FEED-FORWARD AUTOMATIC CONTROL SYSTEM

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Abstract

A feed-forward automatic control system based on a novel control principle is developed, in order to compensate the amplitude and phase fluctuations of the microwave field in the thermionic RF gun cavity. The fluctuations, which are mainly caused by beam-loading effect, can be effectively restrained through this method. It is experimentally demonstrated that the novel control system has the excellent characteristics of stability and reliability.

1 Introduction

Beijing free electron laser facility (BFEL) is operable at infrared wave band. It adopts thermionic RF gun and linac to produce high energy electron beam (~30MeV), in order to yield 5~20μm, 3mJ laser, during about 4μs micro-pulse, through a wiggler and optical cavity system. For long macro-pulse operation, the back-bombardment of the electrons on the gun cathode increases beam current, declines the field amplitude and disturbs the RF phase in the cavity, which degrades the performance of output electron beam, especially energy spread. As we know, the performance of free electron laser strongly depends on the quality of electron beam, hence improvement on the quality of electron beam becomes very important. Though, generally, back-bombardment effect in this kind of gun is inevitable, many methods have been presented for optimizing the RF gun, including feed-forward control method.

Feed-forward control method is based on good reproducibility of system output. It adjusts RF amplitude and phase in a latter macro-pulse to expected value, according to the information from former one. In 1990s, the feed-forward control system was first developed in Brookheven national laboratory, on ATF line accelerator, and then many labs have studied this method on their own facility. Most of these works[1][2] are based on the control principle of "transfer matrix", which is used to describe the relation between input and output signal. Though the transfer matrix method avoids the difficulty of finding out the analytic expressions, it is hard to get the exact matrix because of the error from hardware and computation. On the other hand, the software designing becomes very complicated by using matrix calculation, which leads to unreliability and instability during operation. Therefore, those control systems cannot be applied widely and effectively, just being thought as experimental device.

This paper presents a novel principle for the feed-forward control. An effective control system including hardware and software has been developed and validated through large numbers of experiments.

2 Fundamental Principle

The control principle presented here is summed up as tracking every sample point and approaching the expected value step by step. This theory will be described in detail through Fig.1, the schematic diagram of the thermionic RF gun with feed-forward control system.

The control system includes four parts, data collector, data processing, signal generator and executing component[3]. A digital oscilloscope is used to receive amplitude and phase signal through detector and DBM separately, and the signal is divided into a set of sample points by a certain interval (e.g.10ns). Next, the data of every point will be transferred to a computer for processing. During processing, these sample data are averaged firstly, and the average is considered as expected value; secondly, every sample data will contrast the expected value to find the difference; finally, the control data is to be built according to the difference, and

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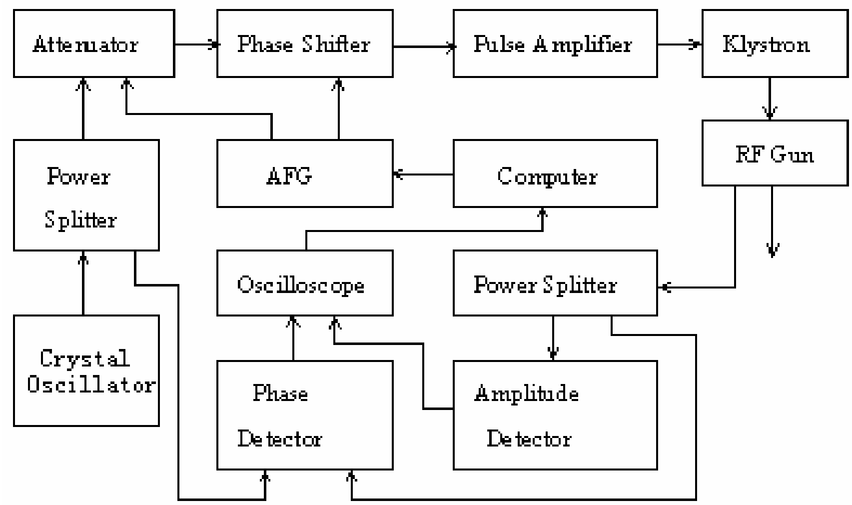


Fig. 1 Schematic diagram of the thermioic RF gun at BFEL with feed-forward control system

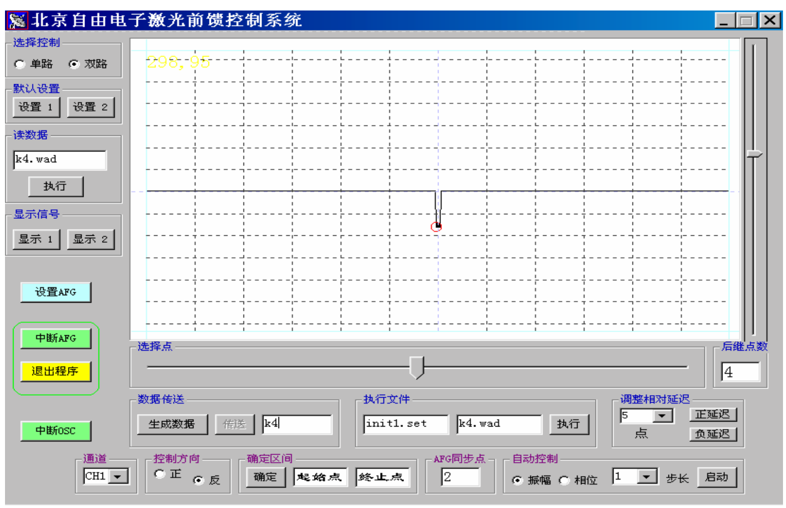


Fig.2 Operating interface for feed-forward control system

then is transferred to AFG to generate the analog signals. As a result, the analog signal will modulate the input microwave before it goes into RF gun cavity, through executing components, attenuator and phase-shifter.

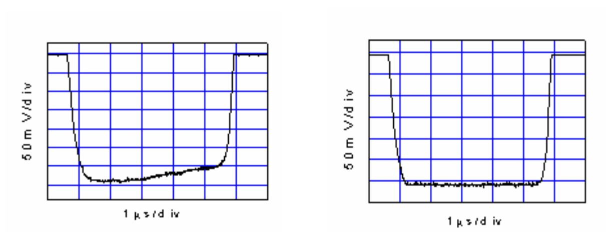
Repeat the above operation until the RF amplitude and phase in the RF gun cavity is uniform enough during a macro-pulse. Certainly, the whole process is operated automatically under the control of computer. The control software,Fig.2, is based on the Windows operating system, and developed by Visual Basic computer language.

3 Experimental Results

The control system has been mounted on the thermionic RF gun of BFEL facility and experiments about the control system have been demonstrated. Fig. 2 shows the amplitude of RF field in the gun cavity before and after control. The amplitude declines nearly 50 mv over a period of 4.5 μ s before control, due to beam-loading effect. Contrast to Fig.2 a, the graph in Fig.2 b illustrates a very flat top. That is to say, fluctuations in the amplitude (peak-peak) reduced from15% to 1% after control. Fig.3 demonstrates the phase of the RF field. While before control, the top of phase signal is obviously inclined with several peaks. And fluctuations are reduced from 6 degree to 0.6 degree after control, during a micro-pulse of 4.5 μ s, too. However, the most advantages of this control system contrasting to the old one[4][5] are the excellent stability and reliability during the operation, and these characteristics are proved through large numbers of experiments. That means, the control system including software and hardware not only is an experimental device, but also can be applied concretely to an accelerator system.

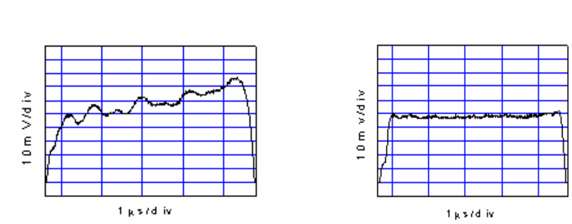
4 Conclusion

A novel principle was presented to realize feed-forward control system to compensate the beam-loading effect in the thermionic microwave gun. The system developed with the principle well does work and demonstrates excellent stability and reliability. Large numbers of experiments show that the control system can apply extensively to the relevant accelerator field.



(a) Before control (b) After control

Fig. 3 Amplitude of the RF field in the gun cavity



(a) Before control (b) After control

Fig. 4 Phase of the RF field in the gun cavity

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Reference

[1] ZHANG Renshan, BEN-ZVI Ilan, Xie Jialin. Nucl Instr Meth, 1993, A324:421-428

[2] Li FengTian, Xie JiaLin, Wang YanShan, HEP&NP (in Chinese), 1998,22(10):932-936

[3] Li FengTian, Xie JiaLin. Nucl Instr Meth, 1998, A 407:332-337

[4] Wang YanShan, Xie JiaLin, Chang XiangYun. HEP&NP (in Chinese),2000,24(7):681-684

[5] Xie JiaLin, Li FengTian, Wang YanShan, Nuclear Techniques (in Chinese), 1999, 22(4):193-199