MEASUREMENT OF THE BUNCH LENGTH IN AN ELECTRON STORAGE RING BY MEANS OF THE SINGLE PHOTON COUNTING METHOD

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Abstract

The longitudinal bunch length in SOR-RING was measured as a function of electron energy, RF voltage and stored current. Contrary to previous measurements, current dependence of the bunch length was observed in the multi-bunch operation mode but not in the single bunch operation mode, which suggests the phenomenon is caused by a bunch-bunch interaction in SOR-RING.

1. Introduction

Synchrotron radiation (SR) from electron storage rings has intrinsic time structure which facilitates time resolved experiments in the time range from subnanosecond to revolution time of electrons in a ring. Recently the single bunch operation of SOR-RING, which is a 400 MeV electron storage ring dedicated to SR experiments[1]), has been successfully made by means of the RF-knock out method[2]), and time resolved experiments as long as 58 nsec have begun. As SOR-RING is suitable for such experiments in short time region, it is important to measure time duration of a SR pulse which corresponds to electron density distribution in a bunch in order to know time properties of the light pulse precisely.

The longitudinal bunch length measured so far in electron storage rings shows a functional dependence on stored current and the measured bunch length is longer than calculated values[3-5]).

We measured bunch length in SOR-RING by means of the single photon counting method and studied a functional dependence on operation parameters of the ring.

2. Experimental Procedure

A bunch length of SOR-RING was measured as a function of electron energy E_e, RF cavity voltage V_{RF} and electron current I_e both in the multi-bunch and single bunch operation modes of the ring. The visible spectral region of SR, passing through a glass window mounted on a vacuum chamber of a bending section in SOR-RING, was attenuated and focused onto a pin hole of about 0.1 mm in diameter and detected with a fast photomultiplier utilizing a chevron multichannel plate (HAMAMATSU TV, R1294UX) which has better time resolution than an ordinary photomultiplier. The time resolution of the detection system was less than 250 psec under this experimental condition and is not subtracted from all the data shown below. The time structure of SR is a copy of the electron density distribution in a bunch. The RF cavity readout was calibrated by making use of a functional dependence of synchrotron frequency on RF voltage.

3. Result and Discussion

Fig. 1 shows stored current dependence of the bunch length in the multi-bunch operation mode. The upper and lower broken lines are the natural bunch lengths, which are expected from the balance of quantum fluctuation and radiation damping[6]), at E_e=380 and 308 MeV, respectively. For stored current less than 0.1 mA, measured bunch lengths at E_e=308 MeV are also in good agreement with the natural bunch length. It is obvious from Fig. 2 that there is a critical current, above which the bunch length begins to increase as the current increases. The measured current dependence of the bunch length is well approximated by $\log I_e^{1/3}$ in that region,

which is shown in Fig. 1 by the solid lines. This current dependence is similar to that observed in ADONE[4]). It is confirmed that the natural bunch length is in good agreement with the measured one in the wide-ranging values of RF voltage as long as stored current is less than the critical value. Fig. 2 shows dependence of the bunch length on stored current for the single bunch operation. Electron number in a bunch at I_e=10 mA for the single bunch operation is 3.6×10^9 and it is equal to the number of electrons per bunch at I_e=70 mA for the multi-bunch operation because the harmonic number of SOR-RING is seven. Contrary to Fig. 1 the measured bunch length is independent of the stored current for the single bunch operation.

The experimental results observed in ACO and ADONE[3,4]) show that the bunch lengthening is a function of current per bunch and no of total current and this suggests the bunch lengthening is due to a electron-electron interaction within a bunch. Our experimental result, however, contradicts with the above results and it is concluded that the bunch lengthening observed in SOR-RING is caused by a bunch-bunch interaction because it is observed for the multi-bunch operation but not for the single bunch operation.

As a conclusion, the bunch length in SOR-RING for the single bunch operation is independent of stored current, at least, up to 17 mA (6.1×10^9 electrons/bunch) and the time resolved experiments as short as 650 psec (E_e=380 MeV and V_{RF}=23.8 kV) are feasible.

Acknowledgment

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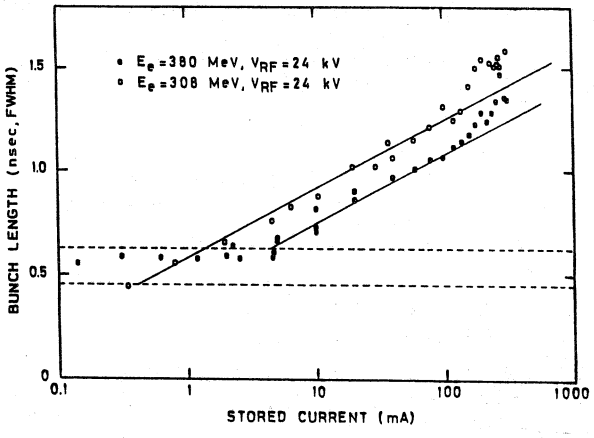

Fig. 1. Stored current dependence of bunch length for the multi-bunch operation.

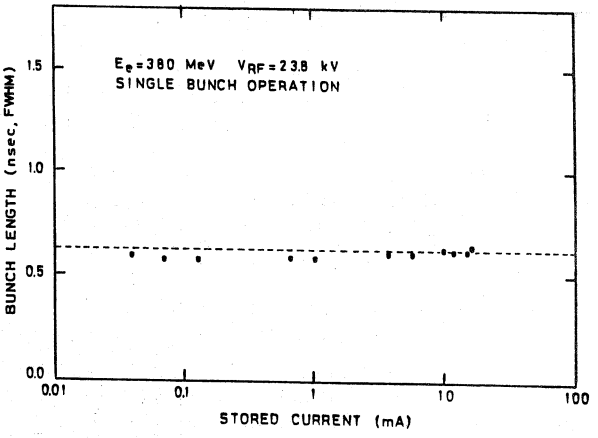

Fig. 2. Stored current dependence of bunch length for the single bunch operation.