平成 22 年 3 月 16 日
独立行政法人理化学研究所
播磨研究所　研究推進部

# 新竹電子ビーム光学研究室　研究業績レビュー報告

新竹電子ビーム光学研究室（新竹 積 主任研究員）の研究業績レビューを下記のとおり実施いたしましたので報告いたします。

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【日時】平成 22 年 1 月 19 日
【場所】独立行政法人理化学研究所　播磨研究所
【レビュアー】Prof. Kwang-Je Kim (Advanced Photon Source, Argonne National Laboratory)
Prof. Marie Emmanuelle Couprie (Synchrotron SOLEIL)
Prof. Katsunobu Oide / 生出 勝宣（高エネルギー加速器研究機構）
Prof. Hiroyuki Hama / 濱 広幸（東北大学大学院 理学研究科）
Prof. Akira Noda / 野田 章（京都大学 化学研究所）

【評価結果の概要】

1. General comments

The Chief Scientist of the AEBPL, Dr. Shintake, is a first rate accelerator scientist with high level of technical skill with unique visions in broad areas, able to find original solutions for challenging problems in accelerator physics and technology. He has built up a research group consisting of highly talented members with diverse expertises covering all AEBPL activities. He has also worked closely with Japanese industry to realize his novel conception to actual accelerator construction. The culmination of this effort is the success of the SCSS Test Accelerator, which serves as the model for the SPring-8 XFEL currently under construction. This Committee congratulates Dr. Shintake and his staff for the remarkable success, and suggest that RIKEN ensure that the creative activity of this unique group be continued.

1.1 Research objectives (novelty, scientific significance, etc.)

Entering relatively late in the international scene of x-ray free electron laser R&D, the AEBPL set an ambitious goal of constructing an novel accelerator-XFEL system which is “compact” with a schedule not too far behind the LCLS at SLAC. It takes a great depth in basic and practical knowledge in accelerator science and technology as well as creative mind to succeed in such endeavor. The success in 2007 of the low energy test-system SCSS Test Accelerator demonstrates the soundness of the AEBPL approach and is the basis of the SPring-8 XFEL construction.

1.2 Research results (originality, scientific significance, social impact, etc.)

The AEBPL R&D accomplishments are many, including:

・2-D synchrotron radiation simulator: an easy-to-use program showing radiation emanating from an arbitrarily moving charge by 2-D graphics. The program is freely available from Shintake's website and is highly instructive.

・An injector starting with a thermionic cathode (CeB6 crystal), pulsed 500 kV DC voltage: This is a highly original approach in view of the fact that all high-brightness electron injectors are based on a photocathode. The performance is remarkable; it has shown an emittance as small as the best rf guns in the world with better stability in the beam, the cathode reaching a lifetime of 20,000 hours.

・C-band high-gradient accelerator: The conception of this iconoclastic approach for high-gradient, choke-mode damped accelerating structures dates back to Shintake's KEK days. With the SCSS Test Accelerator, the practical advantage of the C-band for a high-energy acceleration has been clearly demonstrated, achieving an accelerating gradient of 40 MV/m. The testing of the choke mode operation will need to wait until multi-bunch operation.

・LLRF for C-band accelerator: The C-band LLRF is not simply a rescaled S-band devices but novel approaches have been made. Such as the single-package klystron with modulator, and the multi-cell pulse-compression cavity with high rf stability.

・Cavity BPM: This is another conception dating back to the KEK days and proved to be high resolution and practical. It is copied widely by other accelerator projects such as LCLS and ILC.

・In-vacuum undulator: Although this is a critical part of the SCSS Test Accelerator, it is beyond the scope of this review since it is a contribution of Kitamura's laboratory.

・Pioneering experiment on seeding with higher laser harmonics in gas in collaboration with a French group: The technique is expected to become an important part of the future short wave generation with seeded FELs.

The SCSS Test Accelerator test facility has been delivering UVU light to the users since 2007 in collaboration with laser research group in RIKEN, which would have positive impact for VUV sciences as well as preparing the future x-ray users of the SPring-8 XFEL. The success of the innovative accelerator ideas employed for the SCSS Test Accelerator system has been noticed worldwide by the accelerator community and would influence plans for future light source facilities.

The Committee wishes to make the following observations/suggestions

・The coherent synchrotron radiation (CSR) is identified as one of the major causes of beam degradation in other XFEL projects such as LCLS. The effect was predicted by simulation and confirmed by a detailed experiment at LCLS. However, the effect was not found at SCSS Test Accelerator, neither by simulation nor in experiment. No provisions are planned against the CSR effects for the SPring-8 XFEL project. The Committee finds this unsettling and suggests that the issue to be revisited. This can begin by exchanging the simulation codes used by the RIKEN and SLAC teams; performing the LCLS simulation with the AEBPL code and the SCSS Test Accelerator/SPring-8 XFEL simulation with the ELEGANT code used by the LCLS team.

・In the same spirit, the Committee suggests that the beam dynamics through the 8 GeV linac for the SPring-8 XFEL project be reviewed, taking into account the beam loading, misalignments, wake field, orbit correction strategy, BPM accuracy, etc. Although this may not be the role of AEBPL, the Committee feels that it is important for the SPring-8 project.

1.3 Management of the laboratory (laboratory member composition, researchers' interaction, facilities and equipment, etc.)

・The success of SCSS Test Accelerator, a large accelerator system with several innovative but untested components, was accomplished by the leadership of the CS, the dedicated effort by AEBPL staff, the efforts by industrial partners, and with collaboration from KEK. The Committee also acknowledges the role of the RIKEN management in the oversight of this complex enterprise.

・The CS has established a strong contact with industrial partners in developing innovative ideas to practical devices. A good working relationship with industry should continue in the future and will be required, for example, for developing a solid state based Klystron modulator.

The Committee is pleased to find that all members of AEBPL are accomplished scientists in their own right, with a desirable spread in expertises as follows:

・Dr. H. Maesaka: Beam diagnostics, especially the cavity BPM

・Dr. T. Inagaki: C-band cavity and the associated rf technology

・Dr. K. Togawa: CeB6 Thermionic cathode development with DC voltage

・Dr. Y. Otake: Femtosecond synchronization technology, also acts as the deputy manager of the AEBPL

Interview meetings with AEBPL staff members showed that they are in general pleased with the work environment and proud of their achievement. However, it appears that the duty related to the XFEL project does not leave much time for further R&D and dissemination of the research results. The Committee recommends that this creative and productive group be given at least a minimum of opportunities for research and for publishing the research results in international high-standard journals. This is particularly important for the younger members of the group. The Committee suggests also that the AEBPL takes up the task of training PhD students and postdocs from and outside Japan. An activity that can start immediately is regularly scheduled seminars and/or journal clubs devoted to research topics or scientific news items.

1.4 Future research plan (possibility of cooperation with related fields, etc.)

Several future directions were presented:

・Upgrade of thermionic-cathode injector for a higher repetition rate: The upgrade will widen the applicability of the injector for high average brightness FELs such ARC-EN-CIEL, NLS, XFEL Oscillator, and possibly ERLs. Two international collaborations were mentioned; Cockcroft Institute in UK, and Argonne National Laboratory in USA.

・Solid state klystron R&D: This area is pursued vigorously by other laboratories. For instance, SOLEIL, which employs solid state amplifiers for the 352 MHz superconducting cavities, has done a technology transfer to

ELTA.

・Femto second timing system capable of resolving a few fs:  This is critical for XFEL application in the pump probe experiment. The Committee recognizes the capability and promise of the AEBPL team in this important area and strongly recommend this effort to be continued, or even further strengthened, in view of the large impact for the future XFEL application.

・6-D beam profile measurement: This is essential for the proper full characterization of the electron beam for commissioning as well as for daily monitoring of the electron beam during the user operation.

・Two approaches for seeding to produce harder x-rays, one with the combination of High order Harmonics generated in Gas (HHG) and High Gain Harmonic Generation (HGHG) in cascade, and one with wavelength compression associated with cascade HGHG: This is important as offering another route to temporally coherent hard x-rays other than the self-seeding, the X-ray FEL Oscillator, or possibly the Echo-assisted high harmonic generation.

・Topics beyond accelerator physics, such as the phase retrieval issues:  This is one of the major issues on XFEL applications, on which Shintake proposed a new approach recently.

1.5 Overall assessment

The AEBPL is endowed with the highest calibre of accelerator scientists, in originality and capability. The success of SCSS Test Accelerator is remarkable in view of two major innovations, a thermionic-cathode based injector for stability and C band accelerating system for compactness.  The SPring-8 XFEL, when it begins to operate in 2011, will be one of the highest brightness x-ray sources in the world, together with the LCLS at SLAC and the Euro-XFEL at DESY. Thus the AEBPL completely matches to one of the RIKEN's missions; "Establish a research infrastructure of the highest standard for the research community and provide opportunities for its use."

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