SIMULATION CODE OF BEAM INSTABILITY WITH OBJECT ORIENTED TECHNOLOGY *

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Abstract

This paper describes the design and implementation of an object-oriented simulation environment called SCBI for the Coupling Bunch Instability. The design applies object-oriented technology. By this technology, we can describe an accelerator into several classes, with its Properties and Methods. We use Ring, Beam, and Cavity classes to define the components of an accelerator. All the interactions among them are functions of the accelerator. This makes the codes easier to be read and also makes programmer easier to add module into the program or remove module from the program. We add a beam feedback system into the simulation. With this technology, we can build a user-friendly interface. Some simple examples was simulated and got reliable results.

1 INTRODUCTION

Beam instability is becoming an important problem in the design of new generation accelerator. The complexity of different beam instruments makes it difficult to analysis beam instability directly. People write different simulation codes to analyse the beam-instrument interaction. Old codes are usually written with process-oriented technology. By process-oriented technology, it is difficult to write user-friendly interface, and it's also difficult to add or remove a beam instruments. And codes written by that technology are very hard to be read, understood, and maintained or repaired.

Object-Oriented technology is greatly developed during the last two decades. Programmer can write large program with friendly user-interface by this technology easily. The idea of this technology is similar to people's thinking, so the program is much easier to be read.

We adopt object-oriented technology in the simulation of beam instability.

2 CLASSES DESCRIPTION OF ACCELERATOR

To simulate the beam instability, we should describe the accelerator into classes. Generally, an accelerator

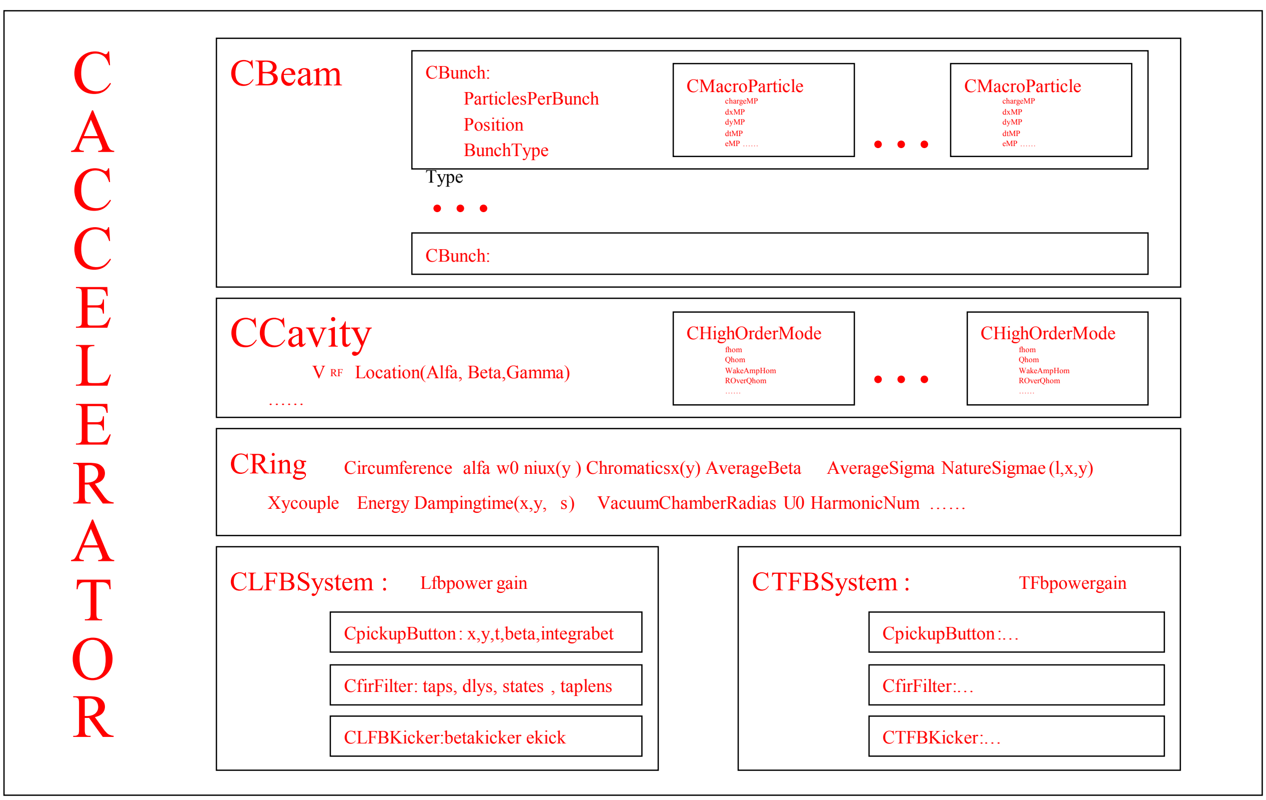

Figure 1 Classes description of an accelerator

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contains a Ring, a set of RF Cavity and Beam. Our accelerator is an object of the class CAccelerator, as show in Figure 1. The class have three basic members: a Ring, a Cavity and Beam. We also add a beam feedback system to the system. We describe the classes in detail now.

2.1 Ring

A ring is the basic component of a circular accelerator. Physically, it is made up of a tunnel, several magnets, vacuum chambers etc. When the tunnel and magnets are fixed, the beta function of whole ring is determined. And then, the natural beam size in three dimensions is determined. Vacuum chambers and several bellows are the source of most short range wakefield.

CRing is a class to define parameters of the ring. It has the following properties: circumference of the ring; designed energy of synchronous particle; synchrotron radiation per turn; momentum compaction factor; chromaticity; natural beam height, width and length; damping time of x, y, s directions; operating point (integral and fractional part);average beta function; average resistivity around the ring; vacuum chamber size; x-y coupling; etc.

2.2 Cavity and its High Order Mode

RF cavity is one of the most important components around the ring. RF voltage is used to supply beam energy. It can also cause synchrotron oscillation. High order modes of RF cavity can cause several kinds of instabilities. It is the main source of the long range wakefield.

CCavity is a class to define parameters of the cavity. CCavity has the following properties: RF frequency; twiss parameters at the RF cavity's position; dispersion function at RF cavity's position; synchrotron phase. CCavity can also Include several high order modes; each high order mode is specified by an object of CHighOrderMode.

CHighOrderMode use the following properties to define a high order mode of a cavity: frequency, Q factor, and R over Q; amplitude of wake-field stored inside the cavity;

2.3 Beam

Beam is the electron stored in the ring. Here assume the beam is bunched before injected into the ring. And the electrons are ultra-relativistic. The bunches are injected into ring at right buckets. At the first order approximation, the bunch can be assumed rigid. Only the center of mass of the bunch is explored. In order to research the bunch motion more exactly, macro-particle model should be applied. A macro-particle is an imaginary model to describe part of a bunch. The number of macro-particles to be used is determined by computer availability.

CBeam is a class to define parameters of beam. It has several bunches. CBunch is a class to define parameters of bunches. It has following properties: charge of the bunch, position of the bunch (specified in buckets); bunch type (rigid or no); position of the bunch's center of mass (relative to synchrotron particle); and several macro-particles. CMacroParticle is a class define parameters of macro-particle. Its properties defined the position and charges of the macro-particle.

2.4 Beam Feedback system

Beam feedback system is used to provide an extra damping to the beam motion. The feedback system include signal pickup, signal process and feedback kicker. Button type pickup is normally used to get beam position errors signal. The error signal is transferred to the signal process array. Typically, longitudinal feedback system use DSP arrays to process the signals. Transverse feedback system use some delay line to process the signals. Anyway, we can consider the signal processing system as a digital filter. The processed signal is sent to the kicker. Beam feedback kicker is a broadband component, which can act on each bunch separately. So the beam feedback system is also called "bunch by bunch" feedback system.

Beam feedback system can be described into several classes: CPickupButton, CFirFilter, CLFBkicker, CTFBkicker.

2.5 Interactions among members of CAccelerator

There are several interactions among members of the accelerator, including acceleration; radiation; radiation damping; quantum excitation; interaction with high order mode of cavity; and interaction with resistive wall. We can also make beam feedback kicker kick the beam. An accelerator contains all the components and methods listed above. The interactions among members of accelerator are defined as methods of CAccelerator.

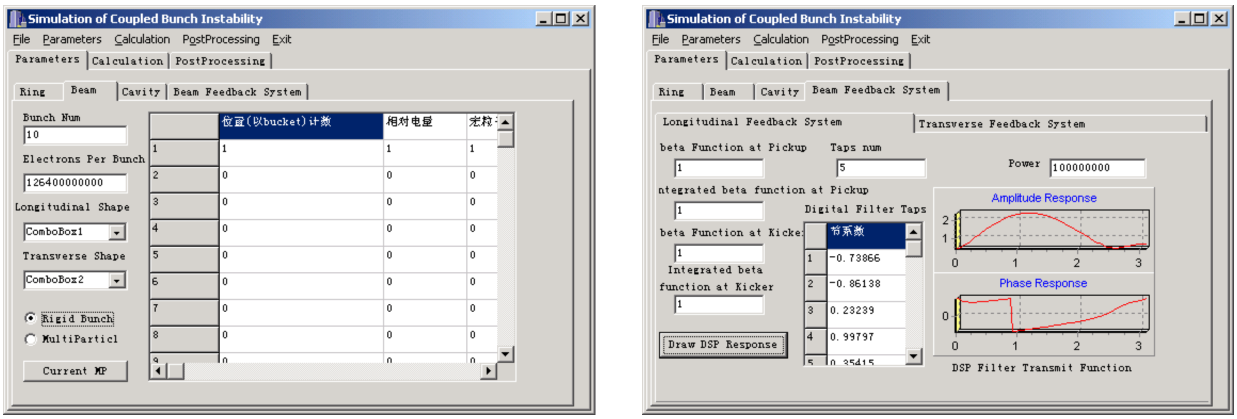
When another type of interaction is considered, a new method can be add to the class.

3 IMPLEMENTATION AND USER INTERFACE

The classes description are implemented by c++ language into a program called SCBI. A graphical user interface is also written as shown in Figure 2. All Properties of objects can be inputted by the user interface.

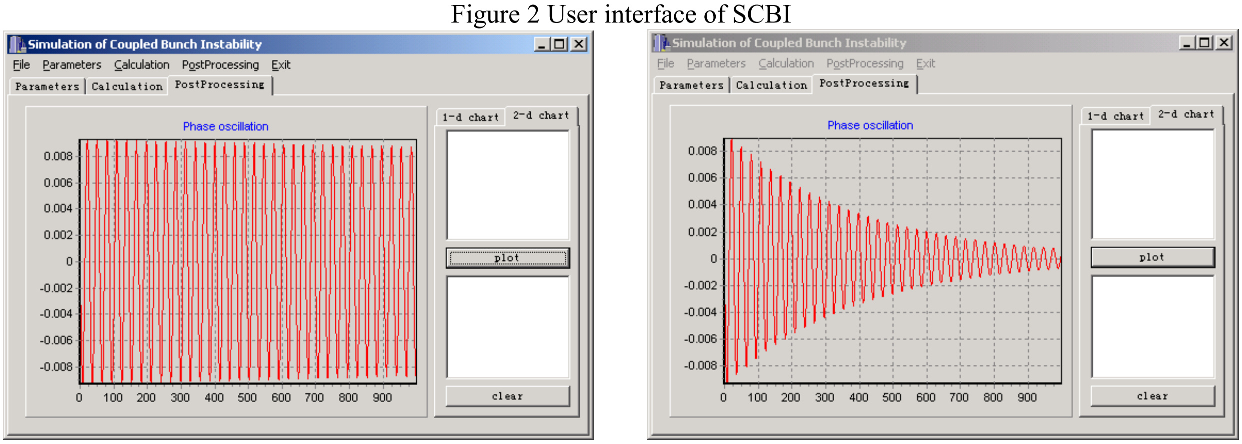
From the calculation page, several options of calculation can also be selected by this interface. The input of a specified accelerator can be saved and modified. The calculation can also be saved and restarted continuously.

The digital filters of beam feedback system can be inputted by this interface. The amplitude and phase response of the transfer function can be calculated and plotted. The taps of the filter can be change dynamically.



a. Beam parameters page b. feedback parameters page

Figure 2 User interface of SCBI



a. without feedback b. with feedback

Figure 3 calculation result of phase oscillation

The calculated results of the program without beam feedback system are checked corresponded with the program written by Wuyong. The results of the program with and without beam feedback system are shown in Figure. 3. If the kicker can kick the beam correctly, a great damping can be added to the system. This can help the system become stable.40

4 RESULT

- Object-Oriented technology is a powerful technology in programming. It can be adopted to simulate the beam instability problem.
- We describe the accelerator and its subsystems into several classes by normal understanding. A new simulation code SCBI is written and compared with some other old codes. It is proved that such a description can describe the accelerator correctly.
- The program structure makes it easier to add or remove new beam instruments, such as beam feedback system.
- Further improvement of such an Object-Oriented Simulation Code SCBI will be done.

5 REFERENCES

[1] M.Bassetti A.Ghigo M.Migliorati L.Palumbo M.Serio, “A Time Domain Simulation Code of the Longitudinal Multibunch Instabilities,” G-19, Frascati, June 3 1993.

[2] A.Chao, “Physics of Collective Beam Instabilities in High Energy Accelerators,” Texas, 1993

[3] Wang Lanfa, “BEPC Multibunch Collision and Coupled Bunch Instabilities,” Beijing, April 1997

[4] Wu Yong “Computer simulation study of collective beam instabilities in electron storage rings” Beijing, 2000