondary electrons generated by the dark currents from the bunching section, which strike the upstream part of the accelerating structure.

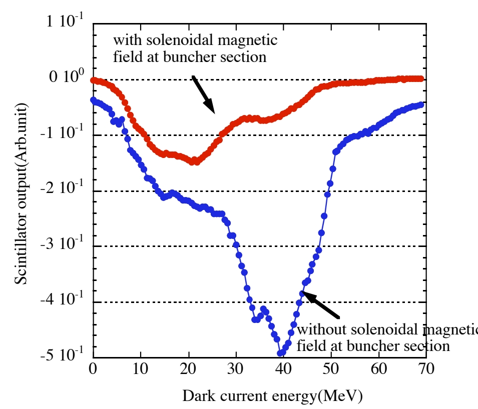

Fig. 4: The effect of the solenoidal magnetic fields on the dark currents at the injector section

Effect of solenoidal fields in first acc. structure

We set the three solenoid coils with the diameter of 20cm at the first accelerating structure as shown in Fig.5. One is 66-cm long holding a field of 143gauss and the other is 58-cm long holding a field of 162gauss. The segmentation of the solenoid coils is due to the supports of the accelerating structure.

Figure 6 shows the energy spectra of the dark currents in the cases with or without solenoidal magnetic field. The rf power fed to the first accelerating structure was 15MW.

Figure 6 compares the small reduction rates that were found in the higher energy electrons disagrees with the prediction by the tracking simulation. The reasons for the discrepancy are expected as follows: The most of the dark currents may originate in the secondary electrons generated as a chain reaction in the accelerator structure. These secondary electrons were not taken into account in the simulation code. However, the accelerated dark currents may holds relatively large beam diameter according to the simulation. That is, it may be able to block a part of the dark currents by means of a beam slit.

Fig. 5: solenoid coils covering the first accelerating structure.

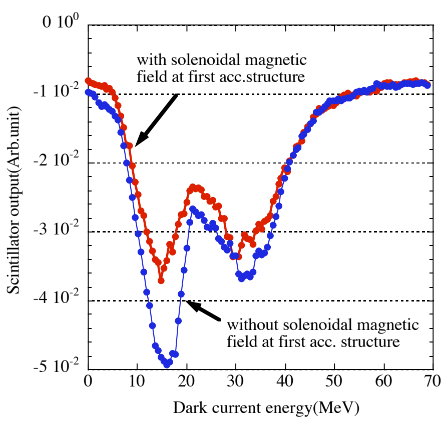

Fig. 6: The energy spectra in the cases with or without solenoidal magnetic field. The RF power fed to the first accelerating structure is 15MW.

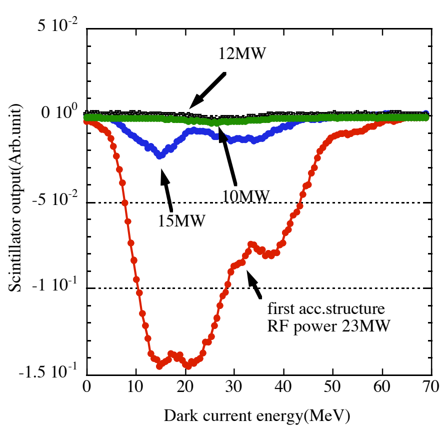

Fig. 7: The energy spectra of the dark currents at the different RF powers

RF power dependence

In order to reduce effectively the field emission currents, we decreased the RF power fed to the first accelerating structure. When we reduced the incident rf power fed to the first accelerating structure from 23 to 10MW, the field emission currents of the first accelerating structure was negligible as shown in Fig.7. The beam transportation from the gun to the second accelerator guide was confirmed at the RF power of 15 MW.

CONCLUSION

The beam tracking code predicted that the field emission electrons holding beam energies higher than 5 MeV could not survive in the solenoidal fields. The experimental results, however, showed that the solenoidal fields provided only the small reduction rates of the dark currents in the higher energy region.

The fact that the reduction of the RF power effectively decreases the field emission was clearly observed in the experiments, whereas the low energy gain may cause the difficulty of the beam transportation in the injector section.

We will ongoingly examine to combine the small reduction of the RF power, the solenoidal fields and a beam slit to find an optimum way to reduce the field emission currents.

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