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LIGO Laboratory / LIGO Scientific Collaboration

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Preliminary Design – AdvLIGO PSL Laser Diode Room

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1 Introduction

The document describes the preliminary design for the laser diode rooms that are required for the Advanced Ligo Lasers that are part of the Pre-stabilized Laser subsystem. Similar rooms are also required for the Enhanced Ligo laser, so the design and construction of the rooms is being accelerated so that they will serve the needs of Enhanced Ligo as well. These facilities are designed to meet the full requirements of the Advanced Ligo PSL subsystem.

2 Design summary and changes since conceptual design

2.1 Room Location

In the conceptual design, the laser diode rooms were located in the Mechanical Areas, adjacent to the Clean Purge Air compressors and the PSL chillers (for both the laser heads and the pump diodes) were located on top of the concrete-block air handler plenum inside the Mechanical Area.

During or just before review of the design requirements and conceptual design, an error was discovered in the LLO conceptual design. Apparently, the location of the Clean Purge Air compressor was incorrectly placed in the design drawing about six feet farther from the proposed Laser Diode Room location than its actual location. Thus, the proposed Laser Diode Room can not be located as shown in *eLigo and AdvLigo PSL Pump Diode Room Design Requirements and Conceptual Design*, LIGO-T070105-00-W.

Realization of this oversight, coupled with the desire to keep the LHO and LLO configurations as similar as possible, led to deeper consideration of alternate locations for the Laser Diode Rooms. In this preliminary design, the Laser Diode Rooms are located inside the Short Term Storage Areas which are adjacent to the Receiving Areas in the Operations Support Buildings. The PSL chillers are located in the Gowning Room at the entrance to the Laser Diode Rooms in the Short Term Storage Areas. Advantages of this location over the mechanical area include:

i. Even at LHO the proposed location inside the Mechanical Area constrained access to the Mechanical Area for large items via the exterior roll-up door. At LLO, even the smaller room (sized for one laser rather than two) simply would not fit without blocking the door to the Large Item Access Area and most of the access to the Mechanical Room via the exterior roll-up door.

ii. When located in the Mechanical Rooms, the Laser Diode Room (at LLO) or the Gowning Room at the entrance to the Laser Diode Room (at LHO) would block electrical panels on the wall adjacent to the Large Item Access Area. The panels would either have to be moved or accommodated inside the new rooms. At LLO, if the panel were not moved, switching the lights in the LVEA would require entering the Laser Diode Room. This is undesirable from both a cleanliness and laser safety perspective.

iii. Personnel access to the chiller location proposed in the conceptual design was via a vertical ladder which is less than desirable for safety considerations. The location proposed in this design will be significantly easier to access for installation and maintenance. Furthermore, both the piping runs from the chillers to the Laser Diode Room and the piping runs from the chillers to the laser heads will be significantly shorter.

iv. The lengths of the cooling lines and the fiber bundles will be significantly shorter (for all three interferometers). If the cables and laser head cooling lines in both configurations are routed to the raceways below the output modecleaner tube, the runs should be about 70 feet shorter with the Short Term Storage Area location. With the Laser Diode Room chillers located in the Gowning Area, the distance from the chillers to the racks will only be about 15 ft. where in the Mechanical Area the hoses would run from the top of the air handler plenum to the plan-west wall then along the wall to the plan-north wall and across to the Laser Diode Room - a much longer run.

v. The Short Term Storage Area is closer to the 4-km PSL areas. Walking between the two areas will be shorter and less circuitous. Access from the control room and other OSB lab areas will also be easier. The touch-screen control panel for the laser system will be located in one of the racks inside the Laser Diode Room. Error messages and alarms will appear on this screen, making location closer to the control room desirable.

The Laser Diode Rooms are located as shown in Figure 1 and Figure 2.

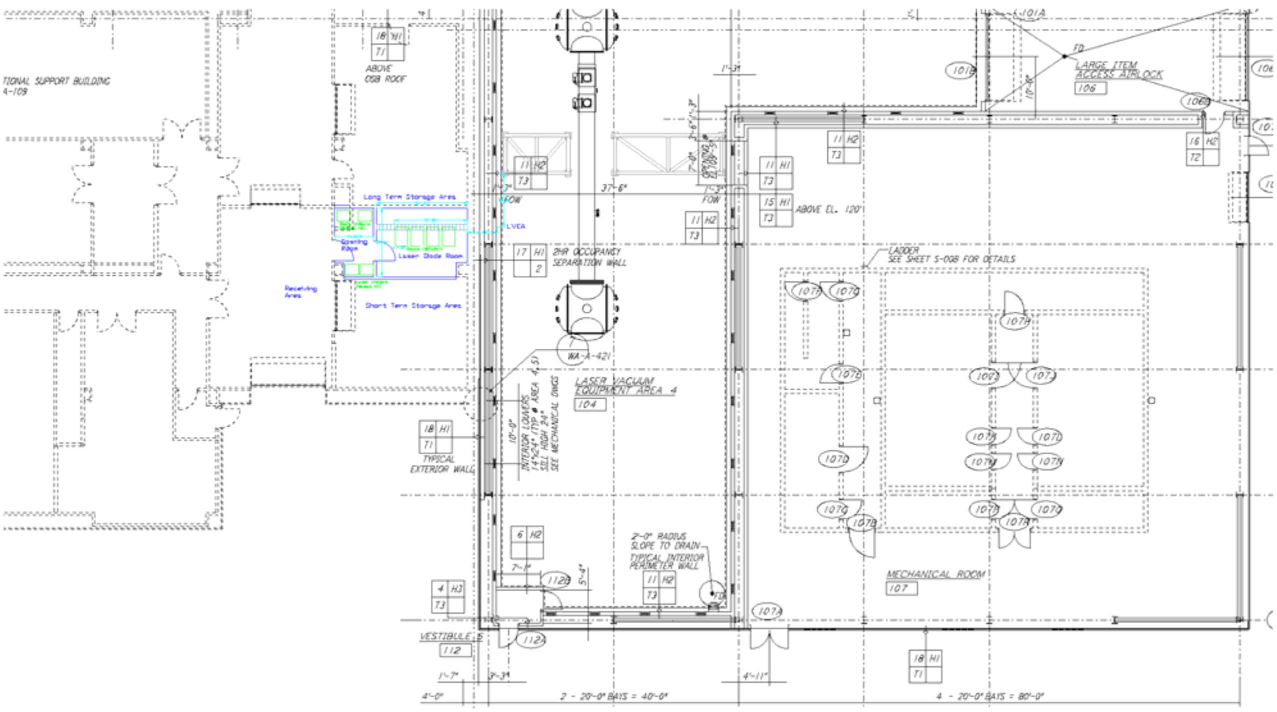

Figure 1 Overview of Laser Diode Room location in the OSB

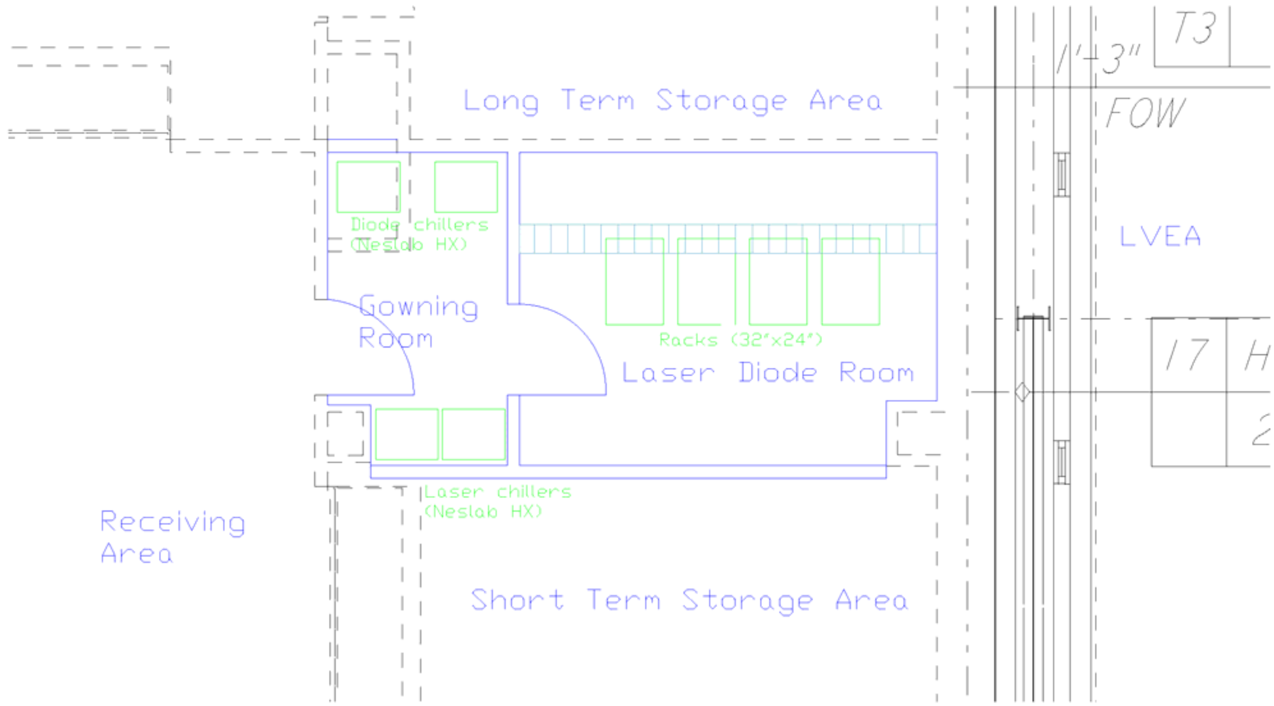

Figure 2 Location of Laser Diode room at the plan-north end of the Short Term Storage Area (both at LHO and LLO).

2.2 Room Size

The room sizes are almost identical to what was proposed for LHO in the conceptual design, except that the Gowning Area is now the full width of the Laser Diode Room. When located in the Mechanical Area its width was reduced to increase access via the roll-up door and to allow access to the electrical panels on the adjacent wall.

The length of the laser diode room is determined by the requirement for four racks (at LHO where there are two laser systems), 3 ft. of access at the entrance door end and 2 ft. of clearance at the opposite end so that 20-kg diode boxes can be lifted into and removed from the racks. The width of the room allows 3 ft. behind the racks for making the electrical, water, and fiber connections. There is about 52 in. of space in front of the racks to allow for a cart and installation and removal of the diode boxes and power supplies by two people.

The ceiling height inside the Laser Diode Room and Gowning Area is 10 ft. min. Note that the ceiling height in the Short Term Storage Area is 20 ft.

2.3 Cleanliness

Same as before except that consultation with LZH personnel has given us better information regarding the connection of the fibers to the diode boxes. They have requested class 1000 working conditions at the locations where the connections will be made. Connecting the fibers is similar to connecting an SMA connector.

The portable lift table with portable HEPA unit is thus replaced with two people manually lifting the power supplies and diode boxes into position on shelves in the racks, then connection of the fibers with a stream of clean air provided by a HEPA blower unit that is similar to one of our HEPA vacuum cleaners run in reverse (design details TBD).

HEPA panels with variable-speed controllers mounted in the ceilings of both the Gowning Area and the Laser Diode Room will introduce filtered air that will be exhausted through adjustable louvers near floor level along the plan-south walls of both rooms (exhausting into the remaining Short Term Storage Area).

2.4 Electrical

As in the conceptual design with the following clarifications: The racks in the Laser Diode Rooms will hold the laser diode boxes (with integral thermo-electric coolers) and their power supplies. The room will also hold a crate for digital and analog I/O (likely a PCI crate which is similar to a VME crate, but newer technology).

The single-phase (input power) power supplies that generate the 2V DC output for the laser diode bars and the TECs draw a maximum current of 16 amps at 110V (1760W) and they deliver a maximum output power of 1505 W (86% efficiency). One power supply is required per diode box and there are four diode boxed per laser. An additional two power supplies are required for the TECs for all four diode boxes.

The 35W intermediate power stage utilizes two power supplies with 98% efficiency that deliver a maximum output power of 600W.

Convenience outlets will be located as required by local codes, approximately every 6 ft. along the walls and approximately 18 in. above the floors.

Power is also required for the room lights and the variable-speed HEPA filter fans.

Power is required for the chillers for the laser diode room racks and for the laser head chillers.

Table 1 Electrical requirements summary.

Item	**Number per PSL**	**Input voltage**	**Max. input current**
Diode power supply	4	110 V	16 Amps
TEC power supply	2	110 V	5 Amps
VME crate	1	110 V	10 Amps
Convenience outlets	TBD	110 V	TBD
Room lights	TBD	TBD	TBD
HEPA fans	TBD	TBD	TBD
Laser diode room chiller Neslab HX-150 (TBD)	1	208-230 V, 1-phase	17 Amps
Laser head chiller Neslab HX-75 (TBD)	1	208-230 V, 1-phase	12 Amps

2.5 Heat Loads

2.5.1 Heat to be removed by laser diode room chillers

One diode bar has a maximum optical output of 45 W. The diode bar consumes 130 W of electrical power (65 Amps at 2V). Thus, the heat that must be removed by the TECs is approximately 85 W (130 – 45 W).

The coefficient of performance for the TECs (heat pumped/input electrical power) is 0.62, thus the TECs generate 137 W of heat to cool one diode bar. This heat will be removed by the LDR cooling water.

There are seven diode bars per diode box, and four diode boxes per laser. The 35-W intermediate stage requires an additional four diode bars, so there are a total of 32 per laser.

Thus the total heat load that must be removed by the laser diode room chiller is 32 x 137 = 4384 W per laser. This sets the cooling requirement for the laser diode room chillers.

2.5.2 Heat to be removed by laser diode room HVAC

Our strategy is to draw conditioned air from the surrounding space, the Short Term Storage Area and blow it into the Laser Diode Room and Gowning Room using variable-speed HEPA filtered fans assemblies in both rooms. The HEPA-filtered air would be exhausted through louvers near floor level on the plan-south wall of both rooms. The temperatures in the rooms will likely rise as much as ten degrees above the ambient Short Term Storage Room temperature and can be regulated by adjusting the speed of the HVAC unit fans.

2.5.2.1 Laser diode and TEC power supplies

The power supplies that drive the laser diode boxes draw a maximum of 1760 W and deliver a maximum of 1505 W (86% efficiency). Thus, at maximum output power they each dissipate a maximum of 255 W of heat into the room. There are six supplies per laser (four diode boxes and two for the TECs) so 4 x 255 = 1530 W.

The power supplies for the 35-W intermediate power stage are 98% efficient switching power supplies that deliver a maximum output power of 600 W. There are two of them, so the maximum power dissipated into the room is 24W.

The total heat load dissipated into the room by the laser diode and TEC power supplies is 1554 W.

2.5.2.2 Digital and analog I/O crates

The design of the electronics that will interface with the laser diode boxes to provide control signals and read status signals is currently in progress. A Beckhoff interface module is being developed by the Hannover group and the CDS group at Caltech is working on interfacing with Beckhoff module.

Because this work has not progressed to the state where the Beckhoff interfacing is a “sure bet,” this design considers a PCI-based solution with digital and analog I/O modules in PCI crates located inside the laser diode room (this is similar to the iLigo solution which utilized VME crates and I/O modules). The large number of expected analog read-back signals (~200 per laser) necessitates two crates per laser.

If the Beckhoff interface issues are resolved and the module and provide the digital and analog I/O interface via EPICS, the PCI requirements would be significantly reduced or eliminated. The two PCI crate solution thus provides an upper limit for the heat load estimates.

The PCI crates that have been selected by the CDS group at Caltech are driven by power supplies that consume 725 W of electrical power (6.3 amps at 115 V). Two PCI crates per laser would thus generate 1550 W of heat in the laser diode room.

2.5.2.3 Personnel working in the laser diode room.

We estimate this heat load based on a maximum of four people working in the laser diode room. This might occur during initial installation. At 160 W per person, this would introduce an additional heat load of 640 W in the laser diode room.

2.5.2.4 Total heat load for laser diode room HVAC

The expected heat loads for the laser diode rooms are summarized in Table 2, below. Note that the Personnel and room light loads are note expected to exist during normal operation when the room will be un-occupied with the lights out. Also, as noted above, if the interface with the Beckhoff module is successful, the load from the I/O crates will be significantly reduced.

Table 2 AdvLIGO HVAC heat load in laser diode room

Item	**Heat load**
Diode and TEC power supplies	1554 W
Digital and analog I/O crate	1550 W
Personnel	640 W
Room lights (TBD)	TBD
Total for one laser (LLO)	**3.8 kW plus room lights**
Total for two lasers (LHO)	**7.5 kW plus room lights**

2.5.3 Heat to be removed by Gowning Room HVAC

If Neslab HX-150 chillers (4.5 kW cooling capacity) with water-cooled condensers are utilized for the Laser Diode Room and located in the Gowning Room, they will dissipate ~1500 W of heat per chiller into the room

If Neslab Hx-75 chillers (2 kW cooling capacity) with water-cooled condensers are utilized for the laser heads and located in the Goening Room, they will dissipate ~670W of heat per chiller into the room. Thus, not counting the Gowning room lighting, the heat load in the Gowning room is expected to be about 2.2 kW at LLO and 4.4 kW at LHO.

2.5.4 HVAC strategy

For the AdvLIGO lasers, approximately the HVAC requirements at LHO are approximately 7 kW for the laser diode room and 4.4 kW for the Gowning Room where the chillers are located.

This cooling load could be accommodated by installing air conditioning units like the ones that were recently installed at LHO for the Mass Storage Area. These are Mitsubishi “Mr. Slim” split-ductless units with the compressors mounted outside the building and the fan unit mounted on the wall or ceiling of the room to be cooled. LHO installed 3-ton units that provide about 10 kW of cooling capacity. If one unit were installed in the Laser Diode Room and one in the Gowning Room, there would be sufficient cooling capacity for each room and redundancy in case of failure of one unit could be achieved by temporarily keeping the door between the two rooms open. These units have the desirable feature that repairs to the compressors would not require access to the clean space of the Laser Diode Room. LLO, where only one laser will be installed, could install smaller air conditioning units.

Note that the fan units should not be installed directly over the electronics and laser diode racks where dripping water due to condensation might land on the electronics.

2.5.4.1 eLigo strategy

For eLigo, the thermal loads are much lower since only a single 35-W laser will be required. The combined laser head and laser diode cooling requirements is only about 700 W. One chiller that circulates water through both the laser diode cold plates and the 35-W MOPA heads is envisioned. Thus a single chiller such as the HX-75 with 2 kW cooling capacity will be sufficient. If this is located inside the Gowning area, the heat load in that room will be about 700 W. The Laser Diode Room heat load is expected to be about 1400 W (670 W for diode and TEC power supplies, 750 W for the I/O crate, if required).

During eLigo, we plan to just use the HEPA air that draws from the Short Term Storage Area and exhausts back to the Short Term Storage Area via louvers near floor level. The LHO architect who investigated HVAC loads for the Laser Diode Room estimated that 1500 W of heat plus 640 W for personnel and the lighting heat load could be removed from the laser diode room by four 2’ x 4’ HVAC filter/blower units operating at half speed (325 CFM). The expected Laser Diode Room temperature with this heat load and HEPA flow would be about 7.5 deg. F above the Short Term Storage Area. Thus it does not appear that dedicated air-conditioning units such as the split-dictless units envisioned for AdvLIGO will be required for eLigo.

2.6 Lighting

Lighting levels in the Gowning Area should be at least 20 foot candles. I the Laser Diode Room, lighting should be at least 30 ft candles in front of and behind the racks. The level should be able to be reduced to reduce electrical consumption and heat load by switching of most of the lighting, but leaving enough for web-cam surveillance of the room. This could also be achieved by “night lights” installed in the convenience outlets along the walls.

2.7 Fiber optic access

The minimum bend radius for the fiber bundles is 30 cm (~12 in.). A cable raceway, approximately 12 in. wide and 4 in. deep is installed above and at the back of the racks. The fibers will be attached to the diode boxes at the back of the racks, then loop into the raceways. Conduits, approximately 4 in. diameter, are installed in the walls at the plan-east end of the Laser Diode Room at the end of the cable raceway. The fiber bundles pass through these conduits to the LVEA where they follow raceways to a “pipe bridge” opposite the main pipe bridge from the mechanical area down to the raceways below the output modecleaner tube. They then follow either the electronics raceways or the vacuum equipment cable raceways to the PSL tables. Details of the LHO fiber runs are given in Appendix 1.

For H1, the approximate length from the bottom of the farthest rack to the farthest corner of the PSL optical table is 190 ft. For H2 this length is 275 ft. The L1 length should be close to the H1 length, depending on the details of the routing.

2.8 Cooling water piping access

For the diode boxed in the Laser Diode Room, the chillers will be located either in the Gowning Area or adjacent to the Gowning Area in the Short Term Storage Area. In either case, the piping will be routed to the plan-north wall of the Laser Diode room near floor level, then across the floor (plan-north to plan-south) between the racks, where it will be plumbed to the diode boxes.

2.9 Laser safety/access control

As in the conceptual design. The laser warning sign and reader would likely be mounted inside the Gowning Area at the entrance to the Laser Diode Area. This would allow servicing the Laser Diode Room chillers in the Gowning Area (if they are located there) without involving the laser safety/access control protocol.

The observatory laser kill buttons would shut down the power to the power supplies for the diode boxes.

2.10 Monitoring and services

As in the conceptual design except that monitoring of the humidity in the Laser Diode Area is also required. The diode modules require less than 60% relative humidity. Monitoring the humidity may also give an indication of a water leak.

The temperature, humidity monitoring may be accomplished by installing Davis Instruments weather unit, similar to what is installed in the Mass Storage Room and Mid and End Stations at LHO. The software is already written to download the unit’s data to EPICS.

The phone jacks shall be RJ45 to be compatible with digital phone systems.

3 Chillers

3.1 Laser Diode chillers

Each laser requires one laser diode chiller of about 5 kW cooling capacity. The Neslab HX-150 chiller has about this capacity and is available with a water-cooled compressor that will minimize the heat dumped into the chiller’s local environment. Locating the chillers in the Gowning Area is desirable from an acoustic perspective since the doors can be more readily sealed than the roll-up doors of the adjacent Short Term Storage Area. If the chillers are located in the Short Term

Storage Area, additional acoustic mitigation measures may be required. This will not likely be known until the AdvLIGO detectors are operating near design sensitivity. In either location, the chillers will likely require vibration isolation. This will likely be accomplished by mounting the chillers on a spring isolators with approx. 3 Hz. resonance frequency.

3.2 Laser head chillers

Each laser system is pumped by about 1500 W of laser radiation that is transported by the fiber bundles from the laser diodes. About 200 W of this heat is removed by the main laser output. The remainder is mostly transferred to the laser head cooling water and removed by the laser head chiller. One chiller is required per laser system. Depending on the length of the cooling lines, the Neslab HX-75 chiller (2 kW cooling capacity) may be sufficient for this application.

One location for the laser head chillers is adjacent to the Laser Diode Room or Gowning Room in the Short Term Storage Area. The chiller lines would be routed along the same path, but separated from the fiber bundles.

Another possible location is the existing chiller closets. The closets at LHO have been treated acoustically to be acceptable for the iLigo PSL chillers. It is unlikely, but possible, that they may be suitable for the AdvLIGO laser head chillers. They have the advantage that they are close to the laser heads.

A third possible location is inside the OSB Optics Labs which are accessible via the under-slab conduits and LVEA interstitial spaces.

Details of the chiller designs are currently under investigation by the people who are building the lasers at LZH in Hannover

4 Other issues

4.1 Return air plenum

There is a shared return air plenum for the Short Term and Long Term Storage Areas that would occupy the plan-northwest corner of the gowning room. Presently there is a register near ground level on the plan-east side of the plenum in the Short Term Storage Area, and presumably another in the Long Term Storage Area.

This plenum would be modified as shown in **Error! Reference source not found.** with a partition at ceiling level. The return air register would then be installed in the remaining section of the plenum that is above the level of the Gowning Area ceiling.

4.2 Re-configuration of racks in Short Term Storage Area

The racks in the Short Term Storage Area would need to be re-configured. One option is to move the racks on the plan-north wall where the Laser Diode Room will go to the plan-south wall. Another option is to just shift the racks 10 ft. in the plan-south direction so that they are adjacent to the Laser Diode Room wall.

At LHO, some of the items that were stored in the Short Term Storage Area might be moved to the Mechanical Room.

4.3 Issues specific to LLO design

The routing of the fiber optics and chiller lines at LLO may differ from the LHO routing because LLO doesn't have a second PSL to consider and because cable raceways and bridges are already in place for the electronics that are located in the Long Term Storage Area.

Appendix 1 Fiber and cooling line routing details

Details of the fiber and cooling line routing between the Laser Diode Room and the PSL tables are given in Figure 3 through Figure 8 and **Error! Reference source not found.** and **Error! Reference source not found.**, below.

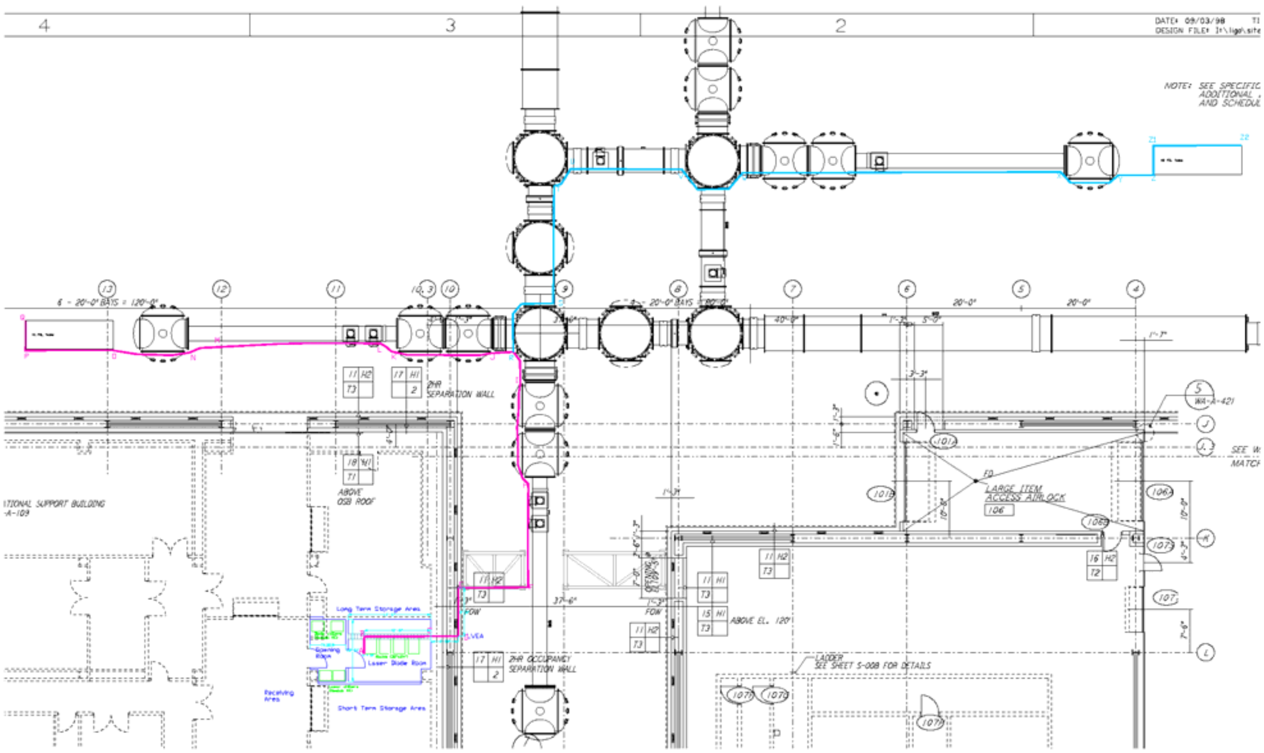

Figure 3 Fiber and cooling line routing overview. H1 is shown in magenta and H2 in light blue.

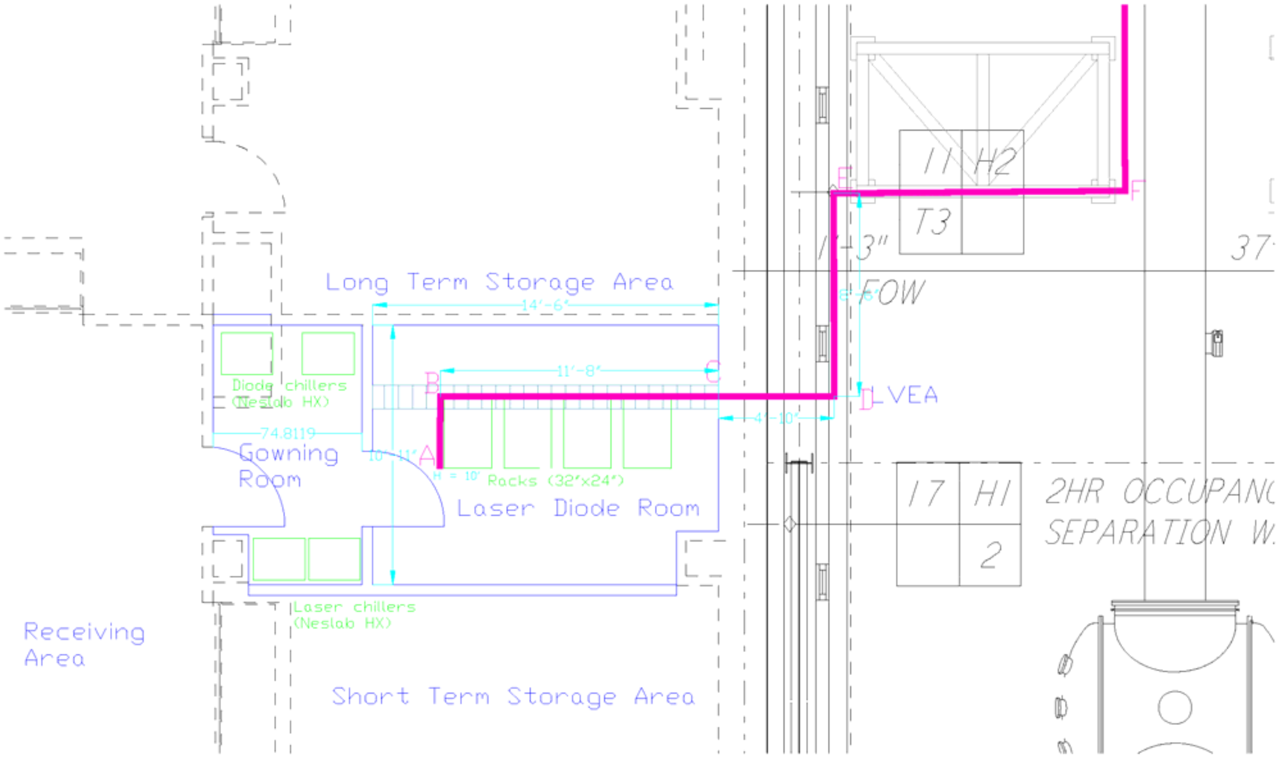

Figure 4 Fiber and cooling line routing – Laser Diode room to pipe bridge in LVEA.

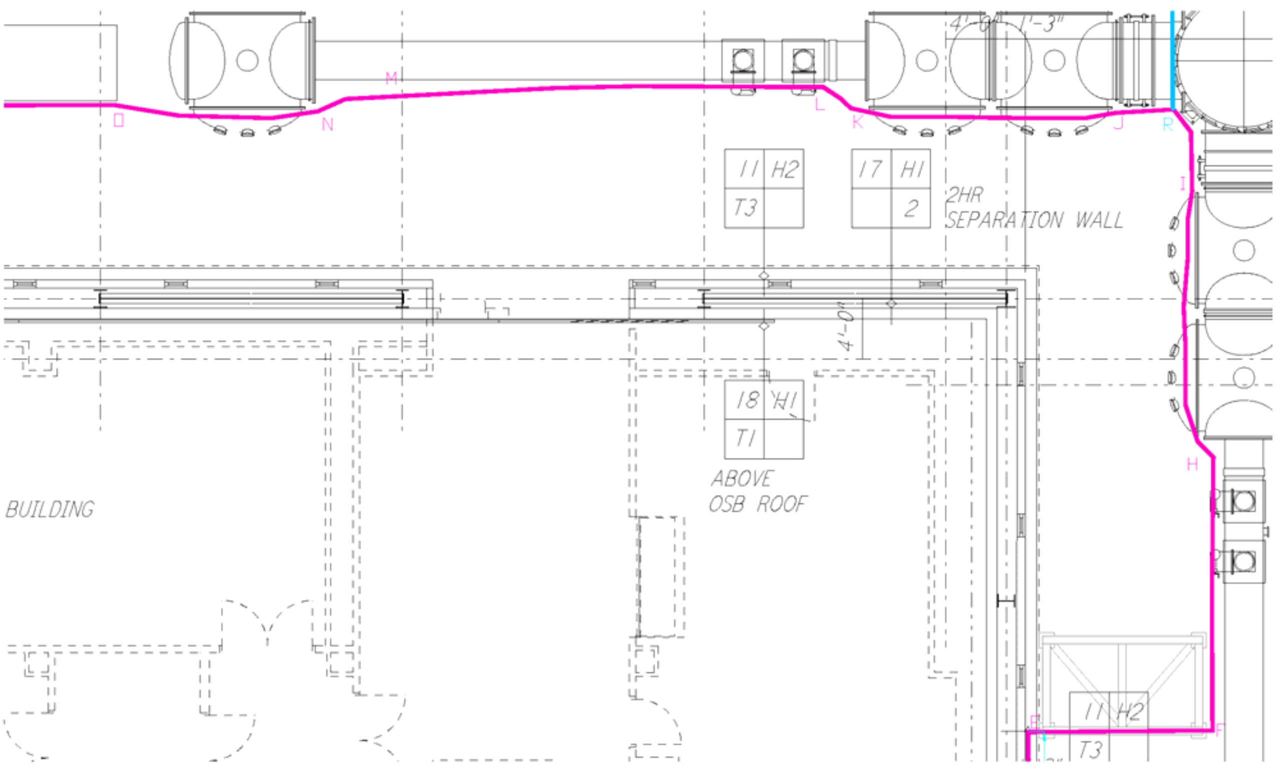

Figure 5 Fiber and cooling line routing – LVEA pipe bridge toward the PSL tables for H1 (magenta) and H2 (blue).

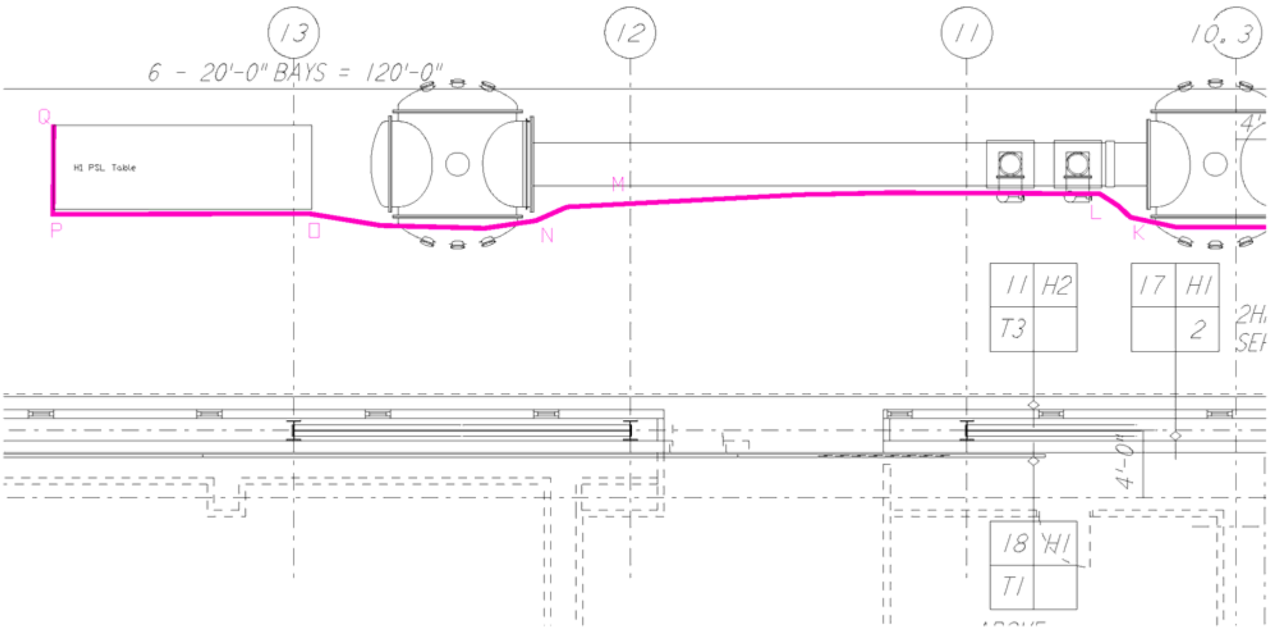

Figure 6 Fiber and cooling line routing – H1 HAM2 to PSL table.

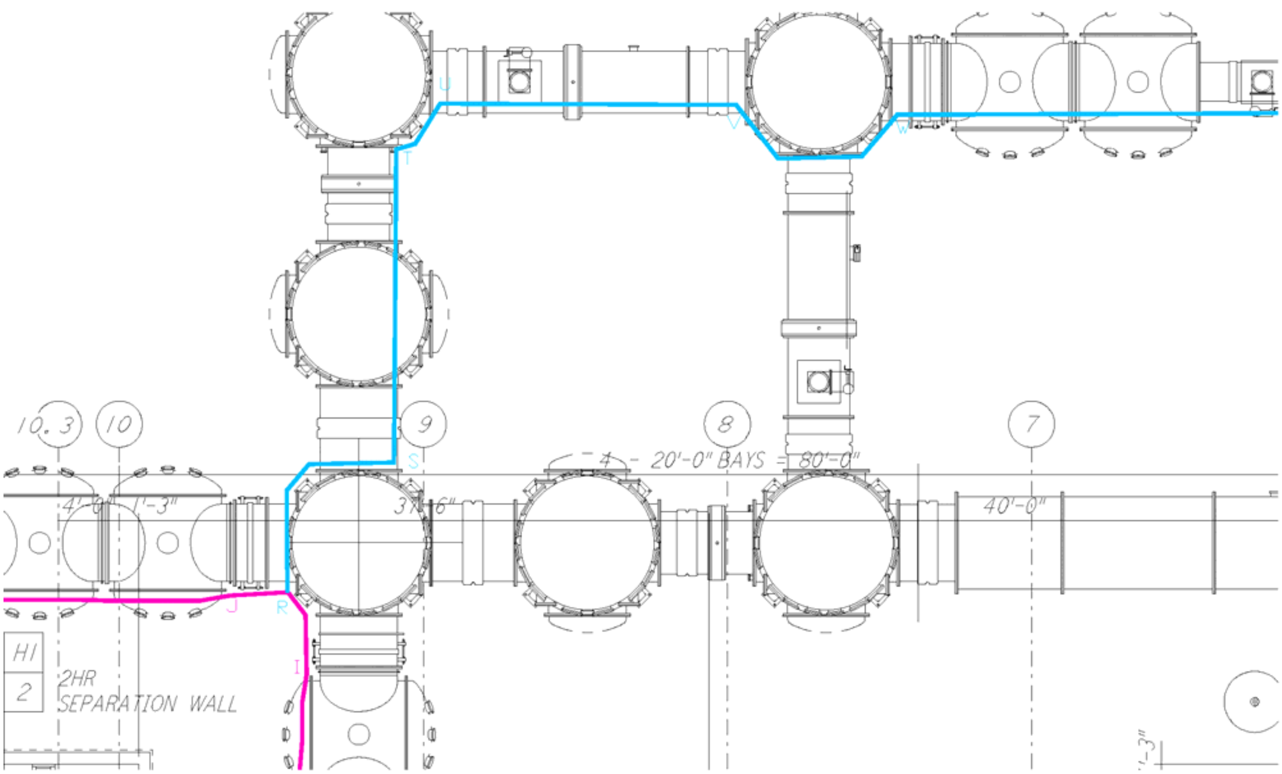

Figure 7 Fiber and cooling line routing – HAM4 toward H2 PSL table.

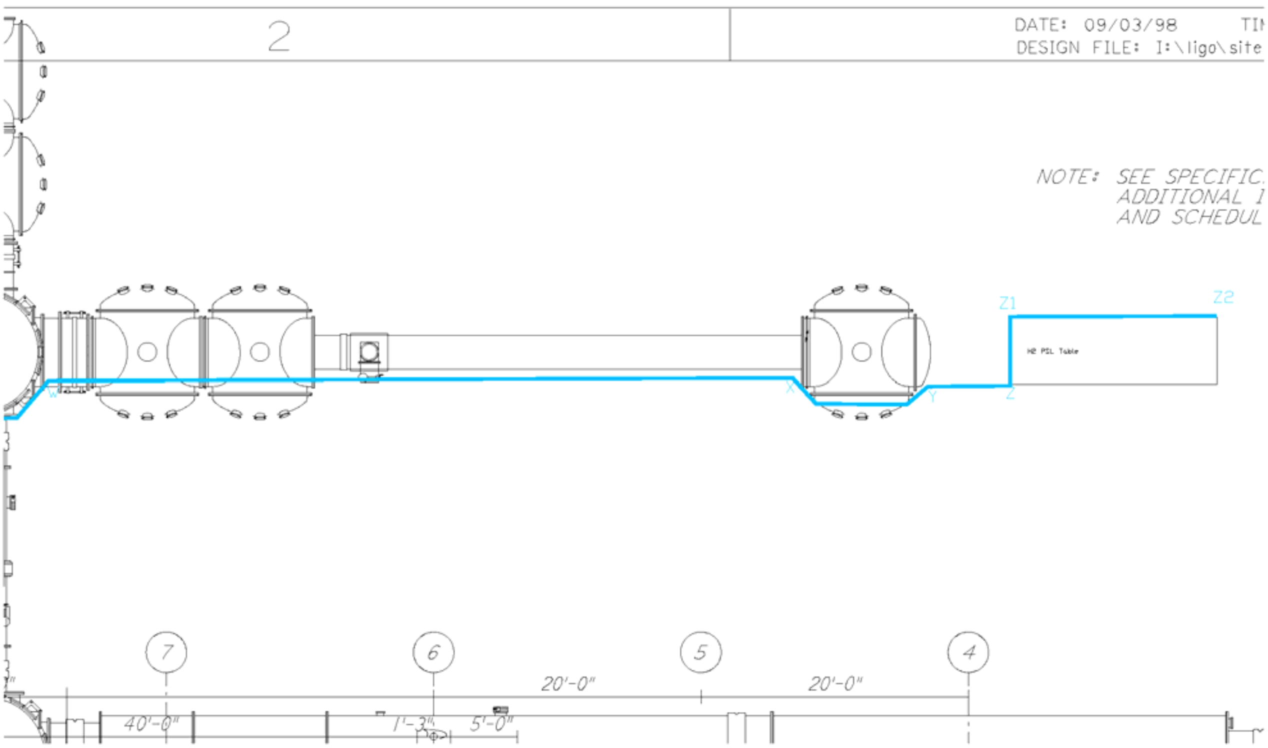

Figure 8 Fiber and cooling line routing – HAM9 to H2 PSL table.

Table 3 Lengths for H1 fiber and chiller line routing.

POINT(S)	DESCRIPTION	LENGTH
A(height)	Diode room floor -SW corner- height	10’
A-B	W wall of left rack	3’
B-C	On cable tray to LDR wall	11’ 8’’
C-D	Through wall Diode Room to LVEA	4’ 10’’
D-E	Along wall to new cable bridge	8’ 6’’
E-F	Over cable bridge	11’ 1’’
F(height)	Drop to cable trays	9’
F-H	To bottom of HAM5	20’ 9’’
H-I	Under HAM5 and HAM4	15’ 4’’
I-R	To corner of BSC2 – split point from H2 fiber run	6’ 5’’
A-R	**Common fiber run with H2 from A to R**	**100’ 7’’**
R-J	Corner of BSC2	4’

J-K	Under HAM3 and HAM2	19’ 5’’
K-L	Curve in cable tray	3’ 9’’
L-M	Around HAM2	26’ 8’’
M-N	Rise in cable tray	3’ 3’’
N-O	Under HAM1 to SE edge of PSL table	6’
O-P	Along S side of PSL table	16’
P(height)	Up to table level	5’
P-Q	Across width of table	5’
	Note: A through E have only been calculated on drawings, while the others have been measured in the LVEA	
TOTAL	**Full H1 fiber run**	**189’ 8’’**

Table 4 Lengths for H2 fiber and chiller line routing segments.

POINT(S)	**DESCRIPTION**	**LENGTH**
A(height)	Diode room floor -SW corner- height	10’
A-B	W wall of left rack	3’
B-C	On cable tray to LDR wall	11’ 8’’
C-D	Through wall Diode Room to LVEA	4’ 10’’
D-E	Along wall to new cable bridge	8’ 6’’
E-F	Over cable bridge	11’ 1’’
F(height)	Drop to cable trays	9’
F-H	To bottom of HAM5	20’ 9’’
H-I	Under HAM5 and HAM4	15’ 4’’
I-R	Split from H1 fiber run at BSC2	6’ 5’’
A-R	**Common fiber run with H1 from A to R**	**100’ 7’’**
R-S	Around BSC2	12’ 1’’

S-T	From BSC2 to BSC8	19’ 2’’
T-U	Around BSC8	8’
U-V	From BSC8 to BSC4	21’
V-W	Around BSC4	13’
W-X	From BSC4 to HAM7	59’ 2’
X-Y	Around HAM7	12’
Y-Z	From HAM7 to SW corner of H2 PSL table	3’
Z-Z1	To NW Corner of PSL table	5’
Z1-Z2	To NE corner of PSL table	16’
Z2(height)	To table level	5’
	Notes: 1)A through E have only been calculated on drawings, while the others have been measured in the LVEA 2) All corners are really arcs satisfying the fiber turning radius	
TOTAL	**Full H2 fiber run**	**274’**