# High Average Power Solid State Laser Power Conditioning System*

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## ABSTRACT

The power conditioning system for the High Average Power Laser program at Lawrence Livermore National Laboratory (LLNL) is described. The system has been operational for two years. It is high voltage, high power, fault protected, and solid state. The power conditioning system drives flashlamps that pump solid state lasers. Flashlamps are driven by silicon control rectifier (SCR) switched, resonant charged, (LC) discharge pulse forming networks (PFNs). The system uses fiber optics for control and diagnostics. Energy and thermal diagnostics are monitored by computers.

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## Introduction

The goals of the High-Average-Power Laser Program at LLNL are to develop a broad technology base for solid state lasers and to demonstrate high-average-power laser operation with more efficiency and higher beam quality than has been possible with current technology. We are placing a dual emphasis on a broad science base and on technology advancement. Our objectives are oriented toward general military applications rather than to specific missions or platforms.

This paper will describe power conditioning research for high-average-power lasers. We will discuss power conditioning, controls, diagnostics, facility layout, and interlocks.

## Power Conditioning System

The test beds, amplifiers, and oscillators currently under study for HAP lasers are pumped by flashlamps that are triggered, simmered, and driven by a pulse-forming network (PFN). The PFNs are switched by silicon-control rectifiers (SCR), chosen for their high rms current ($>100$ A) insensitivity to motion and for their long life. The dc power for the PFNs is derived from two 0- to 4000-V power supplies with a total average output power capability of 900 kW. Individual flashlamps have been driven with 60 kW of average input power continuously for ten hours. The PFN has operated at the following parameters: maximum pulse energy, 8000 J; maximum repetition rate, 125 Hz; maximum SCR di/dt, 1600 A/μs; $I_{RMS} = 220$ A, and maximum voltage, 7000 V. The PFN fault protection system consists of an overvoltage detector that protects against shorted loads and simmer detectors that protect against open loads. The dc power supplies have SCR contactors used for single-cycle shutdown caused by overcurrent on their outputs; they also have circuit breakers on their primaries and secondaries for overcurrent protection.

## Control System

There are several control systems: the PFN charge and fire, the VVT voltage setting, nitrogen flow, and interlocks. The PFN uses a resonant-charge, single-loop discharge topology; the switches are SCR stacks triggered by a fiber-optic-controlled gate driver whose triggers are computer generated. The VVT voltage setting is obtained by a control panel that is relay-isolated from the power supply. The nitrogen control system is computer based and uses a fiber-optic-isolated IEEE-488 bus to control the D/As and A/Ds that control the system; (nitrogen is used to cool one type of test amplifier). Fiber optics are used for operator safety and ground loop removal. The interlocks are fiber-optic-isolated from the control room; they are configured as a single chain that give permissives for HV, nitrogen flow, and laser on.

## Diagnostic System

Diagnostics instrumentation monitors the thermal, electrical, pressure, and flow parameters. Temperature is measured by individually calibrated thermisters that have individual current sources, noise filters, and HV protection; a scanner selects them for measurement and a digital voltmeter converts the four-wire ohm reading. Electrical parameters are measured by current bugs and HV probes; the signals are selected by a scanner and are digitized by a two-channel waveform recorder. Pressure parameters are converted by P/V transducers that are selected by a scanner and measured by a digital voltmeter. Flow is converted by turbine flow meters (water is used to cool flashlamps, SCRs, and some of the test amplifiers); individual flow meters are selected by a scanner and measured by a frequency counter. The scanners, digital voltmeters, frequency counters, and digitizers are controlled over the IEEE-488 bus, isolated from the control room by a fiber-optic link. The instruments are controlled by personal computers; the measured values are recorded and displayed.

## Facility Layout

The facility layout uses a single-point ground and all experiment rooms use the same grounding point. Each set of racks is isolated from the floor and grounded to the single-point ground. The cope trays in the ceiling are isolated from the building and grounded to the single-point ground. There are no wires that connect the experiments or PFNs to the control room. All the control, interlock, and diagnostic signals are fiber-optic isolated. There have been no noise- or fault-related disruptions of our control and computer system.

## Interlocks

The interlocks use a single-chain system. The inputs and outputs in the experiments and PFN rooms are fiber-optic isolated from the control room.

## Conclusion

The HAP power conditioning and controls have been operational for over two years. They have been reliable and fault tolerant. The extensive use of fiber optics has produced a safe system that is noise insensitive. The use of personal computers allows more people involvement with the diagnostics and control software.