OBSERVED FEATURES OF AURORA

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Abstract

We present in this paper the observed features of Aurora to provide the physics of the exactly circular machine. At the full energy the observed beam parameters such as the lifetime, the beam profile, and the bunch length are quite consistent with the designed values. On the other hand beam nature at 150MeV injection energy is puzzling. The observed lifetime is longer than expected. The long lifetime is correlated to the short bunch length and poor vacuum pressure.

I. INTRODUCTION

Aurora is a synchrotron light source which has the most simple configuration among others[1]. The electron orbit is exactly circular under the single dipole magnet. Since the first synchrotron light observation in 1989, we have modified the injector race-track microtron to achieve 5mA peak current which is more than enough for the injection[2]. It takes 1 minute for the injection and 7 minutes for the ramping. We accumulate 500mA beam current which is the maximum value obtainable with the present RF-power. Recently the lifetime has recorded 13 hour at 300mA on average. The machine is now under routinely operation for users programs such as the x-ray lithography, the x-ray microscope, the reflectivity measurement, the x-ray spectroscopy, the solid phase epitaxial growth and so on. The fully automated operation allows users to operate the machine by themselves.

In this paper we focus our discussion to the observed characteristics of the beam at 150MeV injection energy. The behavior of 150MeV beam is unusual in its lifetime and bunch length. A long lifetime is observed at higher vacuum pressure, which is also correlated to the shorter bunch length.

II. Characteristics of 150MeV beam

A. Lifetime

The Touscheck lifetime at 300mA is calculated as 60sec. The observed lifetime is absolutely longer than this value as seen in Fig.1. The lifetime once decreases with the beam current but again increase. Difference are significant between the data set I and II, which are taken in different periods. In general the Touscheck lifetime decreases as the current increase. The effect of intra-beam scattering(IBS) [3] may lead to a longer lifetime as the beam current increase because the beam size grows. Including the IBS effect the lifetime were calculated by the code ZAP[4] as shown in Fig.2. Discrepancy between the experiment and the theory at high current are remarkable particularly for the data set I.

The lifetime is likely governed by other interactions such as the gas scattering. The strength of the gas scattering depends on the ion trap which also depends on the beam current. We have analyzed in Fig.3 the correlation between the lifetime and the vacuum pressure. It has been thought that the lifetime stretches as the vacuum pressure decreases. This is seen at low pressure in Fig.3. The lifetime, however, stretches again at high pressure.

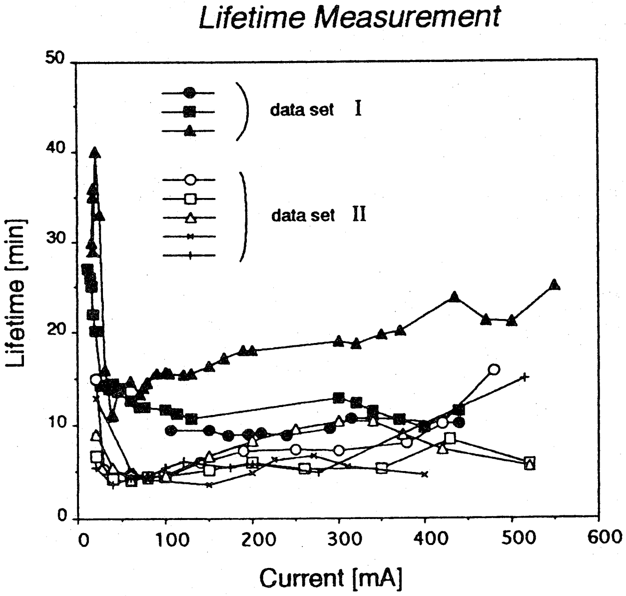

Fig. 1

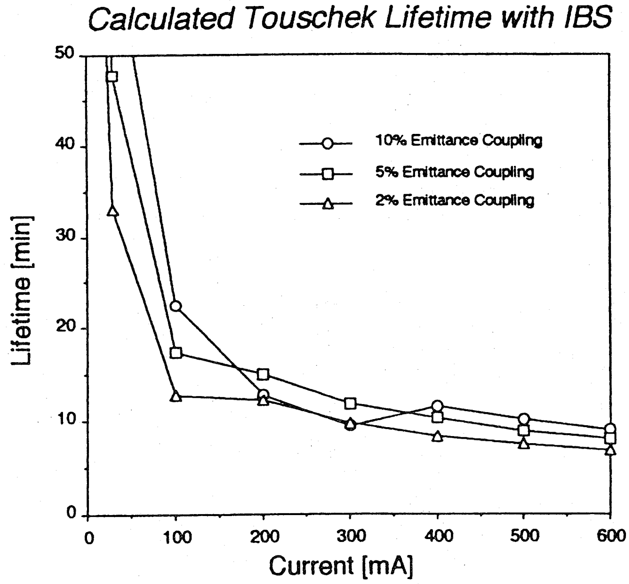

Fig. 2

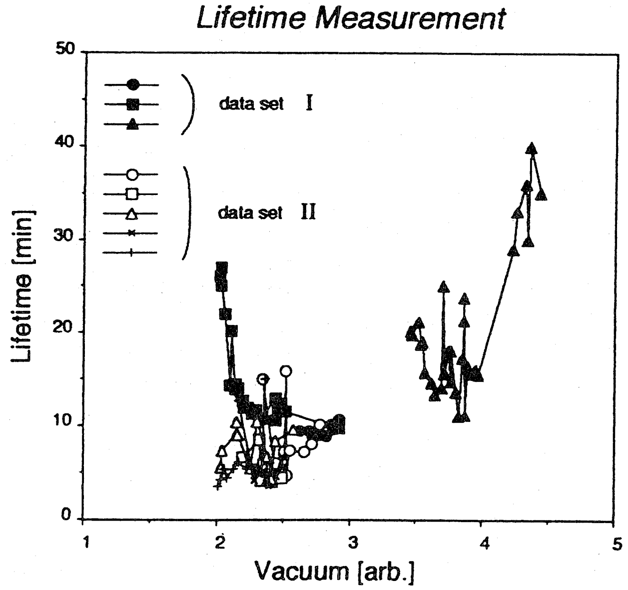

Fig. 3

B. Bunch width and length

The calculated current dependences of horizontal and vertical beam width, and bunch length are shown in Fig. 4. We used the code ZAP for these calculations. In this calculation the following machine parameters are used: magnetic field=1T, field index=0.72,RF-voltage=120kV,RF-frequency=190.86 MHz, and electron energy=150MeV. The result changes when the emittance coupling constant is changed as indicated in each data. In general when coupling constant is large the horizontal beam size shrinks and mean time the vertical beam size grows. The bunch length is shortened as the coupling constant is increased. The effect of the tune shift seems to be small.

The experimental data are shown in Fig. 5. The beam profiles were measured by the micro-telescope[5], and the bunch lengths were by the streak camera. We see here that the beam profiles change day by day. The gross tendency of the horizontal beam width is almost reproduced by the IBS calculation with 2 to 10% coupling constant. The observed vertical beam width is slightly wider than the calculation including even 10% coupling.

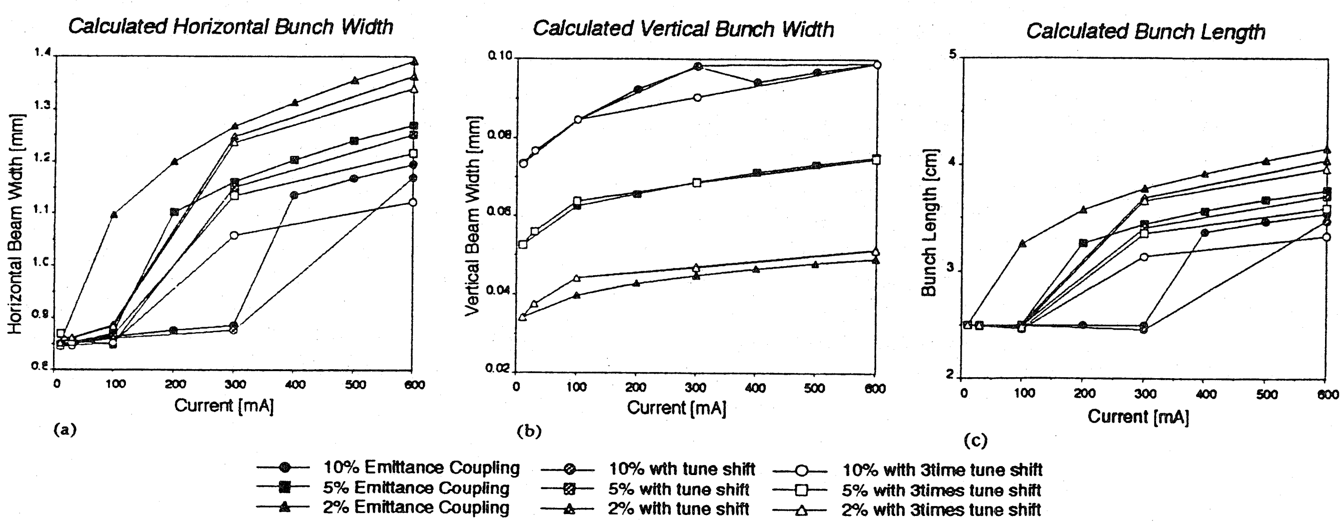

Fig. 4

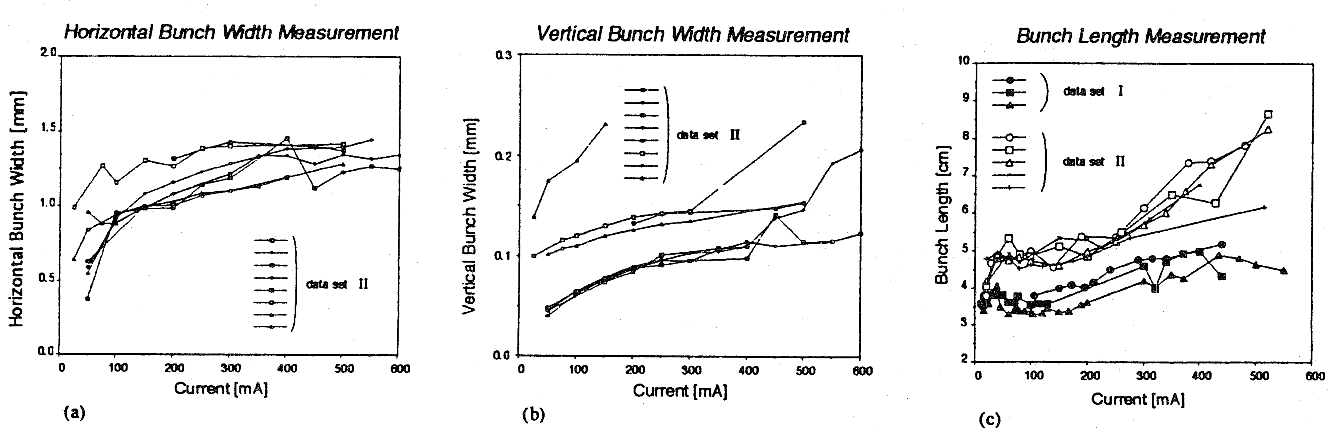

Fig. 5

Effect of the PWD & MWI on the bunch length

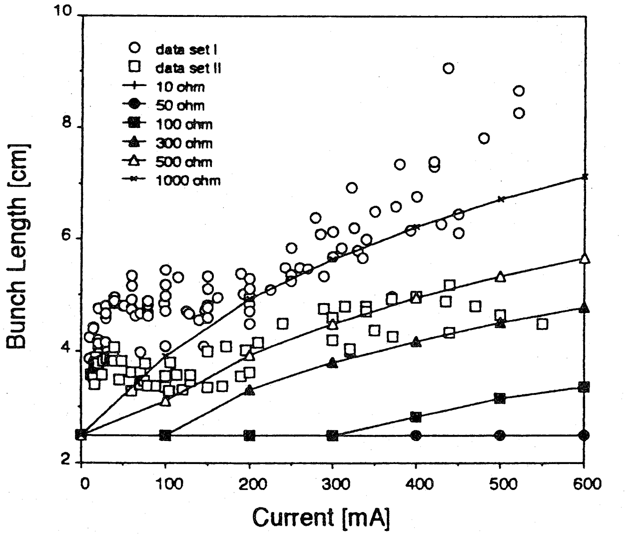

Fig. 6

Effect of IBS & Tune Shift on the bunch length

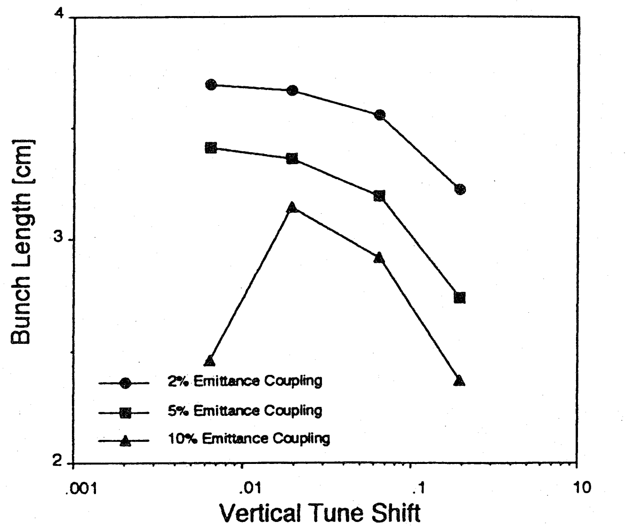

Fig. 8

150MeV lifetime vs. bunch length & vacuum

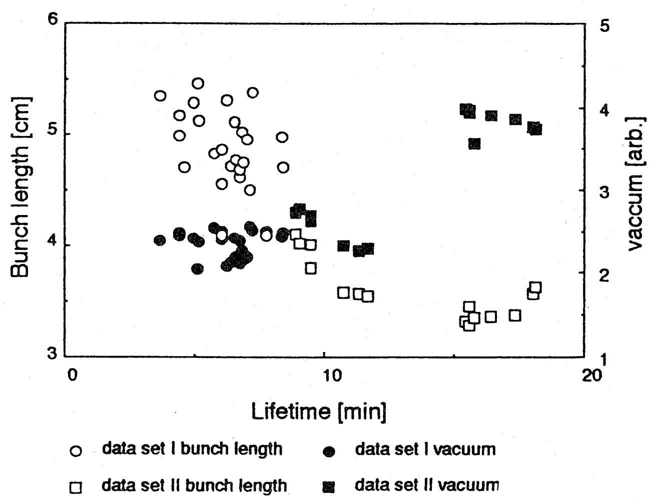

Fig. 7

Similar to the lifetime data the difference between the data set I and II are apparent in the bunch length data Fig.5(c). In this case discrepancy between the experimental values and the IBS calculations are significant even at low current. The shoulder appears in the data set I at low current. To explain these data some interactions other than the IBS must be introduced. If the microwave instability[6] is taken into account the bunch length could be expanded by factor 2 as indicated in Fig.6, but unrealistically large beam impedance must be introduced.

III. Discussion

It seems difficult to explore the bunch length and lifetime data at 150MeV by the IBS theory. When we deduce the correlation between the bunch length and lifetime in Fig.7, the features of the beam turn out more clearly. In order to avoid the effect of the current dependence we have selected the associated current so as be 100~200mA. Strong correlation appears between the lifetime and the bunch length rather than the current. When the lifetime is longer the bunch length becomes shorter. This result can't be reproduced by the IBS theory. In Fig.7 the correlation between the vacuum pressure and the lifetime is also indicated. It is clear that the vacuum in other word the gas scattering is deeply involved in this phenomena.

We easily expect that the gas scattering induces the mixing of vertical and horizontal betatron oscillations, and shifts the tune. Thus we have estimated the bunch length caused by the tune shift. Sizable bunch length shortening due to the tune shift and the increased emittance coupling constant are expected as seen in Fig.8. Actually we have already observed experimentally the large amount of tune shift. We expect that the gas scattering is functioning as a beam guiding. We might use actively this phenomena to make the focused beam.

IV. References

[1] H.Yamada, J.Vac.Sci.Tech. B8 (1990) 1628.

[2] T.Hori et al., Sumitomo Heavy Industries Technical Rev. 116(39) (1991) 46.

[3] J.Bisognano et al., Particle Accelerators 18, 223 (1986).

[4] M.Zisman et al., ZAP USER'S MANUAL, LBL-21270, Dec. 1986. publicaton.

[5] H.Yamada and S.Taguchi, Proc. the 7th Sympo. on Accele. Sci. and Tech., Osaka, Dec 12-14, 1989.

[6] A.Hofmann, Proc. First Course of Int. School of Particle Accelerators, Erice 1976,CERN 77-13, p. 139