Single bunch electron cloud instability for a round beam II (memo)

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1 Coherent or incoherent?

We put 1, 5, 10, 20, 50 points at which a proton bunch interacts with an electron cloud in the ring [1]. Fig. 1 shows the horizontal and vertical emittance growth for various number of the interaction points, N_I. The emittance growth was reduced by increasing the number of interaction points. Fig. 1 (c) and (d) shows the detail of the emittance growth. For $N_I = 20$ and 50, there was no big difference.

Fig. 2 shows the transverse size and centroid of the proton beam, and the centroid of the electron cloud along the longitudinal direction. The positive z indicates the head of bunch. These quantities give information of interactions between them. The sizes and centroids after 5 ms (300 turns) are depicted in the pictures (a)-(f) for various N_I. We could not find any coherent signal in the pictures (a) and (b), which is obtained for $N_I = 5$. The centroids are small values, while the size is enlarged at the tail of the bunch. For small number of the interaction points, $N_I \leq 10$, there was no coherent dipole motion in the centroids. Increasing the number of the interaction point, coherent dipole signals $x_+(z), y_+(z)$ can be observed in both of the horizontal and vertical directions as shown in Fig. 2 (c), (d) ($N_I = 20$), (e) and (f) ($N_I = 50$). The beam size is enlarged in proportion to the growth of the coherent dipole amplitude. The dipole amplitude of the beam seems to be somewhat smaller compare than its size. Fig. 2 (g) and (h) shows the same quantities after 1 ms for $N_I = 50$. The dipole amplitude is larger than that after 5 ms (e) and (f). It means that the coherent motion is smeared out for the time development.

2 Linear stop-band

When the beam does not have any coherent motion, electron cloud is bound in the semi-static beam potential during its passage. We discuss how the electron cloud affects the beam in the situation. We remember the space charge problem in proton rings. When the lattice of the ring is ideal, the space charge force does not cause an emittance enlargement for the K-V beam, though the Twiss parameters are changed [2]. The space charge affects the beam emittance via various causes: i.e., the actual beam deviates from the KV beam,

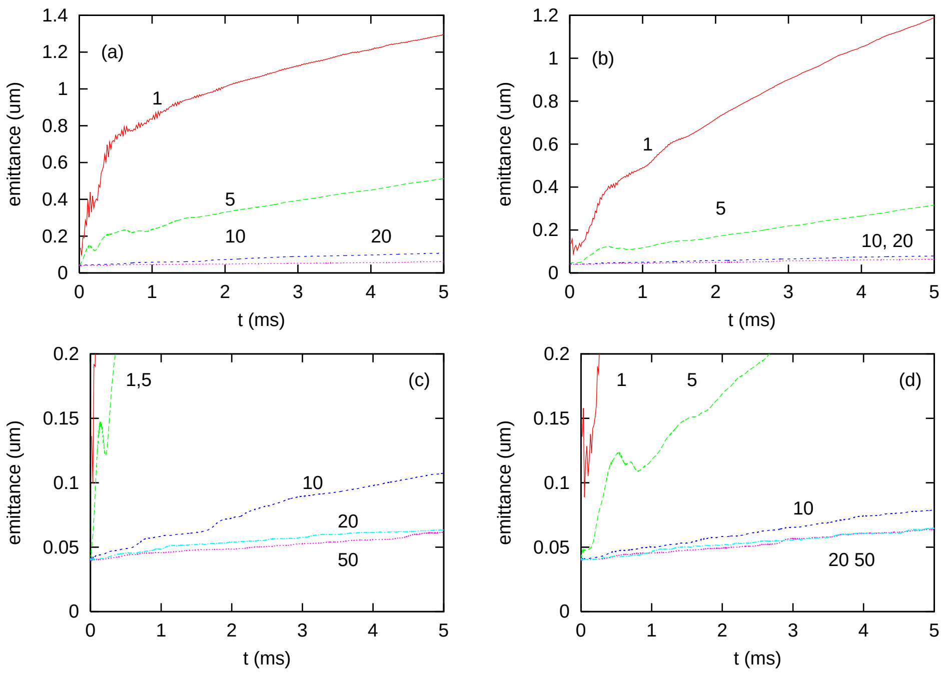

Figure 1: Simulated emittance growth for various number of the interaction points. (a) Horizontal (b) vertical (c) horizontal detail (d) vertical detail.

lattice error, tune, structure of beta function and phase ... etc. We stand the same situation in the electron cloud problem.

The static electron cloud may not have a strong effect for an ideal lattice. We introduce a linear stop band in the ring. A quadrupole magnet, which induces the tune shift of $\Delta\nu_x = \Delta\nu_y = 0.02$, was inserted in a position of the ring. Fig. 3 shows the emittance growth with/without the stop-band. There was clear difference for the presence of the stop-band. The original tunes are $\nu_x = 26.19$ and $\nu_y = 26.24$. We also tried larger tune shift $\Delta\nu = 0.04$, and obtained qualitatively similar results, in which the amplitude becomes larger. For a weak cloud density ($\times 1/10$), there was no remarkable growth of the emittance for the stop band. Fig. 4 shows the dipole amplitudes and beam size along the longitudinal direction. We should compare Fig.4 (a), (b), (c) and (d) with Fig. 2 (g), (h), (e) and (f), respectively. The coherent motion is similar but the size is larger, especially it is larger near the bunch center $z/\sigma_z > -1$. The stop-band seems to affect the beam due to the space charge effect of electron cloud, though we can not declare clearly now.

The actual cloud distribution is neither localized, nor is uniform along the ring. The beta function, nonlinear components and errors affect the space charge effect. The space charge effect of proton beam itself also affect: that is, there is no distinguish from the view point of the mechanism, except the tune shift is opposite. It is even possible that the two space charge effects canceled each other [3].

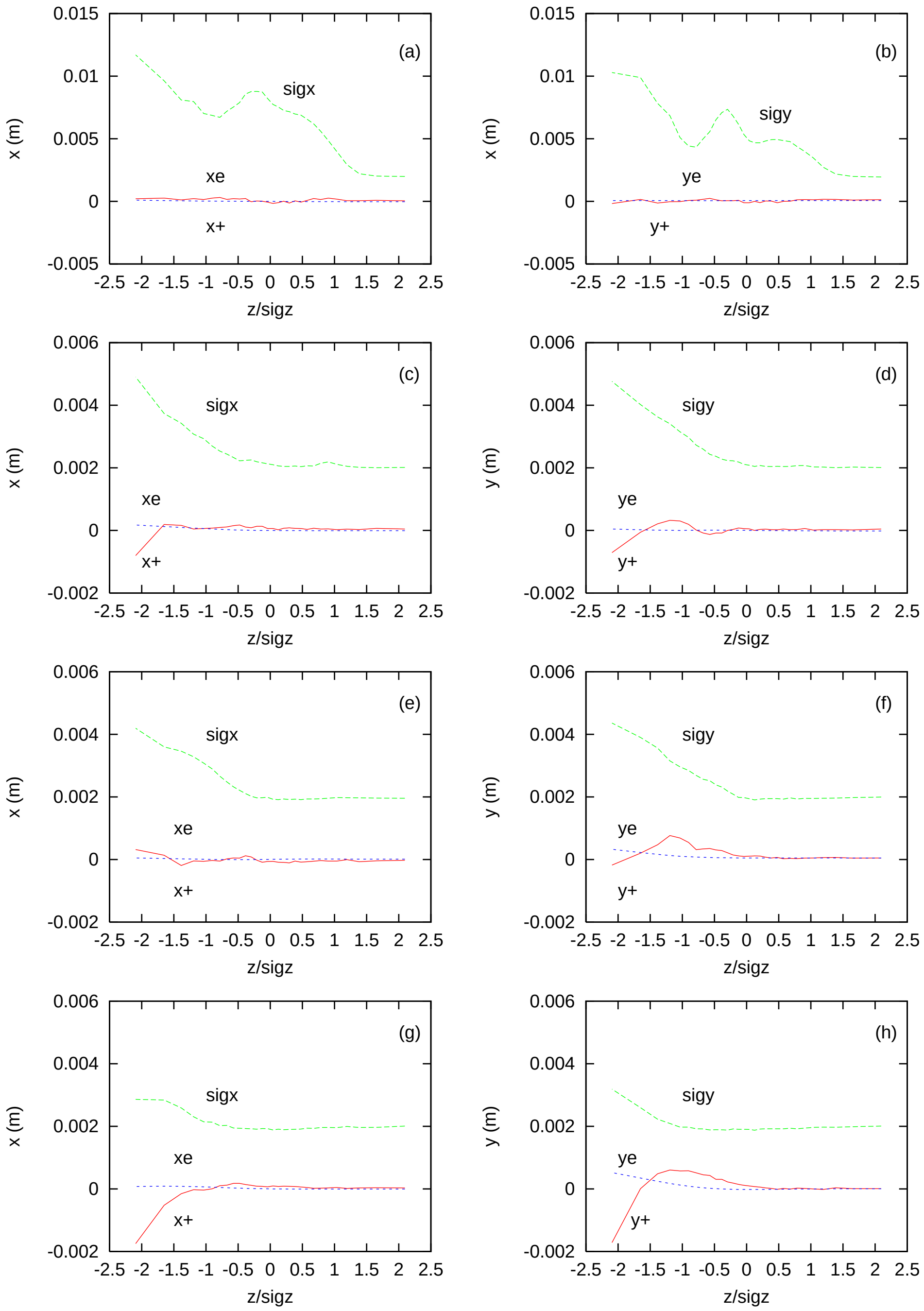

Figure 2: Bunch and cloud structures (a)-(f) after 5 ms. (g) and (h) after 1 ms. (a) Horizontal N=5 (b) vertical N=5 (c) Horizontal N=20 (d) vertical N=20 (e) Horizontal N=50 (f) vertical N=50 (g) Horizontal N=50 (h) vertical N=50

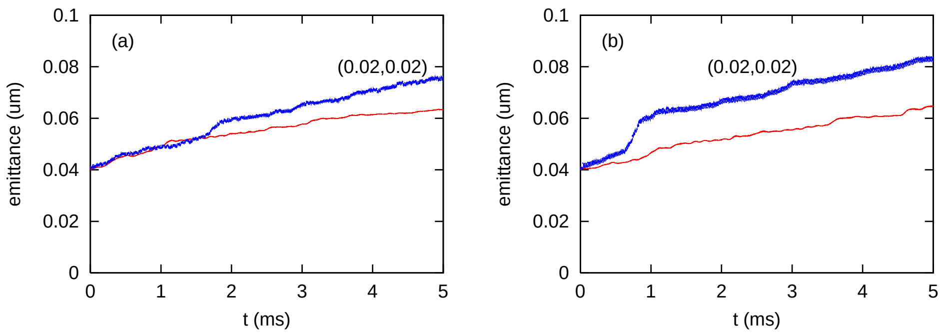

Figure 3: Growth of emittance of the beam for stop-band of $(\Delta\nu_x, \Delta\nu_y) = (0.02, 0.02)$. (a) Horizontal (b) vertical.

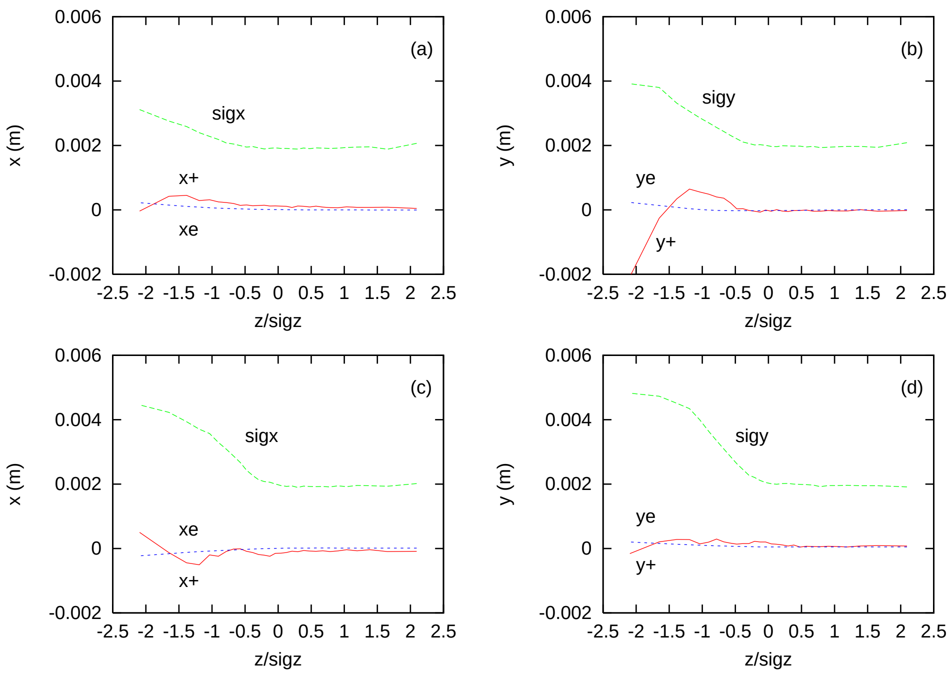

Figure 4: Bunch and cloud structures for stop band of $(\Delta\nu_x, \Delta\nu_y) = (0.02, 0.02)$ after 1ms and 5ms. (a) Horizontal (b) vertical after 1 ms. (c) Horizontal (d) vertical after 5 ms.

3 Strong dipole magnetic field

A strong magnetic field bind electrons along the field flux. We can expect a vertical head-tail break-up of the beam [4, 5]. Fig. 5 shows the growth of emittance for applying strong vertical field. In the simulation, electrons are assumed to be bound along the vertical flux line completely. Fig. 5(b) shows remarkable growth of the vertical emittance. Fig. 6 shows the transverse size and dipole amplitudes of the proton beam and the electron cloud along the longitudinal direction in the strong magnetic field. We find a clear coherent signal in the vertical plane, while no signal in the horizontal plane.

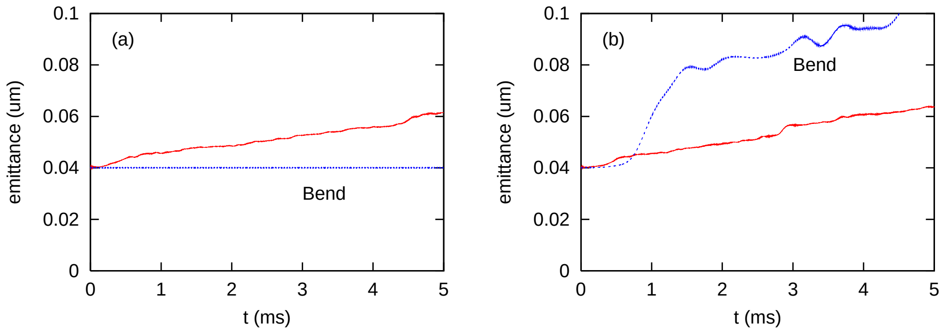

Figure 5: Growth of emittance of the beam in strong dipole magnetic field. Blue and red lines depict emittance with and without magnetic field, respectively. (a) is horizontal, (b) is vertical growths.

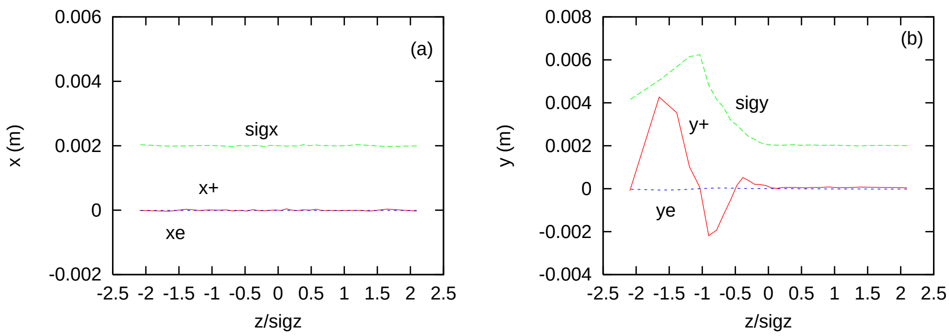

Figure 6: Bunch and cloud structures in strong dipole magnetic field after 5 ms. (a) is horizontal, (b) is vertical structures.

References

[1] K. Ohmi, ECLOUD memo, Nov. 2002.

[2] F. J. Sacherer, UCRL-18454.

[3] Many people say the cancel of the two effects.

[4] L. Wang, G. Rummolo, F. Zimmermann, K. Ohmi, CERN SL-2001-058 (AP), Proceedings of APAC2001, 442 (2001).

[5] K. Oide, private communications.