PIP-II Beam Instrumentation Laser Wire Design Follow-Up Review Report

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Document Approval

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Revision History

Revision	Date Release	Originator: Role:	Description of Change

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1. Introduction

A successful Preliminary Design Review (PDR) of PIP-II beam instrumentation was conducted in the Fall of 2021. Several recommendations were made regarding the PIP-II laser wire beam profile monitor system. The scope of this review is to address these recommendations and determine if the preliminary design of the laser wire systems align with the functional and technical requirements. Specifically this review will compare the cost and performance of a fiber-based laser wire system versus a free-space based laser wire system.

2. Review Agenda

Laser Wire Mini-Review Agenda

Location: Zoom

Date: Monday, Nov 7, 2022

Time: 9:00 AM to 1:00 PM (CDT)

Indico Site: https://indico.fnal.gov/event/56764/

Participants:

Vic Scarpine scarpine@fnal.gov	Fermilab	Role: Coordinator
Yun Liu Liuy2@ornl.gov	SNS	Role: Reviewer
Dave Johnson dej@fnal.gov	Fermilab	Role: Reviewer
Lucy Nobrega	Fermilab	Role: Reviewer

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Brian Hartsell hartsell@fnal.gov	Fermilab	Role: Reviewer
Vic Scarpine scarpine@fnal.gov	Fermilab	Role: Presenter
Randy Thurman-Keup keup@fnal.gov	Fermilab	Role: Presenter
Jinhao Ruan ruanjh@fnal.gov	Fermilab	Role: Presenter
Robert Steinberg rstein@fnal.gov	Fermilab	Role: Presenter
Brian Drendel drendel@fnal.gov	Fermilab	Role: Presenter

Agenda details:

I. Review Charge and PIP-II Laser Wire Introduction – Vic Scarpine
   a. Review charge
   b. Laser Wire Requirements
   c. Laser Wire Systems

II. Laser Wire Performance – Randy Thurman-Keup
   a. Signal to noise analysis for two laser wire systems

III. Laser Options – Jinhao Ruan
   a. PIP2IT laser system
   b. Fiber-based laser
   c. Free-space laser

IV. Free-Space Laser Transport Line – Robert Steinberg
   a. Requirements
   b. Transport line design

V. Laser Transport Optics and Alignment – Randy Thurman-Keup
   a. Requirements
   b. Order of installation
   c. Alignment sequence
   d. Laser alignment feedback system

VI. Laser Wire Cost Comparisons – Brian Drendel
   a. Cost of fiber-based system
   b. Cost of free-space based system
   c. Timeline

VII. Safety, Reliability and Quality – Vic Scarpine

VIII. Summary – Vic Scarpine

IX. Closeout – Review Chair
   a. Summary Statement
   b. Preliminary Findings
   c. Preliminary Comments
   d. Preliminary Recommendations

3. Review Charge Statement

The reviewers are asked to perform an 'mini review' of the laser wire profile monitor system in the context of a recommendation from the Instrumentation Comprehensive Preliminary Design Review:

Non-Invasive Beam Profile Monitor PDR Recommendations:

- The need to resolve issues with the noisy signal seen in the PIP2IT laser wire (lower dynamic range due to lower laser power).
- Do a performance and cost comparison between fiber transport line and the free space transport line. This could help make the decision between the 2 systems.

Specifically, the panel is asked to answer the following charge questions:

1. Do both technologies meet the stated design requirements?
2. Is the free-space system architecture and technology sound and viable?
3. Have risk, safety, and system performance considerations been factored into the preferred choice?
4. Does the cost and schedule comparison information as presented appear accurate?
5. Has the PDR recommendation been satisfactorily addressed?
6. Does the committee affirm the free-space laser technology as the preferred path moving forward?

4. Acronyms

List and define any relevant acronyms as necessary.

BI	Beam Instrumentation
BProM	Beam Profile Monitor
PRD	Physics Requirement Document
FRS	Functional Requirement Specification
TRS	Technical Requirement Specification
ICD	Interface Control Document

5. Reference Documents

List any relevant documents referred to in the Review Charge Statement. Include reference links or locations where the references are found. This list should include all documents with which the review committee should be familiar prior to the review.

1	PIP-II Technical Review Plan – TC ED0008163
2	PIP-II Quality Assurance Plan DocDB # 142
3	PIP-II Systems Engineering Management Plan – TC ED0008164
4	PIP-II IESH Management Plan DocDB # 141
5	121.03 Accelerator Systems Design Plan DocDB # 2599
6	121.04 Linac Installation and Commissioning Design Plan DocDB # 2581
7	121.05 Accelerator Complex Upgrades Design Plan DocDB # 2593
8	121.06 Conventional Facilities Design Plan DocDB # 2587
9	PIP-II Value Engineering Plan DocDB # 2830

The review coordinator should populate this following table with the document list for this review from their SDP.

Table 1 - Document Deliverables for this review from the System Design Plan

	Document Title	Status (preliminary, final, released)	Comments
1	PIP-II BI PRD	Final	
2	PIP-II BI FRS	Final	
3	Non-Invasive BProM TRS	Final	
4	PIP-II BI Quality Control	Final	
5	PIP2IT BI Final Report	Final	
6	PIP-II Master ICD	Released	
7	PIP-II Parameters PRD	Final	
8	PIP-II Global Requirements Document	Final	

6. Attendance List

Review panel	Presenters	Observers
Brian Hartsell (chair)	Vic Scarpine	Elvin Harms
Lucy Nobrega	Bob Steinberg	Craig Drennan
Dave Johnson	Brian Drendel	Parker Landon
Yun Liu	Randy Thurman-Keup	Raul Campos
	Jinhao Ruan	Curt Baffes
		Kyle Kendziora
		Tim DiGrazia
		Dennis Nicklaus
		Rich Andrews
		Lidija Kokjkoska
		Allen Bujak
		Chris Becker
		Brian Chase
		Eduard Pozdeyev
		Mike Geelhoed
		Genfa Wu
		Jerry Leibfritz
		Eric McHugh
		Adam Olson
		Victor Grzelak

7. Findings

- Optical testing with longer path lengths is planned to ensure that transport and stability are modeled correctly, and to study sensors and spot size. -Lucy
- A redundant machine protection system with cameras and power meters will be incorporated into the laser system. -Lucy
- The proposed alignment system seems reasonable and should be investigated further. -Lucy

8. Comments

- Determine if FESHM notes are needed for mechanical/vacuum structures.
- Evaluate vibration requirements and implement mitigations in system if needed.
- Ensure alignment features of the transport line allow for sufficient range of alignment when including the roof variation.
- Conduct further research to understand the effects of radiation damage on the optical window and its coatings.
- Verify that the outgassing rate of window optical coatings is within the outgassing budget.
- Simulation results on photo-detached electrons or detector output as a function of the laser pulse energy should be used to optimize the laser parameters including pulse energy and number of micro-pulses within one macropulse
- It is not clear why two stages of fiber amplifiers are used. They do not simplify the free-space amplifiers as two-stages of free-space amplifiers can bring the nJ pulse energy (output from 1st fiber amplifier) to well beyond 100 uJ
- Simulation of laser beam propagation/collimation should be conducted with more realistic beam parameters and optical setup.
- Since the first a few laser wire measurement stations are quite close to the laser source, possibility of accidental laser beam focusing on vacuum windows should be investigated and mitigation measures should be taken.
- Position sensing inside the measurement box needs to be reconsidered as it is not effective and is very vulnerable to radiation induced damage.
- Determine if both position and angle are needed on the mirror in the OTL pick off boxes
- Evaluate the vacuum level of the transport line selected and determine if it is possible to operate with less stringent vacuum levels.
- Investigate the collimation scheme based on multi-lens or telescope to move the waist of the beam further downstream. Implement a limit switch to prevent overfocusing.

9. Recommendations

Items that require formal action and closure in writing prior to receiving approval to move into the next phase of the project, or items that require formal action and closure in writing prior the next review.

- Conduct more research on the pulse energy density limits of the optical window to determine limits with appropriate safety factors. A better guideline for the maximum allowable laser power density on vacuum windows should be expressed using a unit J/cm^2 for particular laser pulse width.
- Laser beam position sensing in the middle of transport line is critical for alignment and feedback based pointing stabilization. Consider implementing a system in multiple places throughout the transfer line and continuously monitor this system.
- Ensure that all valves, windows, and other locations that might see vacuum loading are adequately supported.
- Verify that friction supports can adequately support a longitudinal load.

10. Response to Charge Questions

If the charge is written in the form of questions, duplicate them and directly respond to them here. These responses should reference the relevant recommendations/comments/findings as appropriate.

1. Do both technologies meet the stated design requirements?
    a. Yes, both systems will meet the design requirements, but the signal to noise ratio of the fiber-based system is problematic.
2. Is the free-space system architecture and technology sound and viable?
    a. Yes, see comments and recommendations for suggested improvements.
3. Have risk, safety, and system performance considerations been factored into the preferred choice?
    a. Yes
4. Does the cost and schedule comparison information as presented appear accurate?
    a. Yes
5. Has the PDR recommendation been satisfactorily addressed?
    a. Yes
6. Does the committee affirm the free-space laser technology as the preferred path moving forward?
    a. Yes