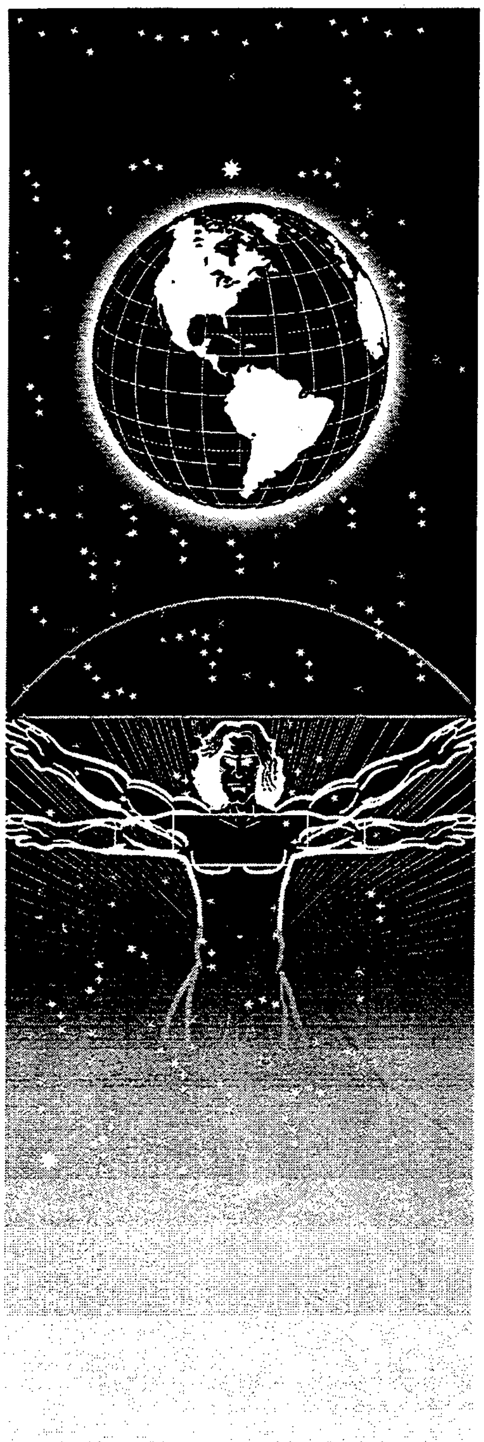
AL/OE-TR-1997-0161



UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

Operating Manual for Ultrashort Pulse Laser System-II (1060 nm Operation)

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December 1997

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1997	Final - September 1996 - June 1997

4. TITLE AND SUBTITLE

Operating Manual for Ultrashort Pulse Laser System-II (1060 nm Operation)

5. FUNDING NUMBERS

C - F33615-92-C-0017
PE - 62202F
PR - 2312
TA - A1
WU - 01

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Armstrong Laboratory
Occupational and Environmental Health Directorate
Optical Radiation Division
8111 18th Street
Brooks Air Force Base, TX 78235-5215

10. SPONSORING/MONITORING

AL/OE-TR-1997-0161

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes the ultrashort pulse laser system, USP-II, installed in the research laboratory and which is comprised of components manufactured by both Spectra-Physics and Coherent Laser Group. This laser system uses state-of-the-art laser technology to provide very high energy single pulses in the visible and near-IR spectra for pulsewidths near 100 femtoseconds. This report describes in detail the turn-on and operating procedures so that the system operator can bring it up to specifications and fine-tune the subsystems to give optimum pulsewidth and energy/pulse outputs. The basic system has been configured to operate on a single 4 by 12-ft optical bench with some diagnostic instruments permanently mounted to the table. The major subsystems which comprise the USP-II are described briefly as to their operating characteristics and how the output characteristics of each unit affects the output of the following unit. This report is not designed to replace the operating procedures of each subsystem but rather to describe how the complete system works in unison. Each subsystem is described in the same order as required to turn on the system and reach specified outputs. The theory of operation is incorporated into this turn-on procedure along with optimizing procedures. If any subsystem output does not meet its specifications, the operator is referred to the manufacturer's operating and maintenance procedures for that particular laser. Correct output signals for each laser are described and optimizing procedures for obtaining these optimum levels are also described. This report should be adequate for the daily operation of the system if no problems occur within any subsystem.

14. SUBJECT TERMS

laser system; optical bench; subsystems; USP-II

15. NUMBER OF PAGES 44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89) Prescribed by ANSI Std Z-39-18
298-102 COMPUTER GENERATED

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ULTRASHORT PULSE LASER SYSTEM II (1060 nm OPERATION)
Theory of Operation and Operating Procedures

INTRODUCTION

This report describes the ultrashort pulse laser system, USP-II, installed in the research laboratory and which is comprised of components manufactured by both Spectra-Physics and Coherent Laser Group. This laser system uses state-of-the-art laser technology to provide very high energy single pulses in the visible and near-IR spectra for pulsewidths near 100 femtoseconds. This report describes in detail the turn-on and operating procedures so that the system operator can bring it up to specifications and fine-tune the subsystems to give optimum pulsewidth and energy/pulse outputs. The basic system has been configured to operate on a single 4 by 12-ft optical bench with some diagnostic instruments permanently mounted to the table.

The major subsystems which comprise the USP-II are described briefly as to their operating characteristics and how the output characteristics of each unit affects the output of the following unit. This report is not designed to replace the operating procedures of each subsystem but rather to describe how the complete system works in unison. Each subsystem is described in the same order as required to turn on the system and reach specified outputs. The theory of operation is incorporated into this turn-on procedure along with optimizing procedures. If any subsystem output does not meet its specifications, the operator is referred to the manufacturer's operating and maintenance procedures for that particular laser. Correct output signals for each laser are described and optimizing procedures for obtaining these optimum levels are also described. This report should be adequate for the daily operation of the system if no problems occur within any subsystem.

LIST OF EQUIPMENT

Argon Ion Laser (Coherent Laser Group, Innova 200)

Titanium-Sapphire Laser (Coherent Laser Group, Mira 900F)

Neodymium-yttrium Aluminum Garnet (Nd:YAG) Laser - (Spectra Physics, GCR-130-10)

Titanium-Sapphire Regenerative Amplifier (Spectra Physics, TSA -02)

SYSTEM DESCRIPTION

The USP-II is comprised of four separate lasers operating synchronously. Each laser has its own output characteristics and certain lasers and combinations of lasers can be used independently of the others. Figure 1 shows the complete system and how the four lasers interact with each other. A brief description of the complete system is given here. However, for a complete theory of operation the reader is referred to each manual supplied by the manufacturers (see Reference List on page 31).

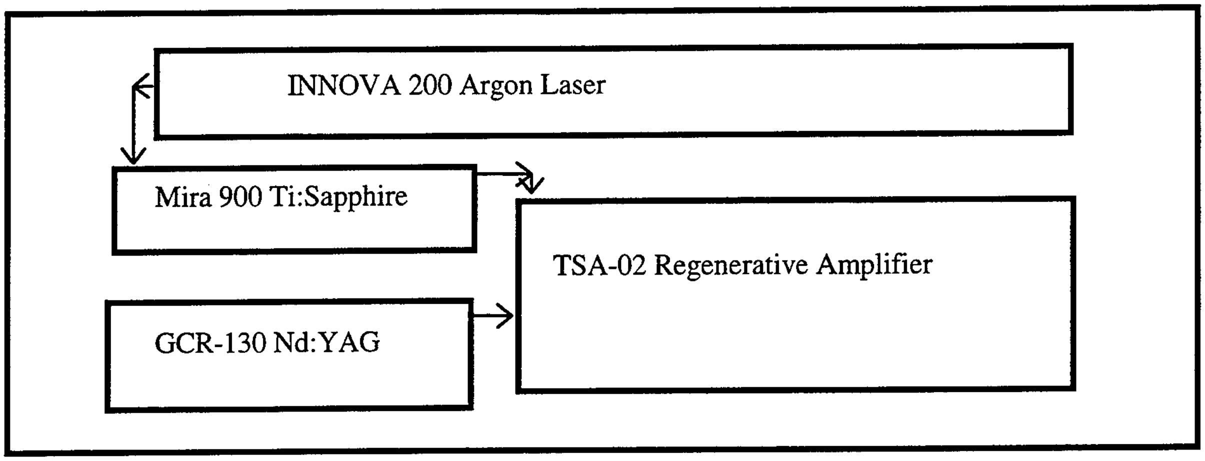

Figure 1. Block diagram of USP-II system with regenerative amplifier.

ARGON ION LASER (Innova 200)

General

The Innova 200 is a large-frame argon ion laser which is used in the USP-II System as a pump for the Mira 900-F Ti:Sapphire laser. It is run in the multi-line optical configuration, at ~15.0 watts output power, in the light-regulation mode (where the laser monitors the actual power by means of a photocell inside the cavity and continually adjusts the laser tube current to provide a consistent desired output). It is operated in the TEM_{00} or "Gaussian" transverse mode. Optimal cavity alignment and long-term stability are maintained through a feature called $PowerTrack_{TM}$, through the servo control of the high reflector. (For a more detailed Theory of Operation of argon ion lasers, see "Operator's Manual, The Coherent Innova 200 Series Ion Laser" Chapter Six.)

Systems Description

Laser Head

This is the component that produces the laser light. It consists of a pressurized tube of ionized argon gas positioned inside an optical cavity formed by two dielectrically coated mirrors. Other laser head components include: axial field magnet, resonator, photodiode, alignment servo, intracavity aperture and shutter, and optical controls. (For more detailed information on laser head components, see "Operator's Manual, The Coherent Innova 200 Series Ion Laser" pages 5-7)

Power Supply

Laser operation is powered by a power supply which is attached to the laser head by means of a large umbilical cord which also provides external cooling water. The power supply provides circuitry to start the laser tube, monitor the safety interlocks and advise of system faults. The operation and control of the laser is accomplished using a remote control module. (For more detailed information on power supply components, see "Operator's Manual, The Coherent Innova 200 Series Ion Laser" pages 7-8)

TI:SAPPHIRE LASER (Mira 900F)

General

The titanium-doped sapphire (Ti:Sapphire) laser is a solid-state laser capable of tunable operation over a broad range (700 nm to 1060 nm) of near infrared (IR) wavelengths. With different sets of optics, this laser can produce pulsewidths of 100-200 fs and 1-2 ps for most of the IR range listed above. This laser is used here as an oscillator to generate the pulses at a desired wavelength and pulsewidth which are then used as seed pulses to be amplified to the desired level of energies and peak powers.

The Mira 900-F uses Kerr lens mode-locking to produce passively mode-locked pulses (100-200 fs pulses at 76 MHz). The titanium-doped sapphire crystal acts as the Kerr lensing element. A pulse with a high enough peak power can change the index of refraction of certain materials. This causes the high powered mode-locked pulses within the laser's cavity to be focused to a much smaller spot size than the CW beam. An adjustable slit which is located in the cavity and adjusted to introduce losses to the CW that is present, allows only a smaller spot size with high peak power pulses to escape the cavity via the output coupler.

The birefringement filter can be adjusted for the desired wavelength. The adjustable slit can be varied horizontally and by width to achieve most stable mode-locked pulses with minimum CW. (For a more detailed Theory of Operation of the Mira 900-F, see "Operator's Manual, The Coherent Mira Model 900-F Laser", Chapter Seven.)

Systems Description

Laser Head

The cavity of the mode locked Ti:Sapphire laser consists of the titanium-sapphire crystal, pump mirror control optics, cavity mirrors, birefringement filter, brewster prisms, end mirror and output coupler. (Major laser head components are shown in "Operator's Manual, The Coherent Mira Model 900-F Laser", Figure 2-3 on page 2-5. Detailed description of all laser head components are found in Chapter Three: Controls and Indicators.)

Controller Box

The controller monitors the output and controls the operational mode of the Ti:Sapphire laser. Photodiodes inside the laser head provide fluorescence level and power level signals (displayed on the controller box) which allow the operator to align and monitor the laser. The controller also monitors the CW component in the output beam and can provide a drive voltage which operates the starter to establish mode-locked operation. (Detailed description of the controller box is shown in "Operator's Manual, The Coherent Mira Model 900-F Laser", Figure 3-12 on page 3-24. Detailed description of all controller box components are found in Chapter Three: Controls and Indicators page 3-25 through 3-27.)

NEODYMIUM-YTTRIUM ALUMINUM GARNET (Nd:YAG) LASER (GCR-130-10)

General

The Nd:YAG, GCR-130, laser is a Q-switched laser capable of operating from single shot to 10 pulses per second at a wavelength of 1064 nm. During Q-switched operation the flash lamp excites the Nd ions for approximately 200 msec to build up to a large population inversion. At the point of maximum population inversion, a fast high-voltage pulse applied to the Pockels cell changes the Q-switch from high to low loss. The resultant pulsewidth is less than 10 ns and the peak optical power is tens of megawatts.

An alternative long pulse mode of operation is built into the GCR. Voltage is applied to the Pockels cell as soon as the flash lamp fires, and the Q-switch is held open for the entire lamp firing. The result is a train of pulses about 200 msec long, with a separation between individual pulses of 2 to 4 msec. The total energy of the pulse train is similar to that of a single Q-switched pulse. This long pulse mode allows a safer alignment and set-up and is useful in experiments where total pulse energy, not its distribution in time, is the critical factor.

This laser operates with an unstable resonator and gets its name from its operation, Gaussian coupled resonator (GCR) because the reflector at one end is a partial reflector which has varied reflectivity and which is capable of producing a Gaussian or near-Gaussian spatial profile at the laser output. The spatial profile of this laser output in the near field is better than 70% Gaussian and in the far field is better than 95% Gaussian. The beam divergence is less than one-half milliradian for a beam diameter of less than 10 mm and the timing jitter is less than ½ ns. (For more detailed information on the theory of operation, refer to "Pulsed Nd:YAG Lasers, User's Manual - GCR Series", Chapter 1.)

Systems Description

Laser Head

This component contains the resonator that produces the 1064nm and 532nm light. The resonator consists of a pump chamber that contains a Nd:YAG laser rod and a pair of flash lamps, a pockels cell which is the active component of the Q-switch, a polarizer, and a pair of cavity mirrors. In addition to the resonator the laser head also contains the high voltage drive and supply for the pockels cell, the heater controller for the harmonic generator, the harmonic generator, and the dichroic mirrors that separate the fundamental wavelength from the second harmonic wavelength. (For more information on the laser head, refer to "Pulsed Nd:YAG Lasers, User's Manual - GCR Series", Chapter 3, page 3-8 and Fig 3-3.)

Remote Control Module

This component contains all of the necessary electronic controls to tune the GCR. It consists of the lamp energy control, the repetition rate control, the Q-switch control, and all of the controls to enable and disable all of these controls as well as the controls to start and shut down the GCR. (For more information on the remote control module, refer to "Pulsed Nd:YAG Lasers, User's Manual - GCR Series", Chapter 3, page 3-1 through 3-3 and Fig 3-1.)

Power Supply

This component contains the power supply for the flash lamps, the pulse forming network for the flash lamps, the cooling system, the circuitry to control the repetition rate, all of the circuitry to control the different modes of operation, and the interlock control circuitry. (For more information on the power supply, refer to "Pulsed Nd:YAG Lasers, User's Manual - GCR Series", Chapter 3, page 3-4 through 3-6 and Fig 3-2.)

TI:SAPPHIRE REGENERATIVE AMPLIFIER (TSA -02)

General

The Spectra-Physics Ti:Sapphire regenerative amplifier is designed to amplify single pulses from a CW mode-locked Ti:Sapphire laser. Typically an input pulse of energy only a few nanojoules can be amplified to over 1 mJ. This represents an overall amplification of greater than 10^6. The amplification takes place as the optical pulse passes through a Ti:Sapphire laser rod, which as been optically excited by a doubled laser pulse from a Nd:YAG laser. Normally the amplification of the laser rod is small, only about 3 times in a single pass, however the regenerative amplification technique enables the pulse to multipass the rod resulting in a much higher overall gain. With each pass the energy increases by a factor of 3.

Normally the maximum output energy would be limited by the damage threshold of the optical elements. However through the use of the powerful technique of Chirped Pulse Amplification, the TSA is designed to operate without the risk of optical damage. The technique, originally developed for radar application, involves temporally stretching the pulse, amplifying at reduced peak power, then recompressing the amplified pulse to close to its original duration. Typical output energies from the TSA and its associated pulse stretcher/compressor are greater than 1 mJ depending on the wavelength. Wavelengths near its operating limits, ~ 1060 nm, will have lower pulse energies than for wavelengths near its center operating characteristics between 800 - 900 nm. (For a more detailed explanation of the theory of operation refer to "Pulsed Ti:Sapphire Amplifier with Pulse Stretcher and Compressor - User's Manual", Chapter 3).

Systems Description

Stretcher

The stretchér stretches the input pulse in time to prevent damage of the resonator optics from high intracavity peak powers. The stretcher consists of a grating, a spherical mirror, and two corner reflectors. The seed beam is directed through the stretcher such that it reflects off of the grating four times and is ejected by a pick-off mirror near the grating.

Resonator

The resonator amplifies the stretched input pulse by trapping one of the pulses in the seed beam in the cavity and ejecting after it has been amplified to approximately a million times its original energy. The resonator consists of a pair of end mirrors, two pockels cells, a polarizer, a quarter wave plate, and a Ti:Sapphire laser rod.

Compressor

The compressor compresses the stretched pulse to 1.5 times its original width before amplification. The compressor consists of a grating, an adjustable slide, and a pair of corner reflectors.

Second Harmonic Generator

The second harmonic generator frequency doubles the infrared laser light into the visible spectrum. It consists of a second harmonic crystal, and two dichroic mirrors.

Synchronization & Delay Generator (SDG)

The SDG generates all the electronic signals that are needed to control the timing of the regenerative amplifier. (For a more detailed description of the SDG refer to "Synchronization & Delay Generator" user's manual.)

Single-shot and Protection Control Box for the TSA-02

This control box was designed to turn off the TSA-02 when the Mira 900 is not mode-locking properly and also to allow the TSA-02 to operate in 10Hz or single-shot modes while being protected. The circuit protects the TSA-02 from potential catastrophic damage to the optics in the resonator and compressor sections. Since the stretcher of the TSA-02 is designed for temporally stretching large bandwidth short pulses (femtosecond pulses), damage can occur when the bandwidth of the input pulse is insufficient (picosecond pulses) or there is a high CW component in the mode-locked output of the Mira. These conditions (lack of bandwidth and high CW component) are present if the Mira is not mode-locking correctly. For a functional diagram of this circuit, refer to Figure 2.

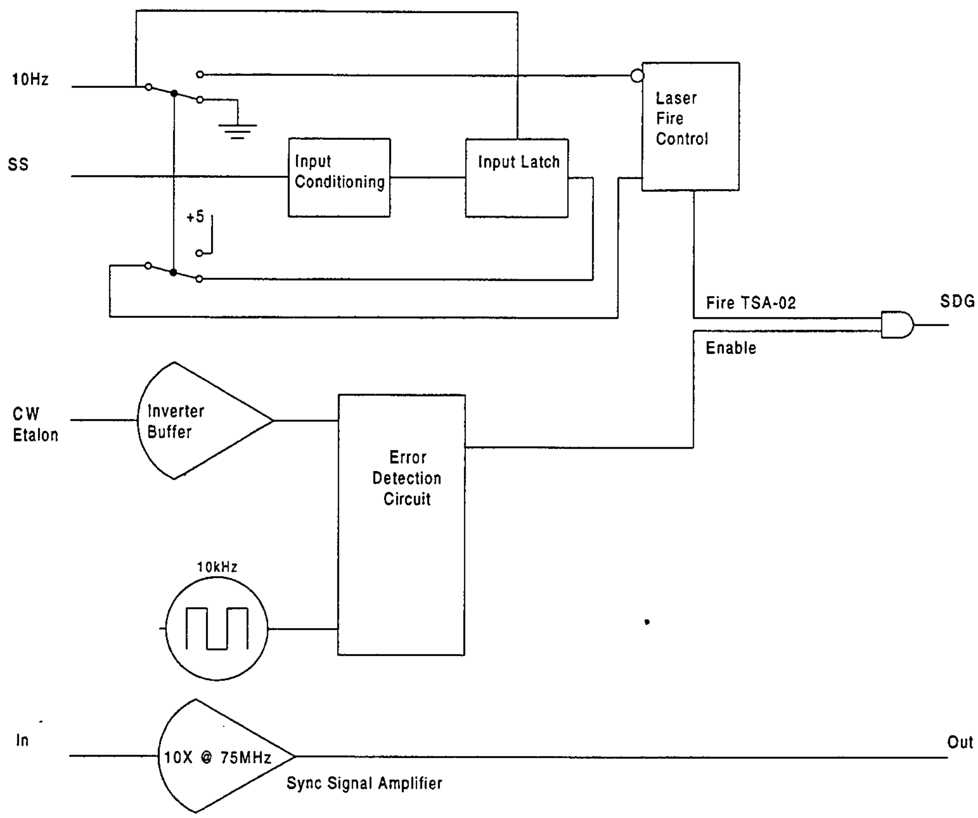

Figure 2. Block diagram for the Single-shot and Protection Control Box.

The control box uses the **CW Etalon Out** signal of the Mira 900 controller box to sense when Mira 900 is mode-locking improperly. When the **CW Etalon Out** signal exceeds the preset trip point, the control box opens the fire control circuit. This inhibits the control box from sending a trigger (fire) signal to the SDG **5V Enable** connector. In order for this to prevent damage the SDG must be in the **Protected** mode and not the **Free Running** mode. When the SDG is in the **Protected** mode the output drive to the pockels cells is not applied to the TSA-02 until the SDG receives a trigger signal on the **5V Enable** connector. This prevents the control box from allowing a pulse with too narrow a bandwidth to be amplified, keeping the intracavity peak power down, thus protecting the optics.

In addition to these functions the Single-shot and Protection Control Box contains a sync signal amplifier. This amplifier amplifies the internal photodiode signal of the Mira to a level that is suitable for the SDG's **sync in.** For a more complete description of this control box refer to Appendix A of this manual.

The **Level** control of the control box must be set properly before it can effectively protect the TSA-02 from damage. The **Level** control should be set after the Mira 900 is mode-locking properly and the output power fluctuation are at a minimum. Set the **Level** control by turning the knob clockwise until the **error** light is not illuminated. Then turn the knob counter clockwise slowly until the **error** light illuminates. Rotate the knob 1/8 turn clockwise. The **error** light should extinguish after ~1.5 seconds.

OPERATING PROCEDURES

Start-up

- Turn on "DO NOT ENTER" illuminated sign.
- Close all doors to laboratory.
- Verify that extra laser eye protection is available in the entryway should anyone require access to the room.
- Clear optical bench/table of all materials extraneous to the experiment.
- Instruct all personnel present to put on laser eye protection.

WARNING - Before starting any laser, refer to "Lab 17 Operating and Safety Procedures."

WARNING - Personnel will not look directly into the beam.

WARNING - The argon laser and its power supply, and the Nd:YAG laser and its power supply have high voltage circuits that are exposed when the covers are removed. High voltage power supplies are also found in the Mira 900 (near output end) and in the TSA-02 box (power supplies for the Faraday Isolator and the Pockel's Cells).

WARNING - Operation of the Ultrashort Pulse Laser System II should be attempted only by trained technical personnel. Failure to follow all operational procedures can result in injury and/or equipment damage.

Note: A cabling interconnection diagram is provided below in Figure 3. Please refer to this figure to insure that all cables are connected as shown.

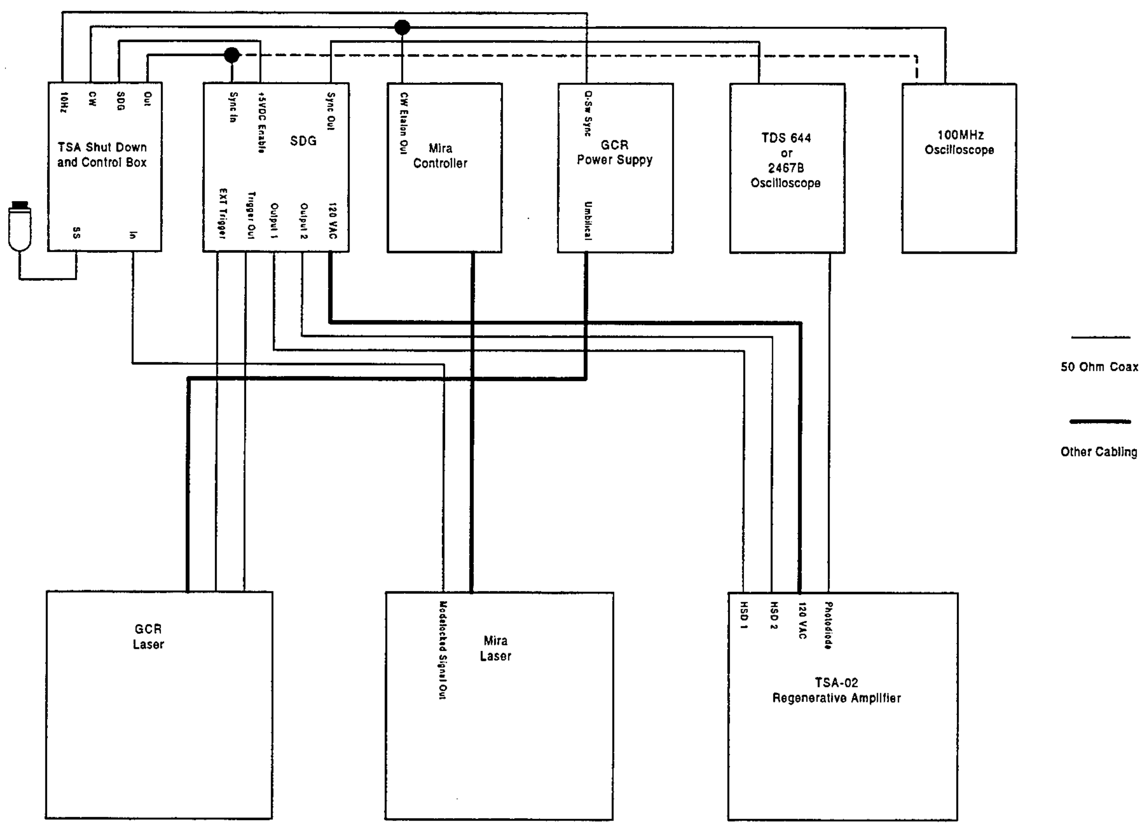

Figure 3. Cabling interconnection diagram.

Innova 200, Argon Laser

- Turn on Innova 200 (I-200) water supply. Make sure that water pressure regulator is set to ~ 42 psi.
- Turn on I-200 circuit breaker and key.
- Press the 'ON' switch on the I-200 laser controller box. Wait for the start delay to complete its cycle.
- When lasing occurs press "Tune" button on controller box and peak output by adjusting horizontal and vertical rear-mirror knobs. Press "Tune" button again.
- Set output power to ~15 W by using orange up or down arrows on controller box. Turn on "Light Reg." control.
- Make sure "Power Track" control is on (when **TRACK** appears after the amperage readout on the controller box - when there is nothing after the amperage readout, "Power Track" is off).

Mira 900, Ti:Sapphire Laser

- When argon laser beam hits the Ti:Sapphire crystal, wait 30 seconds and turn on Ti:Sapphire crystal chiller.

WARNING: do not run chiller when argon beam is not hitting the crystal, or condensation will occur on crystal face and both faces will have to be cleaned before operation.

- Turn slit width control knob clockwise until it stops to open slit completely.

- Turn on Mira 900 controller box. Set the "CW/ML" select switch to "CW".
- Peak the Mira starting with the pump beam controls first. Iterate between the pump beam controls and the rear mirror adjustments until peak output is achieved (~700 - 900 mW).
- Reduce slit width by turning the slit width control knob counterclockwise until the output power is reduced to about 20%.
- Use the horizontal slit control knob to center the slit, as indicated by maximum output power.
- Set the "CW/ML" select switch to "ML".
- Eliminate the CW content in the mode-locked pulse train by adjusting the slit width and horizontal position (output should be ~ 150 mW average power mode-locked and minimum variation on its output power as observed on the oscilloscope).
- Check the alignment of the Mira output beam through the apertures after the external beam collimator. Adjust with turning mirrors as necessary.

<u>Nd:YAG Laser (Pump Source for Regen)</u>

- Before turning on GCR laser make sure that output #2 from sync unit is disconnected, then turn on power to the SDG.
- Turn "Sync enable" switch on the SDG off (down).
- On GCR controller box, turn "Lamp Energy" knob counterclockwise to lowest setting.
- Insure GCR-130 (GCR) controls are set as follows:

Q-Sw Mode	Q-Sw
Rep Rate	Fixed
Lamp On	On
Single Shot	Rep
Lamp Energy	All the way CCW

- Insure that the SDG is set as follows:

Sync Enable	Down
Output Enable	Down
Output 2	Disconnected
Protected/Free Running (rear panel)	Up (Free Running)

GCR STARTUP AND MAIN CAVITY ALIGNMENT

WARNING: Block Mira beam with beam stop or power detector while performing main cavity alignment.

- On GCR power supply turn key switch to "On".
- Temporarily depress "Enable" switch on GCR controller box.
- After simmer lamp comes on, turn "Lamp Energy" knob clockwise until the GCR is just lasing. Check GCR beam path for misalignment (do not adjust unless there is severe misalignment).
- Turn "Lamp Energy" knob clockwise until desired output is attained (usually all the way to maximum).
- Allow 30 minutes for GCR and TSA-02 to thermally stabilize.
- Turn on the "Output Enable" switch on the SDG module.
- Check to see if TSA-02 main cavity is lasing by attaching a photodiode behind **ma2** to an oscilloscope, or by using an IR card or viewer to detect leakage energy after **mc1** (refer to Figure 4 for TSA-02 layout).

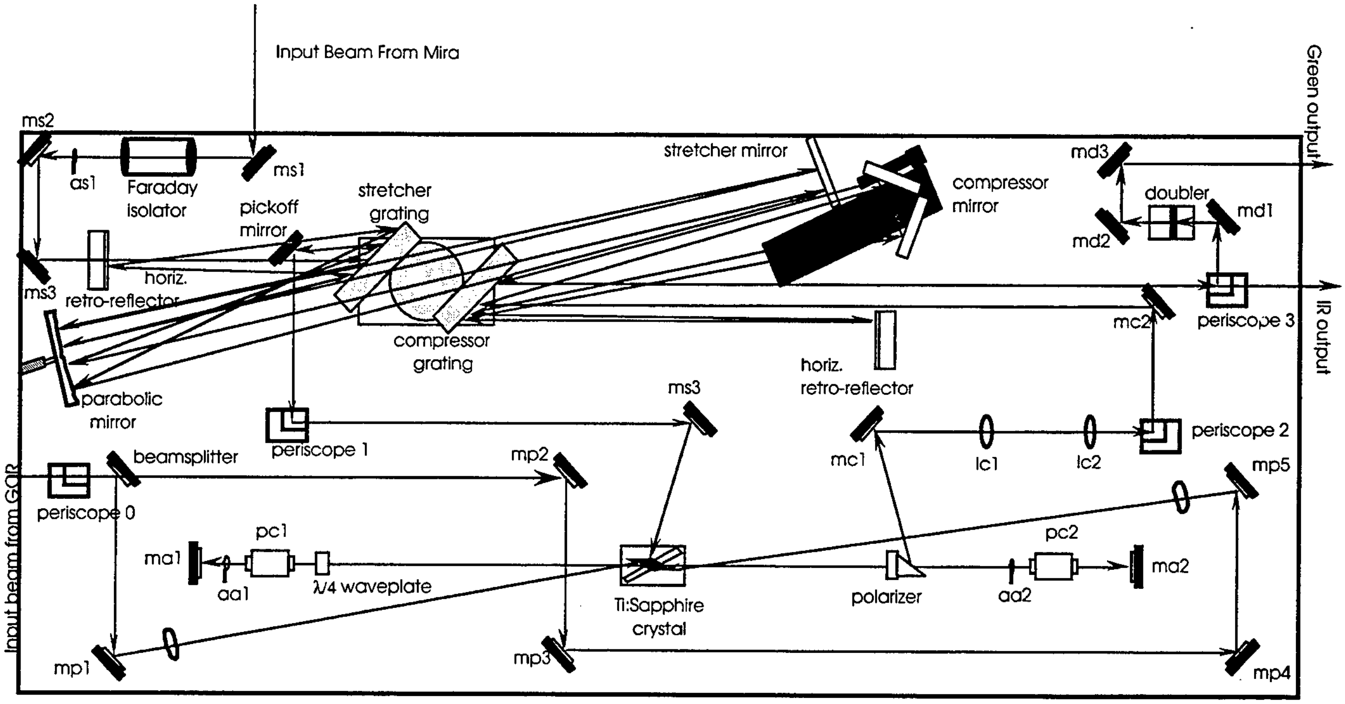

Figure 4. TSA-02 system layout.

- If main cavity is lasing, use photodiode and oscilloscope to minimize buildup time. Buildup time is minimized by adjusting the GCR beam alignment (using **mp1** and **mp5** to center the beam in the Ti:Sapphire crystal), adjusting the doubler crystal angle tuning knob within the GCR Harmonic Generator, and by adjusting the "Q-switch Delay" knob on the GCR controller box. (Note - Do not adjust input polarization rotator, located anterior to the crystal angle tuning knob within the GCR Harmonic Generator. Do not adjust external waveplate, located between GCR output and TSA-02 input port.)
- After buildup time has been minimized by adjusting the GCR, adjust the cavity mirrors (**ma1** and **ma2**) to center the lasing in both of the cavity apertures (**aa1** and **aa2**) and improve the build up time. When the system is optimized, buildup time

should be in the 800-1000 ns range. (If there is difficulty achieving build up time less than 1000 ns, examine cavity optics for evidence of damage.)

- If there is no evidence of lasing perform Main Cavity Alignment Troubleshooting.

MAIN CAVITY ALIGNMENT TROUBLESHOOTING

- Maximize energy out of the GCR using an energy meter. Adjust the angle of the doubler crystal and "Q-Switch Delay" to achieve maximum output. Then check for evidence of lasing at the output of the TSA-02. If there is lasing present adjust pump beam fold mirrors for minimum build up time. Readjust GCR as necessary.
- If there is still no evidence of lasing, check the alignment of the GCR beams on the faces of the Ti:Sapphire laser rod. Watching the fluorescence on the face of the rod, center it with the pump mirrors (**mp1 & mp5**). Check for evidence of lasing while performing this adjustment.
- If there is still no evidence of lasing, set the GCR into the single shot mode.
- Remove the photodiode and align a He:Ne laser through the TSA-02 cavity.
- Check to see if the back reflections of the He:Ne beam are reflecting back through the cavity and into the He:Ne laser.
- If it is not, then adjust the cavity mirrors such that they do reflect back into the He:Ne laser.
- Install the photodiode.
- Set the GCR to the 'rep' mode of operation. Allow the GCR to run for 30 minutes.
- If there is still no evidence of lasing, adjust the cavity end mirror nearest to the GCR (**ma1**) slightly in each axis while watching for evidence of lasing with an IR viewer.

- Repeat the steps above until the TSA-02 lases.

SEED BEAM ALIGNMENT

- Turn GCR to single shot (not lasing, lamps running).
- Open entrance shutter to TSA box and allow seed (Mira) beam to enter.
- Check alignment through entrance aperture (**as1**), and through a second alignment aperture after the horizontal retro-reflector.
- If alignment looks correct, check beam pattern on large gold parabolic mirror, using an IR viewer. The pattern on the mirror should look like this:

- If the pattern is properly oriented and aligned, check alignment through the main cavity by closing down the apertures and assuring the seed beam passes through the centers.
- If alignment through the main cavity is necessary, adjust the pickup mirror and **ms3** until proper alignment is attained.
- If the beam pattern is misaligned, or other than that shown above, or if there is any other evidence of misalignment, pull out the stretcher/compressor grating assembly, install alignment aperture and align stretcher/compressor cavity using **ms2** and **ms3**.
- When seed beam passes through the center of the aperture at both locations, reinstall stretcher/compressor grating assembly (make sure stretcher grating is facing toward **ms3**).

- Loosen locking screw on grating assembly and place Mira laser in CW mode.
- View gold parabolic mirror with IR viewer while moving stretcher grating through the seed beam. At a certain point of adjustment there will be a pattern on the parabolic mirror that looks like this:

- When this is in place lock down grating, and make fine adjustment with micrometer dial.
- Recheck alignment of seed beam (through **aa1** and **aa2**) and adjust if necessary.

SEED BEAM AMPLIFICATION

- Block seed beam from entering amplifier.
- Turn GCR lamp energy up to maximum. Check oscilloscope to assure the main cavity is lasing.
- Minimize buildup time.
- When the system is optimized, buildup time should be in the 800-1000 ns range.
- Make sure the safety circuit is on. On rear of SDG turn "Protected/Free Running" switch down (protected).
- Make sure yellow "Protected" light is illuminated on Fire Control and Protection Box and "SS/10 Hz" switch is on 10 Hz.
- Allow seed beam to enter amplifier.

- Turn on (up) "Sync Enable" switch on the SDG. Minimize buildup by adjusting **ms3** to obtain best alignment.
- Dial "Output 2" on the SDG to 1200 ns, then connect coax cable.
- Slowly reduce value on "Output 2" while watching result on oscilloscope. As the value of "Output 2" goes down, a pulse earlier in time (and closer to the peak energy) is chosen to be ejected by the pockels cell. In choosing which pulse to select, it is best to choose one high enough in energy yet after the peak of pulses in the curve.
- Make sure that only one pulse is being selected by checking o-scope reading from photodoide 2.
- Place a power meter between **lc1** and **lc2** and take a reading. Expect a value in the 40-50 mW range.
- Use burn paper to take a beam profile at the same point. Verify that the beam is round and has no "hot spots".
- Remove power meter and allow the beam to travel through the compressor.
- To obtain IR output remove top mirror on **periscope 3**.
- To obtain green light install top mirror on **periscope 3**. Tune second harmonic crystal angle to optimize output.

OPTIMIZING PROCEDURES

Optimizing the Mira Laser

- Press "enable" button on Safety Circuit box so that red light is on.
- Disconnect "Output 2" on SDG.
- Turn off (down) "Sync enable" and "Output enable" switches on front of SDG.

- Block output of Mira laser with power detector or beamstop.
- Tune argon laser by adjusting horizontal and vertical rear mirror adjustment knobs.
- Set the "CW/ML" select switch on Mira controller box to "CW".
- Turn slit width control knob clockwise until it stops to open slit completely.
- Peak the Mira starting with the pump beam controls first. Iterate between the pump beam controls and the rear mirror adjustments until peak output is achieved (~700 - 900 mW).
- Reduce slit width by turning the slit width control knob counterclockwise until the output power is reduced to about 20%.
- Use the horizontal slit control knob to center the slit, as indicated by maximum output power.
- Set the "CW/ML" select switch to "ML".
- Eliminate the CW content in the mode locked pulse train by adjusting the slit width and horizontal position (output should be ~ 150 mW average power mode-locked and minimum variation on its output power as observed on the oscilloscope).

Optimizing the Nd:YAG Laser

- Set "Rep/Single Shot" switch on GCR controller box to Single Shot.
- Use Molectron PM5200 power meter with a PM30-V1 head (or equivalent) at the output of the GCR. Fire single shot to insure that detector is aligned.
- Switch the GCR to the 10 Hz repetitive pulse mode, turn the "Energy level" knob all the way CCW (maximum), and insure that the GCR is in the Q-switched mode.

- While monitoring output with power meter, adjust Q-switch delay (inner knob on Q-switch adjustment control) and doubler crystal angle tuning control for a maximum of 200 mJ.

Reducing the TSA-02 Buildup Time

- The first step in reducing TSA-02 buildup time is to optimize the Nd:YAG laser (see above), while observing buildup time on an oscilloscope.
- Adjust pump turning mirrors (**mp1** and **mp5**) in horizontal and vertical to center beam in the Ti:Sapphire crystal.
- Adjust cavity mirrors (**ma1** and **ma2**) in horizontal and vertical. (Note: these are very delicate adjustments, and should be made with great care and only when absolutely necessary.)

Reducing Pulsewidth

To obtain minimum pulsewidth of femtosecond pulses, it is helpful to focus the output of the TSA-02 into a water cell and observe the generation of "white light continuum". The more intense the white light, the shorter the pulse.

- Place a positive lens and water cell (or an "artificial eye") in the path of the output beam from the TSA-02. Place a white card behind the water cell.
- Loosen the locking knob on the compressor mirror slide.
- Slowly move the slide forward and backward until white light on the card is most intense.
- Use the compressor motor controller to fine-tune the pulsewidth (typical output is ~ 150 fs).

- Verify minimum pulsewidth with slow-scan/fast-scan autocorrelator.

SHUTDOWN PROCEDURES

Normal Shutdown

- Disconnect "Output 2" on SDG.
- Turn off (down) "Sync enable" and "Output enable" switches on front of SDG.
- Block output of Mira laser with power detector or beamstop.
- Turn "Protected/Free Running" switch on rear of SDG to "Free Running" (up).
- On GCR control module, reduce output by turning the "Lamp Energy" control to "Start".
- Press the "Stop" button, and turn off the key switch on the GCR power supply (leave the circuit breaker "On").
- Shut off chiller for Mira Ti:Sapphire crystal (wait 30 seconds).
- Press "Off" button on argon laser controller box.
- Turn key on argon laser power supply to "Off" position.
- After waiting about 2 minutes turn off argon cooling water.

Emergency Shutdown

- Press red **Emergency Laser Cutoff Switch** button located on the wall near the lab entrance door.

DIAGNOSTIC INSTRUMENTATION

Single-shot Autocorrelator

Slow-scan / Fast-scan Autocorrelator (Inrad, Model 514BX)

500 Mhz Oscilloscope (TDS 644B) or 400 Mhz Analog Oscilloscope (Tektronix, Model 2467B)

100 Mhz Oscilloscope

Spectragraph (Chromex, Model 500IS)

Energy Meter (Molectron JD-2000 or EPM2000, w/ J4-09 Detector)

Power Meter (Molectron PM-5200 or EPM2000, w/ PM30-V1 Detector or PM10 Detector)

Fast-rise Photodiode

IR Viewer

SPECIFICATIONS

<u>Argon Ion Laser (Innova 200)</u>

Manufacturer	Coherent Laser Group
Model No.	I-200-25
Laser type	argon ion
Wavelengths	454.5, 457.9, 465.8, 472.7, 476.5, 488.0, 496.5, 501.7, 514.5 & 528.7nm
Beam divergence	0.4mrad
Pulsed or cw	Cw
Beam power	25W (Multiline visible)
Beam diameter	1.9mm
Electrical power	480VAC, 3-phase, 50 or 60 Hz
Water	6 gal/min, 40 psi, 10-35° C

Ti:Sapphire Laser (Mira 900F)

Manufacturer	Coherent Laser Group
Model No.	Mira 900-F
Laser type	Titanium sapphire
Wavelengths	750-1060nm, (375-530nm doubled)
Beam divergence	1.7mrad
Pulsed / cw	76MHz 125fs or cw
Beam power	60kW peak power pulsed, 1.5W cw @ ~800nm
Beam diameter	0.7mm
Crystal chiller	10-13°C
Nitrogen purge	As required for stable operation.

Neodymium-Yttrium Aluminum Garnet (Nd:YAG) Laser - (GCR-130-10)

Manufacturer	Spectra-Physics
Model No.	GCR-130-10
Laser type	Q-switched Nd:YAG
Wavelengths	1064nm, (532nm doubled)
Beam divergence	<0.5mrad
Pulsed / cw	Pulsed (Single - 10Hz)
Pulse energy	500mJ/pulse @ 1064nm, 200mJ/pulse @ 532nm
Beam diameter	10.0mm
Electrical power	190-250V, single phase, 50 or 60Hz
Nitrogen purge	2scfm (24 hrs a day)

Ti:Sapphire Regenerative Amplifier (TSA-02)

Manufacturer	Spectra-Physics
Model No.	TSA-02
Laser type	Ti:Sapphire regenerative amplifier
Wavelengths	Tunable about 1060nm and 800nm
Beam divergence	N/A
Pulsed / cw	Pulsed (Single - 10Hz)
Pulse energy	5mJ/pulse @ 1060nm, 0.5mJ/pulse @ 530nm
Beam diameter	N/A

REFERENCES

Operator's Manual, The Coherent Innova 200 Series Ion Laser (Coherent Laser Group, Santa Clara, CA)

Operator's Manual, The Coherent Mira Model 900-F Laser (Coherent Laser Group, Santa Clara, CA)

User's Manual, Pulsed Nd:YAG Lasers - GCR Series (1996, Spectra-Physics Lasers, Mountain View, CA)

User's Manual, Pulsed Ti:Sapphire Amplifier with Pulse Stretcher and Compressor (1993, Spectra-Physics Lasers, Mountain View, CA)

Synchronization & Delay Generator (1996, Positive Light Inc., Los Gatos, CA)

Laser Lab - Room 17 Operating and Safety Procedures (1997, USAF, Brooks AFB, TX)

APPENDIX A

Circuit Description for the Single Shot and Protective Control Box for the TSA-02

Circuit Description for the Single Shot and Protective Control Box for the TSA-02

The shut down circuit consists of a buffer inverter section, a level comparator section, and an output gating section (diagrams of these circuits can be found in Figures 5-7 of this appendix). The input section is the buffer inverter section and it has an input impedance of 10KΩ. This section is an inverting amplifier (U1) with unity gain. The next section is the level comparator (U2a) section. This section senses whether or not the **CW Etalon Out** signal has exceeded a preset level. When this level is exceeded the red **error** LED on the rear panel will illuminate. This also fires the one shot (U3a) in the output gating section. The output gating section is designed to disable the SDG for ~1.5 seconds when it is fired. This is accomplished by removing the drive voltage of the transistor (Q1) that enables the optocoupler (U4). When the shut down circuit has disabled the SDG the red **error** LED on the front panel will be illuminated. The control box can also be used to disable the TSA-02 by pressing the **Enable** button. This switch grounds the base of Q1 which disables the output of the control box. When the button is pressed the two yellow LED's (front and rear) will not be illuminated and the red **error** LED on the front panel will be illuminated.

The laser fire control circuit consist of three sections. These are the input signal condition circuit for single shot operation, a one shot, and an output section. These circuits give the TSA-02 the ability to operate in both single-shot and 10Hz modes while still being protected by the shut down circuit. The input signal conditioning circuit is made up of a low-pass filter, a comparator (U2d), and two D flip-flops (U6). The low-pass filter is just a simple R-C network which the input signal passes though to eliminate ringing from the single-shot switch closure. The next section is a comparator set to trigger at 2.5 volts with a +/- 10% hysteresis to eliminate ringing in the signal. The final part of the signal conditioning circuit is a pair of flip-flops used to ensure that only one trigger signal is sent to the TSA-02 for each switch press. The first D flip-flop latches high when it sees a low to high transition from the comparator circuit. The second D flip-flop clocks the state of the first D flip-flop through to the one shot (U3b) on each low to high transition of the 10Hz input. Both D flip-flops are reset when the one shot fires.

The one-shot circuit receives its trigger signal from either the 10Hz or single-shot signal conditioner depending upon the setting of the single-shot / 10Hz switch on the front panel of the control box. When it receives a trigger signal it turns on for 55ms. This pulse turns on transistor Q5, in the output section, which activates the optocoupler U7. The optocoupler in turn pulses transistor Q6 that applies a 55ms pulse to the SDG if the shut-down circuit has not detected an error condition.

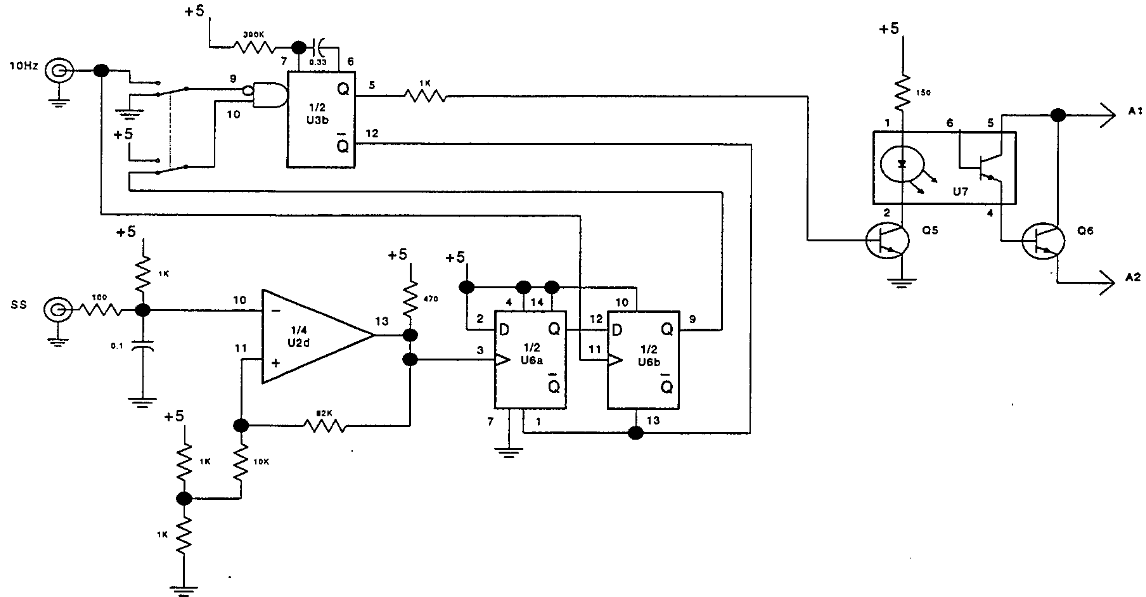

Figure 5. TSA-02 fire control circuit.

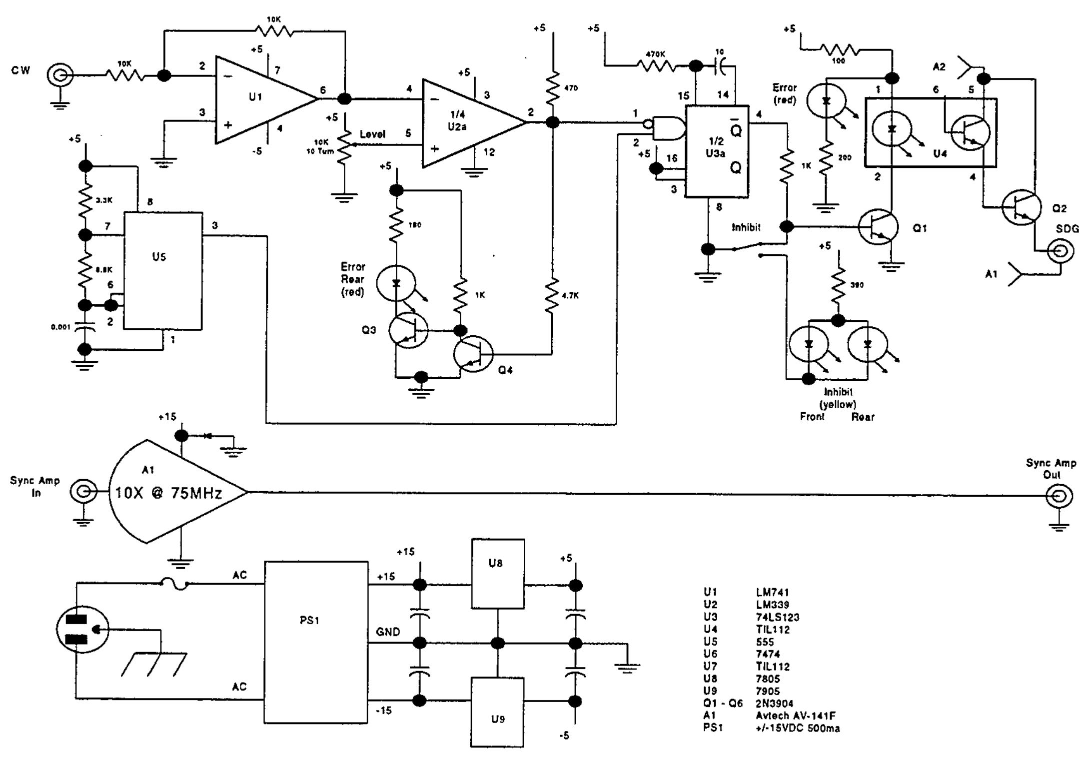

Figure 6. TSA-02 shutdown circuit.

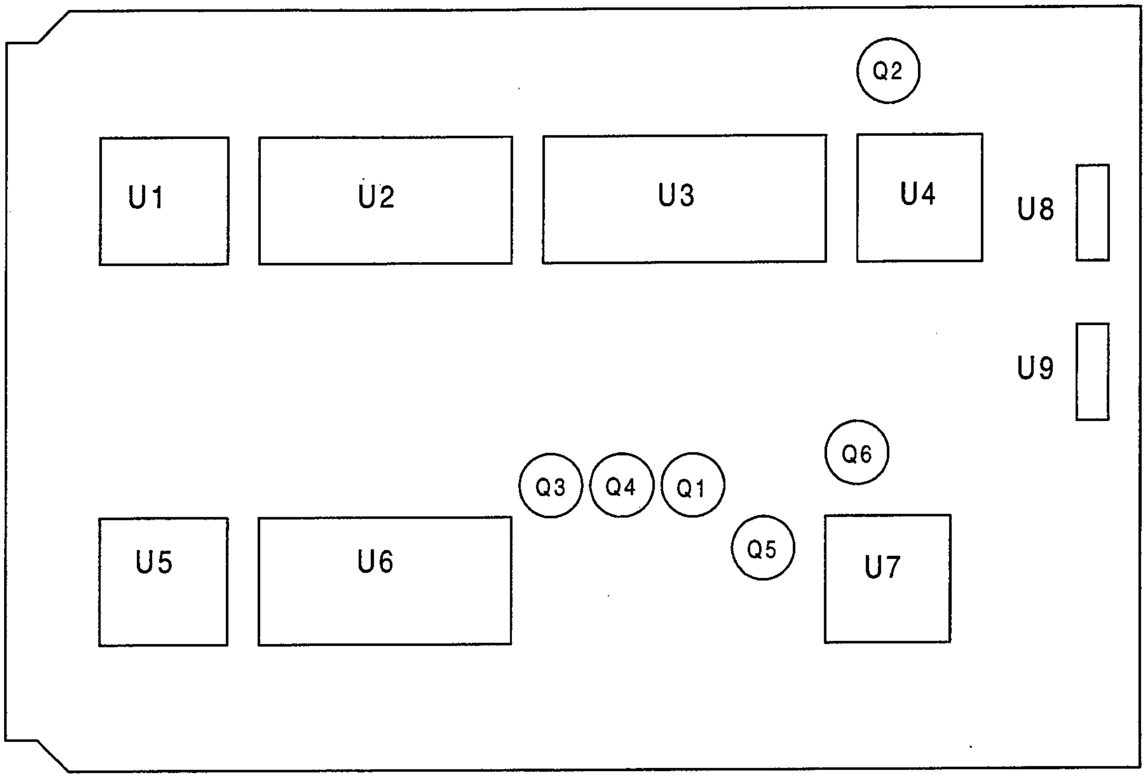

Figure 7. TSA-02 shutdown and fire control circuit board layout.