

ADDENDUM
to the
Memorandum of Understanding
between
US Universities & Accelerator Laboratories
and
Indian Universities & Accelerator Laboratories
concerning
Collaboration on R&D for Accelerator Physics and High Energy Physics
Projects

Addendum VI: "Fermilab and Indian Accelerator Laboratories
Collaboration on RF Power Development for High Intensity Proton
Accelerator"

March 15, 2011

1. Authority and Limitations

Pursuant to the Memorandum of Understanding ("MOU") between the U.S. Universities & Accelerator Laboratories and Indian Universities & Accelerator Laboratories dated January 9, 2006, Fermilab and Indian Accelerator Laboratories (the "Parties") intend to undertake the work described in this Addendum V. The Parties acknowledge that their intended work shall be consistent with the terms and conditions of the MOU, the terms and conditions of their respective contracts and programs, and subject to the availability of appropriated funds as provided to them. The Parties further acknowledge and understand that their agreement with and signature to Addendum V does not create a legal, contractual obligation for either Party nor may form the basis of a claim for reliance thereon. The Parties agree to comport their activities under Addendum V in conformance with all applicable U.S. and Indian laws and regulations, including those related to export control.

2. Introduction

The work detailed in this document falls within the scope of the MOU cited above. It addresses in some detail the two key areas of collaboration mentioned in the main MOU, which are (i) Superconducting Radio Frequency (SRF) Acceleration Science and Technology, including setting up test facilities and (ii) a high current proton driver. All

terms and conditions under which the work will be carried out are found within the main MOU.

This Addendum to the MOU outlines the collaborative work that Fermilab, USA and Raja Ramanna Centre of Advanced Technology (RRCAT), Indore would jointly take for the 650 MHz Solid State RF Power Development.

3. Background

Fermilab and Indian Institutions have been collaborating on high energy physics experiments and on the accelerator research and development under Addendums (I, II and III) to the MOU. Indian Institutions have made significant progress on the work that was outlined in these Addendums. The work outlined in this addendum is extension of this work to other areas of the High Intensity Proton Accelerator beyond the Superconducting Radio Frequency cavity and Cryomodule and related infrastructure.

The CW linac in Project X utilizes two RF frequencies: 325 MHz and 650 MHz. Advances in solid-state FET device manufacturing have enabled solid-state amplifiers to challenge tube amplifiers at the required power levels, albeit at higher acquisition costs. An R&D program to exploit the latest transistor technologies could prove solid-state as a viable alternative to tubes for this application.

650 MHz solid-state amplifier development is a prime candidate for R&D for the Project X accelerator. The current Project X design has need for two levels of RF power in the 650 MHz section of the linac. Current market price for solid-state amplifiers with these requirements is typically two to five times the cost of a tube amplifier on a per watt basis. If innovative design could bring the solid-state costs closer in line with those of tube amplifiers, the advantages of solid-state amplifiers of high reliability, low maintenance, long life time, and lack of high voltage could be enough to sway the decision to solid-state for this application at 650 MHz. This is an ambitious program, which should be directed to achieving the highest possible efficiency.

650 MHz solid-state power has two possible roles in Project X. First is a 1 KW CW amplifier that would be used as a driver for inductive output tube (IOT) amplifiers. The low gain (typically 23 dB) of IOTs requires a significant driver amplifier. The second would be elimination of IOTs and utilizing solid-state for the required 30 KW CW amplifiers. IOTs operate between 50-60% efficiency. A solid-state solution requires similar or superior efficiencies.

4. Work to be performed

The collaborative work under this Addendum to the MOU is to develop 650 MHz Solid State RF Power for the CW High Intensity proton Linac. Fermilab and RRCAT will jointly work on the design, development, prototype and construction of the 650 MHz CW Solid State RF power system.

Here Fermilab will specify the requirements and Indian Institutions will provide all the hardware, design and fabrication effort. There should be interactions between FNAL and Indian Institutions plus design reviews throughout the project.

In particular, the goal for RRCAT is to design, based on specification provided by Fermilab, prototype and fabricate three 650 MHz Solid State RF Power Systems and associated components that would be shipped to and assembled at Fermilab. It will be tested in the Cryomodule Test Area at Fermilab in collaboration with staff from RRCAT. If and when the Fermilab Project-X is approved for construction by US government, this development may result in "In-Kind" Indian contribution to Project-X.

5. Scope of Work in CY11-14

It is expected that the scope of work described by this Addendum will be executed within a three to four year time period. The scheduled date of the start and end of a project may be staggered to meet the overall plan and available resources of the collaboration.

The specific goals are

1. Design, Fabricate and test one 250 W, 650 MHz, Solid State RF system by end of CY 2011
2. Design, Fabricate and test one 1 kW, 650 MHz, Solid State RF system by the end of CY2012
3. Design, Fabricate and test one 30 kW, 650 MHz, Solid State RF system by the end of 2014.

One alternate goal is to get Indian industries involved in fabrication of the components for this 650 MHz RF system. One 30 kW system will be shipped to BARC for integration in the Cryomodule Test System that BARC is developing for Fermilab. It is also expected that RRCAT staff will participate in this integration activities.

6. Schedule and Review

The detailed specification and schedule of work described in this Addendum to the MOU would be elaborated in the Functional Requirement Specification (FRS), Technical Annexes and Technical Project Management documents. The schedule would be

approved by the respective sub-Project Managers in consultation with the IIFC Indian and US Coordinators. The schedule and progress will be jointly reviewed every six months and tasks may be added, deleted, or modified by mutual agreement. Both groups agree to report and evaluate progress at individual laboratory reviews by their respective funding agencies.

7. Funding

Consistent with General Provision 2.3 of the MOU, each Party shall be responsible for funding its participation activities. All participation activities and related procurements are subject to the availability of appropriated funds, personnel, and resources.

Fermilab and the Indian Institutions agree to establish an India Institutions and Fermilab Collaboration Account (IIFCA) at Fermilab. This account will be funded by Fermilab through a credit of fifty percent of the U.S. cost for each hardware component provided by Indian Institutions for use at Fermilab during the R&D phase. If the U.S. cost is unavailable, the amount of Fermilab credit for each component will be decided by mutual agreement of the Parties. The IIFCA would be managed by Fermilab-Indian Institutions for SRF technology-related R&D expenses. Such expenses may include: (1) supporting the local expenses of all Indian scientists and engineers visiting Fermilab for work and meetings under this Addendum and (2) procuring materials and technical components not available in India that will return to Fermilab. IIFCA funds may not be used to purchase hardware components from non-U.S. vendors. If India needs these materials and technical components for their own use, Fermilab will assist in their procurement.

All labor, materials and components available in India will be supplied by the Indian Institutions. Any hardware needed for use and development of the Indian laboratory infrastructure for the work to be performed under this Addendum will be paid by Indian Institutions.. Fermilab will not charge for any technical assistance provided for the design of SRF infrastructure at Indian Institutions. Indian Institutions will provide visiting US scientists and engineers with local accommodations when possible at the laboratory site. The cost of travel for Fermilab staff to India will be covered by Fermilab funds. The Parties mutually agree that costs associated with shipping materials and components shall be borne by the shipping Party and that any customs or duties applied to the items so shipped shall be borne by the receiving party.

8. Proposed mechanism for IPR sharing

The Intellectual Property Rights (IPR) sharing has already been well defined and described in detail between the Institutes involved in two documents: (1) Memorandum

of Understanding between U.S. Universities and Accelerator Laboratories and Indian Universities and Accelerator Laboratories concerning collaboration on R&D for various Accelerator Physics and High Energy Physics Projects and (2) Tesla Technology Collaboration Memorandum of Understanding. (http://tesla-new.desy.de/sites/site_tesla/content/e19/e24/infoboxContent581/MoU.pdf). It is to be noted that for all collaborative work under this MOU the proposed mechanism for IPR sharing will be exactly as envisaged in these two documents.

9. Project Management, Responsibilities and Approval:

The Project management, responsibilities and approval authorities are described in detailed in the document "Management Plan for Fermilab Participation in the Indian Institutions and Fermilab Collaboration"

(http://iifc.fnal.gov/IIFC_FNAL%20Management%20Plan-Final-102210.pdf)

The following concur on the terms of this Memorandum of Understanding Addendum:


Dr. P. D. Gupta,
Director, RRCAT

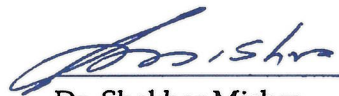
22/8/2011
Date


Dr. Piermaria Oddone
Director, FNAL

8/22/2011
Date


Dr. Rakesh Bhandari,
Chair, IC-IIFC

22/08/2011
Date


Dr. Shekhar Mishra,
Project-X,
International Collaboration Coordinator

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Date

