Short-stay Study Abroad Program

Completion Report

DESY, Germany

2013/10/13 - 2013/11/24

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Period of study	13/10/2013 ~ 24/11/2013
Date of report	25/11/2013

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Chapter 1

Motivation and Preparation

1.1 Relevance of Short-stay Study

The goal of the work during the doctoral course is performing research and developments for the digital LLRF control of superconducting cavities in the scope of ILC. Learning about the hardware, firmware, and software used at CMTB, AMTF, FLASH, and the upcoming XFEL, performing experiments at CMTB and AMTF, developing and testing algorithms as well as developing concepts for FLASH and XFEL is exactly fulfilling this goal, since at the moment FLASH is and XFEL will be the most to ILC similar existing accelerator. With this the stay at DESY was a crucial step towards the completion of the doctoral course and the thesis.

1.2 Preparation before leaving Japan

Before the stay in a discussion between Shinichiro Michizono (SOKENDAI, KEK), Holger Schlarb (DESY), and Julien Branlard (DESY) it was decided that Julien Branlard would be the supervisor in the MSK group (Maschine Strahl Kontrolle, machine beam control) at DESY. In an e-mail correspondence the goals of the short time study were defined to be:

- Get hands on experience at FLASH
- Get hands on experience at AMTF
- Get hands on experience at CMTB
- Understand the klystron linearization implemented by Wojciech Cichalewski for comparison to the one implemented at Fermilab NML

- Improve klystron linearization implemented by Wojciech Cichalewski
- Write klystron linearization package for μTCA.4 boards
- Develop concepts for in the scope of klystron linearization (exception handling, pulse to pulse klystron characterization)

Since the participant of the short-stay study abroad program is German no VISA and no preparation regarding the language was required. A room at the DESY hostel as well as a flight were booked.

Chapter 2

Introduction of DESY

The Deutsches Elektronen-Synchrotron (German Electron Synchrotron, DESY) is a national research center. The main site is located in the city of Hamburg in Germany. Figure 2.1 shows a map of it. DESY was founded in 1959 and is financed by the Federal Republic of Germany, the States of Germany, and the German Research Foundation, which is part of the Helmholtz Association.

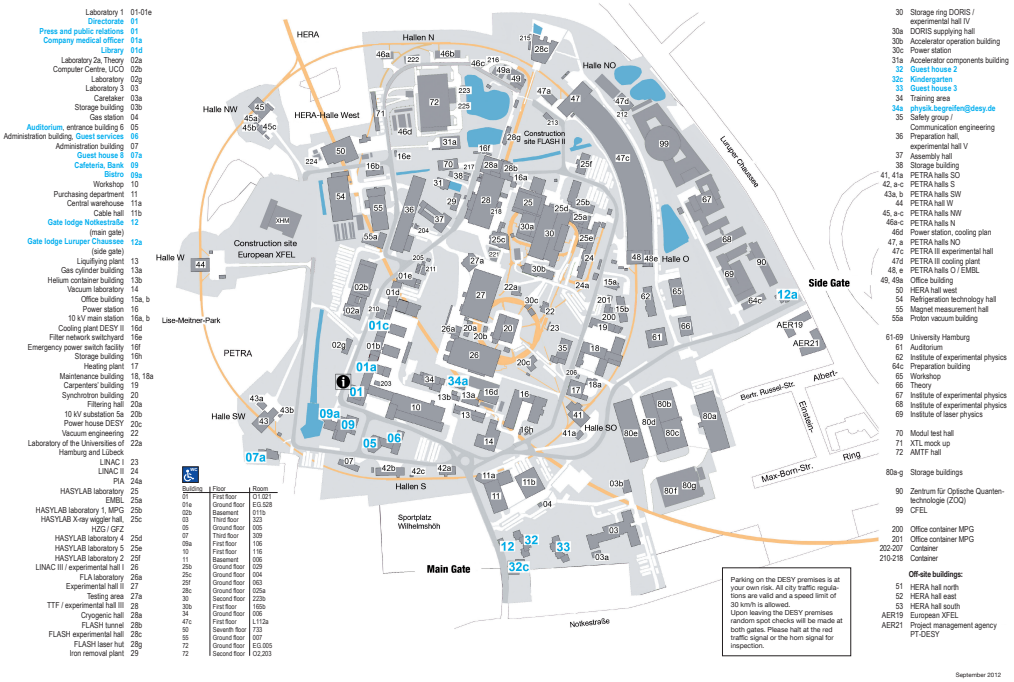

Figure 2.1: *Map of DESY.*

The main purpose of DESY is scientific fundamental research with the focus on:

- Development, construction, and operation of particle accelerators
- Particle physics
- High energy physics
- Research in the fields of physics, chemistry, biology, geology, and medicine using photos

To this end several large scale facilities were and are operated, such as DESY, DESY II, DESY III, DORIS, DORIS II, DORIS III, PETRA, PETRA II, PETRA III, HERA, LINAC I, LINAC, II, LINAC III, FLASH, and the upcoming FLASH II. Further projects DESY is involved are the CFEL, the XFEL (under construction at DESY), and the ILC.
The number of employees at DESY is approximately 2000, including about 650 scientists working in the fields of accelerator operation, research and development as well as more than 700 diploma students, doctoral candidates, and postdocs as young scientists. Each year more than 3000 scientists from over 40 countries are visiting in order to research.

Chapter 3

Study and Research during the Stay

In total two shifts at the FLASH main control room were joined. The first was devoted to LLRF studies and the second to SASE tuning. This gave a good insight about the operation of FLASH, the control system DOOCS, and the GUI JDDD.

The 5 MW klystron of the Accelerator Module Test Facility (AMTF) stand 3 was characterized in matters of output amplitude and phase using an open loop feedforward scan. This data was recorded for several reasons. With this data the phase linearization performance of the formerly implemented klystron linearization was better understood. Furthermore this set of data can be used as the basis of a possible FPGA-based klystron simulator. Beside the klystron output characteristic in matters of amplitude and phase also the performance of the used vector modulator was analyzed. In general experience in klystron operation was deepened.

The 10 MW klystron at the Cryo Module Test Bench (CMTB) was characterized in matters of output powers at different high voltage settings using an open loop feedforward scans. No signal for measuring the output amplitude and phase was available. Since the μTCA.4 system was not operational at CMTB the predecessor the VME system was used. This gave a good insight about the GUI DDD. During the measurements crosstalk in the VME system (in the down converter) towards the cavity probe signals was found.

The formerly at DESY implemented klystron linearization by Wojciech Cichalewski was analyzed and compared to the one the participant of the short-stay study abroad program implemented earlier that year at Fermilab

NML. Since the FPGA firmware implementation consists mainly of a lookup table and multiplications, the actual know-how is located in the MATLAB script for the generation of the lookup table. This script was analyzed and a way for improvements regarding the amplitude and phase linearization performance was found. Based on this a new MATLAB script for the creation of the lookup tables was created. Even no access to the FGPA firmware was granted in order to protect of DESY's intellectual property, a klystron linearization algorithm for the uTCA.4 board was programmed. In a iSim simulation of the klystron linearization package within a test bench a proof of concept was shown. Furthermore by successfully uploading the firmware to an FPGA it was demonstrated that the code quality was already sufficient. The final implementation on the μTCA.4 hardware can only be performed by DESY personal.
Depending on the firmware used this klystron linearization package can also be used for realizing an FPGA-based klystron simulator.

Strategies for exception handling especially in the scope of the klystron linearization were developed. Those cover what possibly can go wrong, how to detect it, how to prevent it, and how to recover from it.

Strategies for pulse to pulse as well as for intra-pulse klystron characterization methods were suggested. These would allow to characterize the klystron during operation. By this the until now required downtime for the klystron characterization could be omitted. The lookup tables can be refreshed during operation in an automated way, which is especially important when the working point (e.g. high voltage of klystron) is changed.

In the scope of the weekly DESY LLRF seminar a talk with the title "*Development and Test of Digital LLRF Control Procedures and Techniques Towards ILC*" was given.

In the scope of a weekly LLRF meeting in the last week of the short-stay study a presentation with the title "*Concepts, Developments, and Tests in the Scope of Klystron Linearization*" summarizing the work at DESY was held.

Tours around the facilities of AMTF, CMTB, and the European XFEL were joined.

Chapter 4

Other Activities

Beside the work at DESY the Helmholtz-Center Berlin in Berlin, Germany was visited for one day in order to give a seminar talk with the title "Entwicklungen und Tests von digitalen Low Level RF (LLRF) Regelungstechniken und Prozeduren im Rahmen des International Linear Colliders (ILC) - Development and Test of Digital LLRF Control Procedures and Techniques Towards ILC", to get in touch for a possible future position, as well as to join a guided tours at the electron storage ring BESSY II as well as at the heavy machine hall, in which a vertical cryo test stand for up to two 9-cell TESLA-type cavities and an undulator test stand are located.

Furthermore also the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany was visited for one day in order to give a seminar talk with the title "Development and Test of Digital LLRF Control Procedures and Techniques Towards ILC", to get in touch for a possible future position, as well as to learn about the recent hardware and FPGA firmware developments for cavity control in the scope of FAIR at the Ring RF group.

Chapter 5

Expenses

Tabel 5.1 lists all expenses for travel and accommodation actually spent. Sokendai covered the part of the expenses as described in the regulations for this program.

Table 5.1: *Expenses of short-stay study at DESY.*

Purpose	Amount	Currency
Transportation to and from airport in Japan	5 680	Yen
Flight from Narita, Japan Narita to Hamburg, Germany and back	231 400	Yen
Transportation from and to airport in Hamburg	7.70	Euro
DESY Hostel for 9 days	252.00	Euro
Room in private apartment for 34 days	584.67	Euro
Transportation between room and DESY	72.20	Euro

Chapter 6

Language, Difficulties, and Advice for Future Applicants

6.1 Language

During work the languages German and English are used. Since the participant of the short-stay study abroad program is German this was no problem. Due to large number of mostly Polish colleagues at the MSK group all meetings are held in English.

6.2 Difficulties

No actual difficulties occurred.

6.3 Advice for Future Applicants

The DESY hostel offers a room only for a period of time of up four weeks. After this one has to stay outside. DESY offers a list of places, where one can rent a room (mostly in private apartments). This is much cheaper than the DESY hostel as well as hotels. If it is planned to stay longer than four weeks at DESY a request for being put on the list for renting a room should be done (at best several weeks) before the trip.
In Germany all shops are closed on Sunday and on holidays. Only some restaurants are open. One has to keep this in mind and plan ahead.
Usually water with gas is drunk in Germany. Water without gas is called "still" or "stilles Wasser".