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Test of fine pixel CCDs for ILC vertex detector

Y. Sugimoto[a,*], C. Calancha[a], A. Miyamoto[a],
H. Ikeda[b], H. Sato[c], A. Dubey[d], A. Ishikawa[d], S. Ito[d],
E. Kato[d], T. Mori[d]

[a] *High Energy Accelerator Research Organization (KEK), Tsukaba, Japan*
[b] *JAXA, Sagamihara, Japan*
[c] *Shinshu University, Matsumoto, Japan*
[d] *Tohoku University, Sendai, Japan*

Abstract

We propose a beam test of fine pixel CCD sensors for ILC vertex detector using π^- beam of K1.1BR beam line. With this test beam experiment, we would like to demonstrate excellent performance of the sensors as a charged particle tracking device, particularly the high spatial resolution of 1 μm order..

1 Introduction

In order to obtain rich results of particle physics at the International Linear Collider (ILC), quark flavor tagging by detecting decay vertices of meta stable particles such as B mesons and D mesons has essential importance. For this purpose, very high performance vertex detectors are required for the detectors at ILC [1, 2]. The goal of the impact parameter resolution of the vertex detectors for charged particles is $\sigma_b < 5 \oplus 10/(p\beta \sin\theta^{3/2})$ μm. In order to achieve this goal, the vertex detectors for ILC consist of several layers of silicon pixel sensors with very high spatial resolution and very low material budget. There are many candidate sensor options. Fine pixel CCD (FPCCD) [3, 4, 5] is one of the candidate sensor technologies.

*Contact person, yasuhiro.sugimoto@kek.jp

An FPCCD sensor for the ILC vertex detector has the pixel size of 5 μm and the epitaxial layer thickness of 15 μm. The epitaxial layer is fully depleted to minimize the charge spread and suppress the number of hit pixels. Because CCDs have a relatively simple structure, large wafer size is easily obtained. Because of the small size of the pixels, excellent spatial resolution can be achieved. A simulation study tells that by using analog data and taking the center of gravity of the deposit charge, spatial resolution as high as 1 μm is expected. Excellent two-track separation capability is also expected thanks to the small charge spread and the small pixel size. For the tracks injected with shallow angles, several successive pixels are hit. Using this cluster information, we can get rough angle measurement of the incident particles with single layer of the FPCCD.

In this test beam experiment, we would like to demonstrate the features of FPCCD sensors described above.

2 Prototype FPCCDs

We will test two kinds of prototype FPCCD sensors made by Hamamatsu Photonics. Both types have the sensitive area of about 6×6 mm^2, the epitaxial layer thickness of 15 μm, and the wafer thickness of 50 μm. The wafer is housed in a ceramic package which has a hole for the sensitive area to minimize the multiple scattering. Each FPCCD chip has 4 sections and 4 output channels. One type of the FPCCD has 4 different pixel sizes of 12, 9.6, 8, and 6 μm for 4 channels, while the other type of FPCCD has all 6 μm pixels for 4 channels. Figure 1 shows a bare FPCCD sensor chip (left) and a packaged chip (right) which will be used for the beam test.

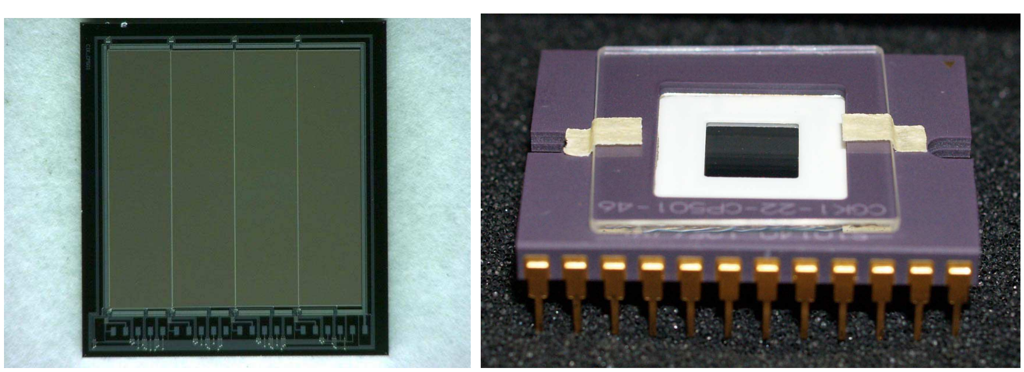

Figure 1: Photograph of a bare FPCCD chip (left) and a packaged chip to be used for the beam test. The glass cover on the package will be removed when used for the beam test.

3 Test beam experiment

3.1 Goal of the experiment

The purpose of this test beam experiment is to demonstrate the advantages of the FPCCD sensors as a tracking device mentioned in Section 1, *i.e.*;

- Spatial resolution
- Two-track separation capability
- Angular resolution using the cluster shape of single layer

The two-track separation capability is studied by looking at the charge spread over adjacent pixels. We will take data with several incident angles, as well as normal incident angle, in order to study the incident angle dependence of the performance.

3.2 Experimental set up

The setup of the experiment is schematically shown in Figure 2. We use 4 layers of FPCCD sensors. For CCD1, CCD3, and CCD4, we use prototype sensors with all 6 μm pixel channels. For CCD2, both types of the CCD sensors are tested. The central 2 sensors (CCD2 and CCD3) are placed with small distance in order to minimize the effect of the multiple scattering. We will take data with different distances of the two sensors ranging from 3.2 mm to 23.2 mm in order to confirm the contribution of the multiple scattering to the measured spatial resolution. When the distance id 3.2 mm, the effect of the multiple scattering by CCD2 is expected to be 0.7 μm (r.m.s.) on the surface of CCD3.

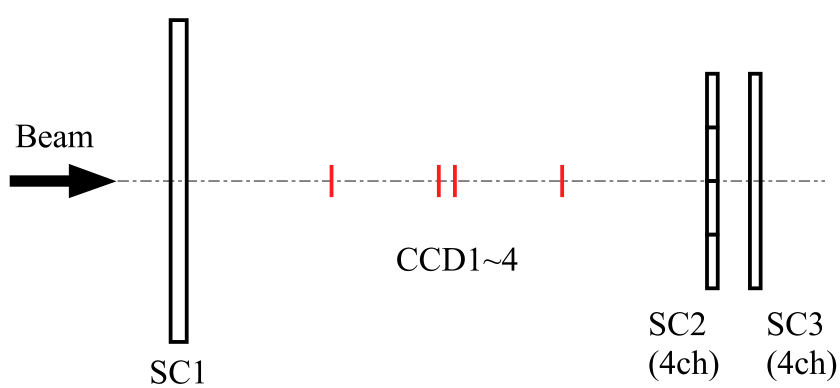

Figure 2: Setup of the test beam experiment.

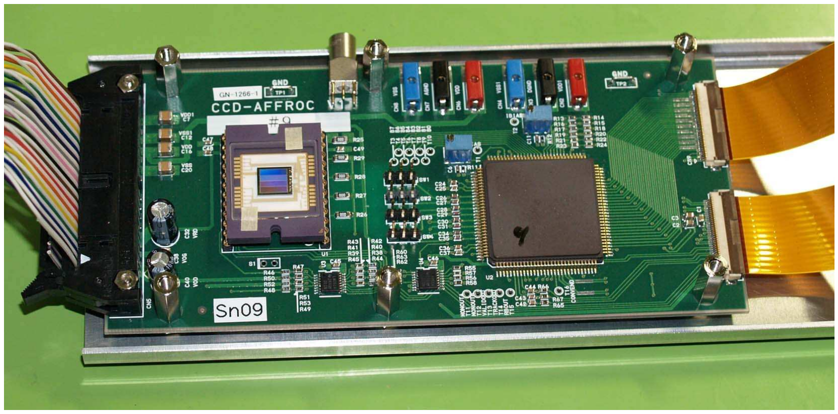

Figure 3: CCD/AFFROC board (CAB).

The signal of the FPCCD sensor is sent to a readout ASIC named AFFROC which has functions of amplifiers, low-pass filters, correlated double samplers, and analog-to-digital converters. The FPCCD sensor and the AFFROC chip for each layer are mounted on a PC board as shown in Figure 3. Four layers of these CCD/AFFROC boards (CAB) are put inside of a shield box. Cool air is flowed inside the box for cooling. The digital data from the CAB is sent to an interface board (a SEABAS2 board [6] with a daughter board) which is placed close to the shield box, and then sent to a DAQ PC through a GbE LAN cable. Clock drivers for the FPCCDs are also included in the interface board.

Scintillation counters are placed upstream and downstream of the FPCCD sensors. These scintillation counters are used for monitoring profile and intensity of the beam. The downstream counter consists of two planes (x and y) of scintillator hodoscope. Each plane of the hodoscope covers 4×4 cm^2 area with 4 scintillator strips of 1-cm wide and 4-cm long read out by multi pixel photon counters (MPPCs).

We don't use triggers for data acquisition. The FPCCD sensors accumulate signals during one beam spill, and read out between the beam spills. The DAQ system is synchronized with the machine cycle of 6 seconds.

3.3 Request for the beam

We would like to use π^- beam at the highest momentum of the beam line. The contamination by electrons is acceptable, but the fraction should be known. The intensity should be about 200/cm^2/spill. To achieve this relatively low intensity, we would like to defocus the beam by tuning the current of quadrupole focusing magnets.

We will take data with several configurations of the FPCCD sensors. We will change the distance between the central two CCD planes, the angle of the CCDs with respect to the beam, and the operation temperature. It will take about 6 hours for one configuration including changing the configuration, cooling down, data taking, and warming up. We will try about 15 configurations. Therefore, we request 5 days of machine time including the setting up of the apparatus and tuning for the detectors and the beam line. We would like to request this machine time in the period between June 15 and June 26.

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