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Laser Beam Failure Mode Effects and Analysis (FMEA) of the Solid State Heat Capacity Laser (SSHCL)

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NATIONAL IGNITION FACILITY PROGRAMS

Mail Station: L-449
Ext: 3-3077

11/24/2008

TO: Lisa Woodrow, Directorate Assurance Manager

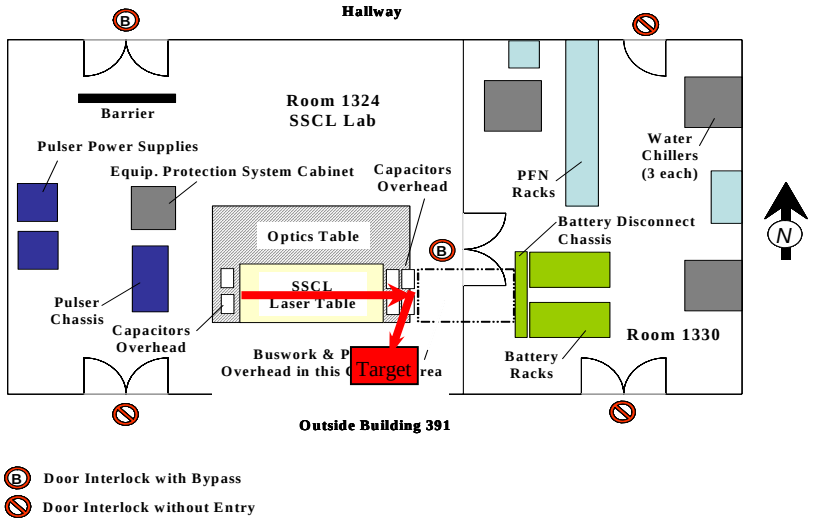
FROM: Jamie J. King, Directorate Laser Safety Officer

SUBJECT: Laser Beam Failure Mode Effects and Analysis (FMEA) of the Solid State Heat Capacity Laser (SSHCL)

A laser beam related FMEA of the SSHCL was performed to determine potential personnel and equipment safety issues. As part of the FMEA, a request was made to test a sample of the drywall material used for walls in the room for burn-through. This material was tested with a full power beam for five seconds. The surface paper material burned off and the inner calcium carbonate turned from white to brown. The result of the test is shown in the photo below.

The SSHCL has a 20kW average power beam at 1062nm. It is pumped by sixteen laser diode arrays (LDA) operating at 808nm. The LDAs diverge very rapidly and the potential hazard from the infrared radiation is mitigated through the use of designated Laser Protective Eyewear (LPE) and utilization of a laser curtain barrier between the laser and the operator station. The LDAs create a thermal load which is removed through the use of liquid cooling. Damage could occur to the LDAs with a loss of cooling. The laser is programmed to shut down on loss of pressure, loss of flow, high temperature in the cooling system, or on a shorted circuit.

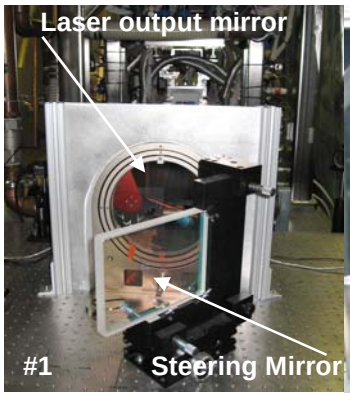
The laser itself is a very simplified setup with respect to the laser beam. The laser is made up of the LDAs, the lasing medium, and two mirrors. The laser beam is directed out of the laser cavity to a steering mirror which directs the laser beam to the target. A drawing of the laboratory setup is shown below with the laser beam path indicated as a red line.

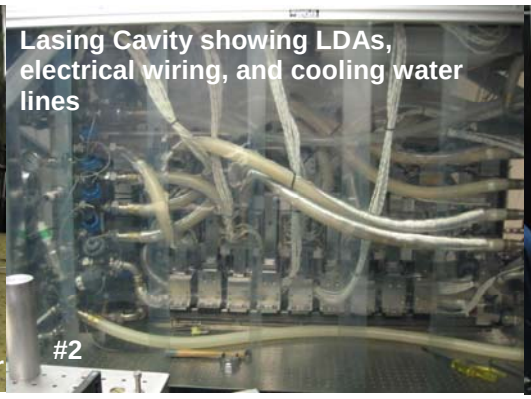


From the drawing above, it is evident that the only real potential for a laser beam related failure would be from by a misdirected beam or missing target. These would include; a missing mirror, a misaligned mirror, failure of the laser to shutdown, or a missing target. All of these failure modes and mitigations are on the attached SSHCL FMEA Form and are described below.

With a missing steering mirror, the beam would impart its energy on the wall and cause damage as observed in the drywall material test. If the beam were misdirected back at the laser, it would cause the laser to shut down on the fault trips described previously. Any of these safety triggers would prevent significant damage to the laser. There is not a possible path for the laser beam to be misdirected back to the laser operator's location, except through the laser which would cause one of the shutdowns. The three photos below show:

1.) The output of the laser with the steering mirror.
2.) A side view of the laser showing the LDAs, electrical wires and the cooling lines.
3.) The operator station which is located behind a laser curtain and the mass of the laser.

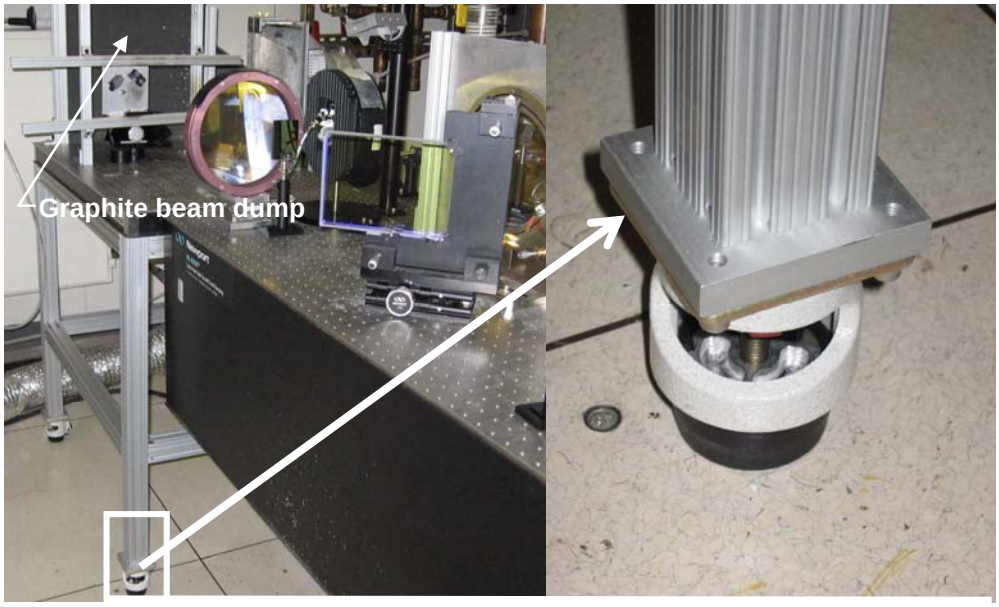




The shot time for the laser is set with the number of pulses the laser will fire. The maximum continuous pulses for a shot are 2000. Should the laser fail to shut down, significant damage

could occur to the lasing medium's ceramic slabs. In a situation such as this, the laser operator would manually shut the laser down from the operator station.

If the target were not installed, the laser energy would impart on the graphite beam dump rigidly mounted to the target stand. This material has been struck by the laser energy and shows minimal physical evidence. The stand is affixed to the target table that cannot be easily moved



All of the discussed potential failure modes were found to be adequately mitigated. If you have any questions or concerns relating to this subject, please contact me at extension 3-3077. Thank you.

Sincerely

Jamie J. King

Enclosure

Cc:
G. Bonanno
C. Barty
B. Yamamoto
P. Pax
K. Cutter

Solid State Heat Capacity Laser Failure Mode and Effects Analysis

SYSTEM/ SUBSYSTEM	FAILURE MODE	CAUSE	EFFECTS	PERSONNEL HAZARD LEVEL[1]	LIKELIHOOD OF OCCURRENCE[2]	MITIGATION (SHORT DESCRIPTION)
Solid State heat capacity laser (SSHCL) Steering mirror	Missing steering mirror	Mirror not replaced by worker	Laser beam is directed to east wall causing burning of drywall material	Minor	Improbable	SSHCL employs the use of an integral single mirror to direct the laser beam to target. Mirror is verified in-place by worker. Video cameras are in place to observe this area.
SSHCL Steering mirror	Steering mirror is not aligned to target	Mirror not installed properly by worker or is bumped out of alignment.	Laser beam is directed to locations including: east wall, south wall, SSHCL and supporting equipment, causing damage to these locations.	Marginal	Remote	Beampath to target is verified with a low powered alignment laser. The mirror is rigidly secured to the optical table to prevent movement. Steering mirror cannot redirect beam to operator location.
SSHCL Target	Target is not in place	Target not installed or falls over.	Laser beam directed at south wall	None	Remote	A large piece of graphite is rigidly positioned on the target stand as a beam dump to absorb the laser energy. This material absorbs the thermal energy should target material not be in place. Target stand is not easily moveable. Video camera directed at target area.
SSHCL	Laser does not automatically turn off.	Hardware or software malfunction	Thermal load on target and on laser components is increased	Minor	Infrequent	An emergency shutdown button is located at the operator control station to shutdown the laser.

1. Personnel Hazard Level definitions: **Catastrophic** = A failure that may cause death. **Critical** = A failure that may cause severe injury. **Marginal** = A failure that may cause minor injury. **Minor** = Failure not serious enough to cause injury. **None** = No hazard for personnel.

2. Likelihood of Occurrence definitions: **Probable** = Expected to happen in the life of the project. **Infrequent** = Could happen in the life of the project. Controls have significant limitations or uncertainties. **Remote** = May happen in the life of the project, but not expected. Controls have minor limitations or uncertainties. **Improbable** = Extremely remote possibility that failure will occur in the life of the project. Proven controls are in place.