EINSTEIN'S GENERAL RELATIVITY EFFECTS ON BEAM DYNAMICS IN A STORAGE RING*

Dong Dong#, Chao-guang Huang, Zhou Zusheng IHEP, Beijing, China

Abstract

In this paper we will discuss Einstein's tide force predicted by Einstein's general relativity, how the new tide force would affect the beam orbits in a storage ring, and how to pick up and recognize it from the beam signals in a storage ring. The result shows this effect can be accumulated by the charged particle beam in a storage ring, it is a very interesting result.

INTRODUCTION

There are two difference kinds of tidal force which will affect the beam position in a storage ring. One is the well known Earth tidal force, given by Newtonian gravitational field. In this case, the tidal force will cause the ground motion, and will cause the change with time of the position of the magnetic elements in a storage ring, which is firmly attached to the ground. Since the beam is not affected by this kind Earth tide, so one can see the beam position change with time by measuring the beam position by using the beam position monitors (BPM) which are fixed to magnetic elements in a storage ring. Such effects of terrestrial tides on the circumference of a storage ring have been observed very clearly in LEP[1] and SPring-8[2] and other machines.

Another kind of tidal force, predicted by Einstein's general relativity is quite different from Newtonian tidal force. Einstein's tidal force will affects the beam in a storage ring and change the beam position directly. So it is a new physics model on beam instability in a storage ring.

EINSTEIN'S TIDE FORCE ON BEAM DYNAMICS

In the Minkowski space-time, Let an x–y plane be defined by a storage ring and z-axis be in the direction of the normal of the ring. Let us consider the motion of the beam in the storage ring in a perturbed space-time, $ds^2 = -dt^2 + (1+h_+)dx^2 + (1-h_+)dy^2 + 2h_\times dxdy + dz^2$ where $h_+ = A_+ \cos(\omega_g t - 2\pi z/\lambda_g)$, $h_\times = A_\times \cos(\omega_g t - 2\pi z/\lambda_g)$, Einstein amplitude A_+ and $A_\times$ are two independent mode. ω_g is the angular frequency of Einstein tidal force. (The c = 1 unit is used throughout the paper. In general, h_+ and $h_\times$ may be functions of both t-z and t+z). After calculation and simplification, one can obtain three equations[3], two describe the local changes of the beam position with time in a storage ring, and the third one describes COD change of the beam in a storage ring, show as follow,

$$\Delta l = \frac{R\omega_0\omega_g^2 \sin\left(\frac{\pi\omega_g}{\omega_0}\right)}{(\omega_g^2-\omega_a^2)(4\omega_0^2-\omega_g^2)} \cdot \left[\omega_g A_+ \cos\left(\frac{\pi\omega_g}{\omega_0}\right) - 2\omega_0 A_\times \sin\left(\frac{\pi\omega_g}{\omega_0}\right)\right]$$

where $\omega_a^2 = \omega_0^2 + \omega_0\omega_B$, $\omega_0 = qB/m$, $\omega_B = qRB'(r)/m$, Δl is the change of the circumference per turn due to Einstein's tidal force, corresponding to the close orbit distortion in an accelerator, that means the effects can be accumulated by the beam in a storage ring.

MEASURE METHOD

One may have chance to observe Einstein tidal force on the beam in a storage ring. One method to recognize it is co-identity beam signals from difference ring in the worldwide side, and this method also can help us to dispel the noise of beam signal.

CONCLUDE

Different from Newtonian tidal force which affects the magnets and BPMs in storage ring, Einstein tidal force changes the particle beam position directly, and has not be distinguished yet. One method to recognize it is co-identity beam signals from difference ring in the worldwide side, and this method also can help us to dispel the noise of beam signal, this is the best way. This experiment may help us find new physics.

ACKNOWLEDGEMENTS

One of authors (Dong) thanks Prof. S. Kurokawa (KEK), Dr. S. Date (SPring-8), Prof. T. P. Li (IHEP), and Prof. Z. Y. Guo (IHEP) for helpful discussions, and Prof. K. Nakahara (KEK) for his hospitality at the Institute of High Energy Physics in Japan.

REFERENCES

[1] L. Arnaudon, et al., Nucl. Instrum. Methods A 357 (1995), 249-252

[2] S. Date, et al., Nucl. Instrum. Methods A 421 (1999), 417

[3] Dong Dong. Huang Chao-Guang, Commun. Theor. Phys. 40 (2003) pp. 299-300.

*Work supported by National Nature Science Foundation of China under Grant No. 10475094
#E-mail: dongd@ihep.ac.cn