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JANUS NEODYMIUM GLASS LASER OPERATIONS MANUAL

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MASTER

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ABSTRACT

This manual has been prepared to guide personnel in operating and maintaining the Janus glass laser system. System components are described in detail. Step-by-step procedures are presented for firing the laser and for performing routine maintenance and calibration procedures.

1. INTRODUCTION

The Janus laser is the third most powerful of the three active glass laser systems at Lawrence Livermore Laboratory, the other two being Argus and Shiva. Although Janus was brought to operation initially in early 1975 with a configuration now considered primitive, it has been upgraded to the level of the latest glass laser amplifier chain configurations.

The Janus system is a complex conglomerate of precision optics, high voltage electrical equipment, ultrafast electrooptic components, vacuum systems, and continuous output alignment lasers. An enormous amount of specialized technical experience is required to keep it operational. This manual is a first attempt to present this experience in written form for use both as a tool for those learning the system and as a reference and procedural guide for those who cannot remember everything.

2. SYSTEM DESCRIPTION

Janus Laser System

The Janus laser system configuration as of September 1978 is described here. This section will be revised as significant new modifications are made in the system.

The Janus laser is a two-beam system capable of putting on target 1.06 μm laser pulses of 30 to 300 ps FWHM in duration, with energies up to 100 J/beam in a 300-ps FWHM pulse. The system's output is limited by the occurrence of damage to optical coatings.

The system can be described by following the passage of a pulse through the complete amplifier chain (Fig. 1). The initial pulse is produced in the

passive mode locked oscillator (PMO). The oscillator uses a 1-mm dye cell for mode locking. The rear cavity mirror is concave with a 4-m radius of curvature and a reflection coefficient (R) of 99% at 1.06 μm . The front cavity mirror is flat, with 26-28%R at 1.06 μm . Etalons can be mounted between the two cavity mirrors to produce the desired pulse widths. The cavity head is elliptical and holds two ILC L-2413 flashlamps and a 3/8-in.-diam YAG rod with wedged faces. The oscillator produces a train of 6-10 pulses at each mode locking, each having an energy of 100-200 μJ . The pulse train is split by a mylar pellicle at the front of the cavity. A small part of the pulse train is diverted to a photodiode on top of the switchout module. The photodiode output goes to a comparator circuit that starts the switchout process. This takes a few nanoseconds, so the remainder of the pulse train traverses a 14-ns optical delay path during which it expands to a 3/8-in.-diam beam and is recollimated by a 5-meter focal length positive lens positioned approximately 4.5 m from the front edge of the oscillator housing. The pulse train then enters the switchout module described in Section 6.

The optical delay and the delay cables in the electronic circuits are adjusted to produce switchout of the correct pulse. After passing through the first Pockel cell in the switchout, the pulses whose polarizations are not rotated are rejected by the first Glan polarizer and are reflected to a photodiode. The output of the photodiode is connected to a Tetrionix 7912 digitizer that allows display of the rejected pulse train, revealing the quality of the switchout. At the output of the switchout, the pulse polarization is rotated to vertical by a 90° passive rotator, then divided by a 75-25% beam splitter. Here, 25% of the pulse is directed to the oscillator streak camera and ultraviolet probe optics, and 75% passes through two YAG preamplifiers with 3/8-in.-diam x 3-1/2 in. YAG rods. These preamplifiers operate independently of one another. Normally, one preamplifier provides sufficient gain; the nominal gain/preamplifier is approximately 10. After passing through the preamplifier, the laser pulse is routed to the front-end spatial filter, which in its present configuration consists of a 200-mm focal length lens and a 200- μm i.d. pinhole mounted on a precision positioner in air. After passing through the pinhole, the pulse traverses a 5-m path that includes several mirrors; these expand the beam to approximately a 25-mm diameter. A 5-m focal length plano-convex lens then recollimates the beam for input to the 9.5-mm aperture that produces the "top-hat" beam profile used for propagation through the amplifier chain.

The pulse next passes through the 9.5-mm aperture, where the Gaussian beam profile is formed into a top-hat profile. The latter profile allows maximum energy extraction from the amplifiers, as the clear aperture of all amplifiers is utilized to the maximum extent. The top-hat profile passes through an open-air 2X Hunt relay consisting of two plano-convex lenses, one of 1-m focal length and one of 2-m focal length. The pulse is now at the input of the 1-in. rod amplifier chassis and has a diameter of 19 mm. The 1-in. rod amplifier chassis contains three 2-in.-diam x 10-in.-long rod amplifiers (Rods 1, 2, 3) with two Faraday rotators (FRL/FR2) and three polarizers between them for isolation. The polarization upon entering the chassis is vertical; leaving the chassis, it is horizontal. The gain of the 1-in. rods has a maximum value of 1000. Care must be taken to run the rods considerably below maximum gain to avoid damaging the output coatings of the third rod and the output polarizer pair. The beam profile at the 1-in. rod output takes the shape of a set of diffraction rings, as this location is not at the image plane of the relayed aperture.

After leaving the 1-in. rod amplifiers, the pulse is turned 90° into the 2X Galilean telescope, where the diameter is expanded to 40 mm. The 98%R turning mirror allows 2% of the pulse to go to a laser calorimeter used to monitor the output of the 1-in. rods. After leaving the Galilean telescope the pulse passes through the first A rod amplifier (Rod A4), which has a maximum gain of 8. At this point the pulse is split to propagate down the two amplifier chains. The splitter consists of an array of mirrors that can be positioned to give an arbitrary delay between the times of arrival of the two beams on target. Two mirrors mounted on a micrometer-controlled positioner provide a 1-ps resolution if desired. After leaving the splitter, the two chains are identical, and the propagation down only one chain will be described.

After leaving the splitter, the pulse passes through a 45° passive rotator that rotates it 45° clockwise (looking down the beam). Next, a Faraday rotator (1FR3 or 2FR3) rotates the pulse polarization back to vertical. The pulse then passes through a vertical polarizer, the second A rod amplifier (1A1 or 2A1), and a second vertical polarizer. For 300-ps FWHM pulses, the pulse now has an energy of 3-7 J. The pulse now passes through the first vacuum spatial filter, the A/B spatial filter, which expands the beam diameter to 80 mm. Each of the spatial filters can utilize either a 300- or a 500- μ m i.d. diamond pinhole. After the pulse leaves this spatial

filter, a B Faraday rotator (1FR4 or 2FR4) rotates the pulse polarization 45° counterclockwise from the vertical (looking into the beam). The pulse passes through the first of three amplifiers (1B1 or 2B1, each with a maximum gain of 3.5), the first B polarizer, the second B amplifier (1B2 or 2B2) and the second B polarizer, and then through a second B Faraday rotator that rotates the pulse polarization to horizontal. The 1B1, 1B2, 2B1, and 2B2 are the main high-energy amplifiers in the chain. A 99%R (at 45° polarization) mirror now turns the beam 90° for passage through the B/B spatial filter, which has a 1X magnification and either a 300- or a 500- μ m i.d. diamond pinhole. The spatial filter has a transmission of 98% if plasma pinhole closure does not occur. Leaving the B/B spatial filter, the pulse is turned 90° by a 99%R mirror and passes through a third B polarizer before entering the booster B amplifier (1B3 or 2B3). The final amplified pulse is now rotated 45° by a B Faraday rotator (1FA6 or 2FA6) before being directed on the target chamber axis by the final turning mirror. The final mirror has a reflection coefficient of 95%; the remaining 5% of the energy is used for the laser diagnostics described below.

The 5% of the pulse energy that passes through the final turning mirrors for both the incident and the reflected light pulses is used in the following optical diagnostics:

East Arm

- Incident energy laser calorimeter (2 in.)
- Reflected energy laser calorimeter (1 in.)
- Near field camera
- Equivalent plane camera
- Reflected light far field camera
- Optical streak camera

West Arm

- Incident energy laser calorimeter (2 in.)
- Reflected energy laser calorimeter (1 in.)
- Near field camera
- Prepulse detector
- Reflected light for field camera
- Equivalent plane camera

A completely diagnosed laser shot includes:

- Incident energy on target
- Reflected light off target
- Streak record of laser pulse
- Prepulse level
- Near field beam profile
- Far field image of reflected light
- Equivalent plane photograph of incident pulse.

Reference drawings (AAA) for the principal laser chain components are as follows:

PMO	73-114265-OE
YAG preamplifier	72-105656-OD
1-in. rod amplifier	73-110902-OD
4-cm rod amplifier	76-107102-OB
B amplifier	73-110904-OO
A* polarizer	73-114028-OA
A polarizer	74-112587-OO
B polarizer	74-112643-OO
A Faraday rotator	73-108327-OB
B Faraday rotator	73-11253-OB
A* Faraday rotator coil	76-101238-OO
A/B spatial filter	76-104769-OO
B/B spatial filter	76-104770-OO

Power Conditioning

This section describes the equipment control and the functions of the Janus power conditioning system exclusive of the oscillator. The oscillator and its power supplies are described in Section 6.

The Janus laser system requires high voltage supplies for:

Two A* Faraday rotator coils
Two A Faraday rotator coils

Six B Faraday rotator coils
 Three YAG preamplifiers
 Three 25-mm rod amplifiers
 Three 40-mm rod amplifiers
 Six B amplifiers.

Future versions of Janus may incorporate in addition a single Alpha rod amplifier.

The six main groups of high voltage supplies and control equipment for the laser amplifiers are located as follows:

Module 1 (East side of Bldg. 174). Charging supply, ignition trigger circuits, ignitron chassis, and capacitor banks for rod amplifiers 1, 2, 3; A rod amplifiers A4, 1A1, 2A1; and three spare capacitor banks for future expansion. The reference LEA drawings for this module are:

25 kV power supply	74-5565-01
Digital control capacitor bank	74-5656-01
Remote control capacitor bank	75-1211-01
SCR phase control	74-5546-01
Indicator panel	74-5561-01
SCR drive board phase control	74-5548-01
ROSS high voltage relay chassis	78-1233
Trigger distribution panel 10 channels/out.	72-5587-01

All rod amplifier capacitor banks are fed from a common power supply through isolation diode arrays and ROSS high voltage relays. There are two high-voltage relays for each bank, one relay for the high voltage and the other for return. Each relay has a sensing microswitch that produces an open (GREEN) or closed (AMBER) position indication on the amplifier select panel in the laser control room. Each diode array provides 40 kV isolation.

A typical signal path from the control room to the bank for firing a particular amplifier in Module 1 includes:

- Digital delay generator (control room)
- Pulse distribution chassis (Module 1)
- Ignitron trigger chassis (Module 1)
- Ignitron chassis (Module 1).

The high-voltage pulse then travels to the amplifier flashlamps via RG 217/U cables and a terminal connector box in close proximity to the amplifier head. Each rod amplifier uses two RG 217/U cables.

Module 2 (East side of Bldg. 174). The charging supply, ignitron circuits, and capacitor banks for amplifiers 1B1 and 1B2 are located in this module. Since these two amplifiers always are fired together, there are no ROSS hv relays for this module. Sixteen RG 217 hv cables transfer the hv current pulse to the amplifier flashlamps. Each amplifier requires eight hv cables. Each set of cables terminates in two hv connector boxes next to the amplifier heads. The reference LEA drawings for this module are:

1B1/1B2 interlocks	74-5521-25
Crowbar control 1B1/1B2	74-5521-26
High voltage cabling 1B1/1B2	74-5521-22
Ignitron fault detector and current monitor	74-5503-01
Pulse amplifier ignitron trigger chassis	74-5540-01
Universal power supply	74-5643-01
Universal indicator panel	74-5644-01
Remote control bank charging	74-5550-01

Module 3 (East side of Bldg. 174). The charging supply, ignitron circuits, and capacitor banks for amplifiers 2B1 and 2B2 are located in this module. Since these two amplifiers always are fired together there are no ROSS hv relays in this module. Sixteen RG 217/U cables transfer the hv current pulse to the amplifier flashlamps. Each amplifier requires eight hv cables. The cables terminate in two hv connector boxes next to the amplifier heads. The reference LEA drawings for this module are:

2B1/2B2 interlocks	74-5521-27
Crowbar control 2B1/2B2	74-5521-28
High voltage cabling 2B1/2B2	74-5521-23
Pulse amplifier ignitron trigger chassis	74-5540-01
Ignitron fault detector and current monitor	74-5503-01
Universal power supply	74-5643-01
Universal indicator panel	74-5644-01
Remote control bank charging	74-5550-01

Module 5 (West side of Bldg. 174). This module supplies power to amplifiers 1B3 and 2B3. Since each amplifier is in a different beam line, charging circuits are available to charge the two capacitor banks either separately or together. For each bank, there is a separate diode isolation board, ignitron switch, double trigger chassis, and a set of ROSS hv relays. The hv ignitron cabling consists of sixteen RG 217/U cables that pass over the ILS and Cyclops laser areas and down into the rear of the Janus laser area. Eight cables go to amplifier 1B3 and eight cables to amplifier 2B3. The hv relays are mounted next to the ignitron chassis. The reference LEA drawings for this module are:

Interlocks 1B3/2B3	74-5521-24
High voltage cabling 1B3/2B3	74-5521-34
Crowbar control 1B3/2B3	74-5521-36
Remote control bank charging	74-5550-01
Universal power supply	74-5643-01
Universal indicator panel	74-5644-01

Laser Area YAG Preamplifiers (Bldg. 174, Rooms 1101, 1103). The power supplies for the three YAG preamplifiers are located in the laser control room. The remaining components are located in the front end of the laser area. The reference LEA drawings for the YAG preamplifier systems are:

PFN (pulse forming network) for YAG preamplifiers	73-5507-01
YAG1/YAG2 preamplifier cabling	74-5521-05
Probe YAG cabling	74-5521-20

The main components in each preamplifier firing circuit are the amplifier head, an injection transformer, a pulse forming network, and a Raytheon 0.5-6 kV power supply. The three preamplifiers are named YAG Preamplifier 1, YAG Preamplifier 2, and Probe YAG.

The first two YAGs are single-pass and in series; the maximum gain/amplifier is 10 at a flashlamp voltage of 5.5 kV.

The probe YAG is a double-pass device with a gain of 25/pass at a flashlamp voltage of 4.7 kV.

The preamplifiers are operated either from the control room or from remote firing boxes located next to the oscillator chassis or next to the target chamber.

The YAG heads are cooled by chill water supplied by a NESLAB chiller unit located outside Bldg. 174, next to the east wall.

Faraday Rotators (Bldg. 174). The laser system uses ten Faraday rotators:

Two A* rotators

Two A rotators

Six B rotators.

The power supply for the A* rotators is located outside Bldg. 174, next to the east wall and is remotely operated. Only one supply is used, since Faraday rotators FR1 and FR2 are connected in series. The power supplies for rotators 1FR3, 1FR4, and 1FR6 are located outside Bldg. 174, next to the east wall. All supplies are in wooden enclosures to protect from the weather. AC power to the supplies must be turned on locally. Charging of the supplies normally is done remotely from the control room.

The power supplies for rotators 2FR3, 2FR4, 2FR5, 1FR5, and 2FR6 are located in Bldg. 174, Room 1101, next to the west wall. AC power to the supplies is turned on locally. Charging of the supplies is done remotely from the control room. Each power supply is rated at 6 kV. The voltage normally used will give a Faraday rotation of 45° . Each A rotator power supply contains two 6-kV Maxwell capacitors and each B rotator power supply contains three 6-kV Maxwell capacitors. The reference LEA drawings for the rotator power supplies and controllers are:

Faraday rotator control	74-5521-16
Rotator fault detector and oscillator timing offset	74-5521-14
Local control module Faraday rotator	73-5542-01
Remote control Faraday rotator	73-5543-01
Capacitor bank Faraday rotator	73-5541-01
Voltage detector fault detector circuit	73-5573-01

The nine remote control units for the Faraday rotators are located in the central control room racks.

Laser System Control

The laser system control is basically a complicated system of interlocks and pulse generating circuits that allows the firing of the system under safe, nondestructive conditions. With the exception of the remote control boxes for firing of the YAG preamplifiers and oscillator shutter control, the control circuitry is located in Room 1103. The LEA drawings for the main control units are:

Control charge and fire	77-1892-01
Firing rate generator	77-1859-01
Faraday rotator select	77-1241-01
Panel and fault detector	73-5576-01
Amplifier select panel	78-1866-01
Cooling gas control panel	74-5580-01
Chiller power and control unit	74-5521-11
B Amplifier remote charging panel	74-5550-01
Rod amplifier remote charging panel	75-1211-01
Raytheon 0.5-6-kV laser power	Raytheon print
Supply control panel	ESL 50391
Oscillator shutter control	77-1858-01

The control system is designed so the oscillator can be fired either independently or in conjunction with any set of amplifiers. Because each amplifier in the chain cannot have an independent voltage the amplifiers are fed from common supplies as follows:

YAG 1	1 Raytheon 0.5-6-kV supply
YAG 2	1 Raytheon 0.5-6-kV supply
Probe YAG	1 Raytheon 0.5-6-kV supply
Rod amplifiers 1, 2, 3, A4, 1A1, 2A1	1-hv power supply in Module 1
Amplifiers 1B1, 1B2	1-hv Power supply in Module 2
Amplifiers 2B1, 2B2	1-hv Power supply in Module 3
Amplifiers 1B3, 2B3	1-hv Power supply in Module 3

All amplifiers can be fired individually by means of the amplifier select panel. When a particular amplifier is not selected on that panel, the amplifier will not fire because there will be (1) a break in the interlock chain, (2) open ROSS hv relays if a common power supply is involved, and (3) for the YAG preamplifiers an open coaxial relay that prevents the trigger pulse from the respective digital delay generator from reaching the ignition trigger circuitry. When an amplifier is selected on that panel, the ROSS hv relays close, the coaxial relay closes, and an additional relay closes the interlock chain. A selected condition with all relays closed is indicated on the panel face by a RED LED ON at the amplifier station. GREEN indicates a deselected condition and a lighted AMBER LED indicates an amplifier has been selected but all relays have not closed. Both the ROSS hv relays and the coaxial relays have sensing solenoids that allow indication of an OPEN or CLOSED position.

Interlock System

The interlock system prevents firing of the laser system in a situation dangerous to personnel or equipment. Rarely, the interlock system may malfunction, so constant good operating practice is essential. A good comprehension of the interlock system is required for fast and efficient troubleshooting, as a break in the interlock chain is an immediate indicator of malfunctioning equipment.

The most common reason for a break in the interlock chain is that a door on a power panel is left open. Every user of the system should be familiar with all power panels with microswitches on the near doors. The LEA drawings showing the interlock systems for major components are:

Module 1 interlocks	74-5521-06
Module 1 power supply interlocks	74-5521-08
Control interlocks charge and fire permissive (This print shows all interlocks that must be made up before a shot.)	74-5521-07
Module 5 interlocks	74-5521-24
Module 2 interlocks	74-5521-27

Module 3 interlocks	74-5521-27
Chill water interlocks (prevents firing YAG with no water flow)	74-5521-12
Power supply interlocks summary	74-5521-31

3. SYSTEM STARTUP

Perform system startup as follows:

1. Turn on four Faraday rotator power supplies on east exterior of Bldg. 174:
 - FRL/FR2
 - 1FR3
 - 1FR4
 - 1FR6
2. Check cooling water unit (NESLAB) for proper condition (located on east exterior of Bldg. 174). Plug fan in for cooling NESLAB motor.
3. Check operation of three vacuum pumps on east exterior of building. Return to laser area.
4. Turn on five Faraday rotator power supplies next to west wall of laser area:
 - 1FR5
 - 2FR3
 - 2FR4
 - 2FR5
 - 2FR6
5. In laser area, complete the following:
 - a. Turn on TV monitor on west wall bracket next to phone.
 - b. Turn on alignment vidicon on west arm table. Turn on west arm TV monitor.
 - c. Uncover west turning-mirror box ports.
 - d. Turn on target-chamber streak camera, streak-camera-alignment TV camera, and monitor on top of camera.
 - e. Uncover east turning-mirror box ports.
 - f. Turn on east alignment vidicon, and HeNe target viewing system vidicon. Turn on east arm TV monitor.

6. Go to horseshoe of optical tables and perform following steps:
 - a. Turn on power to Holobeam CW laser. Fire laser flashlamps. Adjust current to 12 A.
 - b. Close CW shutter.
 - c. Turn on oscillator streak camera.
 - d. Turn on 300-V power supply for photodiodes.
 - e. Turn on storage scope; ensure scope is in non-store mode.
 - f. Turn on PG10 pulse generator for probe YAG if the probe is to be used.
 - g. Turn on flow-to-rod amplifier cooling water system if that system has been turned off.
 - h. Check power supplies of spatial filter ion pump for evidence of normal readings (a few hundred microamperes).
 - i. Inspect all amplifier hv terminal boxes for evidence of foreign objects left on top, loose wires etc. ENSURE NO METAL OBJECTS ARE LEFT ON THESE BOXES.
7. In oscillator area, perform following steps:
 - a. ENSURE ALL HV POWER SUPPLIES FOR SWITCHOUT ARE OFF IN CONTROL ROOM.
 - b. Turn on two switches in switchout module.
 - c. Turn on ACOPIAN power supply.
 - d. Turn on YAG1, YAG2 (YAG1 only if YAG 2 is not in use), and PG10 pulse generators.
 - e. Remove port from first turning-mirror box.
 - f. Adjust oscillator dye motor meter to 26-30.
8. In laser control room, perform the following:
 - a. In control room:
 - (1) On R08 rack, turn on all dark-colored toggle switches.
 - (2) On R09 rack, turn on all scope power switches.
 - (3) Check breaker switches on the four Raytheon power supplies. STANDBY and HIGH VOLTAGE switches on the YAG1, YAG2, PROBE YAG should be up. OSCILLATOR STANDBY and HIGH VOLTAGE switches should be up.
 - (4) Check OSCILLATOR SIMMER SUPPLY ON. Put START/RUN switch to RUN.
 - (5) Turn on three switchout power supplies on R05:
 - (a) Set "Power Designs" supply to 3.95 kV ON
 - (b) Set HP 214A ON
 - (c) Set Pockel cell pulser at 7.5 kV ON

- b. At control panel:
 - (1) Deselect all rotators except FR1/FR2
 - (2) Check that all power supply select buttons are GREEN. On amplifier select panel, all GREEN LEDs ON.
 - (3) On rate generator, check:
 - Rate 1 at "30" and CONTINUOUS
 - Rate 2 at "01" and MANUAL
 - Rate 3 at "01" and MANUAL
 - (4) Check interlock system:
 - (a) Close all doors to laser area.
 - (b) Set Operation Key to OPERATE position.
 - (c) Check all red lights on interlock display on ROB. For a good interlock chain, lights should all be RED up to and including the "CHARGE AND FIRE PERM" light.
 - (5) On cooling gas control panel:
 - (a) Press STANDBY PRESSURE button to ON.
 - (b) Press COOL GAS AUTO button to ON.
 - (c) Check ROTATORS SUMMED ON.
 - (6) Turn on four TV monitors over fault detector panel.
- 9. Start up PMO as follows:
 - a. Verify that NESLAB chill water is ON.
 - b. Verify that oscillator simmer supply is ON.
 - c. Ensure that Raytheon 0.5-6-kV power supply for oscillator has the STANDBY and HIGH VOLTAGE switches in the UP position
 - d. Check that oscillator dye pump is running. Pressure transducer should indicate > 21. Current for dye pump should be adjusted to 26.
 - e. Turn on OSCILLATOR IONIZE and OSCILLATOR FIRE PG10s in control room.
- 10. Ensure that 1.5 kV power supply for rejected pulse train (RPT) photo-diode is ON.
- 11. Turn on oscillator hv power supply. Verify on controller that voltage indicator needle deflects every three seconds. Observe simmer current meter; reading should be ~150 mA. As a supplementary check on simmer quality, remove oscillator chassis cover and verify flashlamps have a steady pinkish glow.
- 12. Ensure GOGGLES ON IN THE LASER AREA. Announce SHUTTER COMING OPEN.

13. Open oscillator shutter and check rejected-pulse-train scope for quality of mode-locked pulse trains. Adjust high voltage or rear cavity mirrors to optimize pulse trains, if necessary. If several missing mode locks are occurring even after a voltage increase of several tens of volts, there is a problem. See maintenance section for troubleshooting procedure.

4. SYSTEM SHUTDOWN

Perform system shutdown as follows:

1. In laser control room, perform the following:
 - a. On cooling gas control panel:
 - (1) Set COOL GAS AUTO to OFF.
 - (2) Set STANDBY SWITCH to OFF.
 - b. Set SIMMER supply to OFF
 - c. Turn off scope power switches on rack R09.
 - d. Turn off SWITCHOUT hv power supplies:
 - (1) Pockel cell pulser.
 - (2) HP 214A pulser.
 - (3) Power Designs 4-kV supply.
 - e. Turn off calorimeter strip chart recorders.
 - f. Turn off oscillator power supply controller. Push CROWBAR button first, then 24-V button.
 - g. Turn off OSC IONIZE and OSC FIRE PG10 pulse generators.
 - h. On R08, turn off all dark-colored breaker switches.
2. In east exterior of Bldg. 174, turn off four Faraday rotator power supplies.
3. In laser area, perform the following:
 - a. Cover east and west final-turning-mirror box ports.
 - b. Turn off target chamber streak camera, its alignment TV camera, and the alignment TV monitor.
 - c. Secure target chamber vacuum system if still operating. See Section 10 for specific instructions.
 - d. Turn off east and west target alignment vidicons and adjacent TV monitors.

- e. Place corks in apertures of 1-inch laser calorimeters. Place cardboard disc covers on 2-inch laser calorimeters.
 - f. Turn off HeNe laser for red viewing system, if on, and also the associated vidicon on the east table.
 - g. Turn off Holobeam CW laser power supply. Close shutter.
 - h. Turn off CW ultraviolet laser if on. This is the LICONIX unit.
 - i. Turn off two switches in switchout power supply module.
 - j. Turn off ACOPIAN power supply.
 - k. Turn off PGI0s for YAG1, YAG2, and PROBE YAG as necessary.
 - l. Turn off oscillator streak camera, reticon scope, and 300-V power supply for photodiodes.
 - m. Turn off rod amplifier cooling water pump (optional, may be left on).
 - n. Turn off TV monitors on east and west walls.
4. In laser area, remove key from operating control panel and place over manual crowbar button to right of rate generator. System is now in routine shutdown.

5. LASER CHAIN ALIGNMENT

This section describes procedures for daily alignment of the laser system. This procedure is divided into three parts: (1) a front-end alignment using pulses, (2) alignment of the main beam lines using a CW laser collinear with the pulsed beam, and (3) alignment of the standard diagnostics.

All mirrors and crosshairs used in the alignment are numbered according to the schematic diagram in Fig. 1. They are numbered sequentially up to the beam division after rod A4. Subsequently, all crosshairs and mirrors used in alignment of the west beam are numbered with consecutive even numbers, and odd numbers are used for the east beam.

When using the alignment crosshairs, always use the same crosshair in the holder and in the same position. Each crosshair has been numbered to match the label on the holder and each is marked to line up with a matching mark on the holder.

FIG. 1. Laser system optical layout.

FIG. 1. Laser system optical layout (continued).

Front-End Pulse Alignment: Oscillator to Switchout

This step in the alignment procedure adjusts the oscillator and switchout module alignment and provides a spatially-filtered pulse for injection into the main beam line. Since the pulse alignment provides the reference for the entire amplifier chain, care in this first step is very important. Proceed as follows to perform oscillator to switchout alignment:

1. Set controls in control room as follows:
 - a. Rate 2 on MANUAL (rate generator)
 - b. RUN/START switch on simmer supply to RUN
 - c. Oscillator shutter closed
 - d. YAG 1 power supply to 5.5 kV
 - e. YAG 1 selected on amplifier select panel
 - f. YAG 1 selected on charge and fire control panel
 - g. LOCAL/REMOTE switch to REMOTE on charge and fire control panel.
2. Enter laser area. Install crosshairs CH-1 and CH-2. Open the shutter and inspect burn pattern of laser spot at CH-1 using a piece of exposed Polaroid film. Adjust beam to center using M-3. Remove CH-1.
3. Similarly, use mirror M-4 to adjust burn pattern on center of CH-2.
4. Repeat steps 2 and 3 above until spot is centered on both crosshairs. Remove CH-1 and CH-2.
5. Position a film holder for 4 x 5 Polaroid film between M-13 and CH-4, close to and facing CH-4. Remove the spatial filter pinhole and the prism if in place, install CH-4.
6. Fire YAG 1 shots (amplified switched-out pulses) using the remote charge and fire control. Observe the centering of the spot image on the crosshairs CH-4 using Polaroid film to record each shot. Adjust mirror M-10 to center the spot on CH-4.
7. Go to control room. Deselect YAG 1 on the charge and fire control panel. Set Rate 2 to CONTINUOUS and the RUN/START switch on the simmer supply to START.
8. Return to the laser area and install the front-end spatial filter pinhole. Open the oscillator shutter; using an exposed piece of Polaroid film, note the burn spots while holding the film just after the pinhole. Roughly adjust the pinhole position to maximize the transmission. If no pulses go through the pinhole, replace it temporarily with a set of

crosshairs and center the crosshairs on the spot. Then optimize pinhole transmission. Close the shutter. Return to the control room and reset controls as in step 1.

9. Fire YAG shots as in step 6. Adjust pinhole position so that the spot image is centered on CH-4. Remove Polaroid film holder from the beam line.

CW Alignment of Main Beams

Alignment of Main Beam Line

In this procedure, the first step is to align the CW laser collinear with the pulsed beam. Care in this step is important, since any errors will be magnified at the target chamber. Once the first step is completed, a simple step-by-step process will assure accurate alignment of the entire system to the proper beam line.

1. Install the CW alignment prism on its kinematic mount and place a white card in front of M-13. Also mount a white card on the porthole in front of the southeast-corner turning mirror M-15. Raise all vacuum spatial filter pinholes out of the beam line. Remove the 9.5-mm hard aperture; open the CW laser shutter.
2. Using an infrared viewer, adjust mirror AM-2 until the spot transmitted through the pinhole has maximum brightness when viewed on the card in front of M-13. For fine adjustments, it may be helpful to defocus the image of the spot.
3. Now focus the image and adjust AM-3 to center the beam on the crosshair CH-4.
4. Repeat steps 2 and 3 above until maximum brightness of the spot is achieved simultaneously with centering the beam on CH-4.
5. As a check, remove the card from M-13. Observe the image on the white card placed in front of the porthole cover. The crosshair and beam should be centered here, as well. Make any necessary small adjustments using AM-3.

Note: The CW laser is now collinear with the pulsed beam and alignment can continue.

6. Install CH-5 at 45° to orientation of CH-3. Remove card in front of M-13.
7. Looking at the spot on the porthole cover, adjust M-13 to align projected images of CH-4 and CH-5. Remove CH-5.
8. Install CH-6 in the same orientation as CH-5. Adjust mirror M-14 to align projected images of the two crosshairs.
9. Repeat steps 7 and 8 until the images of both CH-5 and CH-6 are aligned and centered on the projection of CH-4.
10. Remove CH-4 and CH-5. Install CH-6 and the 9.5-mm hard aperture. Install the negative lens between CH-6 and the porthole cover.
11. Adjust the position of the aperture until its projection on the turning-mirror porthole cover is centered on the image of CH-6. Remove the negative lens.
12. Remove the porthole cover, install CH-7 and place a white card between CH-7 and CH-8. Install the passive rotators in the 1-inch rod chassis.
13. Observe the crosshair images on the card. Adjust mirror M-15 until the images of CH-6 and CH-7 are aligned. Remove CH-6.
14. Move the white card so it rests on the front of M-18. Install CH-8.
15. Adjust mirror M-16 to align the images of CH-7 and CH-8 on the card. Remove CH-7.
16. Now move the card to mirror M-20. Install CH-9. Adjust M-17 to align the images of CH-8 and CH-9 on the card. Remove CH-8.
17. Install CH-10. Move the white card to the front of M-22. Adjust M-20 to align the images of CH-9 and CH-10. Remove CH-9.
18. Install CH-11 and CH-12. Place the white card at M-23. Adjust mirror M-21 to align images of CH-10 and CH-11. Now place the card at the input to 2FR3. Adjust M-24 to align the projected images of CH-10 and CH-12. Remove CH-10. Make sure that crosshairs CH-1 - CH-10 have been removed. Remove the white card from the 2FR3 input.

Alignment of East Arm

Perform alignment as follows:

1. Install CH-13 and place a white card after it. Check to make sure that the A/B spatial filter pinhole is out and that the beam is passing cleanly through the spatial filter.

2. Adjust M-23 to align the images of CH-11 and CH-13. Remove CH-11 and the white card. Remove the bellows at the B/B spatial filter output.
3. Install CH-15 and place a white card on the input port to the M-27 box. While looking on the card, remove the pinhole from the B/B spatial filter beam line. Adjust the pinhole holder so that the beam is transmitted cleanly through the filter.
4. Using the turning-mirror stepper motor control, adjust M-25 to align the images of CH-13 and CH-15 on the white card. Turn off power to the controller. Remove the card and CH-15. Reinstall the bellows between the output of the spatial filter and the port.
5. Install CH-17. Using the pneumatic actuation control box, raise the card inside the box containing CH-17.
6. Using the turning-mirror control, adjust M-27 to align the images of CH-13 and CH-17. Remove CH-17 and lower the card.
7. Now install CH-19. Place a white card over the east target chamber window.
8. Use the turning-mirror control box to adjust the position of mirror M-29 to align the images of CH-19 and CH-13 on the card.
9. Now remove the card. Remove CH-13 and CH-19. Double check that all crosshairs in the east beam have been removed. Verify at crosshair monitor panel.

The adjustment of pinholes for the spatial filters is described below. This completes alignment of the east beam to the target chamber.

Alignment of West Beam

Perform alignment as follows:

1. Install CH-14 and place a white card in the beam following M-28. Check that CH-12 is still in; if it is not, install it in its holder. Check that the beam passes through the A/B spatial filter with pinhole out so the beam is not filtered.
2. Adjust M-26 to align images of CH-12 and CH-14 on the card. Remove the card and CH-12.

3. Remove the output bellows on the B/B spatial filter. Install CH-16 and place a white card on the port cover following it. Move the spatial filter pinhole manipulator so that the unfiltered beam passes cleanly through the spatial filter.
4. Using the turning-mirror control, adjust M-28 to align the images of CH-14 and CH-16. Turn off the control. Remove the card and CH-16. Reinstall the bellows.
5. Install CH-18 and place a white card after it. The north side of the box is a good place for the card.
6. Use the turning-mirror control to adjust M-30 so that the images of CH-14 and CH-18 coincide. Remove CH-18 and the card.
7. Now install CH-20. Place a white card over the west target chamber window.
8. Using the final-turning-mirror control box, adjust the position of M-32 so that the images of CH-14 and CH-20 are aligned.
9. Now remove the card, CH-20, and CH-14. Check that all crosshairs in the west beam are out. Verify at crosshair monitor panel.

The west beam alignment to the target chamber is now complete.

Pinhole and Beam Diagnostics Alignment

West Arm

Perform alignment as follows:

1. Place the gold retro-reflecting mirror in front of west target chamber lens. Place the small aperture with the white paper covering near 2B3 in the beam line. Adjust the retro-mirror so the spot that passes through the aperture is exactly reflected back onto itself on the aperture. It will appear as a thin ring surrounding the aperture. Now remove the aperture.

2. Observe the retro-reflected spot on the 1-in. calorimeter cork. Adjust the diagnostic turning mirror to center the spot on the cork.*
3. Insert N.D. 1 to N.D. 2 in front of the beam viewing vidicon and remove the beam block. Use the 2-in. mirror controls to center the spot on the TV monitor screen. If necessary, adjust the position of the west diagnostic lens to achieve best focus on the vidicon. This focusing should be done only early in the morning, before the B amplifiers have been fired.
4. Remove N.D. filters from both paths of the prepulse detector. Lower the bandpass filter in front of the photodiode and insert the small cork in the front of the prepulse detector diode.
5. Block the beam in path 1 and adjust mirror in path 2 to center spot on cork in front of prepulse photodiode. Then block path 2, unblock path 1, and adjust path 1 mirror to center the spot on the cork. Remove the cork, and raise the bandpass filter, being careful not to disturb the photodiode position. Clear paths 1 and 2, then install the proper N.D. filters in the paths.
6. Move a diffuser wheel in front of the input to the A/B spatial filter and set it rotating. (This spatial filter is between 2A1 and 2FR4.)
7. While observing the diffuse spot on a TV monitor, lower the pinhole in the west B/B spatial filter and adjust its position for centering around the focused spot position. Ensure pinhole is sharply imaged.
8. Now lower the pinhole in the west arm A/B spatial filter and adjust it for center in a similar manner. Ensure pinhole is sharply imaged.
9. Remove diffuser wheel and shut off motor. Cover the alignment vidicon and remove the retro-mirror from the west beam line.

* If west (east) beam is to be used for target illumination during alignment and the east (west) arm for target viewing, the following realignment should be carried out, with no target in the beam line. Adjust the diagnostic turning mirror for the target-viewing arm to center the transmitted beam through the target chamber onto the 1-in. calorimeter cork in the viewing arm. Then adjust the vidicon mirror controls to re-center the spot on the TV monitor screen.

East Arm

Perform alignment as follows:

1. Perform retro-mirror adjustment as in step 1 above.
2. In a similar fashion, adjust the east diagnostic turning mirror to center the reflected spot on the 1-in. calorimeter cork.*
3. Adjust the vidicon as in step 3 above.
4. At the S-1 streak camera, push prism in to reflect CW laser light into the alignment vidicon. Open slit wide and remove all filters from nose of the streak camera. Adjust the alignment mirror and wedge pair to center spot array on slit; adjust wedge, if necessary, to align spot pattern parallel to slit opening. Reduce the slit width to 50 μ m, making sure that the spot pattern remains optimized.
5. Reinstall bandpass and N.D. filters in S-1 nose. Pull prism fully out of camera and secure with tape.
6. Adjust pinhole position in A/B and B/B spatial filters in east beam lines as in steps 6-9 above. Cover vidicon.
7. Make sure entire beam path is clear. Verify clear beam path on cross-hair monitor status panel.

6. OSCILLATOR/SWITCHOUT OPERATION

PMO Description

This section gives operating and maintenance procedures for the Janus PMO (passive mode locked oscillator). The optimum operation of the oscillator

* If west (east) beam is to be used for target illumination during alignment and the east (west) arm for target viewing, the following realignment should be carried out, with no target in the beam line. Adjust the diagnostic turning mirror for the target-viewing arm to center the transmitted beam through the target chamber onto the 1-in. calorimeter cork in the viewing arm. Then adjust the vidicon mirror controls to re-center the spot on the TV monitor screen.

is crucial to good experiments especially where the maximum possible energy is required. The reference LEA drawings for the oscillator system are:

Oscillator chiller power control panel	LEA 77-1280-01
Oscillator chassis wiring diagram	74-5528-01
Raytheon 0.5-6-kV power supply	ESL 50382
Oscillator SCR ionize trigger board	74-5532-01
Raytheon 0.5-6-kV power supply controller	ESL 50391
Oscillator simmer power supply	77-1233-01
Cooling water interlocks	74-5521-12
Oscillator cabling	74-5521-04
Oscillator shutter control	77-1858-01

The PMO oscillator chassis contains the following:

Cavity mirrors and dye cell. The front mirror is flat with a 26-28% reflecting surface at 1.06 μm . The rear cavity mirror has a 4-meter radius of curvature and 99.9%R surface at 1.06 μm . This mirror is at the rear of the dye cell, which has a 1-mm gap and a wedged AR-coated window at the front of the cell. The cell assembly is mounted in a Burleigh precision optical mount for final cavity alignment.

Amplifier head. The head consists of a gold-plated reflector cavity housing, a 25- x 4-in. YAG rod, and two ILC Model L-2113 flashlamps. The head is water cooled by chill water from the NESLAB cooler on the east exterior of Bldg. 174. The two flashlamps are connected in series to the high voltage cables originating from the lower portion of the chassis.

Spatial filter. The filter is mounted midway between the cavity mirrors. It consists of a 1-mm aperture in an X-Y Oriel positioner. The filter when properly adjusted allows only the TEM_{00} mode to propagate.

Pellicle. The pellicle is at the front of the chassis. This membrane reflects 5% of the pulse train energy to the switchout photodiode.

Circuitry. The bottom of the oscillator chassis contains high voltage pulse shaping circuits and the oscillator control and interlock circuits. (The interlocks will be described in later paragraphs.)

The power conditioning equipment for the oscillator consists of the following:

Raytheon 0.5-6 kV power supply and controller. These are located in the control room.

OSC ION and OSC FIRE PG10 pulse generators. These are located in the control room.

Digital delay generator 1 (DDG-1). This generator provides an input pulse for the PG10 pulse generators located in the control room.

Simmer power supply. This supply, located in the control room, provides a 1.3-kV dc voltage to the flashlamps. This voltage along with the OSC ION PG10 maintains the flashlamps in a continuous state of ionization. Correct simmer operation is characterized by a pink glow of the flashlamps. When the OSC FIRE pulse is triggered, the lamps emit an intense flash of yellow/orange light.

Oscillator Dye Transmission Check

The oscillator dye transmission is checked weekly or when suspected of causing poor oscillator performance. The check is made with the General Photonics YAG II laser and United Detector Technology Laser Power Meter located next to the oscillator chassis. The procedure is as follows:

1. Turn on YAG II laser, allow sufficient warm-up time for output to stabilize (30-45 min.). Put N.D. filters in front of laser so meter reads $\sim 10 \mu\text{w}$. Adjust sampling cell stand so cell is in beam line.

WARNING

When working with dye, turn all ventilation fans to high. Wear rubber gloves when handling open containers with dye or solvent. Do not leave dye exposed to intense light for long periods of time.

2. Rinse sample cell three times with 1,2 dichloroethane solvent. Fill cell with 1,2 solvent and place cell in beam line. Record power meter reading = P_1 .
3. Withdraw 30 ml of dye solution from dye pump reservoir. Rinse cell three times with this solution and then fill. Place cell in beam line. Record power meter reading = P_2 . Reconnect all hoses on dye pump and start motor.

Note: Dye transmission = P_2/P_1 . If the dye transmission is not within the desired range, add solvent or dye to the dye pump reservoir to bring the transmission within specifications. A rule of thumb for the transmission change when the reservoir has 600 to 800 ml of solution is as follows: (1) for each 10 ml of solvent added, transmission increases by about 1%; (2) for each 10 ml of dye added, transmission decreases by about 0.5%.

Oscillator Operating Procedures

Optimization of oscillator performance requires maintaining the dye transmission within specifications, the cavity mirrors cleaned and aligned, the flashlamp voltages adjusted, and the simmer circuits in proper operation. Table 1 shows the operating parameters required for the different pulse width regimes used at Janus. The flashlamp voltages show the center range of utilized values. Normal adjustment about this value is ± 30 V. As dye transmission values vary over the week, flashlamp voltage adjustments will be necessary to minimize missing mode locks or double pulse trains.

Table 1. Oscillator operating parameters.

Pulse FWHM	Etalon	Dye transmission	Flashlamp voltage
30 ps	None	30%	1.15 kV
70-100 ps	2 mm Uncoated	18%	1.3 kV
300-400 ps	26%R at 1.06 μ m 4.8 mm	7%	1.5 kV

Symptoms of abnormal operation and corrective actions are listed in Table 2.

Table 2. Symptoms of abnormal operation and corrective actions for the passive mode locked oscillator (PMO).

Condition	Cause	Corrective Action
Missing mode locks (flashlamps operating)	Flashlamp voltage low Cavity misaligned Dye transmission low Simmer supply going bad	1. Raise flashlamp voltage 20 V; if no change, step 2 2. Adjust cavity mirror to improve performance; if no change, step 3 3. Check and adjust dye transmission; if no improvement, step 4 4. Check simmer power supply
Double pulse trains	Flashlamp voltage too high	Lower flashlamp voltage
Low pulse trains (not due to misalignment of pulse train photodiode)	Dye transmission too high	Lower dye transmission and raise flashlamp voltage for optimum operation
Flashlamps do not simmer ^a	Defective simmer power supply OSC ionize PG10 pulse generator defective Bad flashlamps	1. Check simmer voltage; if below 1.2 kV repair power supply 2. Check PG10 pulse output; replace unit if no response to a good input signal 3. Flashlamps are at end of life; replace
Oscillator shutter jams	Various	Remove power cable from shutter box in OSC chassis. This should free shutter control. This condition shuts off hv supply and it must be restarted
Chill water flow stops, oscillator hv supply turns off	NESLAB cooler unit malfunction	Check water level in cooler; fill as necessary. If level is OK try to start unit; if no response, repair/replace
Chill water malfunction; no hv after all interlocks are set	Raytheon hv supply defective	Restart simmer supply after flow is restored Replace supply and/or controller
Low dye flow pressure	Filter needs changing. Dye volume low	Drain dye from pump reservoir. Measure volume and replenish. Change filter and fill reservoir.
Output mode TEM ₀₁ or higher	Front cavity mirror has damage spot (damage to rear mirror possible but unlikely)	Inspect mirror for damage. Displace mirror so beam line is in undamaged area. Raise dye transmission so oscillator pulses are below damage threshold. Replace mirror if damage spots are extensive. 25AR surface points to inside of cavity

^aOscillator flashlamps are such that they may never simmer or do not start to simmer until they are "broken in." Break-in of lamps takes 10-20 min. of pulsing with both the simmer and hv supply on and both the OSC fire and OSC ionize pulsers on. If after this break-in period the lamps do not simmer, another set must be used.

FIG. 2. Functional electrical schematic of the passive mode locked oscillator (PMO) switchout.

Switchout Operation

Electronic

This section describes the pulse switchout system for the PMO. Components of this system are located in the laser area next to the oscillator and in the control room. The switchout has a rejection ratio of 50-52 dB. The pulse gate is 6 ns wide. For comparison, note that the PMO pulse train has pulse separations of 9.5 ns.

A functional electrical schematic of the switchout is shown in Fig. 2. The switchout action is initiated when a small portion of the oscillator train is reflected onto a fast photodiode. A pellicle and mirror in the oscillator chassis divert this portion of the pulse to the photodiode. At the same time the photodiode circuits are processing the light pulse, the main oscillator pulse train is transiting an optical delay line approximately 14 ns in length. This allows the switchout electronics to produce the Pockel cell firing pulse at the same time the light pulse traverses the cells. The delay line consists of five mirrors, arranged as shown in Fig. 1.

The oscillator pulse train is converted into a voltage pulse train by the photodiode. The tunnel diode comparator circuit upon sensing the first pulse larger than the reference voltage sends a pulse to fire the avalanche transistor stack. The output pulse of the stack is used to fire the Krytron switch, which sends a -7.5-kV pulse to the Blumlein circuit. The Krytron is preionized by the keep-alive current pulse circuit. Without this keep-alive current, the Krytron will not fire when it receives the trigger pulse from the avalanche transistor stack. During timing and/or testing of the switchout, Rate 2 on the rate generator module is put in CONTINUOUS so the switchout will work on every pulse train. In a normal-shot sequence of events, the switchout fires once when the amplifiers are triggered. The main trigger pulse that fires the oscillator flashlamps preionizes the Krytron a fraction of a microsecond before the transistor stack pulse fires the Krytron. The Krytron output is shaped by the Blumlein circuit into a train of square (sequentially attenuated) pulses, the first of which produces the Pockel cell gate pulse. The optical delay and electronic delays in the system are used to center the desired pulse in the switchout gate. This is usually the first pulse selected by the diode comparator circuit or the one following it.

Optical

A diagram showing the optical elements in the switchout is presented in Fig. 3. The incident pulse train is first polarized horizontally by a thin film dielectric polarizer. The first Pockel cell rotates only the selected pulse to vertical polarization, causing the remainder of the train to be rejected by the first Glan polarizer. The second Glan prism provides additional isolation. The second Pockel cell rotates the pulse back to horizontal polarization and the second thin film dielectric polarizer. If the isolation of each Glan prism is ϵ_1 and that of each dielectric thin film is ϵ_2 , then the switchout provides an isolation of $\epsilon_1 \epsilon_2$. The function of the 90° passive rotator is to rotate the pulse back to vertical polarization, making it compatible with the "S" polarized optics downstream.

FIG. 3. Optical elements of the passive mode locked oscillator (PMO) switchout.

The beam is aligned along the switchout by four mirrors; two are in the switchout optical delay line and two are on the switchout stand. The alignment falls into two categories:

- Routine Alignment. This is the case where the switchout assembly does not have to be moved. The procedure is described in the front end alignment section.
- Setup Alignment. This is done when one of the mirrors on the switchout stand has been bumped or inadvertently moved or the whole stand has been moved.

The switchout is realigned as follows:

1. Align the oscillator pulse to coincide with the centers of both cross hairs in the optical delay line.

2. Remove the switchout unit from the Gaertner bench.
3. Place the switchout alignment crosshair on the Gaertner rail. With the cross at the north side of the rail, center the pulse on the crosshair using the first turning mirror on the north side of the bench. Then move the crosshair to the south of the bench and center the pulse on the crosshair, using the second turning mirror (Burleigh mount). Iterate this process until the beam follows the crosshair center as it moves along the rail.
4. Remount the switchout unit on the Gaertner rail. If all elements are in their indicated positions, the pulse train should now follow axis of switchout.
5. Movement of switchout unit may have caused slight misalignment of rejected pulse train to the rejected pulse train (RPT) photodiode. When switchout is operating, adjust RPT mirror as necessary to maximize amplitude of rejected train to photodiode.

7. STREAK CAMERAS AND OSCILLATOR STREAK CAMERA ALIGNMENT

Alignment Procedure

The laser system has two permanently installed S-1 streak cameras and a temporary S-20 streak camera. They have the following functions:

- S-1 streak camera for measuring temporal profile of oscillator pulse
- S-1 streak camera for measuring temporal profile of output laser pulses; either incident pulse, reflected light pulse, or transmitted light pulse
- S-20 streak camera for measuring temporal profile of visible light emission from targets.

Corrective maintenance on the cameras is carried out by the Diagnostics Development Group. General conditions maintenance requirements are as follows:

- Essential maintenance requirements are cleanliness and ensuring that the pulse regenerator voltage remains above 580 V. For lower voltages, the two 300-V batteries are replaced.
- Timing is accomplished by changing the delay cables in the line from the trigger photodiode to the camera.
- The streak speed can be slowed from its peak value of 33 ps/mm by addition of a capacitor on the driver board.
- The cameras are aligned with the CW laser or continuously switched-out pulses from the oscillator. Timing shots at the output of the chain are accomplished with rod shots.

For targets that must be imaged on the slit of the streak camera, the intensifier can be run in the dc mode. In this condition a steady image of the slit will appear on the back of the camera's fiber optic bundle. The target at the plane of the camera slit can then be imaged with the available light source.

Oscillator Streak Camera Alignment

The following is a complete alignment procedure for the oscillator streak camera. Under normal conditions, only the final alignment procedure described below is necessary to get good pulse train images on the reticon scope. Refer to Fig. 4 for the following:

CAUTION

Do not touch the tuning mirror or any splitter before crosshair A.

1. In control room, verify following initial conditions:
 - a. Oscillator in operation.
 - b. Rate 2 CONTINUOUS. Simmer switch on START.
 - c. All rotator select switches except FR1/FR2 up.
 - d. All power supply select switches GREEN.
 - e. All amplifier select panel switches DOWN. All green LEDs ON.
2. In front of laser area, perform the following:
 - a. Take crosshair with cardboard disc for use in alignment.
 - b. Get infrared viewing scope.
 - c. Verify that oscillator shutter is OPEN.

FIG. 4. Oscillator streak camera alignment.

3. Mount crosshair in crosshair mount B.
4. Adjust mirror 1 to bring oscillator pulse on center of crosshair.
5. Remove crosshair from Mount B and place in crosshair mount C.
6. Adjust mirror 2 to bring oscillator pulse in center of crosshair at C.
7. Remove crosshair from mount C and place in crosshair mount D.
8. Adjust mirror 3 to bring oscillator pulse on center of crosshair at Mount D.
9. Remove crosshair from mount D and place in mount E.
10. Adjust mirror 4 to bring pulse to center of crosshair at mount D.
11. Remove crosshair at crosshair mount E.
12. Now, with IR viewing scope, check that oscillator pulse is hitting slit of streak camera.
13. Adjust vertical adjustment of mirror 4 to center pulse about slit.
14. Put reticon scope on STORE and press ERASE after each trace occurs so as not to obscure the following trace.

15. Using the vertical and horizontal adjustments on mirror 4, bring the pulse to a position such that the pulse heights on the scope are maximum. The final heights should appear as in Fig. 5.

FIG. 5. Reticon scope trace of aligned oscillator streak camera. 30-ps FWHM pulses and etalon reflection are shown.

8. FULL SYSTEM ROD SHOT

The purpose of the rod shot is to check out the following system diagnostics and components:

- Oscillator streak camera
- Prepulse detector

- CAMAC system
- Rod amplifier current probes
- Output streak camera
- Faraday rotators

After front-end and rear-end alignment procedures are completed, proceed as follows:

1. In control room:
 - a. Put Rate 2 on MANUAL.
 - b. Put simmer supply switch on RUN.
2. In laser area:
 - a. Clear all beam paths. Remove all crosshairs, passive rotators, and YAG alignment prism. Verify path clear on crosshair monitor panel.
 - b. If target is in position in chamber, cover east and west turning-mirror box output ports. Raise target and leave port covers off if transmitted light signals are necessary.
 - c. Turn on 4-V batteries in CAMAC crate.
 - d. Place metal light shields on east and west alignment TV cameras.
 - e. Set up prepulse detector for rod shot.
 - (1) Remove alignment cork from photodiode holder.
 - (2) Place interference filter in front of diode.
 - (3) Place shield glass in front of interference filter.
 - (4) Set up proper N.D. filters for paths 1 and 2 (values based on experience).
3. Set up output optical streak camera for rod shot. Ensure shutter is closed.
 - a. Put proper N.D. filters and 1.06 μm bandpass filter in nose.
 - b. Set slit width at 50 μm
 - c. Ensure film holder is pulled away from fiber optics pack at back of camera. Pull one film out.
 - d. Press film holder back against fiber optics package.
 - e. Check that alignment prism is withdrawn from nose. Tape in withdrawn position.
4. Perform the following in diagnostics room (if computer system is to be tested):

- a. Load information for PDP/11 program for the rod shot. The required teletype input is listed on the console. Programming is completed when computer prints out WAITING FOR EVENT. Details on computer operation are listed in a manual kept in the diagnostics room.
- b. Set scope control panel lights on AUTO.
- c. Adjust traces on SYSTEM TRIGGER SCOPE.
- d. Pull film on SYSTEM TRIGGER SCOPE.
5. In laser area, set up oscillator streak camera as follows:
 - a. Put scope in STORE mode and press ERASE button. Verify that scope screen is dark.
 - b. Pull film in scope camera.
6. In control room, perform the following:
 - a. Select YAG and ROD amplifiers.
 - b. On amplifier select panel, select for single-beam test (YAG 1, Rod 1, Rod 2, Rod 3, A4, 1A1 or 2A1) or two-beam shot (YAG 1, Rod 1, Rod 2, Rod 3, A4, 1A1, 2A1). Verify that AMBER LEDs are on indicating amplifiers selected.
 - c. Set YAG and rod amplifier power supply voltages. The following settings are used for 300-ps FWHM pulses:
 YAG 1: 4.0 kV
 GLASS RODS: 11-13 kV (set as required)
 - d. Select all rotators on fault detector and timing offset panel. In this configuration, all GREEN lights except the leftmost one should be OFF.
 - e. On rate generator, set Rate 1 = CONTINUOUS and Rate 2,3 MANUAL. Set Rate 1 = 3.0 s, Rate 2 = 01, and Rate 3 = 01.
 - f. Charge and fire console. Select YAG 1 and GLASS RODS.
 - g. On crosshair monitor panel, verify all LED indicate GREEN for active channels. This indicates beam path clear, all shields ON.
 - h. Press LOAD button on rate generator; observe all counters reset.
 - i. Press RESET button on fault detector; observe all LEDs are off.
 - j. Check PERMISSIVE lights if PERM light on charge and fire console is RED. Prepare to fire a shot.
 - k. Announce "CHARGING FOR A ROD SHOT." Check "ROTATORS SUMMED" light on gas control console. Press CHARGE BUTTON on charge and fire console.

- l. Observe that all amplifiers and Faraday rotators are charging properly.
 - m. When all rotator controllers indicate HV READY and all banks are charged, prepare to fire.
 - n. Open oscillator shutter, monitor rejected pulse trains and when ready push CAMERA/AUTO FIRE on charge and fire console.
 - o. After shot, immediately close shutter, deselect power supplies and amplifiers on the charge and fire and amplifier select panels, respectively. Then deselect rotators on fault detector panel.
7. Perform other postshot actions as follows:
- a. Get oscillator streak camera record. If film did not come out, retake photograph of stored image. Then put scope in NON-STORE.
 - b. Collect system trigger scope picture in diagnostics room. Check to see that CAMAC system triggered properly.
 - c. In control room, inspect lamp current bug traces to check for abnormal operation. If traces appear abnormal, start troubleshooting immediately. Collect prepulse scope record.

9. FULL SYSTEM SHOT

This procedure assumes the following items have been completed:

- System front end alignment
- System rear end alignment
- Full system rod shot
- Target alignment
- Target chamber diagnostics have been checked out.

Target chamber diagnostics are the responsibility of the physicist doing the experiment and he will be present while they are performed. The diagnostic room when necessary will be manned by an electronic technician.

Conduct full system shot as follows:

1. In laser control room, first ensure that Rate 2 is on MANUAL.

2. All scope film pulled: Prepulse, YAG, Rods, and B amplifier current scopes. For east beam shot, monitor B amplifiers 1B1, 1B2, 1B3. For west beam shot, monitor B amplifiers 2B1, 2B2, 2B3.
3. In laser area (room 1101), put full shot values of N.D. filters in path 1 and path 2 of prepulse detector.
4. Put full shot values of N.D. filters in nose of target chamber streak camera.
5. Uncover all laser calorimeters. Check all amplifiers for proper settings. Zero all amplifiers.
6. Place vidicon light shields in position.
7. Load film into east and/or west multiple image cameras. Load film cartridges also into equivalent plant cameras and back of target chamber camera.
8. Clear entire laser beam line of crosshairs, passive rotators, prisms. In laser area, see that all active LEDs on the crosshair monitor status panel are GREEN. This indicates beam path is clear and all light shields in place.
9. If red (6328 $\text{\AA}$) viewing system is to be used, turn on HeNe laser at this point. Ensure 6328 $\text{\AA}$ bandpass filter is in place over red viewing system vidicon.
10. Put oscillator streak camera scope in STORE. Press ERASE to clear screen.
11. At this point, the diagnostics technician should turn on all BIAS supplies in the CAMAC crate. Then the lights in the laser area can be turned off and the films pulled. These are:
 - a. Target chamber streak camera. Pull film holder away from fiber optics. Pull dark slide out and press film pack against fiber optics.
 - b. Pull film slides in equivalent plane cameras.
 - c. Other streak cameras. Procedure similar to a.
 - d. Pull film slides in the far field and MIC cameras.
12. In laser control room, zero all laser calorimeter strip chart recorders.
13. Select voltages for amplifiers YAG1, YAG2, glass rods, 1B1, 1B2, 1B3, 2B1, 2B2, 2B3 on power supply controllers.
14. On the amplifier select panel select amplifiers to be fired. Ensure all SELECT LED indicators indicate AMBER.
15. On fault detector, select all rotators to be used. Press RESET on this panel to turn off any LEDs. Also press RESET on amplifier select panel.

16. Check crosshair monitor panel to verify beam path is clear and all required shields are ON. Correct any discrepancies at this point. Use flashlight in laser area. Do not turn on room lights.
17. At central control panel, check:
 - a. Rate 1 CONTINUOUS; Rate 2,3 MANUAL
 - b. Local/remote switch in LOCAL
 - c. Rate 1 on 30, Rate 2,3 on 1
 - d. All system interlock lights on Rack R08 panel are RED.
 - e. All power supply select switches on charge and fire control panel GREEN.
18. Play tape to get interlock permissive.
19. After tape stops, interlock lights on B power supplies come on (GREEN) and the PERM light on the charge and fire control panel turns RED. Now prepare to CHARGE for the full shot.
20. Announce CHARGING FOR A FULL SHOT.
21. Press CHARGE button on charge and fire control panel. Confirm amplifiers and rotators are charging by viewing the indications on the various panels.
22. Adjust calorimeter strip chart recorders as necessary.
23. When all high voltage ready lights on the rotator control panels are ON and amplifier voltages are steady, the system is ready to fire.
24. Call diagnostics room and tell technician (if present) a shot is to be fired.
25. Announce OSCILLATOR SHUTTER OPEN, FIRING A FULL SHOT.
26. Open oscillator shutter, inspect rejected pulse trains for quality. When satisfied, press CAMERA/AUTO FIRE button on charge and fire control panel.
27. After shot, perform following actions immediately:
 - a. Close oscillator shutter
 - b. Deselect all power supplies
 - c. Deselect all rotators
28. Without turning on lights, enter laser area and cover all films. Pull film in oscillator streak camera. If a bad film, retake picture. After good image is obtained, then put storage scope in NON-STORE mode.
29. If target chamber is to be vented, ensure diagnostic technician turns off all bias voltages in the CAMAC crate.
30. Turn on lights in laser area.
31. Take all film holders out of cameras for processing; cover laser calori-

meters with cardboard shields.

32. In control room, pull current bug scope traces for amplifier flashlamp. Remove laser calorimeter records from strip chart recorders.
33. Examine current bug traces for any evidence of abnormal operation. Troubleshoot if necessary.
34. If another shot is necessary, one person goes into laser area and puts 1.06- μ m CW laser into the beam line. At this point there is a two-hour wait until the amplifier disks cool.

10. TARGET CHAMBER VACUUM SYSTEM

Instructions start from the situation where the system is completely off. Each section describes a procedure for given initial conditions.

System Startup

Perform system startup as follows:

1. Verify following initial conditions:
 - a. Mechanical roughing pump off.
 - b. Roots blower and turbo-pump off.
 - c. Liquid nitrogen reservoir empty.
2. Get two dewars of liquid nitrogen from nitrogen tank.
3. At vacuum system control console:
 - a. Turn mechanical pump ON.
 - b. Push FOREVAC OPEN switch. When FOREVAC pressure has dropped to 100 mTorr, turn turbo-pump ON.
 - c. Pour the entire two dewars of liquid nitrogen into funnel over turbo-pump.

Evacuating Target Chamber

Perform target chamber evacuation as follows:

1. Verify following initial conditions:
 - a. Mechanical roughing pump, turbo-pump ON.
 - b. All ports and openings on target chamber closed. Gate valve on turbo-pump closed.
2. At control console:
 - a. Push FOREVAC CLOSE button.
 - b. Push VENT VALVE CLOSE button.
 - c. Push ROUGH VALVE OPEN button.

Note: At this point, chamber will start going to vacuum. When pressure in chamber is at or below 3000 mTorr, perform following steps.

- d. Push ROOTS BLOWER ON switch.
- e. Open ROOTS BLOWER VALVE TO CHAMBER.
- f. Push ROUGH VALVE CLOSE switch.
- g. Not less than 30 s after step f, push FOREVAC OPEN switch.
- h. After chamber pressure drops to 100 mTorr or below, push turbo-pump GATE VALVE OPEN switch.
- i. Close ROOTS BLOWER VALVE TO TARGET CHAMBER.
- j. Push ROOTS BLOWER OFF switch.

Target chamber will not go to high vacuum. Monitor pressure with ion gage located at lower vacuum control console.

Bringing Target Chamber Back to Atmosphere

Bring target chamber back from high vacuum to atmosphere as follows:

1. Check that all seven shooter bias voltages are off. Verify with experimenter for this condition.
2. At control console:
 - a. Push turbo-pump GATE VALVE CLOSE switch.
 - b. Push VENT VALVE OPEN switch.
 - c. Wait for chamber to increase to atmospheric pressure.

System Shutdown

With chamber at atmospheric pressure, shut down system as follows:

1. Push turbo-pump OFF switch.
2. Leave mechanical pump ON unless repairs are necessary.

11. PREPULSE DETECTOR

System Description

Prepulse is a term applied to the low-level energy pulse that reaches the target before the main laser pulse. This prepulse occurs because the switch-out does not have a perfect extinction ratio. That is, a small portion of the pulses in the oscillator pulse train that precedes the selected (switched out) pulse propagate down the gain. Nominally, the switchout has an extinction ratio of 5×10^{-5} , but poor switchout alignment and timing can make this ratio considerably lower. Significant target damage or preforming of the plasma can occur for prepulses greater than a millijoule. It is therefore imperative that the prepulse detector be operating for all shots so that anomalous results can be correlated with observed high prepulse levels implying target damage.

Daily calibration and operation of the prepulse detector are described below.

Measurement

The prepulse is measured in two steps:

- Measurements taken from the rod shot (setup shot) are used to characterize the reflectivities of mirrors in the prepulse diagnostics.
- Measurements made during the full shot (disk amplifiers in) yield the ratio of the main-pulse energy to the prepulse energy, once the

mirror reflectivities in 1. are known. Direct calorimeter measurement of the main pulse then gives the absolute magnitude of the prepulse.

Rod Shot Measurement

The prepulse detector setup for a rod shot is shown in Fig. 6. The photodiode produces a scope trace with the typical form shown in Fig. 7. The objective of the measurement is to calculate the ratio of the two mirror reflectivities R_{M2}/R_{M1} . In terms of quantities, in Fig. 6 one has

$$I_1 = (R_s T_s R_{M2} T_{ND2}^2) I_0 \quad (1)$$

and

$$I_2 = (T_s R_s T_{ND1}^2 R_{M1}) I_0 \quad (2)$$

FIG. 6. Rod-shot prepulse detector setup.

FIG. 7. Rod-shot prepulse detector scope trace.

where

R_s = reflectivity of splitter s

T_s = transmission of splitter s

T_{ND1} and T_{ND2} = transmissions of ND1 and ND2, respectively

R_{M1} and R_{M2} = reflectivities of M1 and M2, respectively.

Dividing Eq. (1) by Eq. (2) gives

$$I_1/I_2 = (R_{M2} T_{ND2}^2) / (R_{M1} T_{ND1}^2)$$

or

$$(R_{M2}/R_{M1}) = (I_1/I_2) (T_{ND1}^2/T_{ND2}^2). \quad (3)$$

Thus, the ratio R_{M2}/R_{M1} is found in terms of known quantities.

Full Shot Measurement

For the full shot, the ND is changed in path 1 and removed in path 2. Fig. 8 shows a diagram of the prepulse detector setup for a full shot. Fig. 9 shows a scope trace of the detector output for the full shot. There are three distinct parts to this trace. The first pulse is the main pulse attenuated by the N.D. filters in path 1. This pulse is used as the fiducial in the trace to determine how soon before the main pulse the prepulse irradiated the target. The second pulse to reach the detector is the unattenuated prepulse. The third pulse is the unattenuated main pulse signal arriving at the photodiode. This is large enough to drive the scope trace off-scale.

The following notation is used in the derivation relating the prepulse to main pulse:

- I_{full} = main incident pulse
- I_F = attenuated main pulse
- I_P = unattenuated main pulse
- I_{pp} = unattenuated prepulse.

FIG. 8. Full-shot prepulse detector setup.

FIG. 9. Full-shot scope trace.

The objective is to calculate I_{PP}/I_P .
Referring to Fig. 9, one sees that

$$I_F = (T_{SS} R_{M1} T_{ND_{full}}^2) I_{full} \quad (4)$$

$$I_P = (T_{SS} R_{M2}) I_{full} \quad (5)$$

Thus,

$$I_P = I_f \left(\frac{R_{M1}}{R_{M2}} \right) (T_{ND_{full}}^2)$$

and

$$\frac{I_{PP}}{I_P} = \left(\frac{I_{PP}}{I_f} \right) \left(\frac{R_{M2}}{R_{M1}} \right) \frac{1}{T_{ND_{full}}^2} \quad (6)$$

Now, substitute Eq. (3) into Eq. (4) to get

$$\frac{I_{PP}}{I_P} = \left(\frac{I_{PP}}{I_f} \right) \left(\frac{T_{ND_{full}}^2}{T_{ND2}^2} \right) \frac{1}{T_{ND_{full}}^2} \left(\frac{I_1}{I_2} \right) = 10^{db/10} \quad (7)$$

Transmissions of the ND filters are

$$\left. \begin{aligned} T_{ND1} &= 10^{-ND1} \\ T_{ND2} &= 10^{-ND2} \\ T_{ND_{full}} &= 10^{-ND_{full}} \end{aligned} \right\} \quad (8)$$

Put Eq. (8) into Eq. (7) to get

$$10^{db/10} = \left(\frac{I_{PP}}{I_f} \cdot \frac{I_1}{I_2} \right) \frac{10^{-2 \cdot ND_1}}{10^{-2 \cdot ND_2}} \cdot 10^{+2 \cdot ND_{full}} \quad (9)$$

or

$$db = 10 \log \left\{ \frac{I_{PP}}{I_f} \cdot \frac{I_1}{I_2} \right\} - 2 \cdot ND_1 + 2 \cdot ND_2 + 2 \cdot ND_{full}. \quad (10)$$

Equation (10) gives the number of decibels the prepulse is down from the main pulse. Note that it is independent of the prepulse detector and can be used to relate quantities referring to energy on target. Let E be the energy on target; then the prepulse on target is

$$E_{PP} = E \cdot 10^{-db/10}. \quad (11)$$

12. LASER CALORIMETERS

This section describes procedures for calibrating the laser calorimeters, which are essentially thermopile-based devices. The laser energy incident on the calorimeter heats a slab of BG-18 (95.2% absorption at 1.06 μ m). The thermopile attached to the back of the BG-18 slab generates a voltage as a result of the temperature rise in the glass. This voltage is the output signal of the calorimeter. A small resistance heater attached to the rear of the slab is used to calibrate the calorimeters. Ohmic heat into the slab is related to laser light input by the 95.2% absorption factor.

Three sizes of calorimeters are calibrated:

- 5-in. reference calorimeters
- 2-in. calorimeters
- 1-in. calorimeters

The 5-in. reference calorimeters are used for determining the output beam energy by placing them directly in the beam line. For calibration, a specific amplifier and strip-chart-recorder combination is attached to the unit. The calorimeter calibrator in the control room is then plugged into the heat connection at the rear of the calorimeter. The amplifier and strip chart recorder are set so that the energy from the calibrator will not send either

the amplifier or recorder past full scale. If the energy from the calibrator is a little larger than the expected laser energy, the calibration will be optimum.

The energy from the calibrator is calculated as follows. At the rear of the calorimeter module, a heater resistance R is specified. Let V be the voltage setting on the calorimeter calibrator and Δt be its time interval setting. Then the energy into the heater is

$$E = \frac{V^2 \Delta t}{R} \quad (12)$$

For this E , the recorder deflects a distance Δ . The calibration for laser light in units of energy/unit deflection is

$$\eta = \frac{E}{0.925\Delta} \quad (13)$$

A typical recorder trace is shown in Fig. 10. Δ is determined by drawing a line splitting the area on each side of the rise during heating. Each calibration should utilize three heater runs to get good statistics on the value of

FIG. 10. Typical recorder trace of calibration of a laser calorimeter.

η . The runs should be timed so as to have the calorimeter cooled down before the start of each run.

The 2-in. calorimeters are positioned behind the system final-turning mirrors and are used to indicate the energy/beam on target during full system shots. Their readouts are on two H-P strip chart recorders in the control room. They are calibrated by full system shots against the reference 5-in. calorimeter placed at the output of the final turning mirror. The reference calorimeter produces an energy value that is used in conjunction with the 2-in. calorimeter strip-chart recorder deflection to produce a value of η for the latter calorimeter.

Two shots must be made:

- An ASE shot (no pulse introduced into chain), which gives background levels of ASE and flashlamp light for both calorimeters. Call these values E_{B5} , Δ_{B2} where the E_{B5} is the background energy and Δ_{B2} is the 2-in. calorimeter deflection for the background energies.
- A full shot in which the energy incident on the 5-in. calorimeter and deflection on the 2-in. calorimeter are recorded E_5 , Δ_2 . The calibration factor η' is defined by

$$\eta'_2 = \frac{E_5 - E_B}{\Delta_2 - \Delta_{B2}} \quad (14)$$

where $E_5 - E_B = E_L$, the laser energy. Therefore,

$$\eta'_2 = \frac{E_L}{\Delta_2 - \Delta_{B2}} \quad (15)$$

Thus,

$$E_L = \eta'_2 \Delta_2 - E'_B \quad (16)$$

where E'_B is a "background energy."

Finally, the energy on target E_T is given by the value of E_L multiplied by the target chamber (window + lens) transmission T_C :

$$E_T = E_L T_C = \eta^2 \Delta_2 - E_B, \quad (17)$$

$$\eta^2 = \eta'_2 T_C,$$

$$E_B = E'_B T_C.$$

There are at the time of writing this manual three 1-in. calorimeters. Two are used to measure reflected light off the target. The third is used to measure the output of the 1-in. rod amplifier chassis. This third amplifier is calibrated much like the 2-in. calorimeter. The 5-in. calorimeter is placed in the beam at the 1-in. rod output and background and full shot energy measured. At the same time, the light reaching the 1-in. rod calorimeter gives two recorder deflections that are used to calculate η and a background correction.

The 1-in. rod calorimeters for reflected light are calibrated against the 2-in. incident light calorimeters as follows. A gold mirror is placed in front of the target chamber and oriented so as to reflect the beam back on itself. The reflectivity of the mirror at 1.06 μm is greater than 99%. Shots made at various energies have demonstrated that flashlamp light and ASE have negligible effect on the calorimeters. Therefore, it is necessary only to do a full shot calibration. The laser is fired. The 2-in. calorimeter is used to measure the energy incident on the mirror and a deflection Δ_1 is measured on the 1-in. calorimeter strip chart recorder. The 2-in. calorimeter energy value is divided by the target chamber transmission to give the "equivalent energy" reflected off the target: E_R . The 1-in. calibration is then given by

$$\eta_1 = \frac{E_R}{\Delta_1}. \quad (18)$$

A calorimeter calibration record book should be maintained current. The 2-in. and 1-in. calorimeters must be calibrated when the final turning mirrors are changed. The 5-in. calorimeter must be recalibrated when used with a new amplifier or chart recorder.

13. SYSTEM MAINTENANCE

The number of hours of trouble-free laser system operation is directly proportional to the number of hours of preventive maintenance expended. Therefore, it is imperative that a conscientious program be followed to find

potential problem areas and correct them immediately. This section groups preventive maintenance items according to frequency of accomplishment.

Daily Requirements

Perform daily system maintenance as follows:

1. Check water level in reservoir of NESLAB chiller on east exterior of Bldg. 174. Fill when level approaches more than 1 in. lower than the top. Fill with DISTILLED water only.
2. Check water level in rod amplifier cooling water reservoir. Fill if more than 2 in. below the top.
3. Check tightness of flashlamp connectors on rod amplifiers Rod 1, Rod 2, Rod 3, 1A1, 2A1. Push connectors all the way on flashlamp terminals. A loose connector that falls off can lead to arcing and the following damage:
 - a. Cracked flashlamp shields.
 - b. Melted flashlamp terminals and a useless flashlamp.
 - c. Blown 300 A fuse in the respective capacitor bank.
 - d. MOST IMPORTANT. Loss of a potentially outstanding target shot.
4. Check nitrogen flow to B amplifier heads.
5. Check cooling water reservoir level in Holobeam CW laser power supply.
6. Check dye pump flow reading. A reading below 20 at a current indication of 26 indicates either a low dye solution or a clogged filter. In either case, drain the solution from the reservoir, measure its volume, and inspect the filter. A filter change takes only a few seconds and should be done while the reservoir is open.

Weekly Requirements

Perform weekly system maintenance as follows:

1. Inspect flashlamp reflectors in 1-in. rod chassis. If reflectors show signs of tarnish, clean reflectors with metal polish.
2. Dust tops of optical tables, high voltage terminal boxes, and large optical components.

3. Check oscillator dye transmission; if value is out of specs, add solvent or dye to bring transmission to value within correct range. Record initial transmission, final transmission, and dye and/or solvent added in maintenance log. If dye solution is drained from pump reservoir, record both the initial volume and the volume put back into reservoir.
4. Check voltage in power supply of target camera streak regenerator. Battery voltage should be greater than 550 V. If not, change batteries.
5. Check voltage in system trigger and prepulse photodiode batteries. Battery voltage is 45 V. If voltage is below 42 volts, replace batteries.
6. Check battery voltages in switchout module 22.5-V mercury batteries, 1.35-V mercury battery, and six 2.7-V mercury batteries. Replace if 10% below their rated voltages.
7. Check water level in chill water unit of oscillator dye pump; fill as necessary.

Tri-Weekly Requirements

Perform tri-weekly system maintenance as follows:

1. Polish lamp reflectors in 1-in. rod amplifiers.
2. Clean flashlamp shield tubes. Inspect rod shields for pitting and deposition of material that could significantly decrease energy transfer to rod. Consider replacement of tube if transmission is seriously degraded.
3. Change pump filter in oscillator dye cell.
4. Sweep out capacitor bank modules.

Special Items (Nonperiodic)

Explosion or Arcing of Flashlamp in Rod Amplifier Head

Repair flashlamp as follows:

1. Replace lamp (EG&G FX47C-8) and flashlamp shield as necessary. Replace any neighboring shields or lamps that may have been damaged.

2. Clean head of all debris.
3. Check fuse for corresponding bank in rod module. Replace if fuse is blown.
4. Test-fire head at low voltage before restoring amplifier to full operation.

Failure of Capacitor in YAG Pulse-Forming Network

CAUTION

Do not fire YAG preamplifiers more often than once per minute. Rapid firing can lead to failure of the 6-kV Maxwell capacitors in the pulse-forming networks.

In the event that the YAG preamplifier does not charge, failure of the Raytheon power supply or a failure of the 6-kV capacitor is the cause. If the PFN is suspect, proceed as follows:

1. Open the top of the PFN chassis.
2. Short the terminals of both capacitors.
3. Unhook the cables from the capacitor terminals.
4. Measure each capacitance with the digital capacitance meter. A reading of ZERO indicates a failed component.
5. Replace the failed capacitor(s) and test charge.
6. Dispose of the old capacitor, PLACING A SHORTING WIRE BETWEEN THE TWO TERMINALS.

Replacement of Oscillator Flashlamps

Deteriorating oscillator performance accompanied by poor lamp simmer characteristics indicates the L-2113 lamps must be replaced. Proceed as follows:

1. Secure oscillator head cooling water.
2. SECURE ALL OSCILLATOR HIGH VOLTAGE SUPPLIES.

3. Remove lamps from head.
4. Install new lamps. If new set does not simmer, replace with another set. New lamps have been found to have poor simmer qualities.

Replacement of Reynolds hv Connectors in YAG Pulse-Forming Networks

Rapid firing of the YAG preamps (greater than once per minute) may cause damage to the Reynolds hv connectors at the PFN chassis and at the injection transformers. When the YAG preamp stop operating correctly they and the Maxwell 6 kV capacitors should be inspected.

MS