Review Report of
the SPring-8 XFEL Detector Advisory Committee

Apr. 18, 2011

The 1st committee meeting @ SPring-8

Date: Feb. 16-18, 2011

Committee Members:

Dr. Peter Denes, LBNL, U.S. (Chair of the committee, absent)

Prof. Yasuo Arai, KEK, Japan. (Acting chair of the committee)

Prof. Andrew Holland, The Open University, UK.

Dr. Grzegorz Deptuch, Fermilab, US. (Guest committee member)

1. Introduction

The XFEL project being constructed at SPring-8 is aiming new kind of X-ray beams which has 100% coherency, ultra short pulse width (~10 fs), and 10^9 times brilliance compared with existing light sources. The development of the X-ray 2D detectors for XFEL is of crucial importance because its performance will limit the field of exploration. The first user beam time is scheduled in March 2012 and the XFEL experiments are under strong competitive situation with Europe and USA.

We, committee member, are asked to provide constructive advices and comment on the strategic direction of the activity of the DAQ team (lead by Dr. Hatsui) rather than a critical review. The data acquisition (DAQ) team in the XFEL project head office was placed in April 2009. The team is responsible for the development of detector, data transfer, data storage, and large-scale data analysis. We heard the detector development group at synchrotron facilities have been dismissed, and the DAQ team does not have enough experience for the new detector development. Thus the committee is also requested to advice to bring up such activities.

We started with visiting XFEL accelerator hall and experiment rooms (the accelerator was planned to have first beam at the next week). All committee members are very much impressed with clean and well-prepared equipments. Then we have a whole day meeting at next day, and we could have ~10 nice presentations from the team member.

• Detector Requirements

Following short term requirements are presented for the X-ray detectors,

1) Match the repetition rate of XFEL pulse (60 Hz for SPring-8 XFEL)

2) Single photon detection capability.

3) Better quantum efficiency for 6-12 keV in short term. Wider range in longer term.
4) Higher peak signal. Higher delivers wider applications, and more opportunities to explore.
5) Resistant to estimated 30 Mrad annual dose.

and mid-long term requirements

1) Optical shielding
2) Higher photon energy (may be up to 20-30 keV)
3) Lower photon energy (may be down to 200 eV)
4) Higher frame rate to record background up to 180 Hz
5) Higher frame rate to meet accelerator upgrade toward higher repetition rate, probably 120~300 Hz, and possibly 1000 Hz in future. Then will start soft x-ray regime.

• Strategy of detector preparation

Above requirements demand development of new semiconductor sensor. To prepare these detectors in-time and reduce the development risk, the DAQ team took following strategy.

I) Use proven technology for in-time preparation (CCD sensor)

Use established technology of X-ray CCD with minimum modifications. To increase readout speed, Multi-port CCD (MP-CCD) is being developed collaborate with e2v company. The project is divided into 4 phases depend on the requirements.

II) Pursuing new technology for higher performance detector (SOI sensor).

Develop new detector by using Silicon-On-Insulator (SOI) sensor technology, which implements both sensor and electronics in a same die. This technology is being developed mainly in Japanese consortium (KEK, Riken and universities) and OKI semiconductor Co., Ltd. A new idea of Multi-via (MVIA) Detector is developed by the Riken group. The circuit design and chip layout has been done by A-R-Tec Co.

2. General Findings & Recommendations

The committee is impressed by the great achievements made by the DAQ team which is lead by Dr. Hatsui. The team should be congratulated on pulling together the detector and DAQ system which is on-schedule to take first light measurements within the next couple of months.

The committee understands the strategy they took for the detector preparation. This strategy

enables both in-time detector preparation and creates new activity for developing high performance detector. The committee acknowledges strong collaboration with e2v for the development of the MP-CCD. This collaboration should be continued even after starting XFEL experiments.

On the other hand, the MVIA detector is original idea of the Riken team by using SOI technology. They already demonstrated proof of principle of the detector. Although there remain several issues to be resolved, the committee admits the importance of their own detector R&D to strengthen the DAQ team.

MPCCD specific issues

• The MP-CCD detectors look as though they will achieve most of the objectives set and should perform as an excellent service detection system for the Spring-8 XFEL.

• Mounting system of the MP-CCD detector looks very excellent. Although the cooling power of the system look marginal to fully suppress the dark current after irradiation, it can be used for coming user operation.

• High-resistivity silicon sensor proposed from e2v as MP-CCD phase 3 is very attractive and this will increase energy range of X-ray detection. Since this requires additional R&D and cost is relatively high, careful monitoring of R&D progress should be done during development.

• To shrink readout board, use of more ASICs are required. However, the development of an ASIC takes long time and has some risk. The committee recommend, to search commercial ASICs at first, next ASICs provided by other research organizations, and finally to collaborate with a potential analogue/digital ASIC developer if necessary.

• It was felt that the MP-CCD approach, which should be working within months, should not be overlooked or it's developments prematurely stopped; particularly as it was stated that the MP-CCD may be able to achieve the higher speeds of ~120 Hz required in the near-term future. (A.H.)

• It is possible that the MP-CCD could be exploited for larger mosaic arrays if design effort were expended into exploring production of a suitable mosaic array using the technology. It was suggested that this could be explored through a feasibility study, particularly to address whether a more compact electronics design could be produced to allow a better mosaic array without the need to initiate the development of custom ASICs. (A.H.)

• Results of TCAD simulation for MP-CCD response under the high injection were shown. Although internal potential change is observed, electrons are collected within 10 ns and there is no degradation in spatial resolution. Since the simulation does not yet include spillover of the charge and IR-drop, this work should be continued.

MVIA specific issues

• The MVIA concept was developed by the team, and its large dynamic range and thick sensing region is very attractive. In addition, integration of the electronics on the sensor is very appealing as a future detector.

• Results of FZ wafer look very promising, and this should be pursued further.

• There remains unknown phenomena in the prototype MVIA sensors. The committee feels one more test chip is necessary before going to large area sensor of 65 mm x 27.5 mm.

• It was observed large IR drop in the prototype sensor. This may be compensated by using additional metal layer (5M) and layout optimization. Nevertheless, it is worth to optimize power consumption of the frontend amplifier.

• Noise increase at far-end pixel section was observed after X-ray irradiation. This might be related to the IR-drop problem, and should be investigated.

• Assurance of uniform response is a concern for the MVIA architecture. The committee feels more elaborated tests using existing chips are desired.

• Current work for larger detector size by using larger reticule and stitching technique is essential to realize actual detector. Although the MVIA sensor still need to be studied as mentioned above, this work should be continued.

• It was felt that the MVIA R&D is beneficial to strengthen developing power of the team member. Considering present team size, the development should be performed in close collaboration with other institutes. (Y.A.)

DAQ system specific issues

• DAQ system looks well planned and prepared. Although real performance test is not yet done, the committee encourages enhancing manpower for the development and test of the DAQ system to be ready for the beam test scheduled next spring.

• This is not the comment to the DAQ team, but one of the committee member (Y.A) feel Riken should have a good ASIC development group to support variety of activities in Riken. Even if we use outside ASIC design house, this kind of group is necessary to support the development.

General issues

• The committee agree the present strategy of using 2 technology; proven & new technology. However, it was felt that a clear plan should be developed for the group's objectives on the 5 and 10 year timescales, to help guide the strategic direction.

• It was felt that focusing solely on the short-term delivery of DAQ systems for the XFEL might be too short-sighted, and that a strategy encompassing the broader needs of the Spring-8 synchrotron research community would help provide greater stability and longevity to the activity.

• Since the number of detector to be made is very limited and each manufacturing machine, such as wire bonder, requires engineer to take care of that. Thus we feel it is wise to use outside company in most of the case.

• The work should be written up in publications more to both disseminate the work and build the international profile of the group.

• Number of present committee member looks small. Although it is not easy to invite foreign members to SPring-8 frequently, it may be worth to add one or two member. Especially, Grzegorz Deptuch, who kindly acted as guest committee member this time, is a good candidate for the committee member.

• More frequent meetings than once a year for the fist year or two is preferable, since the XFEL project is moving very first. The more frequent meetings will deliver timely advice. Of course, it is not easy to gather frequently; video conference should also be considered.