NSLS-II Coordination Group Commissioning of the NSLS-II LINAC

Description

The NSLS-II 200 MeV S-Band linear accelerator will be built, installed, and commissioned by the manufacturer, Research Instrument GmbH (RI). The statement of work for the manufacturer includes the demonstration of the beam-design parameters which implies the commissioning to be a part of the manufacturer's responsibility. However, in order to assure that authorization to proceed with commissioning is granted by BSHO, preparatory work needs to be performed to prepare a successful Accelerator Readiness Review which implies the preparation of a fairly large number of documents the generation of which requires interaction with the NSLS-II ES&H group, the manufacturer, the NSLS-II installation coordinator, the accelerator physics group, the injector group, the RF group, the controls group and most of the other AD technical support groups. During commissioning, the vendor activities should be facilitated by supporting NSLS-II staff and last but not least, the information on how to operate the linac needs to be acquired from the vendor and passed on to the technical groups and the operations group. These tasks require a coordinator who will interface between all stake holders and who will direct and guide NSLS-II staff involved in NSLS-II Linac commissioning. The coordinator will drive the preparations for commissioning; he will own the commissioning schedule. The coordination tasks will be completed, once the LINAC is handed to the operations group for routine operating.

Initiated by: F. Willeke, NSLS-II ASD Director, December 1, 2010

Schedule
Start: December 15, 2010
End: After completion of commissioning task, approx. July 1st, 2012

Goals and Responsibilities

The coordinator is responsible for accomplishing the following steps in preparation and during the commissioning and until the end of the machine acceptance testing:

- Interaction with RI on the issues related to the linac commissioning. Prior to communication with RI coordinator will discuss the matter with and reach agreement from the linac project manager J. Rose and Injector group leader T. Shaftan.
- Develop a Commissioning Plan in conjunction with the manufacturer and ESH requirements.
- Preparation of the safety documents required for the linac commissioning. These documents are:
    - Linac Commissioning Plan (a preliminary version attached)
    - Linac Commissioning Safety Assessment Document
    - Linac Commissioning Accelerator Safety Envelope
    - Procedures for commissioning the Linac, including response to abnormal and emergency conditions

  - Conduct of operations document program including necessary procedures, training and qualifications

- Presentation of the Authorization Basis documents to the Laboratory ESH Committee for review and recommendation for approval to the Deputy Director for Operations

- Review of the linac and LtB shielding and radiation monitoring devices prior to the linac commissioning

- Organize commissioning meetings and a kick-off meeting involving the task members (names of task force members to be determined and this documented to be updated)

- Specification of high-level software application for the LtB TL devices and components required for linac commissioning

- Interface with the Accelerator Readiness Review Team and assure that all pre and post start findings are adequately resolved to the satisfaction of the Team

- During the beam commissioning follow the steps of the approved linac commissioning plan

- Organize the commissioning support by accelerator scientists

- Identify necessary level of commissioning support for health physics staff

- Assume responsibility for carrying out commissioning work safely. Plan all commissioning activities in compliance with all the relevant safety regulation, make sure that the safety regulations are strictly obeyed by all those involved in commissioning

- Report commissioning progress to the AD Director

- Compare the measurement results with the developed linac and LtB TL model

- Receive from RI and review documentation on the linac commissioning and operations

- Provide a final commissioning report.

Stakeholders
Members of the Injector Group
Group Leader RF group, Group Leader Controls Group, Group leader of the Instrumentation group, Group leader of the Electrical engineering group, Group leaders of the Vacuum group or their designees.
ESH Group

Task Force Members
Task Force Leader: **Dr. Ray Fliller**
Dedicated LINAC controls engineer
Dedicated LINAC instrumentation engineer
Dedicated LINAC RF engineer
Assigned members of the accelerator physics group, tbd
Dedicated member of the ES&H staff, W. R. Casey
Members of the NSLS operations group, tbd

Accounts to be Charged

The Labor for coordination is by AS pre-operations Accelerator Injector System Commissioning WBS 1.06.02.05.02 cost account. New additional costs should be covered by a project change request (PCR) and allocation of funds from contingency.

Taskforce Reviews

The activities of the coordination group be reviewed monthly during the preparation phase and will be more frequent during the ARR and commissioning phase.

Task Force on Commissioning of the NSLS-II Accelerator Complex

Concurrence:

AD Director _____, 2010/12/16

AD Mechanical Systems Head: _____, 12/13/10

AD Electrical Systems Head: _____, 12/14/10

AD Vacuum Group Leader: _____, 12/14/10

AD Instrumentation Group Leader: _____, 12/14/10

AD Insertion Device Group Leader: _____, 12/16/10

AD RF Group Leader: _____, 12/13/10

AD Controls Group Leader: _____, 12/16/10

AD Safety System CAM and Interface Manager: _____, 12/17/2010

AD Injection Systems Lead _____, 12/16/10

Task Force Leader: _____, 12/14/10

CFD Division Director: _____, 12/16/10

NSLS-II E. S&H Manager: _____, 12/17/10

Appendix: Draft Commissioning Plan:

The following draft should be developed and refined as part of the coordination group Activity:

Draft Commissioning Plan (by T. Shaftan)

The NSLS-II linear accelerator will be commissioned by the personnel of Research Instrument GmbH (RI). The NSLS-II project appoints a staff member that will serve as the coordinator for the linac commissioning. The coordinator is responsible for accomplishing the following steps in preparation and during the commissioning and until the end of the machine acceptance testing:

- Interaction with RI on the issues related to the linac commissioning. Prior to communication with RI coordinator will discuss the matter with and reach agreement from the linac project manager J. Rose and Injector group leader T. Shaftan.

- Preparation of the safety documents required for the linac commissioning. These documents are:
  - Linac Commissioning Plan
  - Linac Commissioning Safety Assessment Document
  - Linac Commissioning Accelerator Safety Envelope
  - Procedures for commissioning the Linac, including response to abnormal and emergency conditions

- Review of the linac and LtB shielding and radiation monitoring devices prior to the linac commissioning

- Specification of high-level software application for the LtB TL devices and components required for linac commissioning

- During the beam commissioning follow the steps of the established linac commissioning plan (attached below)

- Compare the measurement results with the developed linac and LtB TL model

- Receive from RI and review documentation on the linac commissioning and operations

Linac commissioning with the diagnostics available in the Linac-to-Booster Transport Line

The layout of the Linac-To-Booster Transport line (LB TL) is shown in the figure below.

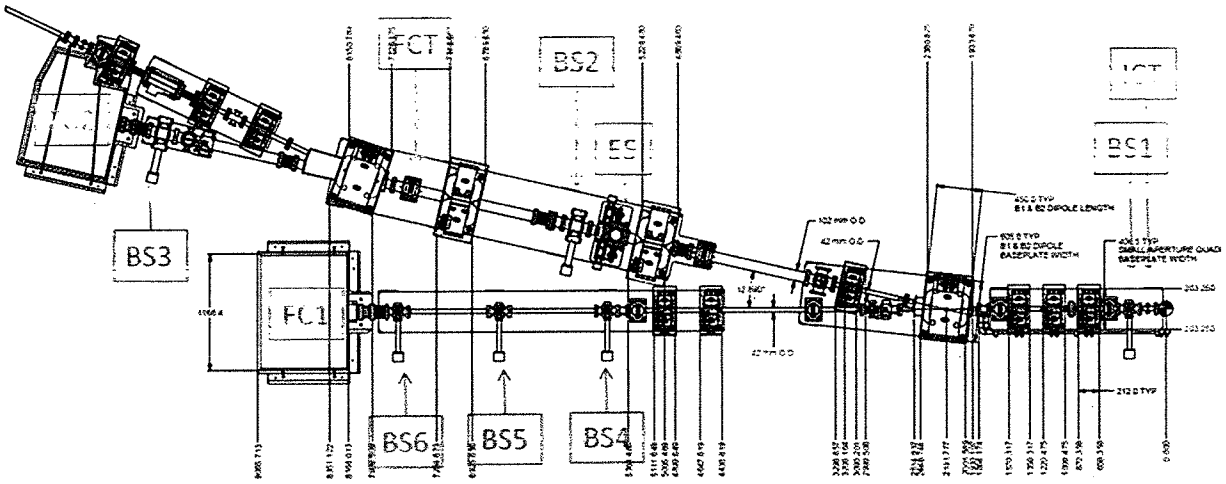

Fig. 1: BS = Beam Screen, FC = Faraday Cup, ES = Energy Slit, ICT = Integrated Current Transformer, FCT = Fast Current Transformer

The LB TL contains three transport line sections: The 1st Diagnostics transport line for measurement of the transverse beam properties, the 2nd diagnostics transport line for energy measurements; and, the line towards the injection into the booster ring.

The LB TL optics contains the following:

- A quadrupole triplet for matching the linac beam to all three lines;
- Achromatic bends composed of two identical dipoles with an energy slit in the middle;
- An 0-dispersion section towards the booster ring.

During the commissioning of the linac, we will restrict the path of electron beam towards the booster, and disconnect the 2nd dipole in the achromat from its power supply. We will lock and tag out the power supply.

The following charge losses are acceptable for the linear accelerator's routine operations:

Low-energy linac (100 keV)	10 nC
Linac (100 MeV)	0.5 nC
Beam damps	23 nC
Energy slit	2.25 nC
Unshielded regions of LB TL	<0.5 nC

Exceeding these values during beam commissioning might be possible, but will require administrative measures, including fencing the linac's cave area, and periodic PA announcements. Operating the linac with radiation levels exceeding the values in the table will be possible for limited time (for about an hour).

This commissioning procedure describes the sequence of beam measurements aimed at establishing the design values of the beam's parameters, and successfully completing its acceptance testing.

Assumptions

- The commissioning of the linac beam will begin in a single-bunch mode with a charge of 50 pC. Once the single-bunch mode at low charge is commissioned, we will switch the linac to the multi-bunch mode with 100 bunches in the train, each with the same charge of 50 pC per bunch (5 nC total) so that the dynamics of a single bunch will be similar to before. We then will compensate for beam loading to attain a small energy spread at the energy of 200 MeV. Thereafter, we will switch again to the single-bunch mode and establish the linac's performance at 100 pC. The same procedure will be repeated for the 100 pC per bunch in the 100-bunch-long train (10 nC total) that is close to the performance specifications stated in the linac contract. At this point, the linac will be well commissioned for studying single bunch scenarios separately with a maximum charge of 0.5 nC (the most difficult in compensating for the space charge) and the shortest bunch train of 80 bunches with 190 pC per bunch (most difficult for the beam loading compensation).

- The commissioning of the linac beam with the LB TL devices will begin after we establish the beam at the location of the ICT at the linac' end. We will use the ICT's signal to optimize the linac's output. In the next step, we assume that the bunching system and beam transmission will be optimized approximately, using the linac-beam's diagnostics according to the Commissioning Plan ASP.pdf, and the beam established at the ICT after the linac.

- We also assume that earlier during experiments with the Linac Front End (LFE) the 100-keV electron beam was established with reasonable quality. In particular, this includes setting the nominal charge per bunch in the both single- and multi-bunch modes, with the parasitic charge in the "empty" linac RF buckets being below the value stated in the linac's specification. Furthermore, we expect that the beam's transverse profiles, measured at the LFE exit, correspond to the model presented at FDR.

- At the beginning of this process of commissioning, the two last linac sections will not be powered, and a beam with energy below 100 MeV will exit the linac.

Commissioning steps

1. First, we will guide the beam to the 1st beam damp and measure the charge at the damp with the Faraday cup. Radiation levels will be surveyed. Shielding verification: locations and how to.

2. Next, the beam will be steered to the beam screen, BS2, in the middle of the achromat so we can measure its energy. We will employ the triplet Q1-3 to create a sharp image on the BS2.

3. We will measure the signal from the FCT in the middle of the achromat and determine charge transmission and amount of the charge in the energy tails.

4. The beam then will be steered and focused into beam damp 2 where the charge will be determined by the Faraday cap. Radiation levels will be surveyed.

5. By optimizing the linac phases, a small energy spread will be obtained.

6. The two last accelerating structures will be powered, and beam's energy optimized until it reaches the required nominal value of 200 MeV.

7. The beam's transmission again will be optimized and energy spread minimized.

8. Then, the beam will be observed with BS3, located at a high dispersion region so that the energy measurements will have higher resolution. Accurate measures of energy and energy spread will be acquired via scanning the RF phase of the last linac tanks. Both BS2 and BS3 will be used, together with scanning the ES aperture and measuring the passing charge with FC2.

9. The beam's emittance then will be optimized. Without changing the RF settings, we will use the low-energy optics (i.e., the correctors and solenoids) to correct the beam's trajectory through the linac, and to minimize the spot size.

10. At this point, the transverse beam's emittance will be measured using 3-screen method using 3 beam screens in the diagnostics transport line.

11. The emittance will be optimized via changing the solenoid fields in the linac's low-energy part. .

12. The energy and energy spread will be optimized again.

13. The emittance value will be acquired using the 3-screen method and confirmed by the quad-scan using the doublet upstream of the 1st diagnostics transport line. The Twiss parameters at the linac's exit, at the location of BS1, will be calculated and validated by measuring the beam's envelopes along the linac and both Diagnostics transport lines.

14. At this stage, we will switch the mode of operation to the multi-bunch one, and we will commission the bunch train of 100 bunches with a total charge of 5 nC by repeating steps 1-12.

15. The beam's transmission will be measured and optimized using signals from FCTs, the WCM, and the sum of the signals from the BPM buttons.

16. Beam loading compensation will be tested by adjusting the tip of the RF pulse and measuring the energy spread first on BS3 and then more precisely on BS4.

17. At this time, we will increase the bunch charge to 100 pC, and repeat steps 1-12 and 14.

18. A radiation survey will take place to determine radiation levels outside the linac cave.

19. The linac's performance will be maximized for a single bunch charge of 0.5 nC

20. The linac's performance will be optimized for a train of 80 bunches with 15 nC total.

21. The linac's performance will be optimized for 30 bunches with 0.5 nC per bunch.