Fermilab

Directorate

MEMORANDUM OF UNDERSTANDING FOR THE 2007-2010 TEST BEAM PROGRAM

T-1007

Optical Cavity Test Bench

July 13, 2010

INTRODUCTION

This is a Memorandum of Understanding (MOU) between the Fermi National Accelerator Laboratory and experimenters of the Holometer and Axion-Search efforts who have committed to participate in this optical cavity test to be carried out during the 2010-2011 laboratory program.

This memorandum is intended solely for the purpose of providing a work allocation for Fermi National Accelerator Laboratory and participating universities and institutions. It reflects an arrangement that is currently satisfactory to the parties involved. It is recognized, however, that changing circumstances of the evolving research program may necessitate revisions. The parties agree to negotiate amendments to this memorandum to reflect such revisions.

MOTIVATION

Experimenters at Fermilab and several university partners are developing separate projects 1) to detect the intrinsic jitter of spatial positions using large Michelson interferometers (the Holometer project), and 2) to search for axion-like particles created by scattering laser photons on accelerator magnetic fields. The sensitivity for each application is determined by the number of photons that are used to make the measurement. In the holometer experiment, a beamsplitter position is detected using the phase of interfering laser beams, and phase resolution improves with the square root of the integrated photon flux used to make the measurement. In the axion experiment, a background-free search for rare events, the sensitivity to the small event rate improves linearly with integrated photon flux.

The current MOU is for an optical cavity test bench for use in developing long, Fabry-Perot optical cavities which are capable of containing large photon flux densities for use in these and perhaps other applications. For technical reasons, the sensitivities of each experiment also scale favorably with the length of the apparatus, length^3 in the case of the holometer, and length^4 for the axion event rate. The 40m cavity length of the optical test bench strikes a balance between cost and technical challenge, and eventual experimental sensitivity. Challenges include controlling the quality of the optics over relatively large surface areas and maintaining their cleanliness, developing high bandwidth piezo-actuated optics mounts for vibrational feedback control of cavity length and alignment, and developing low noise electronics for data acquisition and digital feedback loops for controlling high-Q, narrow optical bandwidth cavities.

PROJECT DESCRIPTION

The experimenters will construct in the MP beamline a 40m long optical test bench consisting of a rudimentary vacuum system in order to avoid refractive effects due to the room air, and cylindrical vacuum vessels at the ends to house the optics and mechanical mounts to be tested. An existing 4'x8' optics table will be placed at one end of the vacuum system to hold the optics and radiofrequency components necessary for launching a 2W, 1064nm laser beam into the vacuum system. RF data acquisition and feedback control electronics being developed in collaboration with the University of Chicago and MIT will also be brought to MP for testing.

The initial effort planned for summer, 2010, is to make a low finesse (low-Q) cavity with cheaper optical components. A partially reflective flat mirror will be installed on one end of the vacuum system, and a highly reflective concave mirror on the other end. An existing 2W continuous wave Nd:YAG laser will be used as the light source. Optics on the table will match the emittance of the laser beam to that of the cavity in order to provide efficient light injection. The laser light will also be modulated at a RF frequency of around 25 MHz in order to provide a control signal to allow the laser wavelength to be adjusted in real-time to match instantaneous changes in the cavity length due to vibrations.

An initial 10' vacuum system will be constructed as a mock-up of the 40m system. This will help us identify and address well in advance, any technical or mundane logistical issues. It will also allow us to quickly begin some R&D activities such as the testing of prototype vacuum-compatible piezo-actuated mirror mounts which are currently being fabricated, and novel vacuum mirror mounting strategies.

The full 40m system will be delivered and installed in July/August. Using this system, we will begin a program of improving cavity control by gradually inserting mirrors of higher reflectivity, thus increasing the intracavity photon flux while simultaneously reducing the cavity bandwidth. We will develop cavity locking and control electronics which are robust to such reductions in the bandwidth. We will also develop clean optics handling procedures to prevent contamination of the mirror surfaces from dust and hydrocarbons which can scatter light out of the cavity. As we reach higher finesse and correspondingly higher intracavity power levels we will study the effects of thermal lensing due to uneven heating of the mirror surface. Techniques necessary for the holometer and axion experiments such as precise alignment control and fringe locking can also be perfected on this nearly full-scale apparatus. Mitigation of RF noise sources will be a high priority.

Finally, we will explore possibilities for expansion of the cavity test bench efforts towards full holometer* and/or axion experiments, sited either in MP8 or elsewhere. Such potential expansions are beyond the scope of the present MOU.

*The full holometer experimental proposal P-990 can be found at:
http://www.fnal.gov/directorate/program_planning/Nov2009PACPublic/holometer-proposal-2009.pdf

PERSONNEL AND INSTITUTIONS:

Project leader: Aaron Chou (co-PI), Fermilab

The group members at present are:

1.1 FNAL: C. Hogan, J. Steffen, C. Stoughton, R. Tomlin, J.Volk, W. Wester
U. Chicago: Stephan Meyer (co-PI), Robert Lanza
M.I.T.: Rainer Weiss, Sam Waldman

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The optical test bench will be conducted in the MP tunnel, from the MP8 roll-up door and extending south 200 feet. The trailer immediately outside of MP8 can be used as office space. This location is operated by the Accelerator Division.

2.1.2 Optical prototypes have been and may continue to be assembled and operated in the Linac Laser lab in the Linac building. This room is configured with an interlock as a safety measure for the operation of a Class IV laser. This area is operated by the Accelerator Division.

2.2 BEAMS (LASER only)

2.2.1 The optical test bench will use a photon beam generated by a Class-IV Nd:YAG laser at 1064nm capable of 2W of continuous wave light.

2.3 SETUP

2.3.1 The optical test bench and support systems will be installed and operated in the MP beamline

2.3.2 The experimental area has been cleaned and freshly painted. Laser safety interlocked double doors will be installed at each end of the 200 ft area of the tunnel. Ventilation will provide a slight positive pressure to keep the area clean and to allow air flow and heat dissipation from electronics within the enclosed area. Safety lights have been installed.

2.3.3 A vacuum system consisting of two end chambers of approximately 2' diameter and 1' height and a 40m length of 6" OD beampipe connecting the two. The ends of the vacuum system will be fixed in place by anchor pieces attached to the concrete floor of the tunnel. Existing unistrut support structures in the walls and ceiling of the tunnel will be used during the assembly of the end stations and in the mounting of the beampipe.

2.3.4 A 4'x8' laser table and concrete blocks for use as stands will need to be moved into the tunnel.

2.3.5 A small number of cables will interface various components of the experiment to the data acquisition system and feedback control system. No extra-ordinary cabling effort is required.

2.3.6 Electronics racks will be placed in the experimental area, and will be outfitted with basic fire protection to turn off power in case of a fire.

2.4 SCHEDULE

2.4.1 May 2010, preparation of MP tunnel, including painting, installation of safety interlocked doors, transport of laser table and concrete blocks for stands

2.4.2 June-July 2010, Installation of mock-up of apparatus including 10' vacuum system. Integration of optical, mechanical, and electronic subsystems and initial tests of apparatus.

2.4.3 July-August, 2010, installation of 40m vacuum system and long enclosed cavity.

2.4.4 August, 2010-June, 2011: R&D on long, high finesse optical cavities.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

3.1 U.Chicago: Stephan Meyer is developing a low noise RF data acquisition system which will be brought to FNAL for testing. These electronics will be used for digital feedback loops to control the phase-locking of the laser to the long cavity. This work is funded through a $90K U.Chicago-FNAL Strategic Collaborative Initiative grant, and will incur no additional M&S cost to FNAL. Professors S. Meyer, C. Hogan or Y.K. Kim may serve as faculty advisors to graduate students working on optical cavity projects.

3.2 MIT: Rainer Weiss and Sam Waldman are contributing their LIGO optics expertise to the design, construction, and operation of the optical cavity. Occasional visits to Fermilab to work on the hardware are expected to be supported through the Fermilab Center for Particle Astrophysics visitors program.

IV. RESPONSIBILITIES BY INSTITUTION - FERMILAB

4.1 Fermilab Accelerator Division

4.1.1 Accelerator Division agrees to make available the space in the MP tunnel as described above for the installation of the optical cavity test bench, insofar as these activites do not interfere with other designated work.

4.1.2 AD will provide support in the assembly, instrumentation, and commissioning of the vacuum system, allowing for the use of residual gas analyzers (RGA), vacuum gauges, and vacuum fittings and valves and supporting Scott McCormick and vacuum technicians to work/consult (few hours/week, totaling ~5 weeks) on the experiment at a modest level of effort of a few hours per week, comparable to that of the recent T-991 (CHASE) MOU. These efforts will be scheduled so as not to interfere with other high priority AD activities such as the Tevatron shutdown.

4.1.3 The AD safety group will assist in all necessary safety reviews. We are presently working with Ray Lewis on safety issues.

4.1.4 The AD interlock group will design and install laser safety interlocks on the doors to the area of MP8 housing the optical cavity test bench, in accord with current laboratory laser safety guidelines.

4.1.5 AD will continue to support the participation of Ray Tomlin (50% time) and Jim Volk (10% time) in this R&D project.

4.1.S Summary of Accelerator Division costs:

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Total new items	\$0.0K	\$0K	38

4.2 Fermilab Particle Physics Division

4.2.1 The Particle Physics Division will be the source of M&S funds for the experiment. The initial costs to set up the testbench and conduct preliminary R&D include approximately \$70K for vacuum components, \$20K for other mechanical hardware, \$60K for a laser, \$20K for preparation of the experimental hall, \$40K for optics and \$40K for electronics. These funds have already been made available in FY10 via R&D budget codes 40.55.01 and 40.51.01.02 and much of the equipment has already been procured. Continuing support of optical cavity work through R&D budgets is anticipated in FY11. This additional funding will pay for upgrades to the facility such as portable clean rooms, as well as for upgraded optical and optomechanical components.

4.2.2 The PPD Mechanical team of John Korienek and Carl Lindenmeyer will be responsible for the design, fabrication, and installation of mechanical components of the system such as support stands, mirror mounts, baffles, etc. Some of the pieces may require machine shop and welding workmanship.

4.2.3 The PPD Electrical Engineering Department will aid in the design and fabrication of front end and control board, advise on the design and implementation of low noise amplification for piezo-actuated devices and otherwise provide support for the electronic aspects of the work.

4.2.4 In the event that AD vacuum technicians are unavailable due to shutdown or other priorities, PPD Mechanical Department technicians may be requested to assist in the assembly of vacuum components when delivered. The request will be contingent on availability of these technicians.

4.2.5 The PPD ES&H Department will assist in all of the necessary safety and environmental reviews, including a review for compliance with the National Environmental Policy Act (NEPA). The PPD Environmental Officer will determine the necessary level of NEPA documentation.

4.2.6 The PPD will provide administrative support through the Experiment Physics Projects office.

4.2.S Summary of Particle Physics Division costs:

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Mechanical design and fabrication			12.0 tech
Electrical engineering support			6.0 engineer
Machine shop fabrication			1.0 tech
Administrative Support			1.0
Vacuum components	$70K		
Mechanical pieces	$20K		
Laser	$60K		
Preparation of experimental hall	$20K		
Optical components	$40K		
Electronics	$20K		
FY11 Upgrades	$100K		28
Existing FY10 funds:			
40.55.01 (holometer)	-$100K		$65K
49.51.01.02 (axion)	-$130K		
Total new items (FY10)	$0K		0.0
Anticipated R&D funding (FY11)	$100K		$100K

4.3 Fermilab Technical Division

4.3.1 The MP beamline is currently used for the occasional transport of clean SRF cryomodules to the Meson Detector building. The transport is done using a cart 24" wide, 42" tall and 74" long. The optical test bench configuration will maintain a clear 36" wide walkway to avoid obstruction of such activities. Technical Division agrees to coordinate with optical cavity experimenters in advance of planned transport activities so that short downtimes can be scheduled for safe entry into the laser interlocked area. Efforts will be made to maintain the cleanliness of the optical cavity lab space during such transport activities.

4.3.S Summary of Technical Division costs:

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Total new items	$0.0K	$0K	0.0

4.4 Fermilab ES&H Section

4.4.1 The ES&H Section will provide assistance with safety reviews and safety approvals in order to help ensure the experiment will be conducted in a safe manner.

V. SUMMARY OF COSTS

Source of Funds [$K]	Equipment	Operating	Personnel (person-weeks)
Particle Physics Division	$350K	$0.0K	20
Accelerator Division	0	0	38
Computing Division	0	0	0
Technical Division	0	0	0
Workplace Development Section	0	0	0
ES&H Section	0	0	0
Totals Fermilab	$350.0K	$0.0K	56
Totals Non-Fermilab	$90K		

VI. SPECIAL CONSIDERATIONS

6.1 The responsibilities of the Optical Cavity PI's and procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters" (PFX) (http://www.fnal.gov/directorate/documents/index.html). The Physicists in charge agree to those responsibilities and to follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating a Partial Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The optical cavity PI's will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.

6.3 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.4 All items in the Fermilab Policy on Computing (http://computing.fnal.gov/cd/policy/cpolicy.pdf) will be followed by experimenters.

6.5 The Optical Cavity PI's will undertake to ensure that no PREP and computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

6.6 Each institution will be responsible for maintaining and repairing both the electronics and the computing hardware supplied by them for the experiment. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.8 At the completion of the experiment:

6.8.1 The Optical Cavity PI's are responsible for the return of all PREP equipment, Computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the CHASE Spokespersons will be required to furnish, in writing, an explanation for any non-return.

6.8.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters. A hazard analysis is attached in Appendix I. No hazardous wastes will be generated by the project. Materials such as the laser and vacuum pipe will be re-used in the optical cavity experiments for which this R&D is being performed.

6.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied, including computer printout and magnetic tapes.

6.8.4 An experimenter will report on the test effort at a Fermilab All Experimenters Meeting.

SIGNATURES:

Aaron Chou (co-PI), Fermilab — / /2010

Mike Lindgren, Particle Physics Division — 7 /16/2010

Erik Ramberg, Particle Physics Division — 7/16/2010

Roger Dixon, Accelerator Division — 7 /20/2010

Giorgio Apollinari, Technical Division — 7 /20/2010

Nancy Grossman, ES&H Section — 7 /20/2010

Dan Bauer, Center for Particle Astrophysics, Fermilab — 7 /14/2010

Greg Bock, Associate Director, Fermilab — 7 /26/2010

Stephen Holmes, Associate Director, Fermilab — 8 / 1 /2010

APPENDIX I - Hazard Identification Checklist

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
	Beam line magnets	X	Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	X	high voltage		
	Liquid Argon TPC		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
	inside diameter	Type:			
	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
2'	inside diameter		temporary use		Beryllium (Be)
Atm–10-3 torr	operating pressure	Type:			Lithium (Li)
BK7 + Fused Silica	window material	Strength:			Mercury (Hg)
0.13"	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		Scintillation Oil		Uranium (U)
X	Temporary installation		PCBs		Other :
	Calibration		Methane	**Mechanical Structures**	
X	Alignment		TMAE	X	Lifting devices
Type:	Innolight Mephisto		TEA		Motion controllers
Wattage:	2W, cw		photographic developers		scaffolding/elevated platforms
class:	IV		Other:		Others

APPENDIX II Laser Hazard Requirements

All personnel on the project who deal with the laser will be required to go through safety training suitable for the Class IV status of the laser.

Further information from Ray Tomlin follows:
The people that oversee safety in Accelerator Division laser labs are listed here.
Ray Lewis, John Anderson. Also, Tim Miller has a nice web page:
http://www-esh.fnal.gov/CourseHandout_Mat/laser_safety_20081028.ppt

Lab laser safety guidelines are here:
http://www-esh.fnal.gov/FESHM/5000/5062.1.pdf

Ray Tomlin operates the LINAC laser labs in AD and has been even more conservative than the ES&H folks striving for zero exposure if possible.
Rich Ruthe (TD, SSO) has attended the class 4 laser committee meetings sponsored by Tim Miller so he has had at least indirect input on the operation of this laser and all the class 4 lasers on site.

The laser to be used for the optical cavity test bench is a Mephisto Innolight which produces a 2W continuous wave beam at 1064nm. This laser was purchased by Aaron Chou for use in optical cavity R&D and has been operated in the Linac Laser Lab overseen by Ray Tomlin. A hermetic shutter system will be installed on this laser to block the beam when an interlock is tripped. Such a system is already in place in the Linac Laser Lab. The entirety of the interlocked area of MP will be considered a laser room, and laser safety goggles will be required. Specific laser safety procedures will be implemented in coordination with Tim Miller and the AD safety group.