ELECTRICITY GENERATION FROM SCATTERED SECONDARY PARTICLES INDUCED BY SYNCHROTRON RADIATION

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Abstract

Electricity generation from scattered radiations induced by synchrotron radiation was preliminary examined at the SPring-8 storage ring. The system and results are reported.

INTRODUCTION

One of recent concerns in the society including the accelerator is a concept of economy and ecology. For an example, concerning the SPring-8, a lower-energy operation than 8 GeV has been studied not only for the suppression of the natural emittance [1] but also for the suppression of the power of magnets.

In this proceeding, power recovery from scattered radiations is objective. In the SPring-8 storage ring (SR), where 88 bending magnets are installed, synchrotron radiation of 10.5 kW is generated per one bending magnet. However, more than 95 % of the power has not been utilized for experiments, and is absorbed at crotch-absorbers and absorbers [2]. A schematic view of a unit cell of the SPring-8 SR is illustrated in Fig. 1. A synchrotron radiation is generated at B1 and B2. Crotch-absorbers (cr1 and cr2) transmit a piece of the synchrotron radiation to an experimental hatch for experiments, and absorb that for non-experiments. Absorbers (ab1, ab2, ab3 and ab4) absorb the remains, which are not absorbed by only the crotch-absorber, for avoiding an interaction with the vacuum chambers. The absorbed synchrotron radiations are exchanged to heat and scattered radiations. It is supposed that if, for example, 1 % of the power can be recovered from the heat and the radiations, the recovered power from the whole ring is about 8.8 kW, which is sufficient for driving some experimental tools.

Concerning the power recovery from the heat generated at the crotch-absorbers and absorbers, a thermoelectric conversion element may be one solution. On the other hand, concerning the electricity generation from the scattered radiations, this is just a radiation monitor.

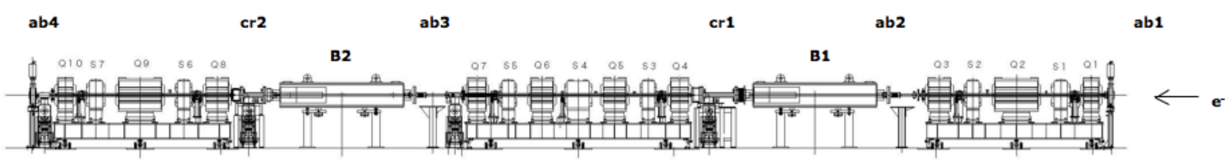

Figure 1: Schematic view of unit cell of SPring-8 SR.

In 2003, a vacuum leakage was caused by melting down of a vacuum chamber at the injection section on timing of a beam abort [3]. In addition, demagnetization of permanent magnets for the in-vacuum insertion devices (IDs) will be caused by the irradiation of circulating electron beam in the SR [4]. For suppressing an irradiation-induced damage on beam loss, a beam loss monitoring system has been developed [5]. In the beam loss monitor, PIN photodiodes without a reversed bias voltage is used from economical point of view for instalment and maintenance. The electricity is generated by an interaction between secondary particles on beam loss and the PIN photodiodes of zero bias voltage in similar to that between sun's ray and a solar cell.

As an application of the beam loss monitor, power recovery from scattered radiations induced by the synchrotron radiation was preliminary examined.

SETUP

In order to generate electricity from radiations, 3 types of test pieces were prepared, which are (1) 4 PIN photodiodes shielded by an aluminium chassis of 50 x 80 x 34 mm^3 (t = 1mm), whose spectral range of the sensitivity is 780 ~ 1100 nm, and the radiant sensitive area is 2.65 x 2.65 mm^2, (2) the aluminium chassis of (1), and (3) aluminium and copper plates of 120 x 170 mm^2 (t = 1mm), as shown in Figs.2. The reasons to choose (2) and (3) are that (a) a lifetime of semiconductors seems to be shorter than that of metals because of irradiation damages; power recovery on beam loss at hadron accelerators is also in the scope, where damages induced by neutrons should be taken into account, (b) the work function (Al: 4.08 eV, Cu: 4.70 eV) may induce a voltage difference between the aluminium and copper plates or the aluminium and the ground, and (c) they are commercially available.

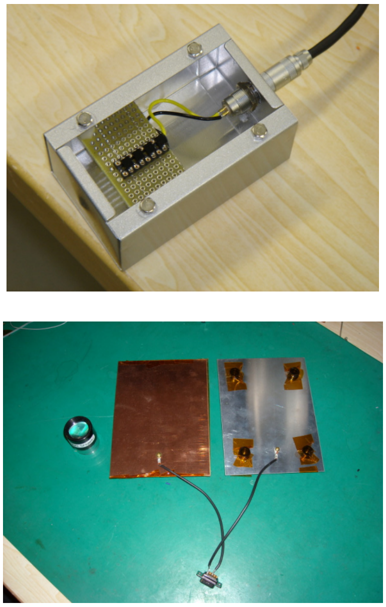

Figure 2: Test pieces. (upper) PIN photodiodes and aluminium chassis and (lower) aluminium and copper plates.

Test pieces were set near cr2 (see Fig.1) of cell48, at which 50 ~ 60 % of the power of the synchrotron radiation from B2 is absorbed [2], and was set far from the vacuum chamber as shown in Fig.3.

The electrons of 8 GeV and 100 mA were stored in the SR, and 4 types of the bunch filling modes (multi-bunch, 203 bunches, 11 bunch trains x 29, and 1/7 filling + 5 bunches) were adopted.

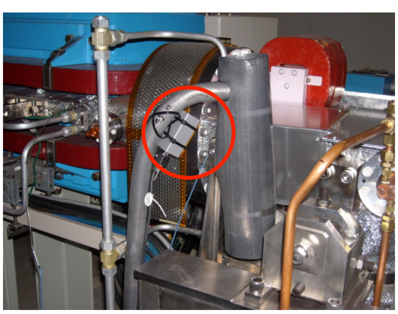

Figure 3: Setup of test pieces at cr2 of cell48.

RESULTS

In the case of the bunch filling mode of 1/7 filling + 5 bunches, the induced voltage by the test pieces is shown in Figs.4, which was measured at 100 Ω outside the tunnel. The time structure corresponding to the bunch filling was observed. This means that the induced voltage was dominated by the beam. The aluminium chassis indicated the higher induction voltage than the others, and 4 mW of the power was generated by the aluminium chassis.

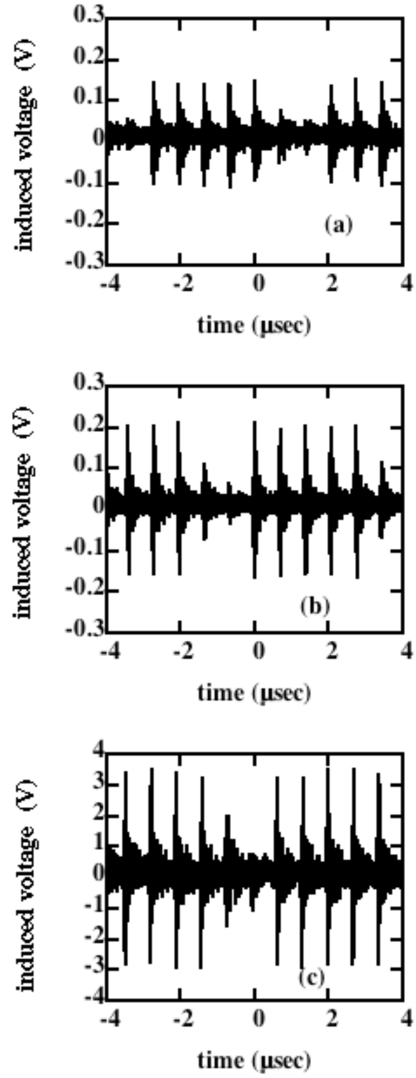

Figure 4: Induced voltage at 100Ω. (a) aluminium and copper plates, (b) 4 PIN photo diode and (c) aluminium chassis.

In order to rectify the induced voltage and to accumulate it in a capacitor, the Cockcroft-Walton (CW) circuit of two stages consisted of Schottky diodes of Vf = 0.36 V and ceramic capacitors of 100 uF was utilized.

The dependence of the accumulated voltage on the bunch filling in the case of the aluminium chassis is shown in Table.1. The electron current was 100 mA for these bunch fillings, but the dependence on the bunch filling was observed. The bunch current of the multi-bunch, 203 bunches, 11 bunch train x 29 and 1/7 filling + 5 bunches are 0.05mA, 0.5mA, 0.3 mA and 3 mA, respectively. So, it seems that accumulated voltage depends not only on the bunch current but also on the dominant frequency of the bunch filling because of the bandwidth of the system consisted of the test piece, the cable, the CW and so on.

Table.1: Accumulated voltage. Case of aluminium chassis.

Bunch filling mode	Accumulated voltage (V)
Multi-bunch	0.4
203 bunches	0.3
11 bunch train x 29	3.6
1/7 filling + 5 bunches	7.2

For a demonstration, a LED lamp (aL8pr26-R) was connected parallel with the capacitor for the accumulation. As shown in Figs. 5, the LED lamp was continuously turned on in the case of the aluminium chassis and the filling mode of 1/7 filling + 5 bunches.

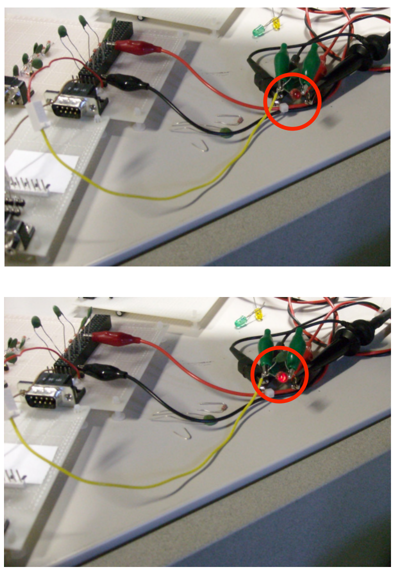

Figure 5: LED lamp (upper) before and (lower) after turned on. Aluminium chassis. 1/7 filling + 5 bunches.

These are preliminary results for power recovery by using test pieces, which were set near the crotch-absorbers and far from the vacuum chamber. Since there is the threshold of the power for the LED lamp to be turned on, the fact that the LED lamp was turned on suggests some power was truly recovered by the system. The problem is what was picked up by the system. The induced voltage indicated the time structure corresponding to the bunch filling, and the wall current should not be picked up because pieces were set far from the vacuum chamber. So, it seems that the radiation was picked up by the system. However, the system is very sensitive to the environment surrounding the SR, so that additional and careful, which mean non-preliminary, experiments should be carried out to check the representation and the others.

Energy recovery from heat is in the future. A thermoelectric conversion element may be one solution but irradiation damages should be taken into account.

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