S-AA-M-##

System Operations Manual
Volume I–System Description

Chapter 2: Drivers

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Chapter 2
Drivers

2.0 INTRODUCTION

The Laser Drivers subsystem consists of four distinct driver lines or "drivers;" three that can be injected into the OMEGA beamlines and one that provides an optical timing reference used by diagnostic instruments. Each driver includes the equipment needed to generate, shape, amplify, propagate, and diagnose infrared pulses. The pulses range in duration from 100 ps to 4 ns and are delivered at a rate of 5 Hz.

The names of the driver lines that seed the OMEGA beamlines are historical and do not definitively reflect their capabilities and uses.

- The "main" driver is a basic configuration.

- The "SSD" driver is similar to the main driver and is outfitted for two-dimensional smoothing by spectral dispersion (SSD). Because smoothing can be turned on or off within minutes, this driver tends to be used for the majority of shots.

- The "backlighter" driver is similar to the main driver, but is configured to be injected into any *one* of the three OMEGA beamline legs. This allows up to 20 beams to have a pulse shape and on-target arrival time that is different from that of the remaining beams. While these beams are often directed to targets that produce x rays that backlight other shot targets, they are not limited to that use.

Either of the main or SSD drivers can be injected into the stage-A splitter and on into the three beam legs via a 64-mm booster laser amplifier. The "64" makes up for the energy loss at the three-way split so that pulses with identical shapes, timing, and energy may be propagated onward. When the backlighter driver is in use, the main or the SSD driver can be used in either or both of the legs that are not seeded by the backlighter driver.

Figure 2.0-1 provides an overview of the components that make up each of the driver lines. Each driver has a separate laser master oscillator that provides 1053-nm optical pulses to the aperture-coupled stripline (ASCL) equipment. Electrical signals originating in the Hardware Timing System (HTS) are used to generate synchronized triggers that cause the ACSL equipment to produce time-varying ("shaped") optical pulses. This configuration is the result of an integrated front-end source (IFES) project that introduced the laser master oscillator and the IFES fiber amplifier (IFA). The IFA and improved ACSL components are grouped into a single rack-mount package referred to as the "IFES Box."

The main, SSD, and backlighter drivers include an OMEGA diode-pumped regenerative (ODR) amplifier, and a flash-lamp–pumped, large-aperture ring amplifier (LARA). The fiducial driver is used as a timing reference for diagnostics and has a different amplification scheme (see Sec. 2.5, Fiducial Subsystem).

The laser-driver subsystems are located in the Driver Electronics Room (DER), the Pulse Generation Room (PGR), and the driver-line area (DLA) of the Laser Bay. The DER and PGR are located within the same electromagnetic-interference-shielded walls, but have separate heating, ventilation, and air-conditioning systems. In addition to the pulse-shaping subsystems, the DER houses the HTS, along with various timing circuits. The DER and the PGR are fiber-optically coupled for flexibility and alignment insensitivity. The PGR contains several major elements of the driver line, including pulse switch-out, regenerative amplification, pulse truncation, driver diagnostics, amplification, smoothing, and alignment.

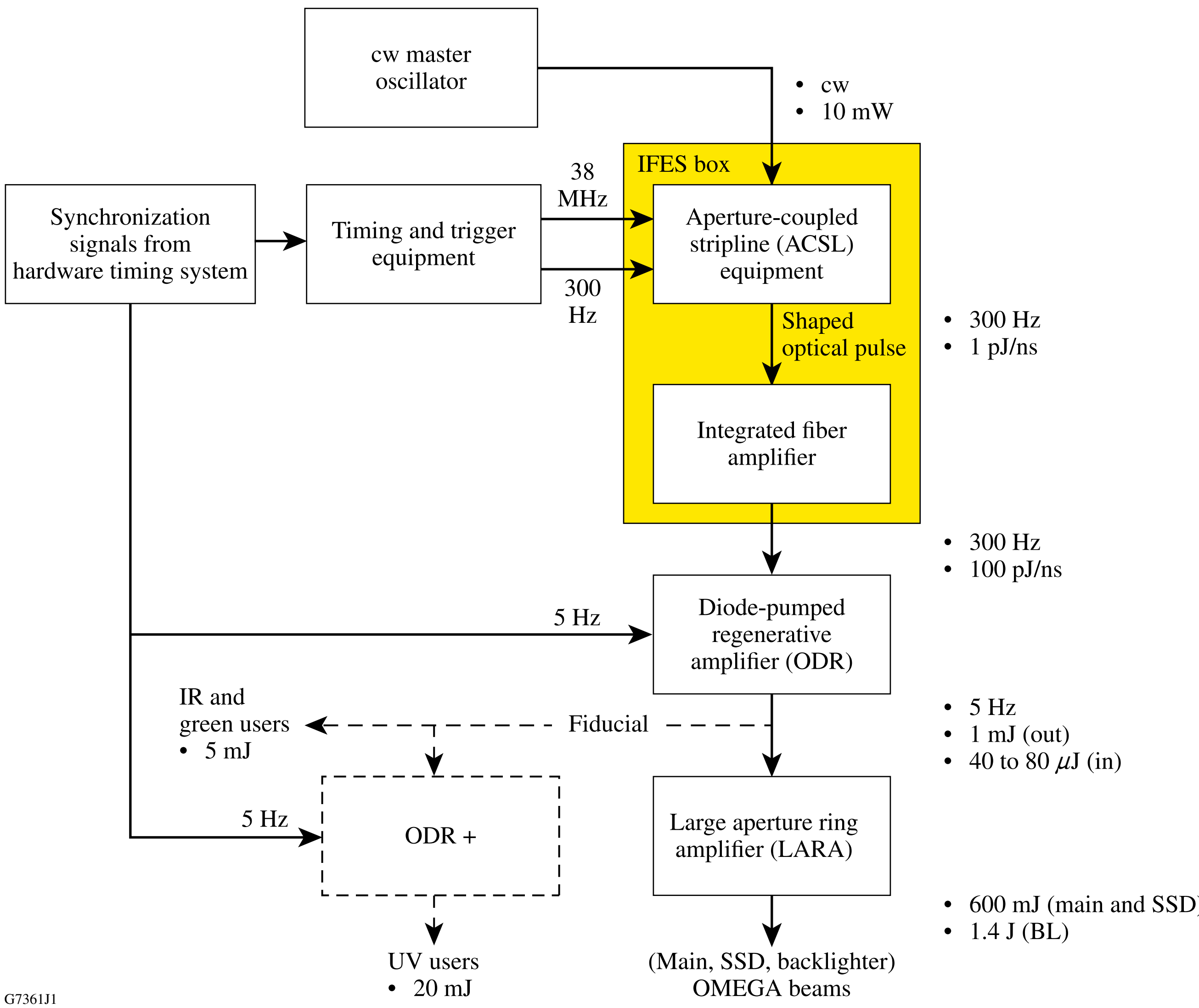

Figure 2.0-1
A block diagram of the equipment that makes up a typical driver line. An oscillator provides a continuous-wave signal. Timing signals from HTS are provided to create, shape, and synchronize a pulse train that is amplified for use in the laser system. The fiducial driver line uses a second diode-pumped regenerative amplifier (ODR+) instead of a LARA.

Directly above the PGR, at the east end of the Laser Bay, is the driver-line area, which consists of several optical tables containing the three large-aperture ring amplifiers (LARA's) and associated equipment that are used to amplify the laser seed pulse for injection into the beamlines. Figure 2.0-2 provides an overview of these items.

The optical pulses used to drive the OMEGA Laser System are generated continuously at a rate of 300 Hz in the DER, where the pulses originate and are shaped (see Fig. 2.0-1). The pulses are sent to the PGR via fiber-optic cables, where they are amplified by regenerative amplifiers (regens) at a rate of 5 Hz. The 100-pJ/ns outputs from each regen are separately directed upward, via a vertically mounted periscope, to the 40-mm LARA's in the driver-line area. One LARA is provided for each of the main, SSD, and backlighter pulses. Each LARA is capable of providing a gain of up to 20,000 in four round-trips, but is operated at a lower gain to increase the life of the rods.

Either the SSD or main driver is selected by the position of a kinematic mirror for injection to OMEGA. Prior to leaving the DLA, the selected driver (main or SSD) is amplified to ~4 J by the 64-mm rod amplifier. The pulse is then spatially filtered and injected to the stage-A beam splitter, where the driver-line pulses are split three ways and propagated into the OMEGA power amplifiers.

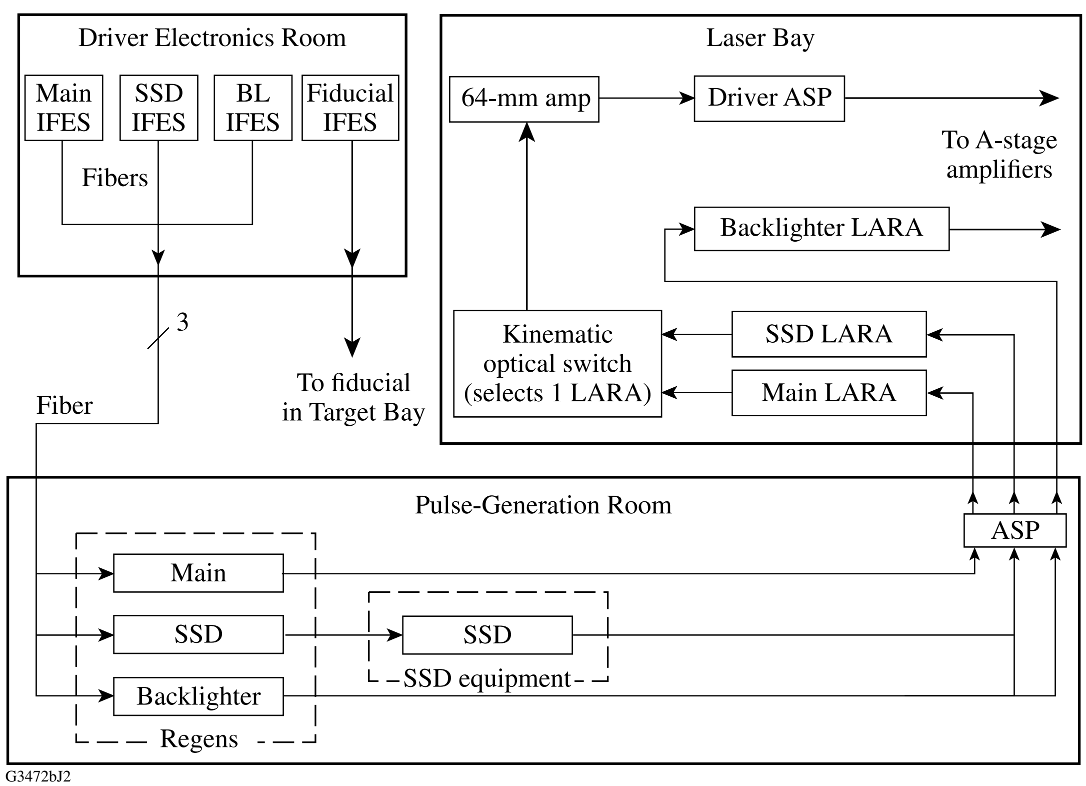

Figure 2.0-2
A block diagram of the laser-driver subsystem. The equipment is located in three areas: Driver Electronics Room, Pulse-Generation Room, and the Laser Bay. The fiducial driver line is located in the Target Bay.

The backlighter driver generates a 1.4-J laser pulse capable of driving one of the three legs from the A-split in lieu of the main or SSD driver pulses. The backlighter pulse arrives at the stage-A splitter by a path that is separate from that used by the other drivers.

Driver controls consist of several Sun workstations and PC-compatible computers to operate and monitor critical operating parameters, diagnostics, and applications within the drivers subsystem. These computers connect to peripheral equipment by means of the general purpose interface bus (GPIB), local operating network (LON), or directly via serial ports. Each computer communicates with the Laser Drivers Executive, which contains device control, energy diagnostics, access to imaging, and various GUI's. The executive also interacts with the Shot Executive using the proprietary OMEGA intercommunication protocol (OIP) over ethernet.

2.1 PULSE SHAPING/INTEGRATED FRONT-END SOURCE

The pulses for each driver originate in the DER, where a commercially available Koheras Adjustik® 1053-nm, single-wavelength, distributed-feedback fiber laser serves as the cw master oscillator for each channel. The laser is inherently single mode with a stable wavelength and requires no optical alignment from the photon generation to the regen fiber launch. Shaped pulses are provided by an all-fiber-optic integrated source. The integrated front-end source (IFES) generates an optical pulse in the 100-pJ range using: a compact, stable, single-frequency fiber, distributed-feedback laser; dual lithium niobate modulators; and a high-gain polarization-maintaining fiber amplifier. Complex pulse shapes are created by using an ACSL pulse-shaping system, housed within the IFES box.

Section 2.1.3 describes the concept of the ACSL and how this microwave radio technique is applied to produce the time-varying electrical signals that are used to shape optical pulses. Stripline assemblies for each of the pulse shapes that can be used on OMEGA have been designed and tested and are available for installation in the IFES box. The shape of the aperture in each of these assemblies was designed by using a comprehensive computer model of the OMEGA system to determine the IR temporal profile required to produce the required on-target UV profile. Figure 2.1-1 illustrates the predicted changes that occur to the pulse shape of the IR input from the DLA (in green) compared to the IR output (in red) to the frequency-conversion crystals and the UV output (in blue) at the target.

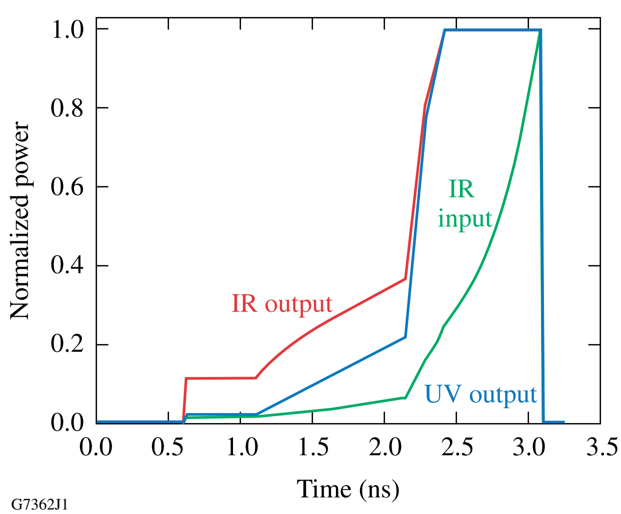

Figure 2.1-1
A temporal pulse shape in the 0.1-5 ns range is critical to the safe operation of OMEGA. Gain saturation in the IR along with the intensity-dependent frequency-conversion efficiency reshapes the temporal pulse shape. High-dynamic-range measurements at the input and a good predictive capability are required to accurately set the on-target pulse shape.

Figure 2.1-2 shows four typical pulse shapes used in OMEGA. The appropriate stripline assembly is inserted into the IFES box for the required driver to produce a pulse train at the rate of 300 Hz, with the desired shape and width. The shaped output pulse is then sent to the PGR and injected into regens for the first stage of amplification.

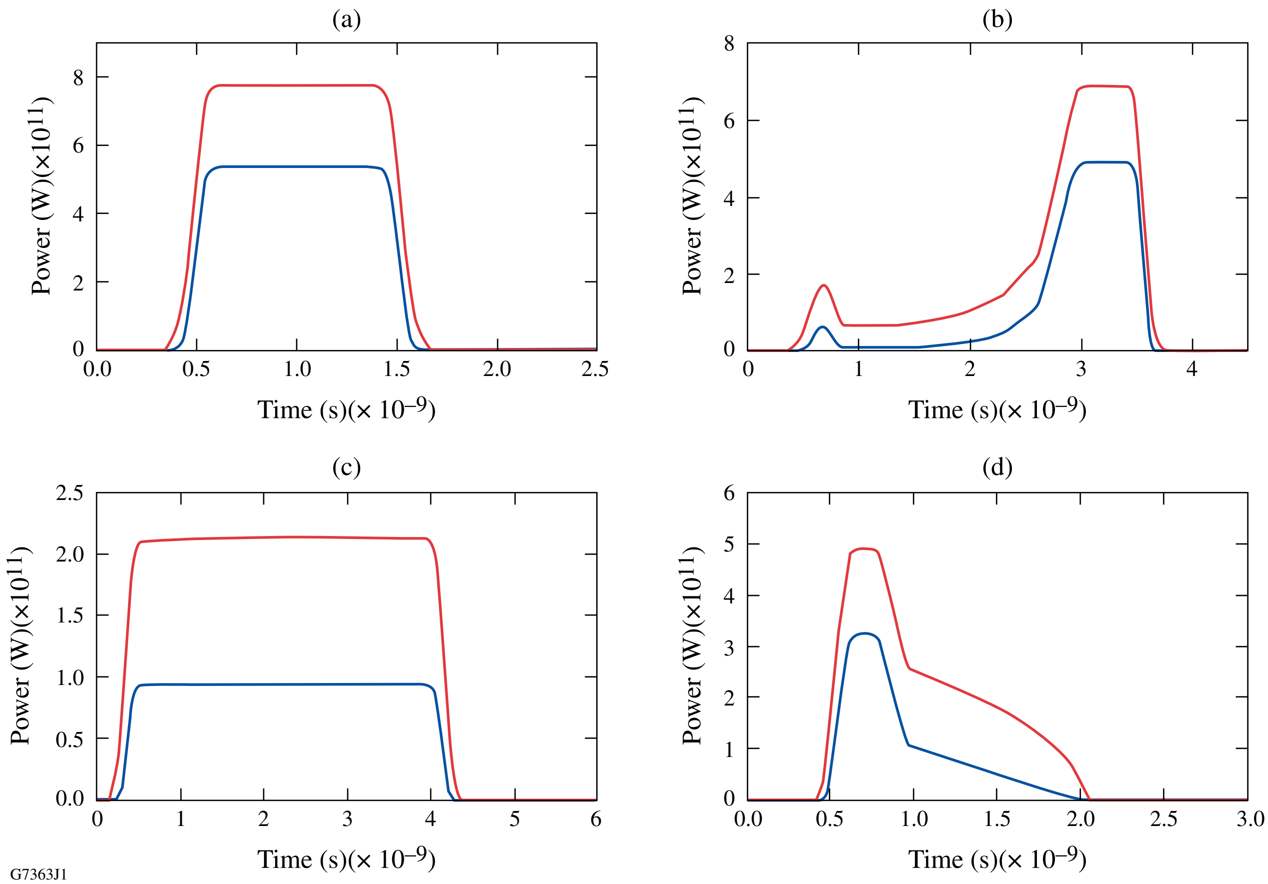

Figure 2.1-2
Four examples of OMEGA pulse shapes. (a) SG1018—flat 1-ns pulse, (b) ALPHA201P—picket pulse, (c) SG3702—flat 3-ns pulse, and (d) RR1501—1.5-ns reverse-ramp pulse. The red traces indicate the predicted IR pulse shape in the F-stage prior to the frequency-conversion crystals. The blue traces indicate the predicted UV pulse shape on the target.

The pulse shaping equipment for all four drivers is rack mounted in the DER. Figure 2.1-3 shows the layout of the DER racks. Racks 2, 3, and 4 contain the IFES/ACSL pulse-shaping systems for the backlighter, fiducial, and SSD, and the main drivers, respectively. Racks 1 and 6 contain Hardware Timing System equipment. Rack 5 contains video equipment.

Figure 2.1-4 shows the physical layout of the OMEGA IFES channels with their associated diagnostic equipment. Each driver source is located in a single rack. The server—*ecleto*—is mounted on the wall in front of Rack 4. Each module in the subsystem is connected via fiber-optic cables. The pulses travel through fiber-optic strands and do not require clean-room facilities to protect the laser seed pulses from environmental contamination.

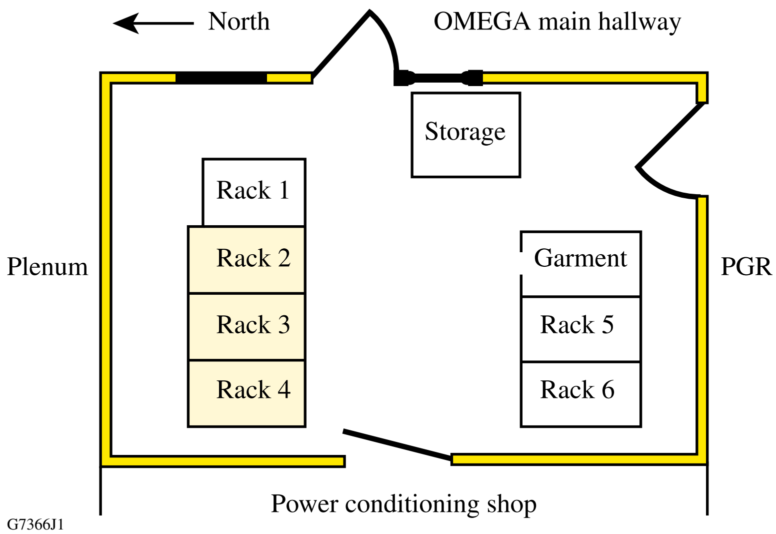

Figure 2.1-3
The DER floor layout. The IFES equipment is located in Racks 2 through 4 (shaded). The Power Conditioning shop is located between the DER and Capacitor Bay 2.

Figure 2.1-4
Physical layout of the IFES racks in DER with open space omitted.

2.1.1 Pulse Generation

The basic components in each channel are two electrical square-wave pulse generators, a delay generator, an ACSL assembly, and a dual-amplitude optical modulator, all fed by a Koheras cw laser.

Figure 2.1-5 shows a block diagram of the pulse-generation process. A Koheras master oscillator provides 1053-nm continuous-wave laser energy to the dual-amplitude modulator (DAM). The ACSLv2 software controls the pulse-shaping process within IFES, including the dc bias-control voltages.

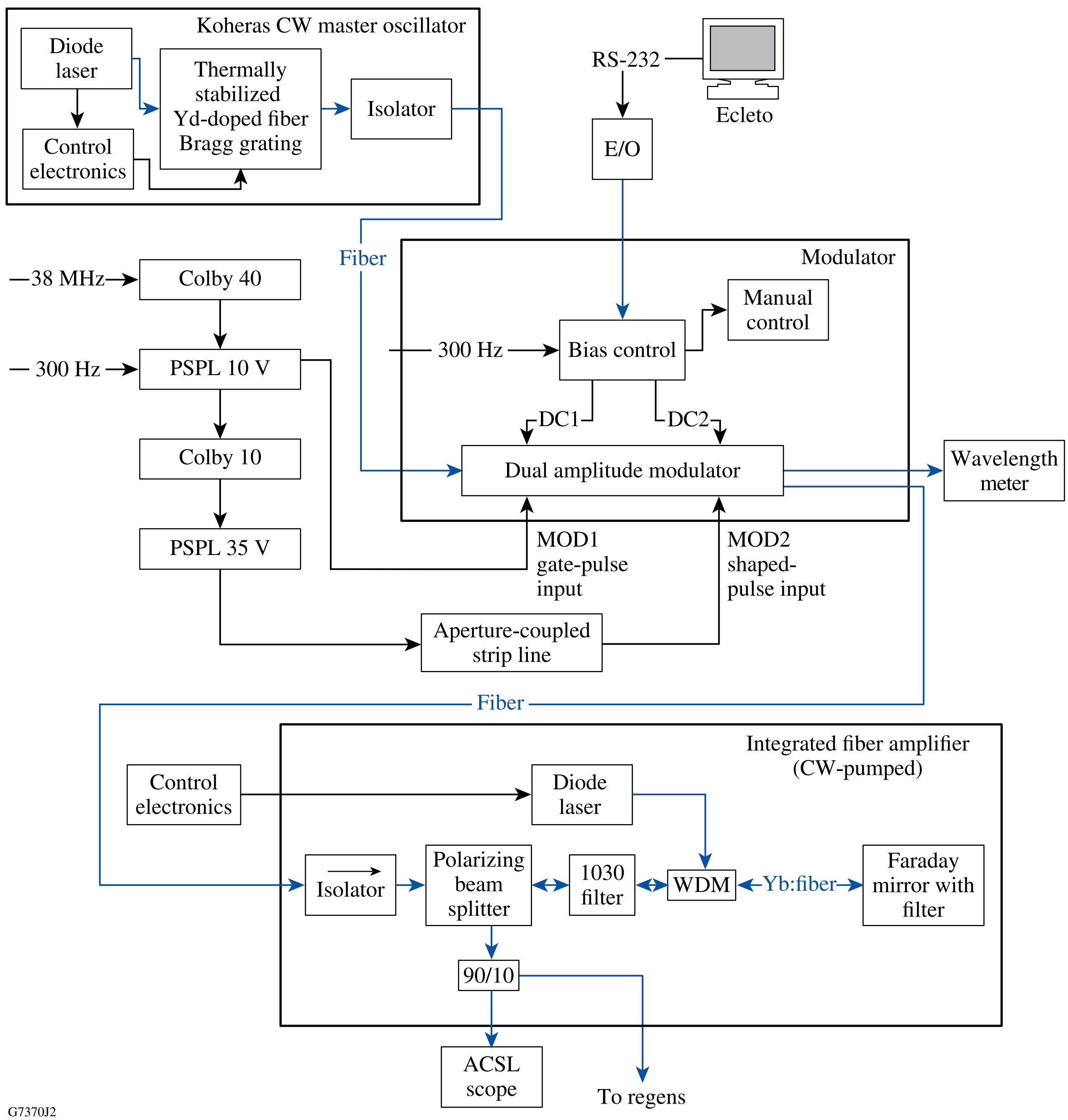

Figure 2.1-5
A block diagram of the main and backlighter pulse generation process in DER.

The 38-MHz reference frequency (RF) from the OMEGA Hardware Timing System is fed into a Colby 40 programmable, mechanical, delay-line instrument, with a standard delay extension range of 40 ns. Using the internal delay line, the Colby 40 controls the phasing of the RF input to the 10-V pulse generator with an accuracy of within tens of picoseconds.

The 10-V amplitude DAM gate signal is generated by a Picosecond Pulse Labs Programmable Pulse Generator (PSPL 10V). The output of the pulse generator is synchronized to OMEGA using the 38-MHz and 300-Hz electrical inputs. The 300-Hz gate input comes directly from the HTS, and the trigger is synchronous with the 38-MHz RF distribution through the Colby 40. The 10-V pulse generator uses the 300-Hz electrical gate to enable the trigger circuit, which looks for the next positive slope zero volt crossing from the 38-MHz signal. If either of the input signals to the PSPL 10V is absent or if the pulser is disabled, the output trigger pulse will also be disabled. The ACSL v2 software controls the output timing by making two adjustments; course output-timing adjustments (with 26-ns resolution) to the 300-Hz gate input, and precise timing adjustments to the electrical phase of the RF signal using the Colby 40 RF-programmable delay line over a range of 13.1 ns.

The process of providing the signal to the aperture-coupled stripline is unique for each configuration and will be discussed individually. The shaping of the pulses is achieved by using the shaped-pulse input from the stripline. Each aperture-coupled stripline is designed to produce a specific electrical pulse shape that drives an optical modulator to produce the desired optical pulse.

In order to achieve the desired pulse shape, it is critical to set up a pulse using the conditions for which the stripline was designed to operate.

2.1.1.1 Main, SSD, and backlighter channels

The same optoelectronic hardware configuration is used for the main, backlighter, and SSD pulse-shaping channels. In each case, precise optical pulses can be generated by the combination of a properly defined stripline and a suitable gate.

A 10-V square-pulse generator (PSPL 10V) is used to produce the electrical gate signal applied to the MOD1 port of the modulator (see Fig. 2-1.5). The optical pulse shape is determined by the electrical waveform, as defined by the aperture dimensions in the stripline.

The 10-V pulser-trigger output feeds the gate channel as well as the pulse channel. For the pulse channel, this input passes through a 10-ns delay (Colby 10) into the trigger input of a 35-V Picosecond Model 4500E Step Generator (PSPL 35V). This 35-V square pulse is fed to the ACSL. The PSPL 35 provides extremely stable pulses with a fast rise time of 100 ps, to a high amplitude of 35 V with only 1.5-ps of jitter.

2.1.1.2 Picket option

The "picket" option permits the addition of a short optical pulse (picket) to a shaped pulse. This channel type is an adaptation of the SSD channel type and is produced by reconfiguring hardware from the SSD pulse-shaping channel (see Fig. 2.1-6).

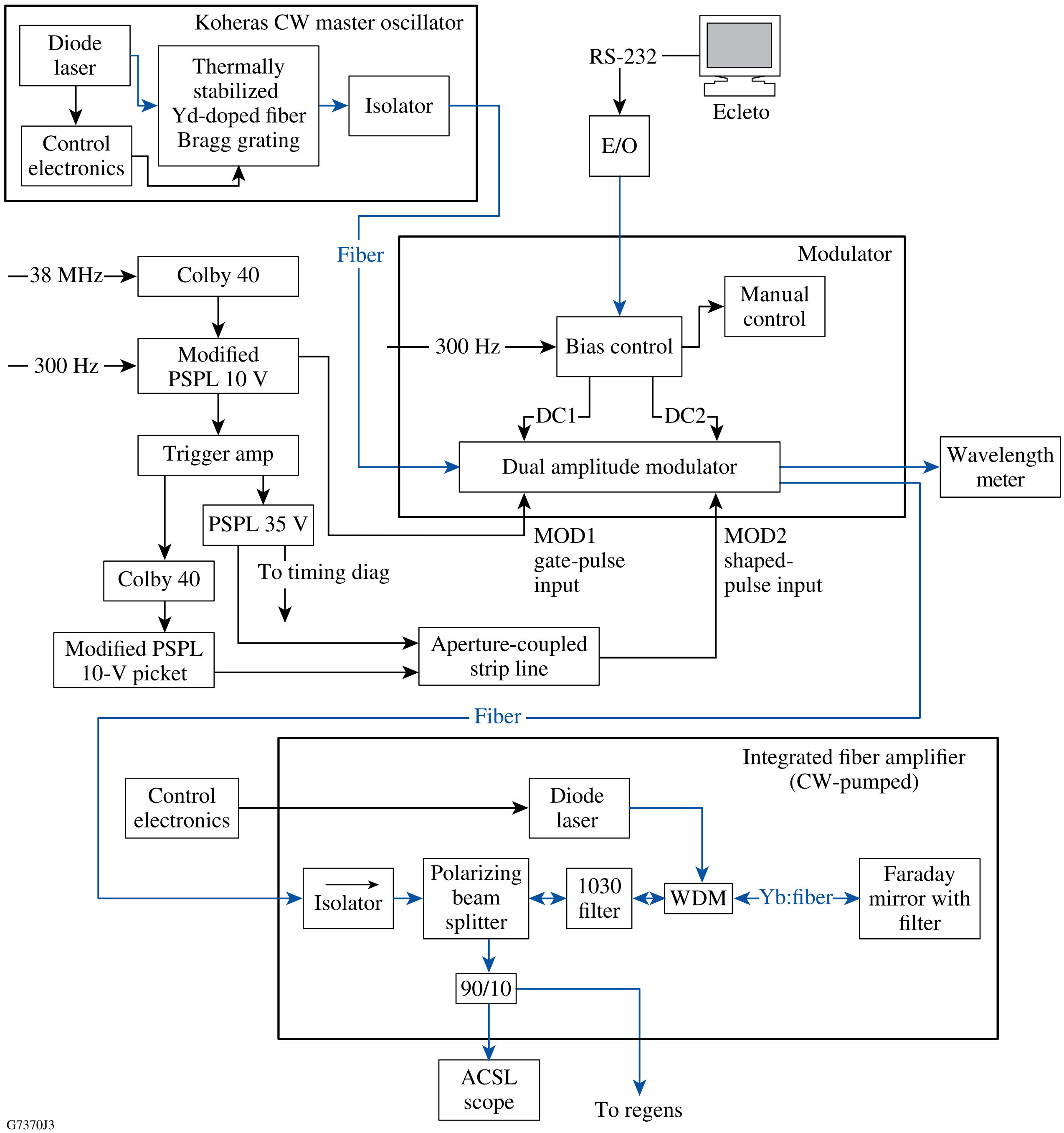

Figure 2.1-6
A block diagram of the SSD picket-option pulse-generation process in DER.

The picket process is set up on the SSD pulse-shaping channel by disconnecting the 50-ohm termination on the back of the stripline and replacing it with the output of the modified PSPL 10V picket box. This allows a "picket" to be formed on the leading edge of the pulse. The pulse width is controlled by a fixed electrical differentiator after the PSPL 10V picket box. Picket amplitude is controlled by attenuation to the picket electrical signal applied to the modulator. A trigger amp is used to split the PSPL 10V output and send it on to the PSPL 35V that feeds the aperture-coupled stripline, and to a Colby 40 used to adjust the picket-timing control. The picket signal is generated by the modified picket PSPL 10V unit.

2.1.1.3 Fiducial channel

The fiducial channel produces a series of eight optical pulses spaced 0.5 ns apart in time. Diagnostic instruments used on OMEGA rely on these pulses as a timing reference (see Fig. 2.1-7).

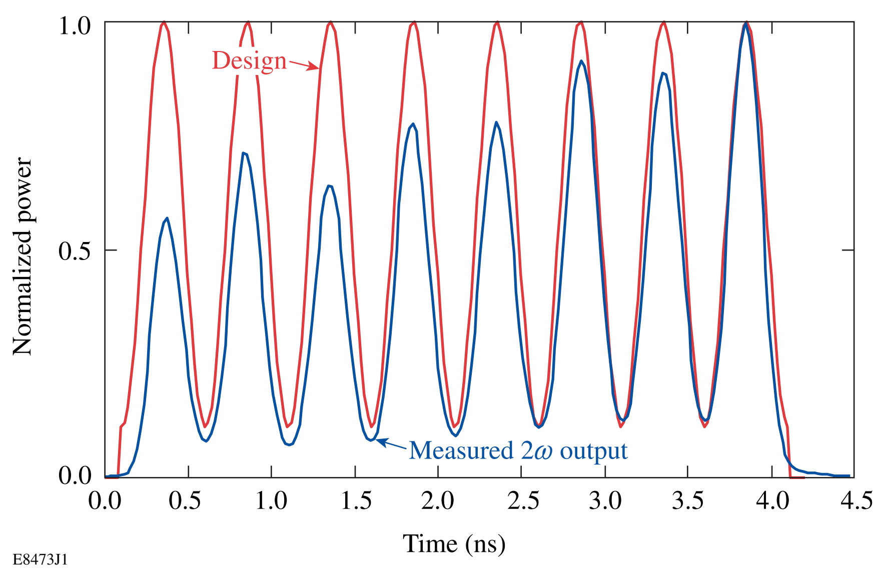

Figure 2.1-7
The fiducial "comb" consists of eight pulses that are 0.5 ns apart.

A comb generator produces high-frequency electrical pulses. These pulses are applied to the MOD2 port of the modulator, and a gate-pulse is applied to the MOD1 port of the modulator (see Fig. 2.1-8). The fiducial gate width is unique from the other drivers in that the shape is determined by the stripline, controlling the number of optical pulses produced by the first modulator that are allowed to pass through the second modulator. The output of its 10-V pulse generator (PSPL 10V) provides a time-base reference for the ACSL diagnostics. This pulse is used to trigger the high-speed sampling scope used to diagnose pulse shapes produced by the system.

A manual radio-frequency trombone is used to delay the trigger output. This manual device minimizes the possibility of device failures that could cause unwanted system-timing-delay changes. Section 2.5, **Fiducial Amplifier Subsystem**, provides more details.

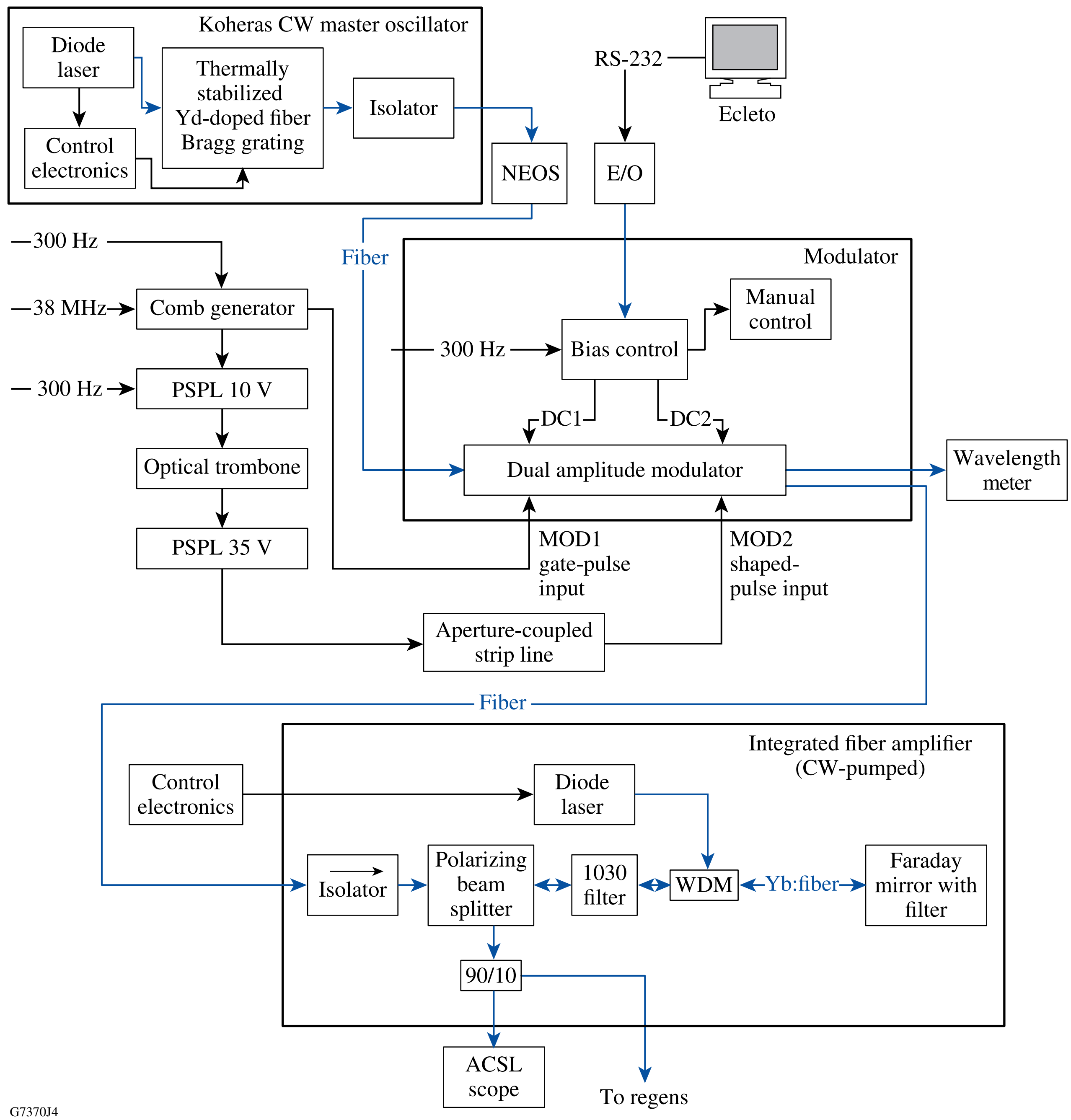

Figure 2.1-8
A block diagram of the fiducial pulse-generation process in DER.

2.1.1.4 Pulse-shape setup

Two important steps are required to set up a pulse shape

1. The rising edge of the optical pulse must occur at the correct time, and

2. Instrument settings are systematically adjusted until the measured pulse matches the design template.

If previous shots have been executed using the desired pulse shape, instrument settings from that shot may be restored from the database. Otherwise, the operator must go through a set-up procedure to achieve the desired results. The set-up procedures, although very similar, are unique for each channel type. The channel types are main, SSD, backlighter, and fiducial. In addition, the SSD channel has a picket option.

2.1.1.5 ACSL v2 software

The ACSL v2 software application is used to set up, control, and monitor the pulse-shaping process. The user interface allows laser-driver personnel to open a graphical user interface to access data and make necessary adjustments during the pulse-shaping process. Only one application at a time can be run on OMEGA.

2.1.2 Koheras Laser Source

The Koheras Adjustik® system is a compact, single-wavelength distributed-feedback fiber-laser system. The 1053.044-nm wavelength has 0.002% stability over 24 h of operation, compared to the required 0.03%. The power stability is 0.7% over 10 h of operation (The requirement is <1% over 2 h). The noise floor was measured at greater than –57 dB, which is within the limits of the measuring instrument.

2.1.3 Aperture-Coupled Stripline (ACSL)

A high-bandwidth electrical-waveform generator based on an ACSL has been designed and implemented for pulse-shaping applications on OMEGA. An exploded view of an ACSL is shown in Fig. 2.1-9.

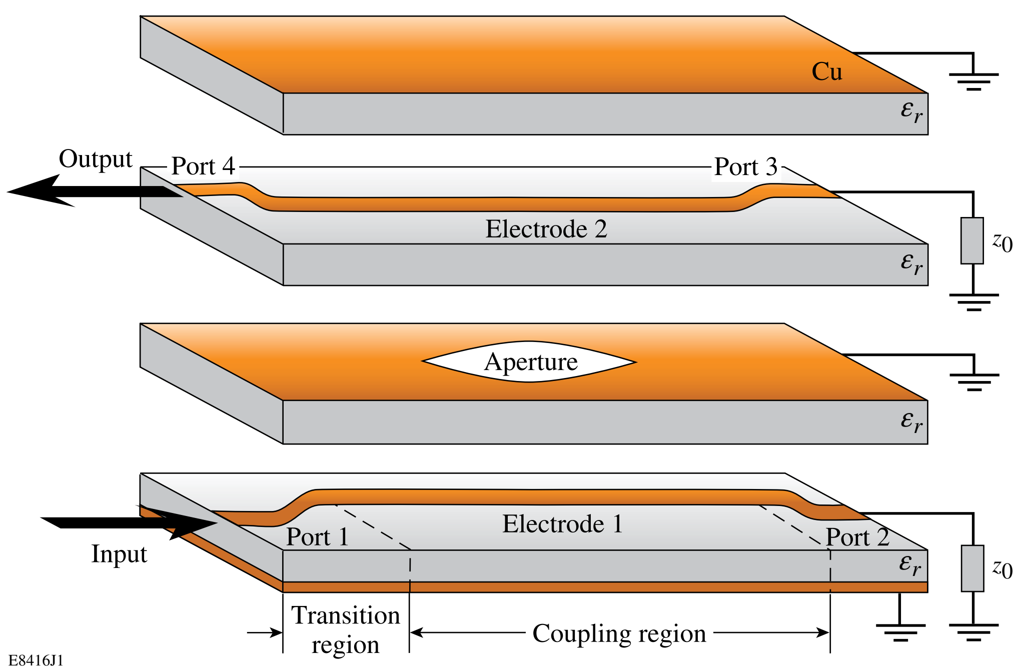

Figure 2.1-9
An exploded block diagram of an ACSL.

A stripline consists of a stack of three copper plates, separated by two dielectric (insulating) layers. The center plate has an aperture (hole) of a prescribed shape. In use, a 35-V pulse is launched from a Picosecond Pulse Labs 35V pulse generator into port 1 from one end of the stripline and propagates along electrode 1 to port 2 of the ACSL, and is terminated at 50 ohms. As the square pulse propagates along electrode 1, a fraction of the propagating electric field is coupled through the aperture into electrode 2 in the opposite direction. The fraction of the field coupled between the electrodes is determined by the aperture shape. By tailoring the aperture width along the length of the stripline, any desired electrical waveform can be generated at the output at port 4 and sent directly to the electro-optical modulators for pulse shaping. Therefore, the aperture shape controls the electrical-output pulse shape.

2.1.4 Dual-Amplitude Modulator (DAM)

An optical modulator changes its optical transmission as a function of the applied voltage. The modulator used for ACSL requires two electrical inputs. The dc bias voltage is applied to ensure zero transmission as the natural state: two electrical pulses allow transmission determined by the gate and shape to define a given pulse shape. The pulses are provided to the DAM from the 10-V pulse generator (gate) and the aperture-coupled stripline (shape) (see Fig. 2.1-10).

A gate is required to improve the rise and fall times of the optical pulse, control the optical pulse width, and to suppress prepulse artifacts that are not adequately controlled by the first modulator. Ideally, the gate would turn on and off instantly, permitting 100% optical transmission while on and 0% transmission when off. The actual behavior is taken into account when designing apertures.

The "shape" feature of the ACSL v2 software is used to adjust the optical pulse produced by the stripline so that it coincides with the design template.

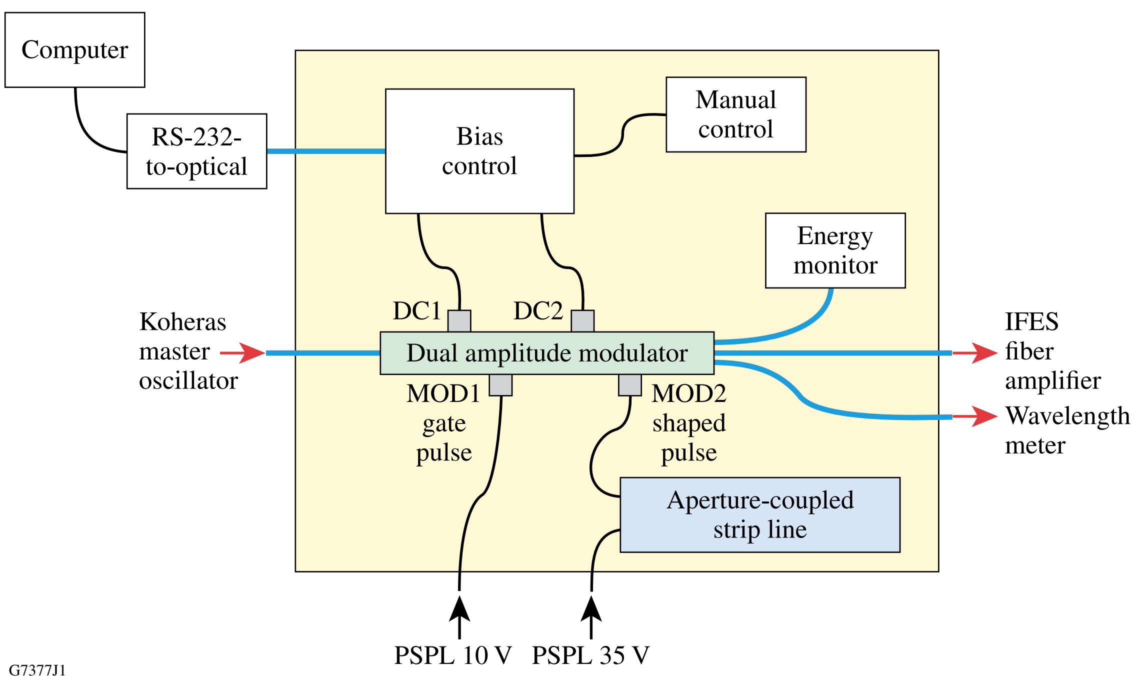

Figure 2.1-10
Block diagram of the dual-amplitude modulator.

2.1.4.1 Electrical-pulse inputs

The two pulse inputs control the time-varying optical transmission of the modulator, allowing the modulator to act like a high-speed optical switch or pulse shaper. The gate channel provides a narrow "window" for the seed pulse to be propagated from IFES to the regen amplifier. This allows the cw seed to be trimmed of any electrical noise, such as prepulse, postpulse, or excessive noise floor signals, immediately before and after the pulse. The shaped-pulse signal adds the pulse shape created by the ACSL to the second modulator stage where the shape is then applied to the gated optical pulse and then sent on to the IFES fiber amplifier (IFA).

2.1.4.2 DC-bias-voltage input

The bias is generally set to minimum transmission at all times. A pure dc bias causes the DAM to quickly accumulate unwanted charge, resulting in a dc-bias drift of ~13 mV/h. A balanced duty-cycle approach was adopted to maintain zero-average applied voltage, while keeping instantaneous voltage at a transmission minimum, or other set point (see Fig. 2.1-11). The value of V_{set} is fixed. The pulse widths (T) are calculated to get an average voltage of zero based on the period of the 300-Hz pulse (~3.33 ms).

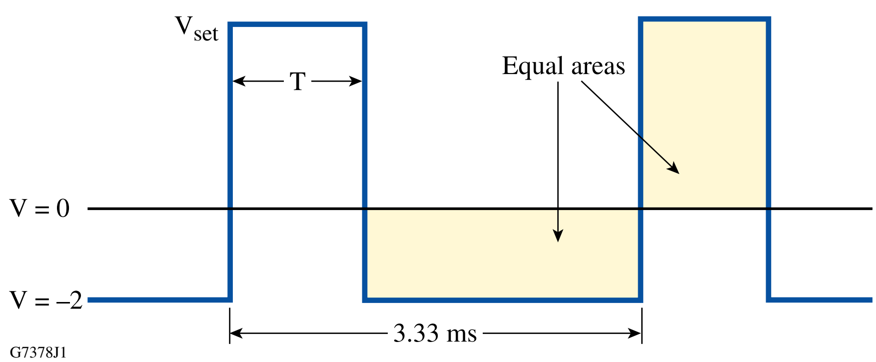

Figure 2.1-11
Illustration of the balanced duty cycle approach where the average voltage is equal to zero.

2.1.4.3 DC-bias control

The modulator bias-voltage function is handled by ACSL v2 software to directly input the new bias voltage to the modulator. The bias voltage (V_{abs}) establishes the steady-state optical transmission of the modulator when no electrical pulse is applied. The response range is ±4.096 V in increments of 2 mV, ±1 mV, producing a range of 4096 counts.

The modulator control is used to adjust the dc-bias voltage to a modulator. Modulator calibration for V_{min}/V_{max} is controlled from the ACSL v2 software, which will also rescale the V_{min}/V_{max} range for different modulator values. The voltages corresponding to the V_{min}/V_{max} transmission points are accessed by selecting the modulator icon (see Fig. 2.1-12) from a schematic and setting the attributes V_{min} (dc minimum transmission voltage) and V_{π} (dc half-wave voltage).

The V_{abs} adjustment, shown in Fig. 2.1-12, is used to adjust the actual operating voltage. This will change the placement of V_{min} around the null of the sine wave. This is required to fine tune the pulse shape before amplification.

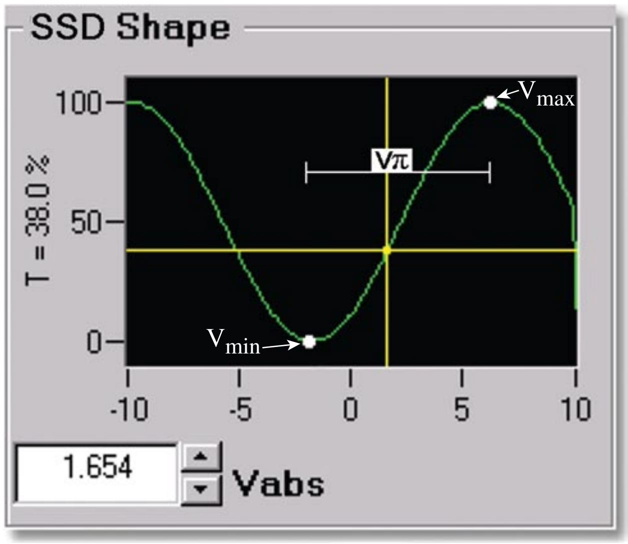

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Figure 2.1-12
The ACSL v2 software graphical user interface shows the modulator bias settings. V_{π} refers to the time between V_{min} and V_{max}.

The modulator drift has been measured to be less than 10 mV over 16 h, compared to the specification of <30 mV. A manual modulator-calibration routine (ModCal) was developed to periodically sweep the voltages from –4 V to +4 V to accurately determine V_{min} and V_{π}. ModCal is used to reset the bias voltage to the proper normalized relationship to V_{min}.

2.1.4.4 Modulator output

The output of the DAM is passed on to the IFA, with a small portion split off and fed to two diagnostic instruments: an energy meter and a wavelength meter. The output energy is measured on a high-bandwidth sampling oscilloscope. One scope can serve up to four ACSL channels simultaneously. A WaveMaster Laser Wavelength Meter can measure the wavelength of both cw and pulsed lasers of any repetition rate. The display can be set to measure frequency in gigahertz, bandwidth in nanoseconds, or actual wave count.

Because the DAM has two internal modulators that potentially operate at different V_{min} and V_{π} levels, there is interference in the form of small amplitude "bell" pulses generated in the output of the modulator unit. These bell pulses correspond to the amplitude changes of each individual modulator bias voltage, as illustrated in Fig. 2.1-13.

The large pulses on the output correspond to the electronic-timing pulse from the Hardware Timing System and the leading edges of the DC1 and DC2 bias voltages. The two bell pulses correspond to the zero-crossing of the DC2 and DC1 bias-voltage switching from the V_{min} (high) state to the V_{min} (low) state. These bell pulses are filtered out of the optical laser pulse in the IFA.

2.1.5 IFES Fiber Amplifier (IFA)

The IFES fiber amplifier (IFA) boosts the shaped-pulse energy from the dual amplitude modulator (DAM) to the input energy required by the regenerative amplifier. The IFA is assembled from commercially available parts. The fusion-spliced system reduces long-term degradation. The amplifier operates with cw pumping that eliminates timed components. A block diagram of the IFA is shown in Fig. 2.1-14.

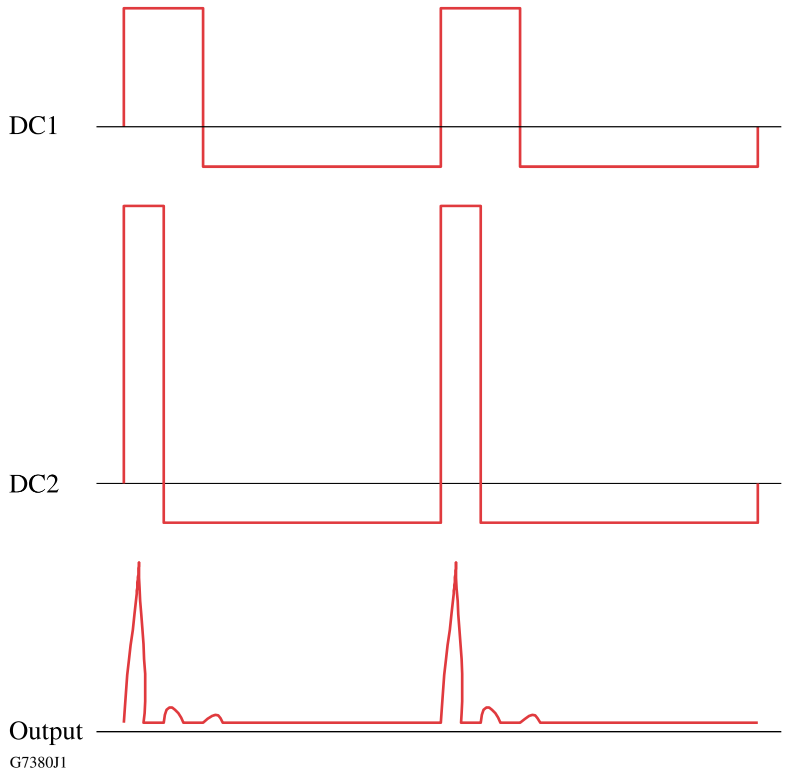

Figure 2.1-13
Illustration of bell pulses that appear on the output of the DAM as a function of the rising and falling edges of the dc-bias voltages. It is more pronounced where the square waves are changing synchronously.

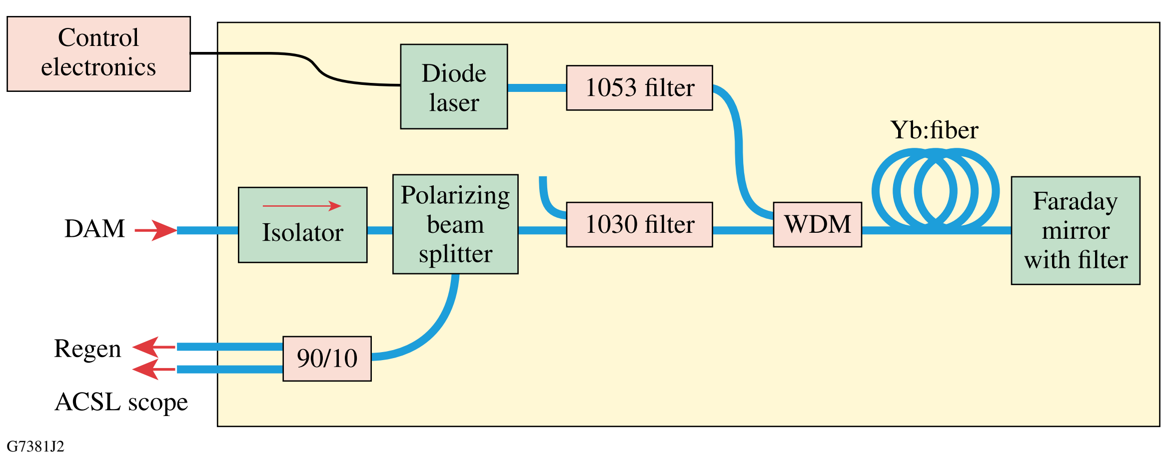

Figure 2.1-14
Block diagram of a cw-pumped IFA.

The shaped pulse arrives from the DAM and passes through an input isolator, a polarizing beam splitter (PBS), and a 1030-nm filter to the wavelength division multiplexer (WDM), where it is combined with the cw-diode laser signal to pump the energy for the fiber amplifier. The Yb:fiber provides the amplification component within the IFA. This fiber is essentially the same as the amplification fiber inside the Koheras cw master oscillator, except that this fiber does not contain a grating factor.

The shaped pulse enters the IFA with a polarity which is inherently shifted as it progresses through the system components. The WDM acts as a multiplexer in the initial direction and a demultiplexer in the return direction. The Faraday mirror acts as a bandpass filter and reflector for wavelengths near 1055 nm, and absorbs the remaining energy. The Yb:fiber acts to amplify the signal in both directions. The bidirectional signals passing through the fiber do not interfere due to the differences in polarity in the two directions. The inverted shaped pulse will return to the PBS with a polarity perpendicular to the input creating the switch out to the output fiber, which feeds the regenerative amplifier.

The amplified shaped pulse passes through the 1030-nm filter (another WDM), where any 1030-nm light will be split off (including the bell pulses that were introduced in the DAM), and pass the remaining 1053-nm shaped pulse on toward the PBS, where approximately 10% is split off and sent to the ACSL scope for monitoring purposes and the remaining 90% is passed on to the regen. The input isolator prevents any optical signals that might pass through the PBS in the reverse direction from reflecting back into the DAM.

The IFA resides inside the IFES box, as shown in Fig. 2.1-15. The IFA is mounted on a removable fiber-amplifier shelf for easy maintenance access. The DAM and ACSL are in close proximity to provide short transmission paths during the processing of the pulse.

Using only 3.0 m of Yb:fiber, the IFA provides >100-mW peak power to the regen with <0.2% distortion measured over the flat top of a square wave in the unsaturated amplifier. IFES meets the 40-dB prepulse suppression requirement, and the ASE suppression between pulses exceeds OMEGA requirements, with an OSNR of >56 dB. The energy stability is <1% rms over 2 h. The slow-axis polarization extinction ratio exceeds 100:1.

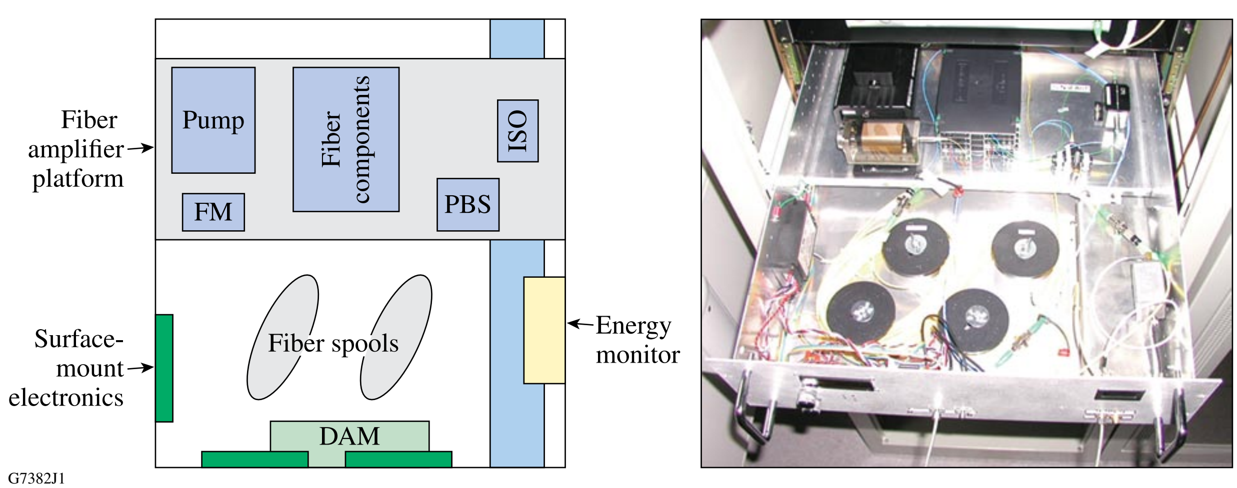

Figure 2.1-15
The IFES box contains the aperture-coupled stripline, dual-amplitude modulator, and the IFES fiber amplifier.

A single-mode, polarization-preserving optical fiber provides the link between each IFES (in DER) and the corresponding regen (in PGR).

2.2 REGENERATIVE AMPLIFIERS

The diode-pumped regenerative amplifiers (regen or DPR) for the main, SSD, and backlighter are located in the Pulse Generation Room (PGR). The fiducial regen is located in the target bay (the fiducial driver line is covered in Sec. 2.5). The regens are essentially identical and are used for pulse selection and amplification. Reliable performance requires injection of a high-contrast, single pulse. Each regen is seeded by pulses from their respective IFES in the DER. The regens are synchronized to each other through the Hardware Timing System.

Each diode-pumped regen contains a Pockels-cell-enabled trigger that provides both the cavity injection trigger and the cavity dump trigger (see Fig. 2.2-1). The regen cavity is a stable resonator operating in the TEM_{00} mode. The diode pump provides repeatable gain. HTS timing triggers provided to the Pockels cells and the pump diodes are used to select single pulses from the 300-Hz pulse train coming from the IFES to produce a pulse train at 5 Hz. Figure 2.2-2 shows the layout of a typical diode-pumped regenerative amplifier.

The single-shaped pulse is switched-out using another Pockels cell, which provides improved signal/noise contrast. The Pockels cells, including their high-voltage drivers, have flat transmission windows over

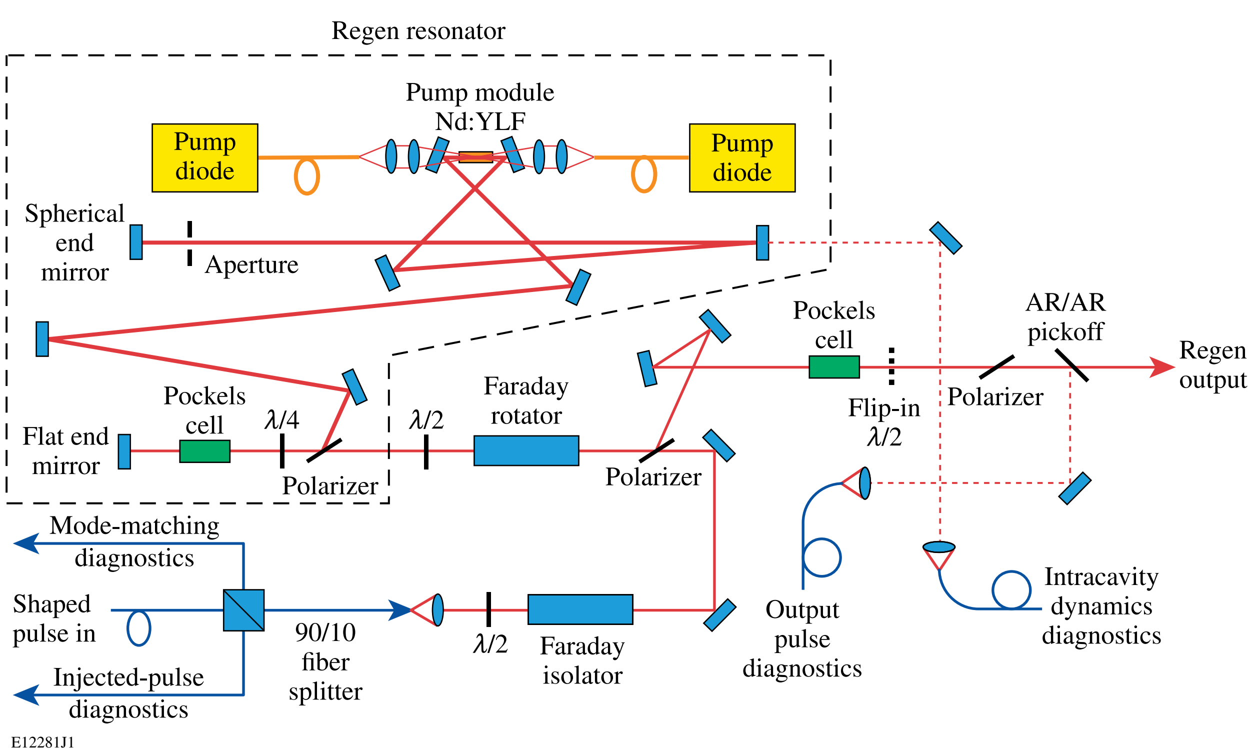

Figure 2.2-1
Pockels cells (labeled "PC") are used with the diode-pumped regenerative amplifier to isolate one shaped pulse from the pulse train provided by IFES.

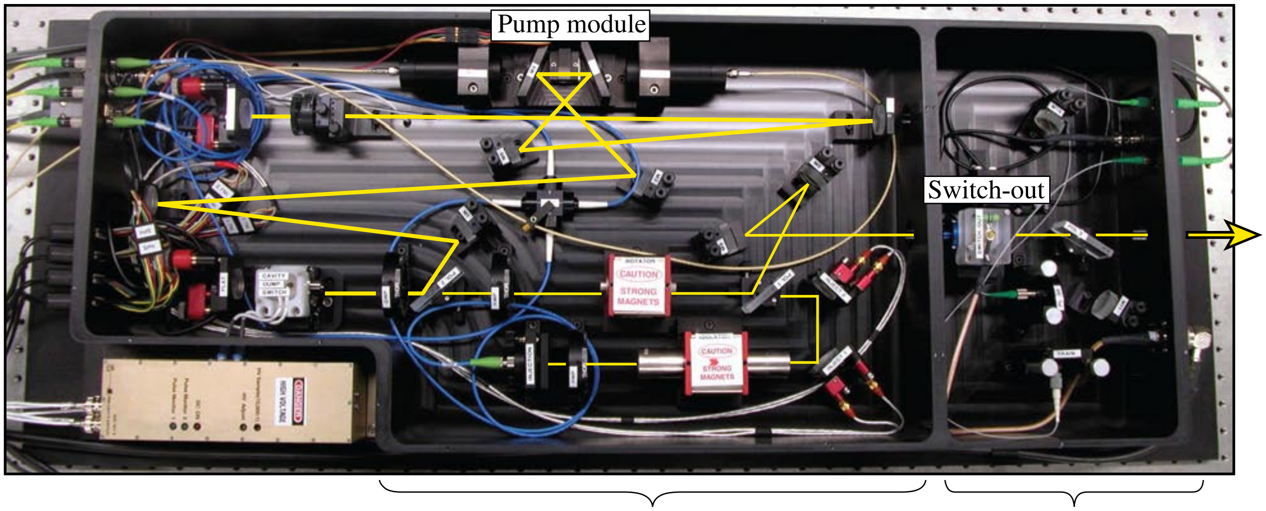

Figure 2.2-2
Photograph of a diode-pumped regenerative amplifier (DPR).

5 ns. The only significant distortion is due to predictable saturation caused by square pulse distortion. Single pulse energies are nominally ~1 mJ after the switch-out Pockels cell. Amplitude stability of the 5-Hz pulse train at the regen output is essential. Output-energy fluctuations have been measured at <0.9% rms over 24 h. The performance requirements for these regens are shown in Table 2.2-1. Diagnostics located in the PGR measure the energy, timing, alignment, and stability of the regens. Figure 2.2-3 shows the orientation of the main and SSD regens in the PGR.

After the regenerative amplifiers, the pulses in the SSD driver are directed to the electro-optic modulators and gratings that initiate the smoothing by spectral dispersion (SSD) process. The pulses always pass through the modulators; however, the SSD modulation can be either on or off. Figure 2.2-4 shows the layout of the optical tables in DER.

Table 2.2-1: Performance requirements of principle oscillators.

	Main, SSD, and backlighter oscillators	Fiducial oscillator
Seed pulse	cw mode-locked master oscillator	
Oscillator type	Regen	Regen
Input energy	~100 pJ/ns	~100 pJ/ns
Output energy (single pulse)	~1 mJ	~1 mJ
Amplitude stability	≤2%	≤2%
Pulse duration	0.1 to 4 ns	4.8 ns comb
Temporal jitter	≤30 ps	≤30 ps
Pointing stability	≤10 μrad	≤10 μrad
Energy contrast	>100,000:1	>100,000:1

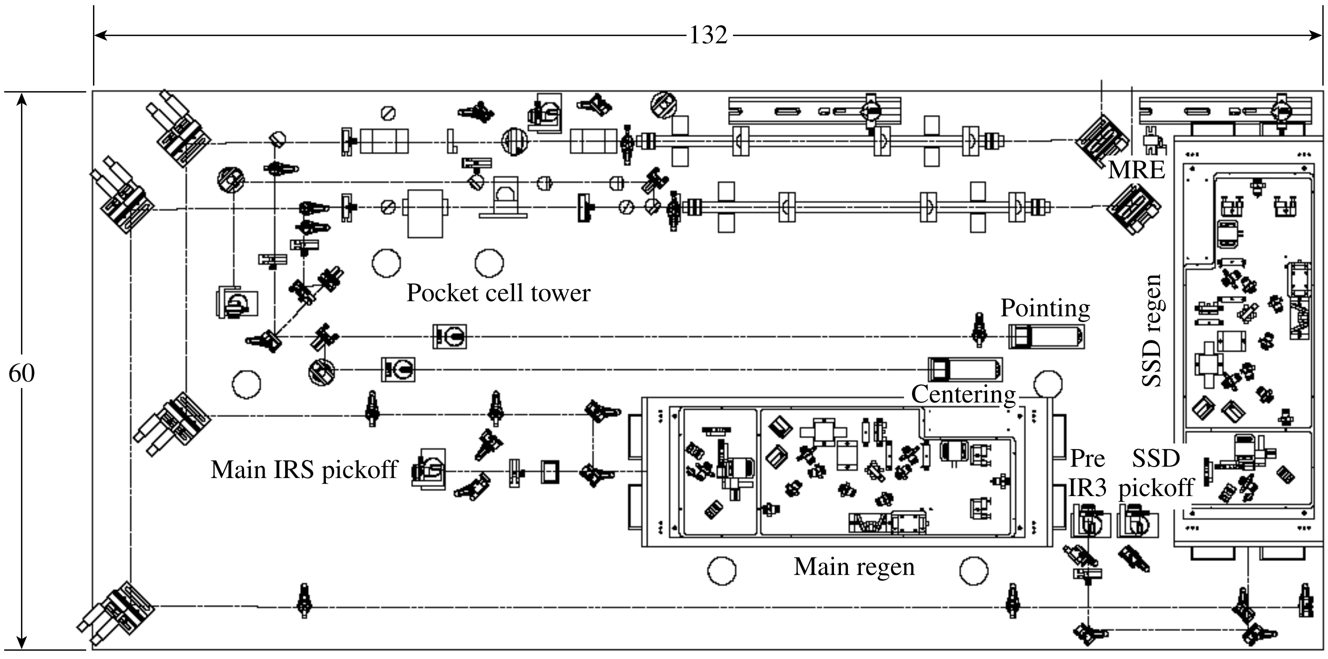

Figure 2.2-3
The main and SSD diode-pumped regenerator amplifiers are located on the same optical table in PGR.

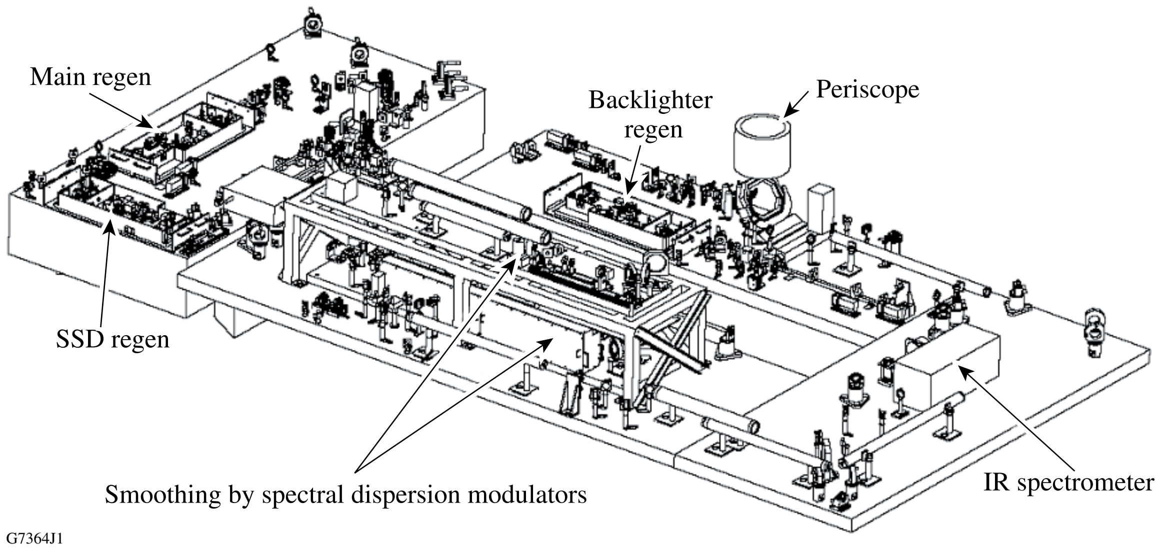

Figure 2.2-4
A three-dimensional view of the PGR optical tables containing the main, SSD, and backlighter diode-pumped regenerators, the SSD modulators, and the periscope that delivers the beams to the driver-line area in the Laser Bay. The tables also contain diagnostic equipment and various optics used to point, center and collimate the beams. The 2-D SSD modulator is located inside the *x*-band box.

2.3 SMOOTHING BY SPECTRAL DISPERSION (SSD)

Smoothing by spectral dispersion (SSD) is a technique that improves beam uniformity at the target by imposing a time-varying wavelength shift on the driver pulse. The SSD driver is the designation applied to the train of laser-driver elements that can provide pulses with the smoothing effect. The SSD driver line is fully outfitted for two-dimensional (2-D) SSD operation (refer to Fig. 2.3-1, below). The main, backlighter, and fiducial drivers do not have SSD capability.

Smoothing by spectral dispersion is implemented on OMEGA to achieve high-irradiation uniformity on direct-drive inertial confinement fusion targets. Beam smoothing must occur before the target can significantly respond to the laser nonuniformity. Two factors determine the level of uniformity that can be achieved with SSD: bandwidth and spectral dispersion. The amount of bandwidth determines the rate of smoothing, and the amount of spectral dispersion determines the maximum reduction in nonuniformity that can be achieved, as well as the longest spatial wavelength of nonuniformity that can be smoothed.

When combined with polarization beam smoothing using distributed polarization rotators (DPR's) and multiple beam overlap, the 1-THz, 2-D SSD system (1.5 × 11 Å) available on OMEGA produces a large number of independent speckle patterns and achieves asymptotic nonuniformity in the range of 1%–2% with a smoothing time of ~500 ps.

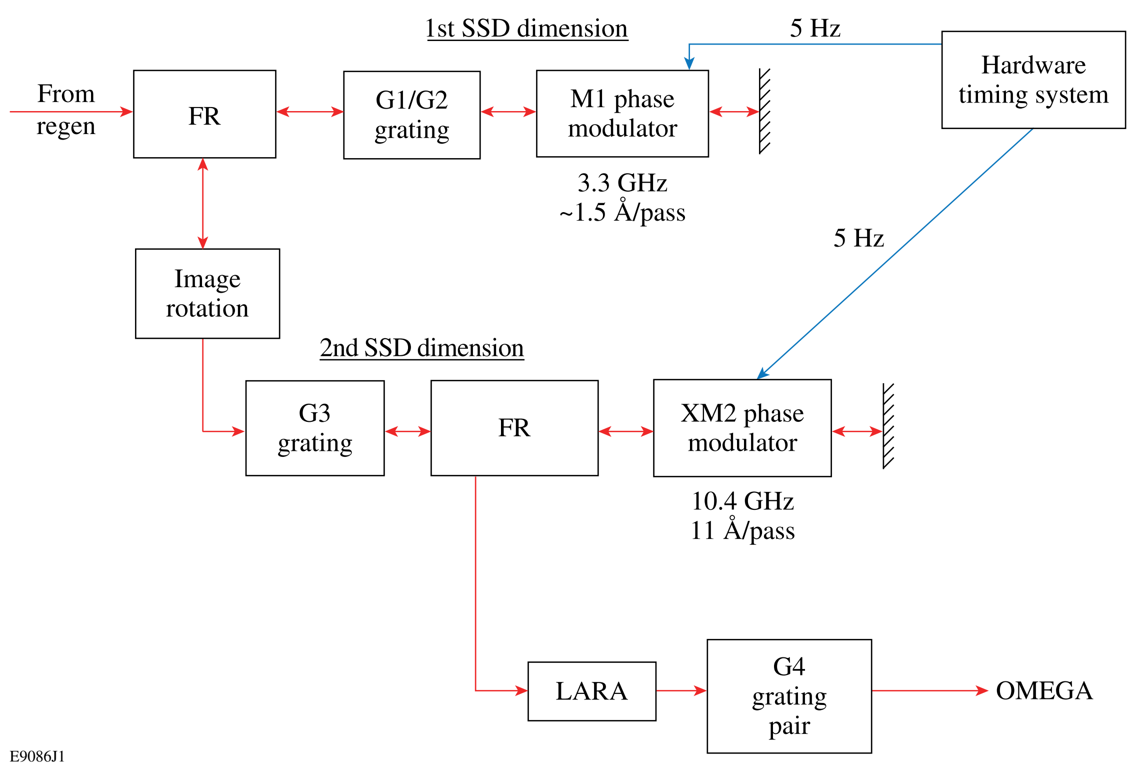

Figure 2.3-1
Block diagram of the smoothing by spectral dispersion system with hardware timing system triggers. Faraday rotators (FR's) provide optical isolation to prevent any signal system back-reflection.

Bandwidth and spectral dispersion are both constrained by the frequency-tripled, glass-laser configuration used in OMEGA. High-efficiency frequency tripling of laser light with a single tripling crystal limits the bandwidth to ~5 Å (FWHM) in the infrared, but a dual-crystal tripling scheme increases this to ~14.5 Å (FWHM). Spatial-filter pinholes in the laser chain also limit the spectral spread of the beam to four to nine times the beam's infrared-diffraction limit. Even with these constraints, the levels of uniformity required for OMEGA experiments can be achieved using SSD.

The focus of a high-energy laser beam, such as OMEGA, contains significant nonuniformity, as shown in Fig. 2.3-2(a). A speckle pattern produced by a phase plate[a] is characterized by a smooth, well-defined intensity envelope on target. The speckle is a highly modulated intensity structure produced by interference between light that has passed through different portions of the phase plate. SSD smoothes this speckle structure in time by progressing through a sequence of many copies of this speckle pattern, each shifted in space, so that the peaks of some fill in the valleys of the others at different times. When averaged in time, this effect is qualitatively similar to whole-beam deflection, as shown in Fig. 2.3-2(b).

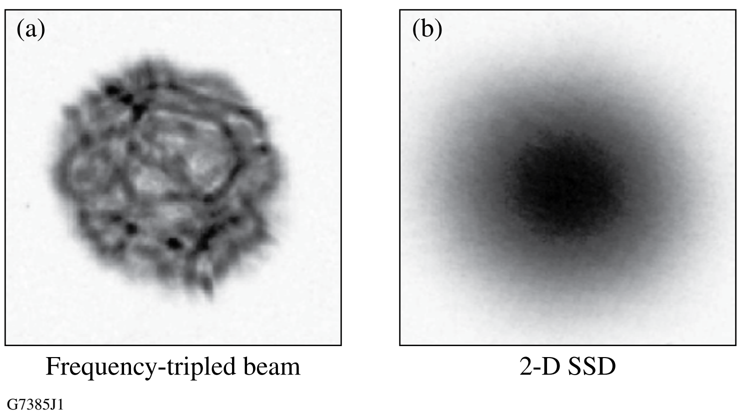

Figure 2.3-2
(a) An infrared beam that is amplified and frequency tripled to the ultraviolet has irregular uniformity at its focus. (b) Two-dimensional smoothing by spectral dispersion introduces high spatial-frequency speckle with a distributed phase plate (DPP) that is rapidly shifted at focus in two orthogonal directions to produce a more-uniform-intensity beam.

These shifted speckle patterns are generated by two key SSD components. The beam is passed through an electro-optic phase modulator, which imposes a range of frequencies (bandwidth) upon the laser light. The bandwidth is then spectrally dispersed by means of diffraction gratings. In OMEGA, two modulators of different frequencies are used with diffraction gratings oriented such that each bandwidth is dispersed in a perpendicular direction (see Fig. 2.3-3). Because of the dispersion, each spectral component focuses onto the target in a slightly different position, producing the required shifted speckle patterns that change in time.

For OMEGA, implementing large bandwidths and divergence in the second SSD dimension is advantageous because the bandwidth from the second modulator is not dispersed until after the most limiting spatial-filter pinhole, which is located in the LARA in the driver-line area. The constraint results from a spatial-filtering requirement associated with the serrated aperture apodizer used to set the OMEGA beam profile. A slotted LARA spatial-filter pinhole with its long axis aligned along the direction of dispersed bandwidth from the first SSD dimension is employed to maximize spatial filtering of the beam.

[a]The System Description document, S-AA-M-012, Chap. 5, and Sec. 5.9 contains a description of the distributed phase plate.

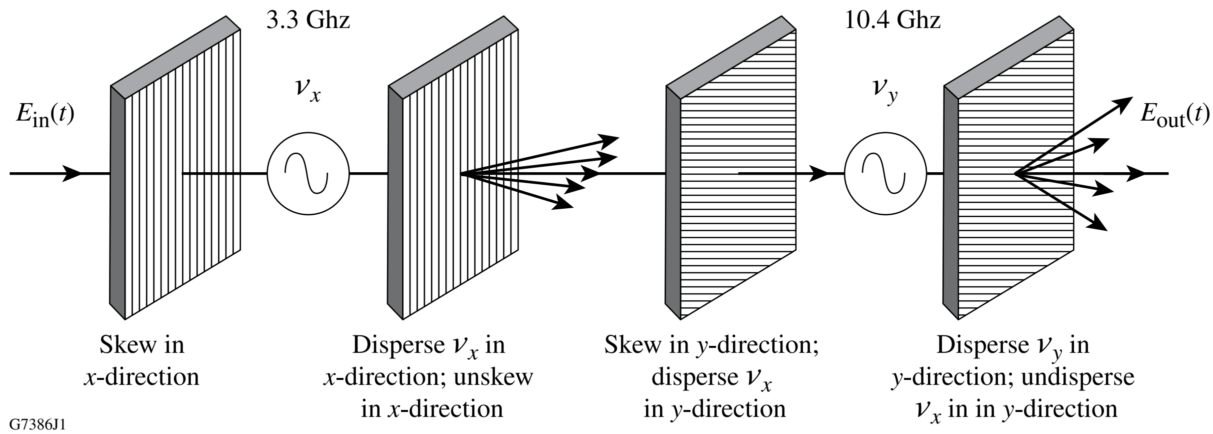

Figure 2.3-3
The basic 2-D SSD implementation uses two modulators and four gratings.

2.4 LARGE-APERTURE RING AMPLIFIER (LARA)

The optical layout of the amplifiers and the other driver equipment located in the Laser Bay is shown in Fig. 2.4-1. The most important amplifiers are 40-mm LARA's. One is provided for each of the main, SSD, and backlighter pulses. Each amplifier provides a typical gain of 12,000 in a total of four round trips, thereby producing a 0.6-J output pulse.

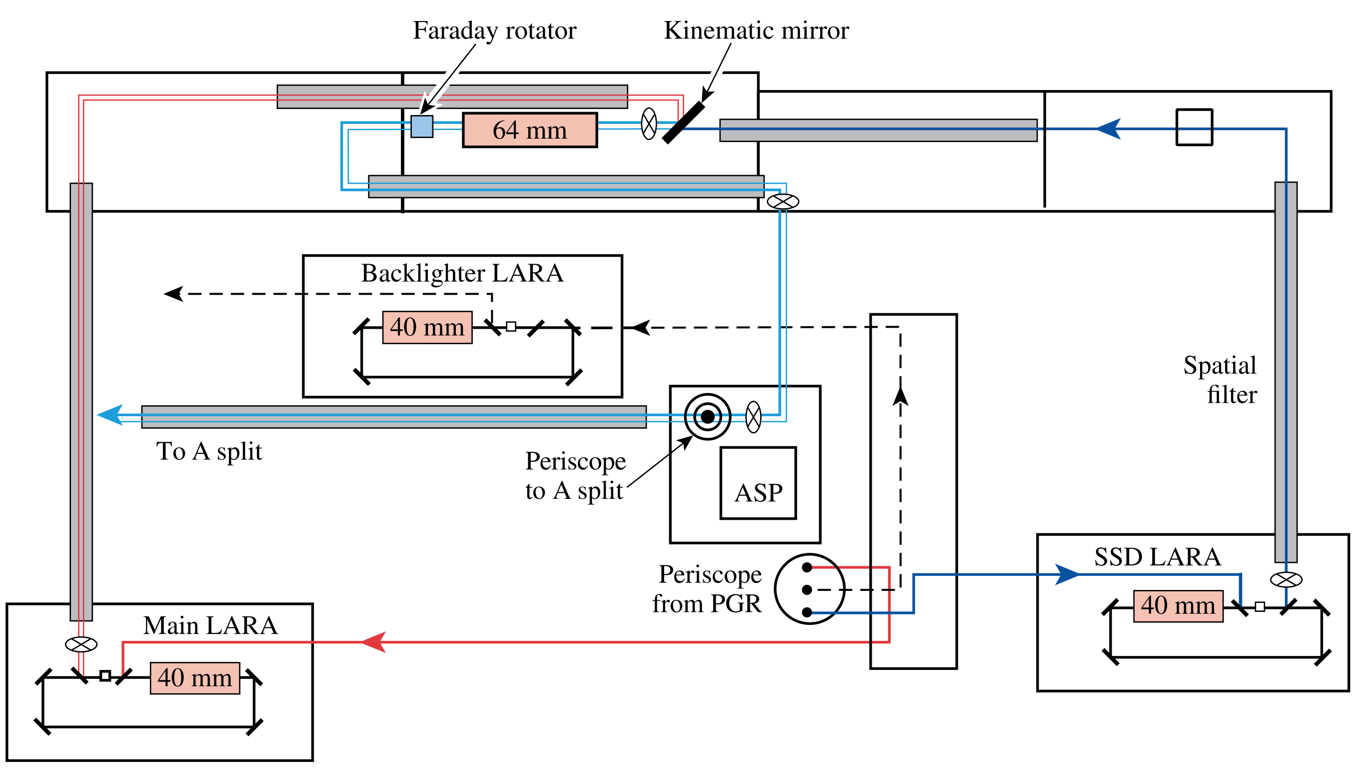

Figure 2.4-1
The driver line has three LARA-s and a 64-mm amplifier. The beams enter the driver line at the periscope from PGR.

OMEGA uses four-pass LARA's to provide the bulk of the gain needed to boost the regen output to the ~5-J level required for injection into the main OMEGA amplifier chain. This represents a departure from the traditional linear amplifier chains and was chosen for its compactness, excellent performance characteristics, and relative ease of maintenance. This amplifier can provide high-gain and high-quality beams for pulses in the 0.1- to 5.0-ns range. A schematic of the optical layout for the LARA is shown in Fig. 2.4-2.

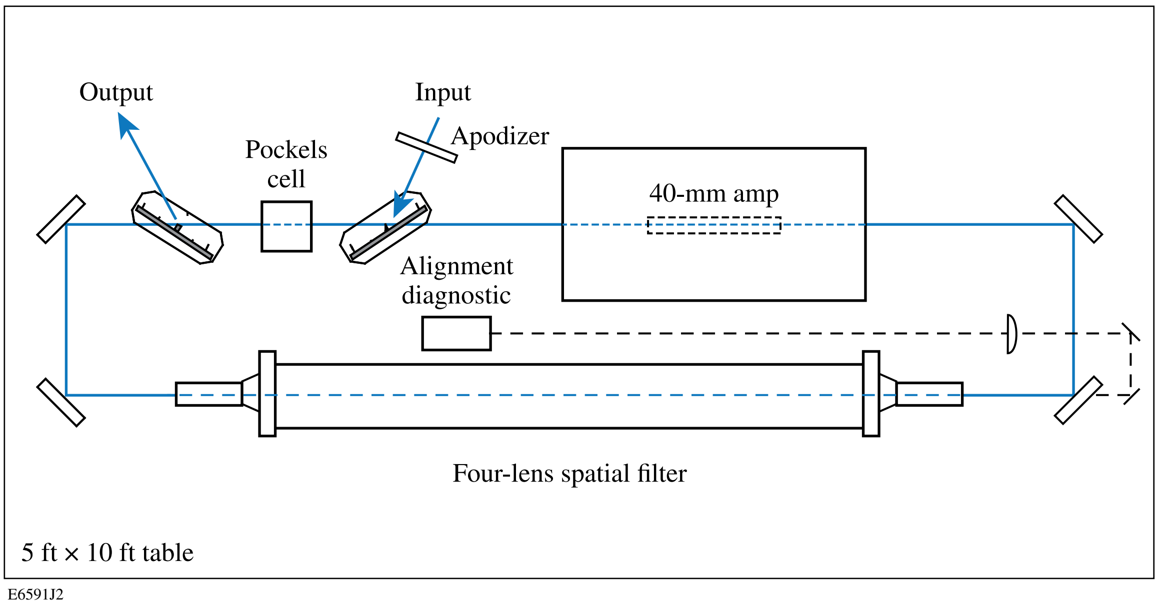

Figure 2.4-2
The LARA used in the OMEGA laser driver. The Pockels cell admits the input pulse and then, after four round trips, switches the amplified pulse out. The four-lens spatial filter is used in defining the alignment axis.

The LARA is a type of regenerative amplifier that uses a relatively large (40-mm) rod amplifier, an imaging spatial filter, and an electro-optical switch, all contained in an optical ring. Pulses pass through the input apodizer and are injected into the ring. The radial transmission of the apodizer is specially designed to compensate the radial gain variation in the 40-mm amplifier rod. The pulses then make four round trips, and are switched out. During each round trip the pulse is amplified by a factor of ~10.5. This gain value is very conservative since the 40-mm amplifier is capable of providing gains of 15 to 20 per trip. This conservatism helps improve the reliability of the amplifier and provides ample reserve gain for future needs.

Central to the performance of the LARA is the four-lens spatial filter that provides image relaying such that any location within the ring is mapped onto itself on subsequent round trips. This feature affords the ability to accurately align the ring and ensure that the optical path is reproducible, thereby allowing control of beam quality at high gain. The round-trip path length is approximately four times the effective focal length of each lens pair.

The spatial-filter pinhole is mounted to a prealigned position that serves as a pointing reference for alignment of the ring. The mount is kinematic so that the pinhole can be removed during fine alignment and accurately replaced. The internal alignment of the LARA's can be precisely maintained by aligning an intra-ring crosshair to itself and by aligning the beam to the spatial-filter pinhole using mirrors within the ring. The pulsed regen input beam is then injected into the ring and aligned to these references using external mirrors.

The injection and rejection (input and output) of pulses are performed using a Pockels cell and two polarizing beam splitters. The Pockels cell is driven by a thyratron-based switching circuit feeding a charge line; a switching time of much less than the cavity round-trip time (22 ns) is achieved. The system uses a 66-ns charge line to produce four passes through the amplifier.

If the Pockels cell is passive, the pulse passes through the ring exactly one time. If a half-wave voltage is applied to the Pockels cell before the optical pulse has finished its first round trip, the Pockels cell compensates for the half-wave plate and the laser pulse will continue travel around the ring. Optical amplification will continue as long as the voltage is applied. After the half-wave voltage is switched off, the amplified laser pulse is ejected out of the ring. The IR contrast specification of the Pockels cell is maintained to within 3.4×10^4 by careful alignment of the Pockels cell and the half-wave plate.

The gain performance of the LARA versus the capacitor-bank energy is shown in Fig. 2.4-3. Total gains of greater than 40,000 have been obtained with no appreciable degradation in beam quality.

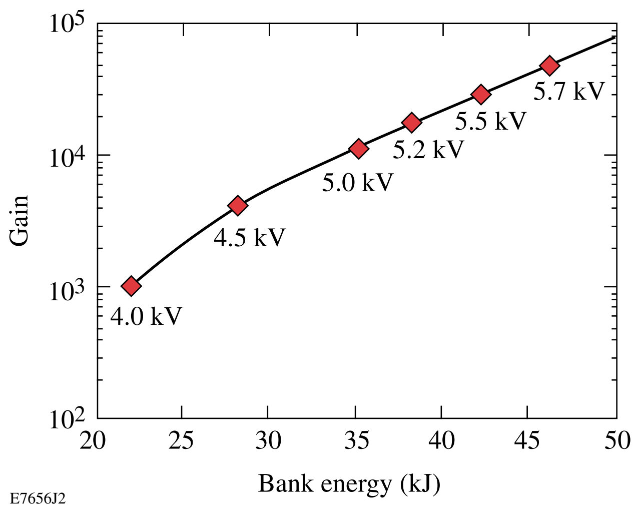

Figure 2.4-3
The total gain of the LARA system as a function of capacitor-bank energy. Gains of greater than 10,000 are easily achieved with four passes through the ring.

The selection of the main or the SSD driver as the source for the OMEGA beams is made by using a kinematic mirror that reflects the output of the main driver into the 64-mm laser amplifier. The mirror can be removed to allow the SSD pulse to enter the 64-mm laser amplifier directly. The selected beam is amplified to ~4 J by the 64-mm, single-pass amplifier, which is the last driver-line amplifier. A permanent magnet Faraday rotator and liquid crystal polarizer (circular) isolate the driver from any system back-reflection, is located directly after the final 64-mm amplifier. The driver-line outputs are spatially filtered and injected into the first beam splitter (stage-A), where the driver-line pulse is propagated into the OMEGA power amplifiers.

The backlighter LARA produces a 1.4-J output and goes through one spatial filter and Faraday isolator. This energy is appropriate for driving one of the three stage-A legs.

2.5 FIDUCIAL SUBSYSTEM

The fiducial driver line is located on the north end mirror structure in the target bay. The fiducial driver line uses a series of amplifiers to provide three fiducial wavelengths. These are an OMEGA diode-pumped regenerative amplifier (ODR), like the units in the PGR, and a higher-powered "ODR+," which replaces the traditional LARA.

Infrared, visible, and ultraviolet timing-fiducial signals are needed to match the wavelength sensitivity of various diagnostics. The fiducial-amplifier subsystem provides a compact, all-solid-state, diode-pumped, laser fiducial system that satisfies all OMEGA requirements.

The OMEGA fiducial laser system must produce a 3.5-ns comb of 200-ps full-width at half-maximum (FWHM) optical pulses separated by 0.5 ns at IR, green, and UV wavelengths (see Fig. 2.1-7). An Nd:YLF laser system with second- and fourth-harmonic generators is used to produce IR, green, and UV fiducial signals. The amplitude variation of each pulse in the comb must not exceed 50% of the maximum. The required IR/green comb energy is 1 mJ. The most critical requirements for the fiducial system are 10-mJ energy at UV (4ω) fiducial and a stable time delay (~165 ns) between the IR/green and UV fiducials.

The relatively long delay between UV and IR/green fiducials is dictated by the physical location of various OMEGA diagnostics. Since IR/green fiducials must be generated ~165 ns before the UV comb, a 165-ns delay line is required between the IR/green and UV fiducial launchers to provide the simultaneous arrival of the fiducials to all OMEGA diagnostics.

The fiducial system provides an optical timestamp to identify and measure information about the timing and shape of the laser pulse delivered to the target, along with the events recorded by various streak cameras. The signals provided by UV and x-ray streak cameras provide important information about the time-dependent target development under illumination by shaped laser pulses, and is very important for correct and unambiguous interpretation of the data generated from a shot. Figure 2.5-1 shows how a fiducial comb can be used to locate activity in time during a shot using a visual streak camera.

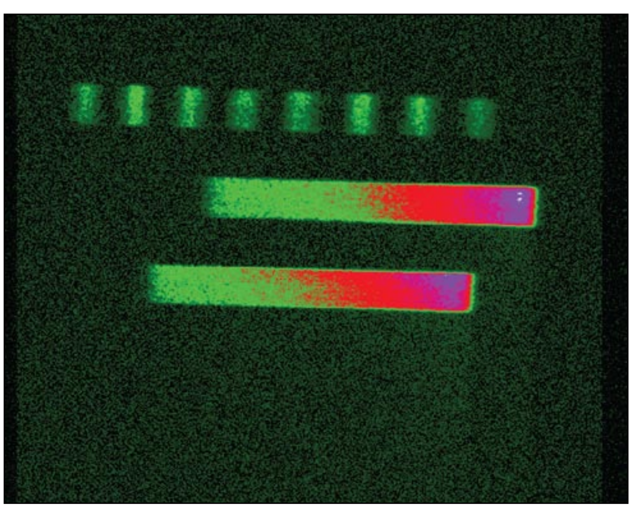

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Figure 2.5-1
Raw data from the IR3 streak camera in PGR illustrates that the eight fiducial pickets can be used to synchronize the activity in the system.

A block diagram of the system is shown in Fig. 2.5-2. The system is seeded by the shaped comb produced by the IFES. The fiducial is unique in that the output of its 10-V pulse generator provides a time-base reference for the entire ACSL system. This pulse is used to trigger the high-speed sampling scope that diagnoses pulse shapes produced by the system. An Nd:YLF OMEGA diode-pumped regenerative (ODR) amplifier boosts the comb energy from tens of picojoules to ~4 mJ. The main portion of this signal is used as an IR fiducial and for generating a green fiducial via a second-harmonic generator (SHG).

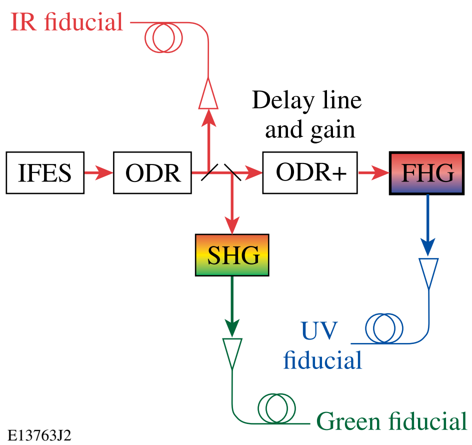

Figure 2.5-2
A block diagram of the OMEGA fiducial-laser subsystem.

2.5.1 ODR and ODR+

The fiducial ODR is pumped with one 150-W fiber-coupled diode array. The ODR output energy is >13 mJ at the maximum pump energy (see Fig. 2.5-3). With this input, the amplifier produces ~50 mJ of IR, meeting the energy requirement.

A portion of the ODR output is used to seed the second regenerative amplifier, designated ODR+. The higher power ODR+ is added to produce the additional gain required to achieve the UV energy specification. At the same time, it provides the required 165-ns delay with a small footprint and without beam degradation. Second-harmonic generation (SHG) and fourth-harmonic generation (FHG) are realized with beta-barium borate (BBO) crystals.

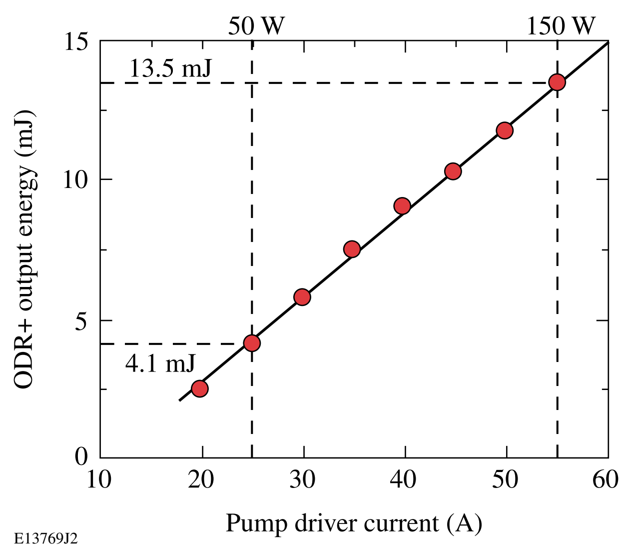

Figure 2.5-3
ODR+ is able to produce sufficient energy for effective double-pass amplifier energy extraction.

2.5.2 Fiducial Frequency Conversion

Figure 2.5-4 shows a block diagram of the frequency conversion setup. Beta-barium borate crystals (BBO) are utilized for frequency conversion to the fourth harmonic. An 11-mm-long type-I crystal is employed for second-harmonic generation (SHG), followed by a 6-mm-long type-I crystal for fourth-harmonic generation (FHG). A fused-silica prism is used to spatially separate the UV fiducial beam, and a telescope matches the beam size to efficiently launch the UV pulses into a multimode fiber bundle.

With the IR beam resized for efficient FHG, the energy requirement has been met. The fiducial comb (a) in Fig. 2.5-5 injected into the ODR has been precompensated such that both the (b) green and (c) UV fiducials meet amplitude requirement.

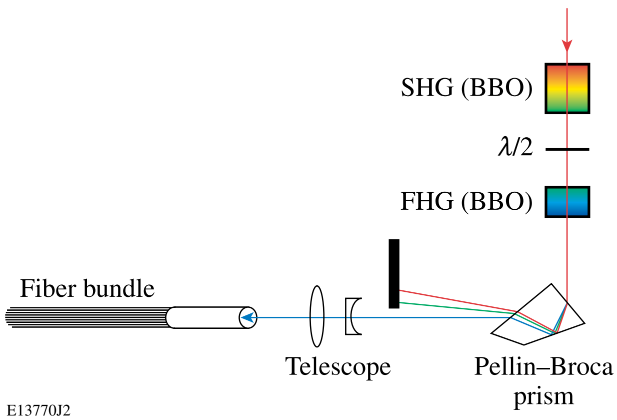

Figure 2.5-4
A block diagram of UV frequency-conversion setup and fiber bundle launching.

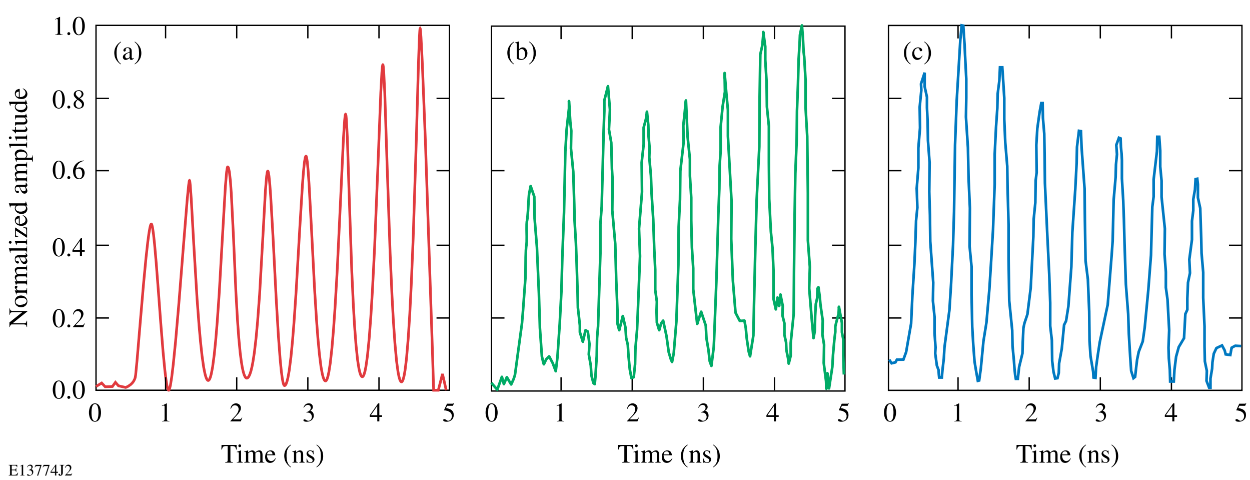

Figure 2.5-5
The ODR injection fiducial comb (a) is precompensated such that the (b) green and (c) UV fiducials satisfy the requirements.

2.5.3 Fiducial Delivery

High-UV fiducial energy is required because of the low-UV sensitivity of the x-ray streak camera photocathodes employed in OMEGA target diagnostics. Frequency-conversion efficiencies of 50% to 75% for both second- and fourth-harmonic generation have been demonstrated; therefore, the required IR energy is ~10 mJ.

A UV multimode-fiber delivery system is used to couple fiducial combs into the diagnostics. OMEGA needs up to 19 channels of UV fiducial; therefore, a 19-fiber bundle is used to launch the UV comb into the delivery fibers. To provide equal energy distribution and misalignment insensitivity for the fiber-bundle launcher, a UV fiducial beam must significantly overlap the 19-fiber bundle, bringing the total UV-comb energy required to 10 mJ. To avoid optical damage of the active element, the fluence is kept below 5 J/cm^2, and the delivery fiber is re-imaged into an active element with 2× magnification.

2.6 HARDWARE TIMING SYSTEM

The Hardware Timing System (HTS) provides precision-timing signals that synchronize the subsystems of the OMEGA and OMEGA EP Laser Systems to produce a laser pulse and acquire diagnostic data. End-to-end synchronization is provided by the reference frequency (RF) source that drives the laser's master oscillator, the Master Timing Generator (MTG), and the timing crates. The MTG provides derived rates that are also distributed. Local timing stations, known as "crates," include programmable modules that provide synchronized, precisely delayed rate and trigger signals.

The signals are distributed throughout the facility and provided to equipment via co-located Computer Automated Measurement and Control (CAMAC) timing crates. A software control interface is provided to allow operators to select rates and set delays to these timing signals. A block diagram of this system is shown in Fig. 2.6-1.

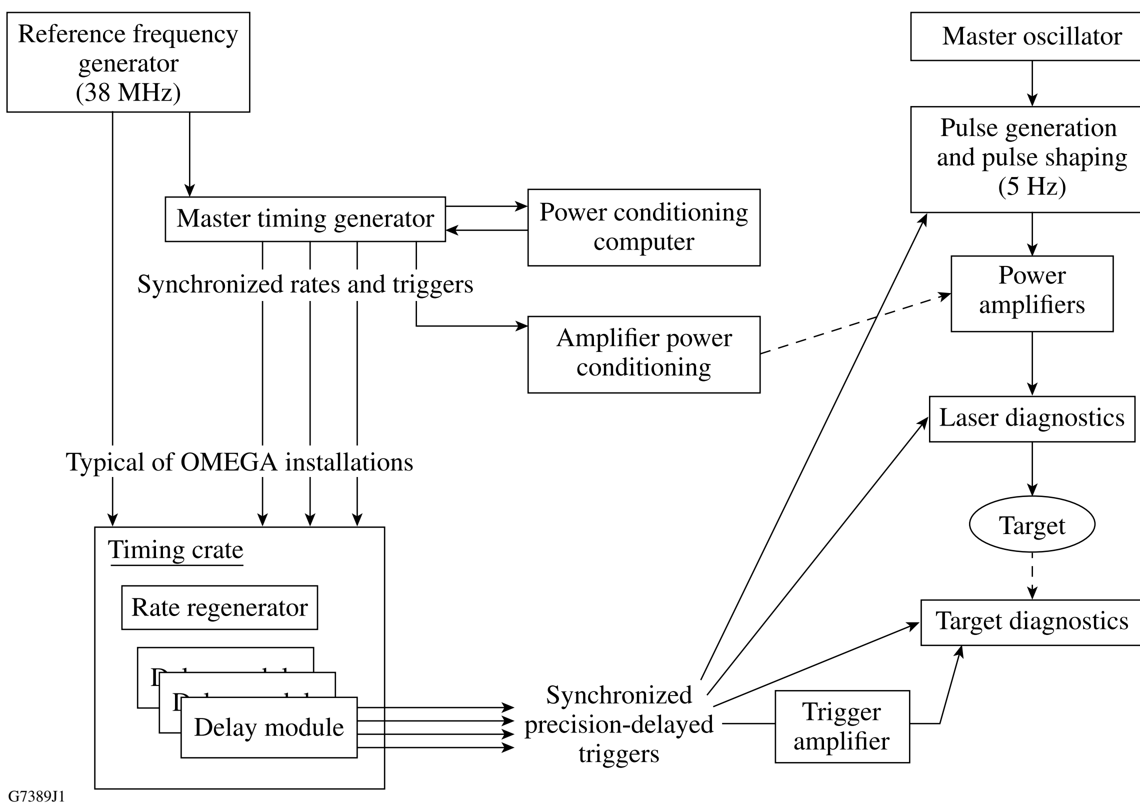

Figure 2.6-1
Block diagram of the Hardware Timing System used in OMEGA. All signal rates are synchronized to the 38-MHz reference frequency.

The MTG is located in the Driver Electronics Room (DER). This unit accepts a master-timing reference frequency signal (nominally 38 MHz) from the reference frequency generator (RFG), which is located in the drivers test bed (formally the oscillator room). The timing system is referenced to the 38-MHz reference frequency signal. Various slower rates are generated and distributed by this system. The MTG also accepts two separate, hard-wired asynchronous “enable” signals from the power-conditioning host workstation to control the shot sequence. The shot sequence coordinates the firing of the laser, which includes the selection of a seed pulse from the IFES shaped-pulse train in the regen, firing the amplifiers in the driver-line area and injecting the laser pulse into the OMEGA Laser System. See Hardware Timing System Definition Document (S-SH-M-001) for more details.

The MTG sends out synchronized periodic timing signals to associated digital “fan-out” units. The fan-out units feed signals to modular timing units, called “timing crates.” There are fan-out units for horizontal and vertical video synchronization and all logic level outputs.

The modular timing crates are located near the equipment they control and provide a precisely delayed synchronous output signal of the appropriate voltage and duration. The synchronization rate source is software selectable and is based on the master-timing-assembly outputs. The output signal is delayed to the input signal by a programmable value determined by the user.

2.7 LASER-DRIVER DIAGNOSTICS

The driver-line diagnostics may be divided into five main categories

- Pulse-energy
- Pulse-shape
- Timing
- Spectrum (wavelength and/or bandwidth)
- Pointing and centering

Most diagnostics produce signals at the 5-Hz pulse-repetition rate, except the IR streak cameras, which run at a 0.1-Hz pulse rate. Key diagnostics also acquire and log the characteristics of the particular pulse that is amplified in the LARA’s and power amplifiers.

Diagnostic data is monitored continuously between shots and may be stored in the database on demand. On-the-shot data acquisition logs the diagnostic data with all the other shot information in the database. Data acquired in either way can be displayed on the driver console in the OMEGA Control Room and is also available for display on workstations located in the PGR and the DER. The following measurement systems are used:

- Integrated Front-End Source (IFES) monitoring
- Regenerative amplifier (regen) characteristics
- SSD, laser-bandwidth broadening
- LARA characterization

The IFES diagnostics are illustrated in Fig. 2.7-1. The diagnostics listed in Table 2.7-1 are provided in the laser drivers.

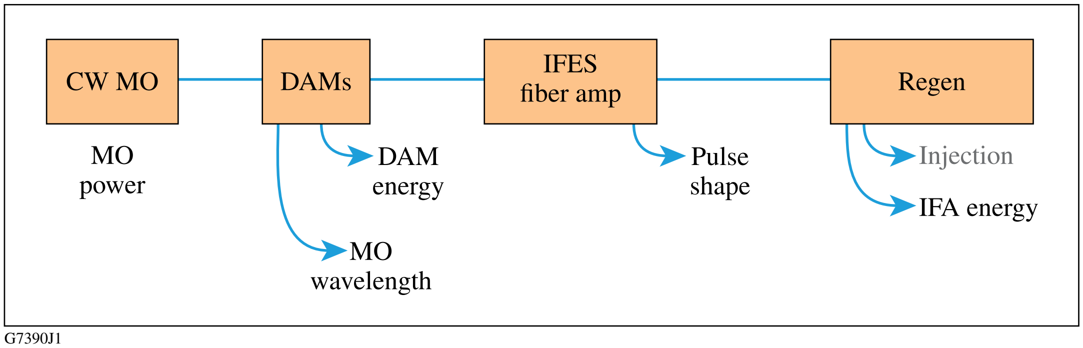

Figure 2.7-1
Block diagram of the IFES diagnostics. The signal generation runs from left to right.

Table 2.7-1: Laser-drivers diagnostics.

Diagnostic	Location	Main	SSD	Backlighter	Fiducial
System timing	PGR	X	X	X	X
Wavelength monitoring	DER	X	X	X	X
Spatial beam profiles	PGR and DLA	X	X	X	
Laser spectrum	PGR		X		
Pockels-cell timing jitter	PGR and TB	X	X	X	X
Laser energy	PG, DLA, and TB	X	X	X	X
Pulse shape	PGR	X	X	X	X
IR streak timing	PGR	X	X	X	X
Prepulse contrast	DLA	X	X		

2.7.1 Laser-Energy Measurements

Energy measurements are made at several points along the laser drivers using photodiodes that can view a sample of the beam regardless of the system configuration. These diodes are calibrated against a laser-probe energy meter in the PGR and calorimeters in the driver line that are temporarily inserted in the direct beam.

Single-pulse photodiode signals are sent to CAMAC-gated integrators for computer acquisition. Characteristics of regens in the DER and PGR are diagnosed by sending the photodiode signals through bandpass filters to multichannel digital oscilloscopes. The oscilloscope records are acquired through a GPIB interface and analyzed by the acquisition device manager (ADM) software application to provide peak amplitude, FWHM, and time of peak amplitude. See Fig. 2.7-2 for an example of a typical ADM GUI.

The proper functioning of each unit is verified on a continuous basis. The energy measurements are made close to the 5-Hz cycle rate of the system, and real-time running statistics are computed from this data stream.

2.7.2 Pulse-Shape Measurements

Rough pulse-shape measurements are made using single-mode fibers connected to fast diodes mounted directly at the input of a Tektronix TDS 8000 Series oscilloscope. The fibers sample the single

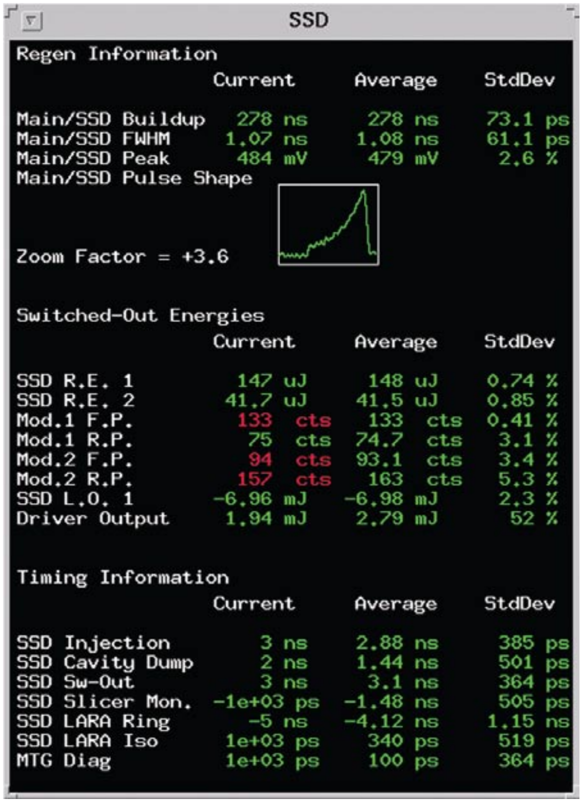

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Figure 2.7-2
Screen shot of the SSD driver ADM graphic user interface. Readings that are out of tolerance are shown in red.

pulses selected from each of the three PGR regen pulse trains that seed the OMEGA driver lines. The dynamic range of these oscilloscope traces allow verification of the pulse shapes injected into the driver lines, but is not sufficient for detailed analysis or input *RAINBOW* simulations. For that purpose, a multichannel streak camera was installed in the PGR.

The IR streak cameras in PGR are used to monitor the relative timing and pulse shapes from the four regens. Each streak camera has five-channel fiber inputs to accomplish this. Each input is imaged onto a streak tube via an all-reflective optical system. The photocathode is dedicated to the four regens in the following proportions: 40% main, 20% SSD, 20% backlighter, 10% fiducial, and 10% interchannel gap. This arrangement can be easily reconfigured. The output of the streak tube is coupled to a 515×512 CCD array through a 2:1 fiber-optic reducing bundle. The streak ramps are synchronized to the laser by a 0.1-Hz pulse rate from the Hardware Timing System. This guarantees the capture of one pulse every 10 s. In addition, the camera can be synchronized via software to capture data on the shot.

For calibration purposes the camera has a self-contained flat fielding system and a dedicated multichannel fiducial mode for rapid sweep calibration. A local PC controls the streak camera and CCD camera. Custom software is used to coordinate all acquisition, calibration, and data management.

2.7.3 Pulse-Timing Verification and Pockels Cell Timing Jitter

Pockels cells are used throughout the laser drivers to facilitate the operation of the system. The variation in the time delay between the origination of the Pockels-cell trigger signal and the time when the full electric field appears across the cell is a key parameter that affects the pulse-to-pulse uniformity of the laser-driver output. These timing variations, called “jitter,” are of the order of ~1 ns.

Pulse-timing and timing-jitter measurements of various Pockels cells in the OMEGA Laser System are carried out by using CAMAC-based, high-speed, time-to-digital converters (TDC's). The TDC's use separate electrical-input triggers to start and stop the internal counters. The start-counting trigger is derived from the master timing fan-out, and the stop-counting trigger is generated by the electronics that drive the electric field on the Pockels cell. The number of counts within the TDC is read out, and the data are uploaded to the host computer for analysis. Real-time running statistics are computed from this data stream and used to monitor the operational status of the system. This system continuously verifies the proper firing sequence of approximately two dozen devices, with nanosecond accuracy in general and with 50-ps accuracy in some selected cases. This is particularly important for the Pockels cells in the system because the mistimed firing of any one of them lead to the incorrect firing of the full OMEGA system.

Pulse-timing verification has turned out to be of increasing importance since different pulse shapes are being propagated through the laser system. For that purpose the single pulses from any of the PGR regens injected into the OMEGA driver lines are checked for proper timing at the regen output. Photodiodes at these locations feed appropriate TDC channels for continuous surveillance.

2.7.4 Spectral Bandwidth and Central Wavelength from SSD

In IFES, the correct central wavelength and amount of bandwidth broadening of the laser after SSD are important for high-efficiency, third-harmonic conversion at the end of the OMEGA Laser System. A Wavemaster laser wavelength meter located in the DER allows measurement of the center wavelength to ±0.02 Å.

In the PGR, the detector coupled to the spectrometer output following SSD modulation is a slow-scan, cryogenically cooled, charged-coupled-device (CCD) array with 18 bits of dynamic range. The low quantum efficiency of the detector at 1 μm is overcome by efficiently coupling the light into the spectrometer (i.e., matching numerical apertures) and by sampling a high percentage (4%) of the laser-beam energy. The output of the array is buffered by an intermediate local controller and then passed along to the executive computer. The same interferometer also allows the SSD bandwidth and the associated modulation parameter of either SSD modulator to be measured, as long as there is no wavelength dispersion.

To measure the combined bandwidth of both SSD modulators, including dispersion, the IR Fabry–Perot spectrometer system are being characterized (see Fig. 2.7-3). In this case, the laser beam to be diagnosed enters an integrating sphere, the output of which is the source for the interferometer. This system is independent of wavelength dispersion and is able to measure the bandwidth to ±0.02 Å in the IR and yield an estimate of the modulation parameter to better than 2%.

2.7.5 Pointing and Centering Diagnostics

CCD imaging devices are used throughout the laser system as alignment aids, as beam profile diagnostics, and for various other applications. Since these are used for preshot alignment, the images are not incorporated into the shot database. See Table 2.7-2 for a list of driver-imaging diagnostics.

The 5-Hz output of the regen is propagated through the optical train that is to be aligned and imaged on a video camera. In the laser drivers, separate cameras are provided for pointing and centering except at the DL-ASP at the end of the driver-line train. As a result, the DL-ASP (which is the same design

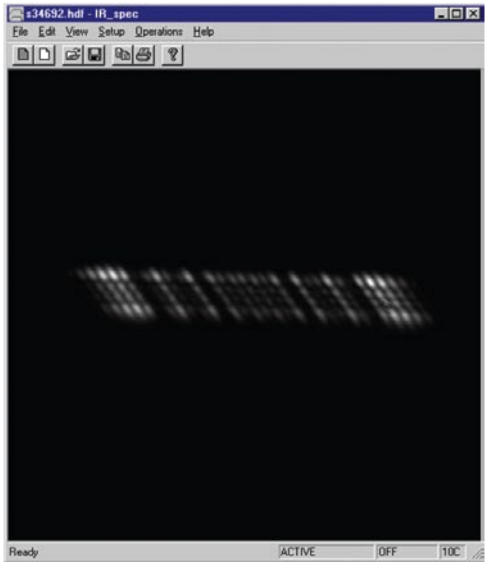

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Figure 2.7-3
Infrared spectrometer images showing bandwidth of both SSD modulators, including dispersion.

Table 2.7-2: Driver imaging diagnostic cameras.

Camera	Beam	Location
Crystal centering	Main, SSD, and backlighter	PGR
Crystal pointing	Main, SSD, and backlighter	PGR
Regen and centering	Main and SSD	PGR
Regen pointing	Main and SSD	PGR
BL regen centering	Backlighter	PGR
BL regen pointing	Backlighter	PGR
Output centering	Main, SSD, and backlighter	PGR
Output pointing	Main, SSD, and backligh-ter	PGR
Main LARA centering	Main	Driver line
Main LARA pointing	Main	Driver line
SSD LARA centering	SSD	Driver line
SSD LARA pointing	SSD	Driver line
BL LARA centering	Backlighter	Driver line
BL LARA pointing	Backlighter	Driver line
Driver line ASP	Main and SSD	Driver line
Fiducial regen centering	Fiducial	Target Bay
Fiducial regen pointing	Fiducial	Target Bay
Fiducial LARA centering	Fiducial	Target Bay
Fiducial LARA pointing	Fiducial	Target Bay

as the A- and C-ASP's) is the only place in the laser drivers where it is necessary to change the optical configuration to get both pointing and centering data. The ASP's are equipped with optical elements on two movable stages controlled by two-state device-control modules, which receive commands from the executive via a LON. The stages can be positioned to provide coarse pointing, fine pointing, or centering images to a single camera that is part of the ASP.

The cameras are controlled by one of three Sun workstations located in the PGR, DLA, and Fiducial, which contain two frame grabbers each. Commands to the cameras originate from the OMEGA imaging GUI (OIGUI). The image that the frame grabber acquires and digitizes is analyzed locally in the image server.

In general, the image processing gives the *X* and *Y* locations, in pixels, of the center of a spot, a crosshair, or a reticle to the camera detector array. Other parameters, such as lineouts or *X* and *Y* from an input set of pixel coordinates are provided by some of the algorithms.

The executive can command the image-analysis computer to perform the appropriate processing and return the results over the network. The results are also impressed on a video image that is output to an RF modulator and is available on the video distribution system for display to the operator.

The image-analysis results are interpreted as a deviation from the reference crosshairs by the operator or by alignment processing in the executive. If an adjustment of the optical train is necessary, commands are passed from the executive to the appropriate dual-axis control module(s) via a LON. Pointing and centering alignment generally involves commands to two dual-axis control modules (DACM's), one that positions a pointing mirror and one that positions a centering mirror. The pinholes in spatial filters are positioned by a single DACM.

Note that these alignment "control loops" are closed step-wise (measure, compute, move, measure) over a period of from 10 s to ~1 min; these are not real-time loops.

2.8 LASER-DRIVER CONTROLS

The laser-drivers subsystem has a relatively small number of unique control and sensing elements in comparison to the alignment and power conditioning subsystems, which have a large number of identical elements to serve parallel beamlines. Also the laser drivers will always be more developmental in nature and will always require a high level of involvement by the operators. These factors, combined with the fact that the laser-drivers equipment is in four separate locations, led to a configuration that provides control systems in four locations (the DER, the PGR, the driver-line area, and the fiducial area in the Target Bay, in addition to the Control Room) and permits operations in support of system shots from either the PGR or the Control Room.

2.8.1 Configuration

Driver controls consist of several Sun workstations and PC-compatible computers to operate and monitor critical operating parameters, diagnostics, and applications within the drivers subsystem. These computers connect to peripheral equipment by means of the general-purpose interface bus (GPIB), local operating network (LON), or directly via serial ports. Figure 2.8-1 (drivers controls) is a block diagram of the laser-drivers computer controls. This configuration provides control and data acquisition for the

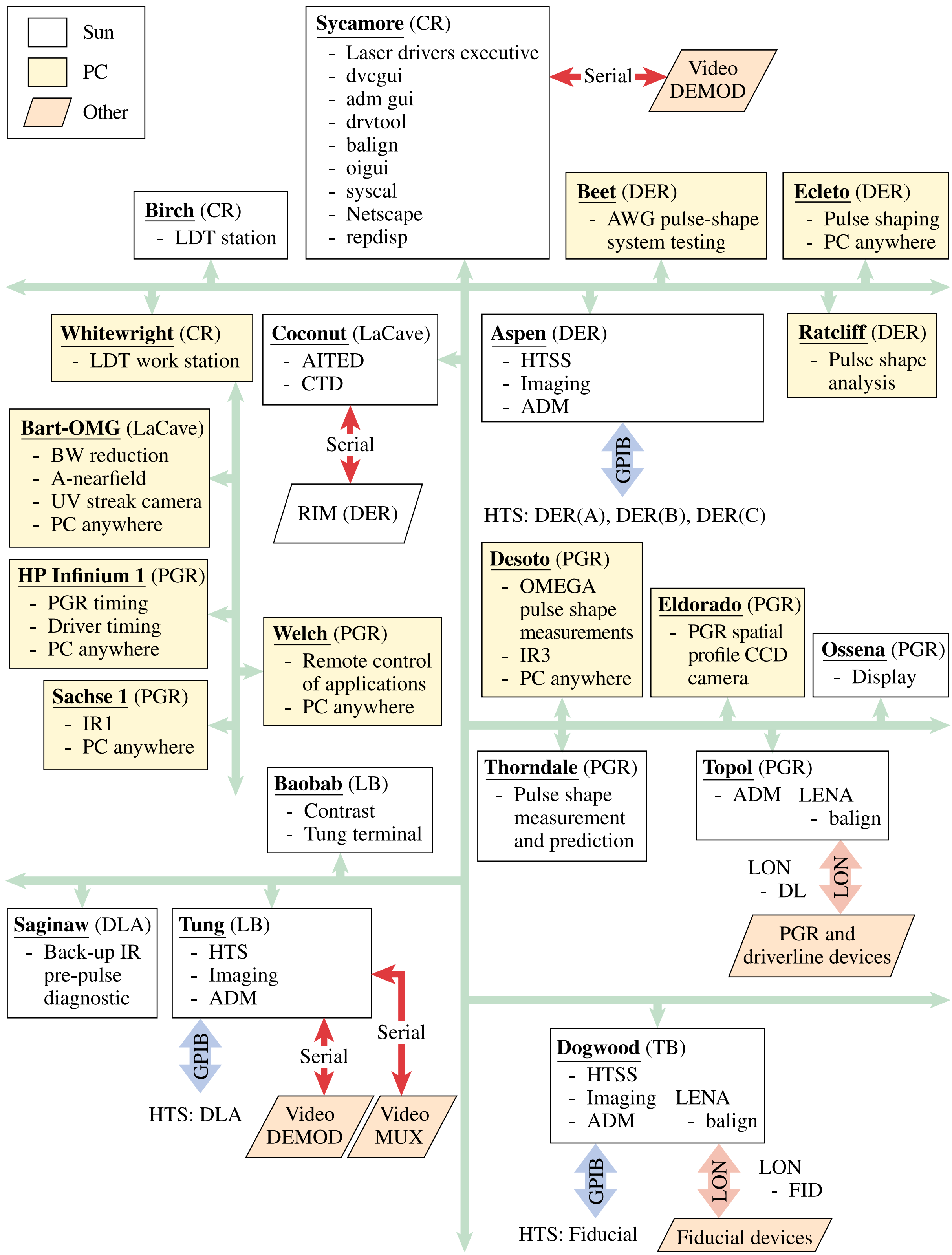

Figure 2.8-1
Block diagram of the laser-drivers controls that illustrates the elements of the control tree that is used for remotely controlled alignment throughout the OMEGA Laser System. The current OMEGA computer hierarchy is maintained in document C-FC-M-017.

alignment of laser-driver optics from initial amplification in the PGR through injection of the amplified beam into the relay to the stage-A splitter. It also provides ADM data acquisition for the driver diagnostics and control of the timing-system crate in the driver electronics room (DER). The rod amplifiers in the driver-line area are controlled by the power conditioning subsystem.

Each computer communicates with the Laser Drivers Executive, which contains device control, energy diagnostics, access to imaging, and various GUI's. The executive also interacts with the Shot Executive using the proprietary OMEGA Intercommunication Protocol (OIP) over ethernet.

2.8.2 ACSL v2 Software

The ACSL v2 software application is used to set up, control, and monitor the pulse-shaping process. A server is started for the system when the client is first launched. Personnel may view ACSL v2 in a second location by using VFN software. All of the settings that operators need are provided through the client interface.

The information used to configure the system resides in three locations

- Oracle database tables
- National Instruments Measurement and Automation Explorer
- Registry entries

Under most circumstances, the user never needs to manipulate the information stored in these locations. Only ACSL system administrators should modify these settings. Administrative tools are provided through the server interface.

ACSL v2 has several advantages. The Oracle database schema has improved the efficiency, allowing shot settings to be restored accurately. The administrative and user settings are now separated. Instrument settings have been assigned security levels to partition data and restrict control. Universal channel delay is now available to change pertinent delays for an entire system at once. Arbitrary trigger timing can be used to "sync" multiple Tektronix 8000 scope channels for better reference.

The stripline (Shape) ID is not automatically sensed by ACSL v2. Information entered by the Operator during pulse shape setup is used to retrieve the pulse shape design and set-up data.

2.9 REFERENCES

1. The System Description document, S-AA-M-012, Chapter 5, and Section 5.9 contains a description of the Distributed Phase Plate.