Electro-Gravitational Induction Predicted by Beam Instability in Charged Particle Storage Rings

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Abstract

Changes in beam position within charged particle accelerator storage rings have been observed due to changes in gravity (Δg) caused by the moon and sun. The terrestrial tidal model has been used to explain this type of beam instability. Further analysis reveals that these instabilities arise from changes in the electron beam energy, rather than from movements of the accelerator components due to terrestrial tidal forces. We suggest a potential model to better explain this type of instability. Consider a charged particle beam ring rotating with the earth, perpendicular to the moon' s line of gravity. We induce an electromotive force along the ring, referred to as electro-gravitational induction (EGI). The circular motion of the charged particles causes the accumulation of the EGI in the storage ring, turn by turn. We used existing data from storage ring beam signals to estimate the maximum value of the gravity coefficient of the induced electromotive force.

Full Text

Preamble

On the Electro-Gravitational Induction Predicted by Beam Instability in Charged Particle Storage Rings

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Abstract: Changes in beam position within charged particle accelerator storage rings have been observed and attributed to gravitational variations caused by the moon and sun. The terrestrial tidal model has been used to explain this type of beam instability. Further analysis reveals that these instabilities arise from changes in the electron beam energy rather than from movements of accelerator components due to terrestrial tidal forces. We suggest a potential model to better explain this phenomenon. Consider a charged particle beam ring rotating with the Earth, perpendicular to the moon' s gravitational field line. We induce an electromotive force along the ring, referred to as electro-gravitational induction (EGI). The circular motion of the charged particles causes the EGI to accumulate in the storage ring turn by turn. Using existing data from storage ring beam signals, we estimate the maximum value of the gravity coefficient of the induced electromotive force.

One Sentence Summary: We have postulated the existence of electro-gravitational induction (EGI) in a particle storage ring.

Introduction

In particle accelerator storage rings, beam position monitors (BPMs) have detected changes in beam position as variations in the amplitude of closed orbit distortion (COD) following a 12-hour cycle. These position changes have been attributed to the gravitational pull of the moon and sun—that is, to the effects of gravitational forces on the orbits of charged particles in the storage ring. Current research has employed a terrestrial tidal model [**?**]. The terrestrial tidal force deforms the ground surface and consequently affects all storage ring components, including BPMs and bending magnets, that are anchored to the ground. Ground movement thus alters the beam orbit, which in turn changes the beam energy. We note that two groups of BPMs are positioned alternately around the storage ring: one group in the dispersive region measures beam position changes due to energy variations, while the other in the non-dispersive region measures position changes arising from other sources—that is, not from energy changes. For example, the SPring-8 ring has 88 BPMs in the dispersive region and 200 BPMs in the non-dispersive region. BPM data [**?**] show that the COD exhibits changes in the dispersive region, indicating that these COD variations result from beam energy changes, a behavior attributed to terrestrial tides. However, the COD remains unchanged in the non-dispersive regions [**?**], meaning that the positions of bending magnets and BPMs are not changing.

Therefore, we suggest that in the dispersive region, the COD change is caused solely by the change in beam energy; it does not arise from BPM position changes due to ground expansion as predicted by the terrestrial tidal model.

This phenomenon, in which the moon and sun cause energy changes in the charged particle path, involves two significant physical quantities: the intensity variation of the gravitational field and the energy change of the charged particles. We consider whether this phenomenon implies that gravitational force has a direct effect on moving charged particles. We discuss the possibility that the gravitational field produces an induced electric field that changes the energy of charged particles, and we investigate whether this electro-gravitational induction (EGI)—the interplay between gravitational force and electromagnetic induction—can be observed. We also present results for the EGI coefficient.

Model of the Electro-Gravitational Induction

In this section, we present the method used to quantify the EGI.

Let the line perpendicular to the intensity of the gravitational field be denoted by . When moves perpendicular to with a velocity , it produces an electromotive force along g where is the EGI coefficient. The line integral of (1) gives the electromotive force

$$\mathcal{E}_g = \oint (-\vec{v} \times \vec{g}) \cdot d\vec{l} \tag{1}$$

Then the net gravity-induced electromotive force after one turn in the accelerator storage ring is . If a charged particle with velocity moves in an accelerator storage ring with radius , the energy change of the particle within the given time will be

$$\frac{dE}{dt} = q\mathcal{E}_g \cdot v_p \tag{2}$$

For a given storage ring, we have the following expression:

$$\Delta E = \oint q\mathcal{E}_g \cdot v_p \frac{dl}{L_0} \tag{3}$$

where is the expected path perimeter, is the beam energy for the expected central orbit in the storage ring, and and are the change in the expected path perimeter and the corresponding change in energy, respectively. is the rest energy of the charged particle, and are the change in the .

To calculate equation (2), we used the following approximation:

$$\mathcal{E}_g = \oint (-\vec{v} \times \vec{g}) \cdot d\vec{l} \approx R_{ddrdr} \sin\theta + R_{eeddh} \cos\phi \tag{4}$$

where is the radius of the storage ring, is the latitude of the storage ring, is the rotational angular velocity of the Earth, is the distance between the storage ring and the moon or sun, is the radius of the Earth, and and are the integrals of the angle variables of the storage ring.

Thus equation (2) can be expressed as

$$\mathcal{E}_g = \int_C (\vec{V}_{ddr} \times \vec{g}) \cdot \vec{S}_{ddr}\, dr \tag{5}$$

where the charged particle ring is bounded by an open surface with unit normal . is the velocity of the surface in the direction perpendicular to the gradient . This means that the EGI would be proportional to the gradient , surface , and velocity of the surface in the direction perpendicular to the gradient .

Discussion

As a preliminary estimation, we disregarded the influence of any factors other than gravity on the beam position and used the maximum daily change in COD amplitude in our calculations. We did not know what kind of feedback systems were operating in the storage ring when the BPM data were measured or what the primary influence on the beam orbit was. Table 1 shows the relative expected path perimeter and the corresponding change in energy for several major storage rings [**?**].

Table 1. Parameters for different storage rings

Parameter	LEP[**?**]	SPring8[**?**]	APS[**?**]
NL			
L0 (m)			
E0 (GeV)			
ΔLmax (maximum)	0.1 mm		

NL: Northern latitude; L0: Expected path perimeter; E0: Beam energy in GeV; ΔLmax: maximum COD change per day; : calculation of the EGI coefficient

The EGI coefficient is found to be less than 3.78 stat · kg · s. There remains a question of whether this value actually exists or is zero; we may be able to obtain a more accurate measurement from a setup with no feedback systems in place—that is, with no beam energy compensation systems, beam orbit correction systems, and so on.

Furthermore, the EGI coefficient can also be formulated using existing constants:

$$\xi = \frac{G\epsilon_0}{c^2} \leq 9.77 \times 10^{-??} \tag{6}$$

where is the gravitational constant, is the dielectric constant, and is the speed of light in a vacuum. From equation (6), we see that the resulting value of would be less than that obtained above if the EGI does in fact exist.

Conclusions

In this paper, we have postulated the existence of electro-gravitational induction (EGI) in a particle storage ring. The expected changes in particle paths obtained from our model coincide with the results of the terrestrial tidal force model. By neglecting the effects of tidal forces and the synchronization and feedback systems of the storage ring, and making use of existing COD signals from the LEP, SPring-8, and APS facilities [?], we found that the induction coefficient should be less than 3.78 stat · kg · s. The electro-gravitational induction described above is weak. The charged particles move through the large accelerator storage ring at approximately the speed of light in successive turns, which produces an energy change. The movement of charged particles can accumulate the effects of electromagnetic induction such that they become observable. We have presented this idea of electro-gravitational induction, which is an interesting and valuable quantity to investigate in detail; however, we could not conclusively determine the existence of a gravity-induced electric field.

We imagine two rings at the same location—one a positive particle ring and the other a negative particle ring—with both types of particles moving in the same direction. Under EGI prediction, we should observe the energy of one particle type increasing while the other decreases simultaneously; the corresponding particle paths will then change in opposite directions. "Same location" means the terrestrial tidal force makes identical changes to both the positive and negative particle rings. This differs from the terrestrial tidal force model. Therefore, we can measure the closed orbit distortion of the positive particle beam and for the negative particle beam. The BEPC (Beijing Electron and Positron Collider) has two rings—one electron ring and one positron ring. If we modify the machine so that the electron and positron beams move in the same direction in the two rings, then we can check the EGI model by measuring in the future.

Furthermore, EGI may also explain how clouds become charged with different charges. For example, based on , the signals will be independent of the terrestrial tidal force.

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Note: Figure translations are in progress. See original paper for figures.