UCRL--88995

DE83 018185

NOVETTE PULSE-POWER-SYSTEM DESCRIPTION*

D. G. Gritton, D. J. Christie, R. W. Holloway
B. T. Merritt, J. A. Oicles,
K. Whitham, R. B. Wilcox

This paper was prepared for submittal to
5th Topical Meeting on the
Technology of Fusion Energy

April 26-28, 1983

Lawrence Livermore National Laboratory

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

NOVETTE PULSE-POWER-SYSTEM DESCRIPTION*

D. G. Gritton, D. J. Christie, R. W. Holloway,
B. T. Merritt, J. A. Oicles, K. Whitham, R. B. Wilcox

Lawrence Livermore National Laboratory
P.O. Box 5508, L-494
Livermore, CA 94550
(415) 422-5321

ABSTRACT

Novette is a large, two-beam, two-wavelength laser facility at Lawrence Livermore National Laboratory. The Novette laser projected performance exceeds that of the 20-arm Shiva laser and the frequency-multiplying capability provides more-efficient target interaction.

Novette is comprised of two arms of the Nova laser. New designs allow these two arms to exceed the performance of the 20 arms of Shiva. Assembling these two arms on an accelerated schedule allow the experimental program to continue with minimum interruption. The laser has been operational since January 1983.

More efficient laser amplifiers allowed the performance to be achieved with half the capacitor bank used on Shiva. The pulse power for Novette uses high-density capacitors, instrumented dual ignitron switches, 100 KV KVA power supplies and a control system based on LSI/11 Front End Processors (FEP's) and fiberoptic links. The bank contains 11 MJ of stored energy at 22 KV. Construction of the pulse power system took a year. The laser was completed in about 15 months.

This paper is a summary of the pulse power systems for Novette; the flashlamp power system, the pulsers for the various optical shutters and the pulse power control system.

INTRODUCTION

The Novette Laser Fusion Facility is a two beam irradiation facility which provides a capability to perform high power fusion experiments at 0.53 μm. The facility consists of two Nova phosphate glass laser chains, appropriately designed master oscillator and preamplifier stages, large aperture potassium dihydrogen phosphate (KDP) arrays for frequency doubling, the Shiva target chamber modified to accept two large aperture beams, and target diagnostic systems consisting mainly of modified Shiva and Argus instruments.

The Novette Laser was built to fill a gap in experimental data. The laser occupies about 32,000 ft^2 in in LLNL building 381. About 40% of this space is located in the 28 foot high main laser bay. About 7,000 ft^2 is devoted to support laboratories and 12,000 ft^2 is used by the power conditioning equipment in the basement. Novette is a $25M facility of which $4M represents power conditioning. The full system has been operating since January 1983 and has delivered 25 TW in a 94 ps pulse.

NOVETTE POWER CONDITIONING INTRODUCTION

Because the Novette Power Conditioning is a two beam subset of the Nova system, it represented an ideal opportunity to prove the design at a reduced scale and in advance at the Nova activation. Even the grounding of the Novette and Nova Systems was arranged to be electrically similar by arranging cables in the Novette basement to substitute for the ground matt built into the Nova building. The details of the Nova hardware are presented elsewhere[1].

NOVETTE BANK

The Novette capacitor bank was designed to make use of Shiva hardware and operating experience. Much of the existing hardware from Shiva was reused. The power supplies are all reused after being modestly upgraded. The switches were modified to a larger degree primarily to accommodate the current monitors on each circuit. Most of the major components were also reused; i.e. capacitors, inductors, charge resistor etc.

*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48

NOTICE
PORTIONS OF THIS REPORT ARE ILLEGIBLE.
It has been reproduced from the best available copy to permit the broadest possible availability.

STAGING AND LAYOUT

Figure 1 illustrates the layout of the Novette Energy Storage System. 11 MJ of capacitors comprise the Novette bank. Each circuit stores from 18 to 50 KJ of energy depending on the load requirement. Each circuit is packaged in a module with its own pulse-forming-network (PFN) and vacuum-formed plastic tray which provides 25 KV of isolation between the rack and the circuit common. The rack that hold the circuits is set on insulators and tied to ground through a 1 K ohm resistor. Each circuit has its own safety dump resistor circuit which is mounted on a vertical channel adjacent to the capacitor circuit. See Figure 2. This vertical channel has up to seven dump circuits on it and is called a totem pole. The switches for the circuits are located along the bank wall. Up to five switches are grouped together with a switch control rack which contains fire circuits along with computer interface and diagnostic circuitry. Table 1 give the energy storage circuit count for the entire Novette bank.

The power supplies and switches are staged to provide maximum operator flexibility while minimizing component count and cost. The bank is staged so that each arm of Novette can be charged and fired separately. Also, along each arm, sections of the arm can be selected for firing from the control room. This allows the laser operators to fire both arms, one arm, parts of one arm or parts of both arms on any particular shot. The staging of the power supplies is given in Table 2.

POCKELS CELL DRIVERS

Novette makes use of Pockels cell based optical shutters in both the Master Oscillator Room and in the Laser Bay. Drive requirements are application dependent, and we have categorized them as follows:

Type 1: less than 2 nsec risetime (1 nsec preferred) to 5 kV into 50 ohms; for pulse carving of the long pulse oscillator.

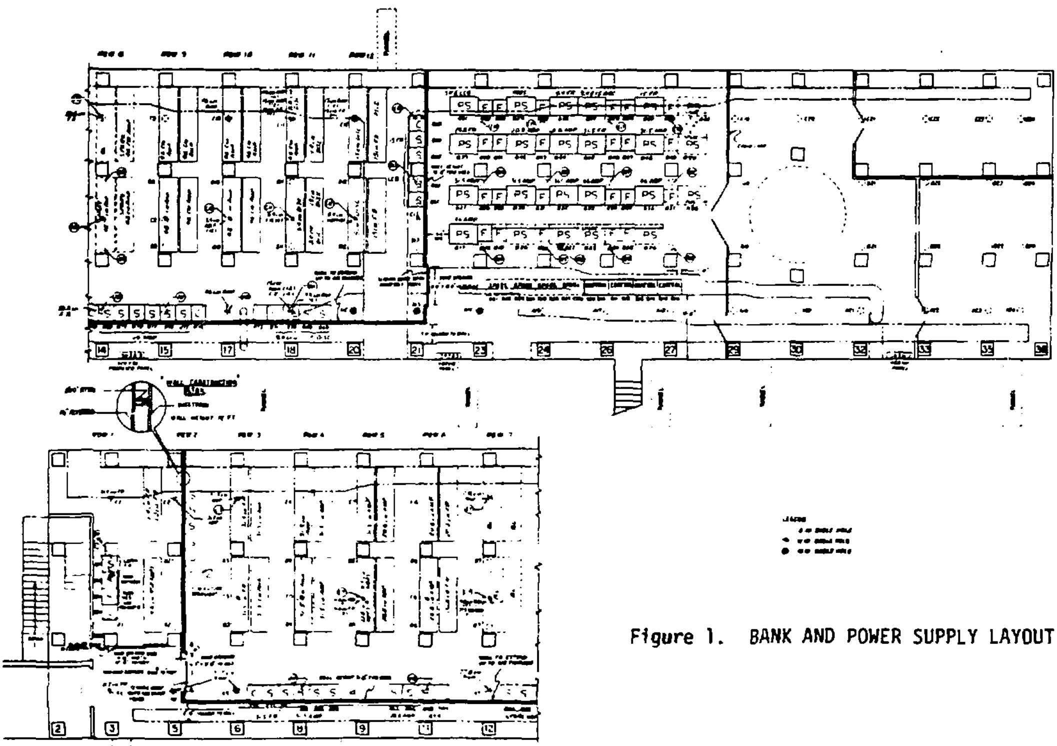

Figure 1. BANK AND POWER SUPPLY LAYOUT

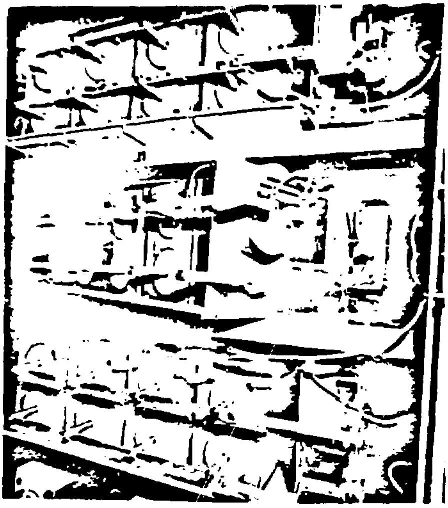

Figure 1. BASIC ENERGY STORAGE MODULE

Type 2: Less than 4 nsec risetime to 5 kV into 50 ohms (or dual 93 ohm cables), for MOR switchout and preamp ASE suppression.

Type 3: Less than 10 nsec risetime to 10 kV into 10 ohms, (or less) fanned out to laser bay ASE suppression Pockels cells.

Type 1 requirements have been met for the first time by a bulk silicon photoconductive (Auston) switch system. Shiva had used a planar triode driver which was too slow to carve pulses less than three nanoseconds long. Since the short pulse oscillator can only generate pulses out to one nanosecond, a temporal performance gap existed. Using 150 microjoules from the short pulse oscillator to activate the switch, electrical risetimes of 250 picoseconds have been demonstrated (Figure 3).

The device consists of two silicon chips in series in a transmission line structure. When simultaneously illuminated they discharge a charge line with a round trip time equal to the pulse width. The charge line is charged by a pulse generator which applies up to 10 kV for one microsecond. This pulse generator is triggered by a fast delay channel from the oscillator controls so that it is synchronized with the optical pulse.

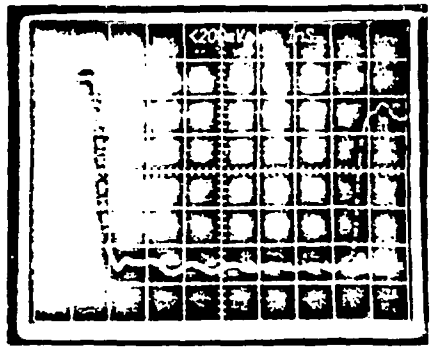

Figure 3. AUSTON SWITCH PULSER OUTPUT WAVEFORM

Type 2 requirements have been met previously by in-house built planar triode drivers (Reference 2). Based on the performance of three of these units on Shiva, we carried out a fairly extensive redesign. The redesign has been breadboarded and circuit development work completed. Goals of this effort are to increase reliability, manufacturability and flexibility of this two chassis set.

Three versions of Type 3 drivers have been developed recently. An in-house design able to drive 20, parallel 50 ohm cables simultaneously was assembled and tested. In this unit, 20 RG-213 charge lines are switched out using a single hydrogen thyratron. Both EEV Ltd. CX1167 and EG&G HY-1102 tubes were tried, with the grounded-grid HY-1102 giving superior results for this heavily loaded application.

A similar, six-way driver was resurrected from Argus to support the Novette laser bay. We were unable to obtain the desired risetime from the CX1157 installed in that unit, so a simple magnetic sharpening addition was implemented which yielded an acceptable nine nanosecond risetime.

The six-way driver was replaced late last year with a prototype five-way driver from Cardon Instruments Co., in England, (Reference 3). Built to LLNL specifications. the unit employs a new ultrafast thyratron from EEV, Ltd., the CX1588. The driver is housed in a standard 8.75 inch high rack mount chassis which also contains all necessary power supplies and an internal, changeable charge line module which determines output pulse width. Based on the success of this prototype, a production order has been issued and Nova will use these drivers in the laser bay. Also initiated was an order for two similar prototype units which will meet Type 2 requirements.

CONTROLS

Operators control the system using display/touch video panels, selecting control functions from a series of menus. Operator touch panel commands are sensed by a VAX 11/780 computer which then generates the corresponding sequence of device commands. Device commands are put into memory shared with LSI-11/23 front-end processors (FEP's) that route the commands to the hardware via fiber optic links. The FEPs constantly poll the hardware devices for status information, placing it in the common memory. The control computer thus has constant access to system status. This status data is converted into a number of graphical displays that may be viewed by the operator.

Interconnection between the FEPs and the controlled/monitored devices is implemented by extending the FEP's internal bus throughout the laser facility. This method of instrumentation is software transparent; i.e., the computer transfers data to hardware devices exactly as it transfers data to memory and maximizes the data transfer rate (no communication protocol). Bus signals are sent from the computer to a device which relays (repeats) the message to the next device. Message relaying continues from device to device until the last device of the chain returns the message to the computer. At each device, the message is examined to determine if that device should respond--a response being either to accept a command from the computer or to send status data to the computer. Figure 4 shows the control system organization.

Each device on the power conditioning bus is serviced by two identical bus systems. Either bus can perform all control and monitoring required for each device. Part of the justification for the incorporation of a redundant bus is related to reliability. Should a segment of the primary control system become inoperative for any reason, the redundant but can be used to continue laser operations.

If electrical power to a device is removed, other devices on the same chain will continue to function. This feature is realized by using the redundant bus as illustrated in Figure 5. Each optical receiver contains circuitry with which it can detect the loss of incoming data. When this occurs, it notifies the transmitter to obtain data from the appropriate bus.

OPERATIONAL EXPERIENCE

Our operational experience with Novette has shown the strength of our design approach. The pulsed power system was designed to be a good electromagnetic compatibility (EMC) neighbor and has shown itself to be such. To date, the target diagnostics, laser alignment, and diagnostics subsystems have not been adversely affected by noise from the pulsed power system. We attribute this to our design of the facility grounding system, to the use of coaxial cables for distribution of pulsed power to laser amplifiers, and to the use of fiber optics for isolation.

Table 3 shows the operating statistics from the first six months of operation. This was subsequent to the installation of the pulse power system and during the activation of the laser/target systems. The operational phase of the laser did not begin until January 1983. Note that even in this early phase, overall system availability was 74% and power conditioning system availability was 98%. Table 4 shows the pulse power components that failed and the total count of that component.

The power-conditioning control system interfaces have been designed to work in close proximity to the ignitron switches we use in the capacitor banks. They have continued to work properly, both controlling and diagnosing these switches which, in some cases, switch in excess of 100 kA. Our pulsed power diagnostic system[4] has detected failures in flashlamps and PFN circuitry in preshot tests, preventing expensive damage that is caused when firing into a faulty flashlamp or circuit element at full energy. The ability to record all pulse power waveforms and display them at a computer terminal has also proven to be useful in locating problems in the pulse power system.

A redesign of the PFN circuitry [5] was done in response to a failure mode we experienced on the Shiva laser system [6]. In this failure mode an arc internal to a capacitor or from a bushing of a capacitor to its case precipated a scenario in which flashlamps inside the amplifier exploded, causing extensive amplifier damage. Our Novette experience is that capacitor failures of the type described above cause no amplifier damage.

In general, we have experienced high reliability and availability of the Novette pulsed power system so far. The system has continued to work as designed with very few problems. Most failures have been attributed to infant mortality failure of components.

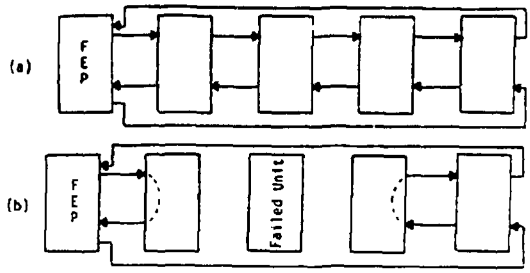

Figure 5. REDUNDANT BUS SYSTEM. (a) NORMAL OPERATION (b) OPERATION WHEN ELECTRICAL POWER TO A DEVICE IS REMOVED.

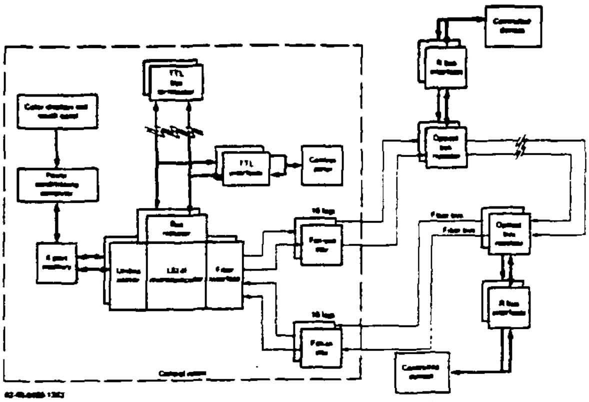

Figure 4. NOVETTE POWER CONDITIONING CONTROL SYSTEM

Table 1. NOVETTE BANK LAYOUT

	Number Per Arm	Total Number of Components	Circuits Per Component	Total Number of Circuits	Energy Per Component (kJ)	Energy Per Circuit (kJ)	Total Energy Per Component (kJ)	Number of Flashlamps Per Circuit	Total Number of Flasnlamps
COMPONENT									
RODS	1	6	1	6	50	42*	252-3	6	36-19'
SPLITTER	4								
9.4 DISC	2	4	8	32	174	18*	576-3	2	64-44"
9.4 FR	1	4	1	4	21	21	84-3		
SPLITTER	2								
15 disc	1	2	12	24	261	18	432-3	2	48-44"
15 F.R.	1	2	4	8	100	24*	192-3		
20.8 F.R.	3	6	8	48	200	25	1200-12.5	2	96-44"
20.8 F.R.	1	2	5	10	200	40	400-5		
31.5 DISC	4	8	10	80	375	37.5	3000-12.5	2	160-44"
31.5 F.R.	1	2	5	10	200	40	400-5		
46 DISC	3	6	16	96	600	37.5	3600-12.5	5	480-19"
				318 TOT		624	7900-12.5		516-19"
				32 F.R.		160	800-5		368-44"
				286 DISC		512	1536-3		

*Energy with 3 KJ cans at 20 KV. Actual voltage 22 KV.

Table 2. NOVETTE POWER SUPPLY STAGING

	Number of Supplies	Energy Per Supply (kJ)	Total Energy Per Component (kJ)	Capacitance Per Supply (μF)	Charge Voltage (kV)	Charge Time (Sec)
COMPONENTS						
ROCS	1	300	300	1218	22	11.42
9.4 F.R.	1	84	84	406	20	3.05
15.0 F.R.	1	200	200	928	22	8.70
20.8 F.F.	1	400	400	2000	20	15.0
31.5	1	400	400	2000	20	15.0
9.4 & 15	1	1008	1179	4872	22	45.65
20.8	2	600	1700	2496	22	23.29
31.5	4	750	3000	3120	22	29.24
46.0	3	1200	3600	4992	22	46.77
SPARE/PILC	1	18				
	16					

Table 3. NOVETTE SYSTEM AVAILABILITY AUGUST 1982 - JANUARY 1983 (ACTIVATION PHASE)

	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	TOTAL	
SHOT ATTEMPTS	128	129	90	124	80	44	595	
FULLY SUCCESSFUL	83	103	60	92	63	38	439	74%
PULSE POWER PROBLEM	1	4	1	1	1	2	10	2%

Table 4. PULSE POWER OPERATIONAL FAILURE EXPERIENCE (6 MONTHS)

COMPONENT	NUMBER FAILED	POPULATION
FLASHLAMPS	13	884
CAPACITORS	5	1,296
FUSES	6	318
IGNITRONS	2	50
DIODES	1	44
DUMP RESISTOR	1	318
POWER SUPPLY	1	16
	29	

REFERENCES

1. Whitham, et. al.; "Nova Power Systems and Energy Storage", 9th Symposium on Engineering Problems of Fusion Research, Chicago, Illinois, October 1981.

2. J. Oicles, D. Downs, D. Kuzigena; "Fast, Versatile Pockels Cell Driver", 3rd IEEE International Pulsed Power Conference, Albuquerque, NM, June 1981.

3. J. Oicles, H. Kitchin; "A Low Jitter Hydrogen Thyratron Pockels Cell Driver", 4th IEEE International Pulsed Power Conference, Albuquerque, NM, June 1983.

4. Christie, Dallum, Gritton, et. al., Pulse Power Diagnostics for the Nova Laser, 1982 Fifteenth Power Modulator Conference.

5. 1980 LLNL Laser Program Annual Report, pages 2-29 - 2-30.

6. 1981 LLNL Laser Program Annual Report.

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government thereof, and shall not be used for advertising or product endorsement purposes.