OPTICAL TRANSITION RADIATION MEASUREMENTS ON THE BEIJING FREE-ELECTRON LASER*

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Abstract

The measurement system have been developed for use with the Beijing free-electron laser (BFEL), based on the techniques of optical transition radiation (OTR). The 32-channel OTR detector forms part of a high-resolution (0.02%) electron spectrometer. Design parts of the spectrometer are presented, and the experiment result in the BFEL is summarized.

1. INTRODUCTION

From 1980's to 1990's tens of countries developed the theory and experiments of free-electron laser (FELs) [1]. At the same time a lot of electron spectrum diagnostic techniques are represented, such as Cherenkov Radiation (CR), Second Emission (SEM), Spontaneous Emission Radiation (SER), Optical Transition Radiation (OTR) and so on. However the development of FELs operating in the infrared region has begun to realize the potential of optical transition radiation (OTR) as one of the electron spectrum diagnostic techniques because of the excellence of OTR [2] . They are summarized as the following:

Quick response, high space resolution

Not obvious saturation, to be the same with high current

To observed from the direction vertical to the beam, more convenient in compared with CR

Light influence to the beam

2.THEORETICAL BACKGROUND [3][4]

Transition radiation occurs when a charged particle crosses the boundary between two media with different dielectric constants. Because of the strong dependence of optical distribution of transition radiation on the parameters of the beam, the Optical Transition Radiation (OTR) is one of the best means in charge particle beam diagnostics. At the same time, the dependence of transition radiation on the transmitting characteristic of charge particle beam should be noticed, for instance, the angle between the optical transition radiation and the particle beam is reverse ratio of the energy of particle.

According to the characteristics of transition radiation, if the electron beam incidence to the boundary at $45°$ the backward transition radiation appears at $90°$ to the electron beam direction. So, using the optical acceptance devices and optical sample devices at the perpendicular direction to the beam, the transition radiation distribution will be analyzed. Further, we can get some useful information about the beam.

3. SYSTEM CONFIGURATION [5]

A set of integrated real time spectrum analysis system based on OTR must have a series of control and result display system, besides optical sampler. In this system, there are five parts: magnet, OTR equipment, photoelectricity conversion equipment and amplifier, data sampler and data analysis, synchronization equipment. The sketch map of system is shown in Fig. 1.

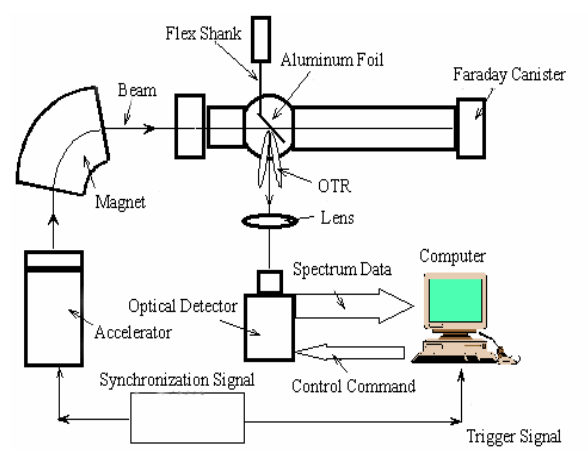

Fig. 1 Sketch of the system

1) Magnet and OTR equipment

The electron beam, which is spread by the magnet, go through an aluminum foil whose axes is at $45°$ to electron beam. In experimental the heat effect by cumber

* Work supported by the Chinese National Foundation of Natural Sciences, contracts 19875029.

of foil to the electron beam can't be ignored. The heat effect is given by

$$\Delta T = \frac{\Delta U}{V \cdot \rho \cdot C}$$

Here ΔU is the wasted power of electron when it go through the medium. V is the effect volume of the medium. ρ is the density of the medium. C is the specific heat of the medium.

2) Photoelectricity conversion equipment and amplifier

This part is composed of the lens, photodiode array, amplifier circuit and multiple route switch. The elements framework is shown in Fig 2.

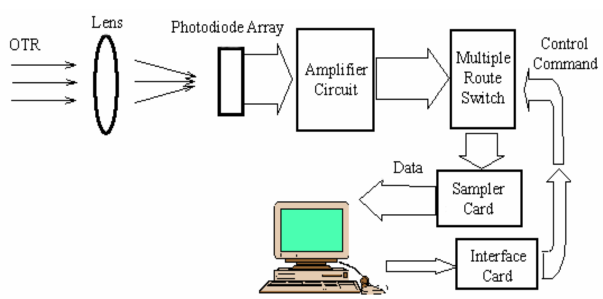

Fig. 2 Magnifying system and data-sampling system

OTR can be recorded by the sensitization part of photodiode. The energy resolution of the detector is given by

$$R = \frac{\delta}{32}$$

Here δ is energy distribution. On the BFEL δ is 0.7%, the energy resolution is about 0.02% if only the magnet resolution is high enough.

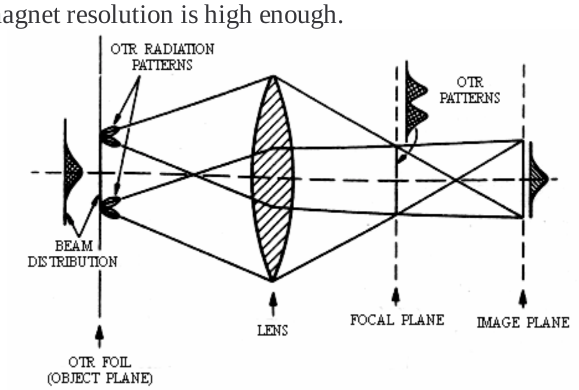

Fig. 3 A schematic representation of the focus-at-the-object (beam spot) and focus-at-infinity (angular distribution) techniques[6]

Fig. 3 schematically shows how both the spatial intensity (beam spot profile) and the OTR angular-distribution pattern can be recorded by focusing at the image plane and the focal plane (infinity), respectively. On the BFEL，if we place the detector at the focal plane to record the angular-distribution pattern, the structure with two apexes will be recorded.

3) Data sampler and data analysis

Analog signal amplified is sampled and digitalized, using A/D board (AC1030). Sample card used in this system has two input ports. That is said, there are only two channels sampled during one macro-pulse. In order to get all signals of 32 channels it must last 16 pulses period. The noise signal will be filtrated from the data of A/D board, by using the software for the measurement system.

4) Synchronization control

The whole system starts up with the sending of the synchronization signal. At first, the synchronization signal is sent to the accelerator and sampling system, respectively. Then, electron beam is accelerated, and incidence to the aluminum foil at $45°$. OTR generated is focused on the optical detector through the lens group. In the optical detector, the optical signal is conversed into the electronic signal. At the same time, the sampling system, initialized by the synchronization signal, is ready to receive the signal. Because the synchronization signal can adjust all parts to the same work pace, we can get the integrated electron energy information after 16 pulse-periods.

4. RESULT

The electron spectrometer was installed in the Beijing Free Electron Laser Laboratory (BFELL) in 1997, and the synchronization equipment was installed in 1999. The OTR on BFEL is shown in Fig. 4. But the energy resolution of the magnet is 2.8%, the energy distribution of the electron beam is 0.7%, so we can't observe the stripe in the term of the energy. It is hard to detector the fine energy spectrum of beam.

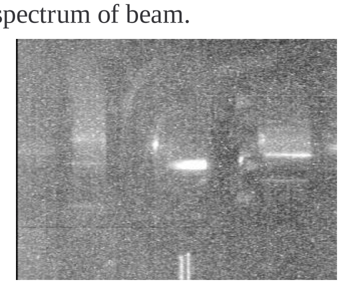

Fig. 4 Optical transition radiation on BFEL

Further, we place the detector at the focal plane, the recorded part of OTR angular-distribution pattern is shown in Fig. 5. Obviously, we can find two apexes in the

Fig. 5. But due to the energy distribution of the electron beam, two apexes are extended. We can’t find two clear ones.

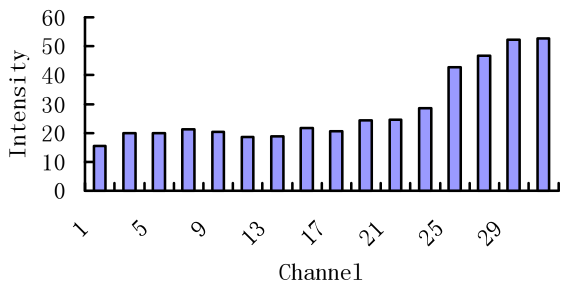

Fig. 5 The OTR angular-distribution pattern recorded by the measurement system

5. SUMMARY AND CONCLUSION

Measurements system can record the angular-distribution pattern of OTR when the detector is installed at the focal plane. If the magnet’s energy resolution is high enough to distinguish the energy distribution of the electron beam (0.7%), the energy spectrum will be recorded.

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