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Safety Aspects Relevant to Flowing Medium Liquid Laser

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Abstract: High power flowing medium chemical laser have apparently achieved significant level power levels capable of target destruction. Few flowing medium lasers are still working towards these power levels and are at various stages of development. All Liquid medium lasers employing aprotic liquid, Lewis acid and rare earth ions termed as Liquid Laser (LL) are one amongst them. Development of these lasers essentially requires in depth understanding of multiple disciplines with overlapping influences. Safe operation of Liquid Laser is a critical concern, which needs to be sufficiently addressed prior to laser experimentation. This entails not only safe handling of subsystems, but also safety of human being/operator from any potential hazards posed by the chemicals employed in the laser system. The present paper discusses both manual and automatic safety schemes using suitable acquisition and control system for flowing medium Liquid laser.

Index terms: Liquid Laser, Flowing medium, Acquisition and Control, Laser Diodes, Hydrogen Chloride (HCl)

INTRODUCTION

Since the origin of flowing medium chemical laser [1-5], present lasers have reached to a stage to be useful for obliterating military projectile targets such as missiles, UAVs etc. They have demonstrated their utility for industrial applications including drilling, dismantling of obsolete nuclear reactors. Generic safety schemes have been discussed for flowing medium chemical laser in Ref. [6-7] and specifically pertaining to Chemical Oxygen Iodine Laser (COIL) in order to safely handle Basic Hydrogen Peroxide (BHP) solution, Iodine and Chlorine.

Aprotic liquid laser [8-9] is a potential future candidate with its advantages of compactness and low weight, which is highly lucrative in terms of its practicability as compared to other lasers. Fig. 1 shows the schematic of a Liquid Laser system.

It employs an aggressive aprotic solvent viz., Phosphorous Oxy chloride ($POCl_3$) with Lewis acid ($SnCl_4$) doped with rare earth ion (Nd^{3+}) as lasing medium. Liquid medium has a measured viscosity of ~ 3-5 cP (centi-poise) and specific gravity of 1.8. The liquid is circulated in closed loop and is continuously cooled the online in order to reap benefits both of ease of pumping and minimal thermal effects on beam quality. The active medium is pumped with laser diode stack of required wavelength and power levels, powered by laser diode drivers and is water cooled in the heat exchanger (HX) through a chiller module.

Broad safety concerns relevant to flowing LL laser are proper handling of lasing medium during initiation into the system and it extraction form the system, precise control of parameters viz., Cavity temperature (inlet/ outlet), HX cold side temperature, Pump Pressure (inlet/outlet)and surge tank pressure, coupled with interlocks for laser diode protection. Further, detection of Hydrogen Chloride (HCl) vapours in case of a possible leak during medium circulation also needs be addressed.

The paper focuses on discussing the safety considerations central to flowing medium Liquid Lasers along with dwelling on their implementation. The open literature data with respect to safety aspects in high power lasers is typically minuscule and specifically with regards to Liquid Lasers the present paper is potentially is one of the first study.

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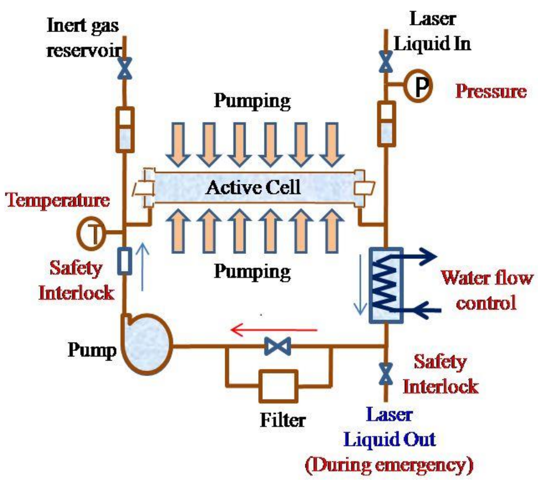

Fig. 1: Liquid laser basic schematic

ACQUISITION AND CONTROL SYSTEM

Basic building blocks of the acquisition and control system [6], [10-15] applicable for remote operation of flowing medium LL are shown in Fig. 2. Various sensors (Pressure, Temperature) are distributed over the entire flowing medium laser system at different locations. Acquisition and analysis module gathers information with respect to different laser subsystems from these sensors. Display and control unit controls actions of various actuators by supplying the proper digital output signal and initiating various laser run actions. The actuators follow a preset temporal sequence for the desired laser operation and optimization.

Diagnostic module undertakes measurement of parameters such as small signal gain, power measurement, laser wavelength, power duration and subsequent communication of the signal to the Acquisition/ Analysis and control module.

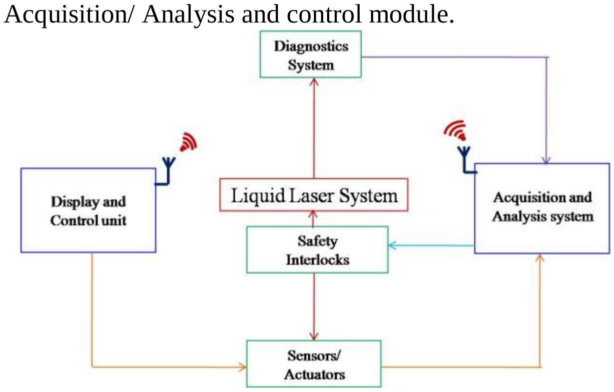

Fig. 2: Schematic of operation of liquid laser using acquisition and control system

Safety schemes are activated depending upon the variation of critical parameters beyond the safe limits on receiving the signal from the master controller loaded with preapproved parameters limits in the software. Safe remote operation requirements are fulfilled by the laser operation from a distance of 80 m line of sight and 35 m with obstacles by wireless communication between Acquisition and Analysis module and display and control unit.

Safety Aspects

Safety aspects for flowing medium liquid laser inevitably requires an Acquisition and Control system to introduce safety interlocks in addition to complete the laser runs within time interval with all event's sequencing. Proper earthing is also required to prevent human beings from any shock/electrical hazards/transients and maintains the health of the costly equipment like laser diodes/ laser diode drivers/ acquisition cards etc. from being damage due to any static charges. Chemical earthing is chosen over conventional earthing for their long life, maintenance free, less space requirement, low resistance (<1ohm) high temperature sustainability, insolubility of backfill (e.g. Bentonite) compound in water etc.

Safety measures can be divided into two phases: manual and automatic. In order to ensure safe operation of Liquid Laser, the major safety interlocks implemented are:

- Liquid medium parameter control
  - Liquid Flow rate
  - Pressure- Pump, Suction and Storage tank
  - Cavity Inlet and Outlet Temperature control
  - Cooling water temperature
  - HCl vapour concentration
- Diode pump module
  - Water Flow rate
  - Diode array temperature
  - Cooling water temperature

Manual safety considerations

- Continuous circulation of the lasing liquid medium in the laser circuit due to highly acidic nature. The liquid is passed through the heat exchanger to make the liquid cool.
- Laser diodes are also cooled down to around 25^{o}C by the circulating cold water from the chiller systems for their protection.
- Testing of proper voltages by the use of a socket

tester (model: SOK32, RS components- stock no. 719-3001) and measurement of earthing voltages to ensure safe environment to both human beings and costly equipments.

- DC power supply to acquisition cards and sensors through surge suppressors (Make: CYBEX, RS components- stock no. 312-2759), which are operated from mains AC power (220V, 5Hz).
- Continuous monitoring of different pressures and temperatures, like pump inlet (≥ 0.3 bar) and outlet (≤ 7 bar) pressure, suction (≤ 2 bar) and surge tank (≤ 5 bar) pressures, cavity inlet (≤ 25^{O}C) and outlet medium temperature(≤ 35^{O}C), heat exchanger cooling water temperature (≤ 18^{O}C).
- Cross-check before opening of the valves. When we press any actuation button, it shows "Are you sure to open the valve".

Automatic safety considerations

Automatic safety check has also been implemented in order to avoid the adverse conditions e.g. in order to cater the HCl vapour leakage it automatically switch ON of the aeration system by the acquisition system and the idea is shown in Fig. 3. As per American Industrial Hygiene Association, max. limit for presence of human being near the system during operation is 5 ppm. If leakage goes beyond this prescribed limit, it gives a sound alarm and starts the aeration system automatically and laser liquid drains out to ensure the safety of manpower.

In addition to automatic safety interlocking scheme implementation, an additional manual safety feature has also been incorporated in the form of an emergency switch. In case of failure of automation system, beep sound comes and we can press the emergency switch to perform the safety function.

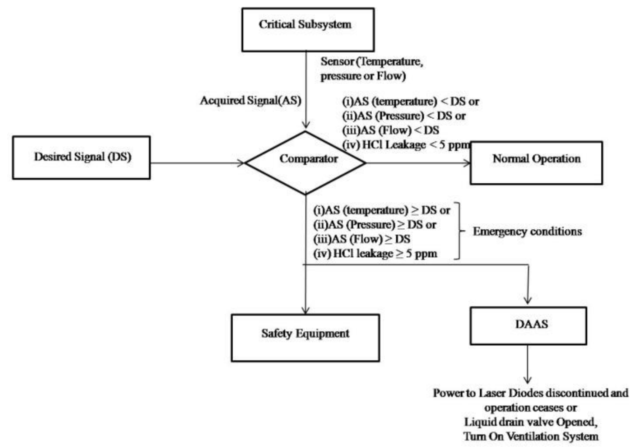

Fig. 3: Safety interlocking idea

Additional safety measures, which are followed during experiments:

- Wearing of a positive-pressure Self-Contained Breathing Apparatus (SCBA) and
- Wearing of chemical protective clothing with thermal protection.

All the parameters (temperature, pressure, level and flow) are continuously observed on graphical user interface (GUI), 'MAIN', depicted in Fig. 4. LabVIEW platform based software application invariably compares current value of these parameters with the referenced values already included in the program and required decision is taken further by developed acquisition and control system through safety topolgy.

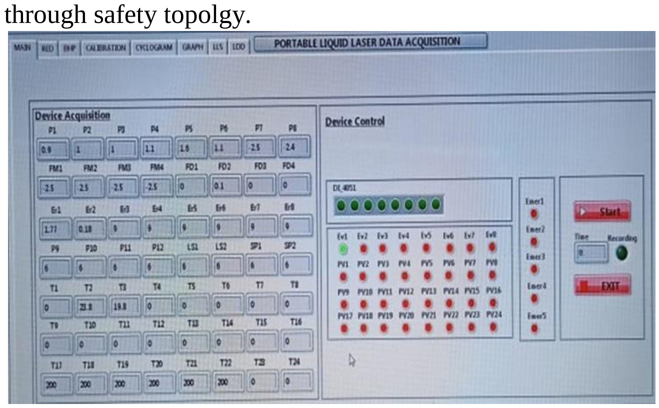

Fig. 4: 'MAIN' GUI

Conclusion

Safe handling of various parameters and systems in flowing medium liquid laser has been successfully achieved using acquisition and control system by implementation of both manual and automatic safety considerations. Many experiments of liquid laser were carried out without any safety hazard from a distance of 35 m and 80 m without and with obstacles respectively by wireless acquisition and control system.

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