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MASTER

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Efficient and accurate alignment of the laser beam from oscillator to target is essential for productive operation of a laser system. Because manual techniques are often too slow for efficient day-to-day operation even on the present one- and two-beam systems, beam alignment on Shiva will be automated to the greatest extent possible. Adjustments requiring physical access to individual components (which may be four or five stories above the laser-bay floor) will be minimized.

Figure 1 is a diagram of the basic Shiva alignment system. Table 1 lists the alignment requirements, as originally specified and as presently estimated, together with the performance obtained to date from the prototype equipment. We expect that this performance will be satisfactory for even the most alignment-sensitive targets and significantly better than is needed for experiments not requiring highly uniform illumination. Figure 2 illustrates the hardware arrangement planned for a typical Shiva chain.

Because high repetition rates are not possible with the pulsed preamplifiers that will be used on Shiva, both system and target alignment will be accomplished with an amplitude-modulated cw laser. Therefore, except for the oscillator section, all of the alignment procedures and hardware described below are designed to be used with a 630-Hz, 1.06- μ m source. A separate cw mode-locked oscillator will be used for pulse synchronization.

Oscillator/Preamplifier Alignment

The oscillator-alignment system automatically points and centers both the pulsed and cw oscillators with respect to a pointing and centering sensor (see Figure 3). This sensor is mounted on the preamplifier table, which is rigidly attached to the laser spaceframe. Signal processing is done in such a way that full corrections for angle and position can be calculated and

Figure 1. Diagram of the alignment system for a representative Shiva amplifier chain.

Table 1. Requirements and performance for the Shiva alignment system.
All values are the standard deviation measured at the appropriate alignment sensor.

<u>System</u>	<u>Requirements</u>		<u>Performance σ</u>	
	<u>1975 Estimate</u>	<u>Present Estimate</u>	<u>Demonstrated to Date</u>	<u>Expected Achievement</u>
<u>Oscillator Coalignment</u>				
Pointing	$\pm 2 \mu\text{rad}$	20 μrad	2.3 μrad (CW) 3.5 μrad (pulsed)	1.0 μrad
Centering	$\pm 0.5 \text{ mm}$	$\pm 0.25 \text{ mm}$	0.1 to 0.25 mm	0.1 mm
<u>Chain Input</u>				
Pointing	$\pm 60 \mu\text{rad}$	$\pm 60 \mu\text{rad}$	15 μrad	15 μrad
<u>Chain Output</u>				
Pointing	$\pm 1 \mu\text{rad}$	$\pm 5 \mu\text{rad}$	1 μrad	1 μrad
Focusing	$\pm 25 \mu\text{m}$	$\pm 60 \mu\text{m}$	23 μm	20 μm
Centering	$\pm 2 \text{ mm}$	$\pm 2 \text{ mm}$	0.2 mm	0.2 mm

SHIVA PROTOTYPE ALIGNMENT SYSTEM

Figure 2. Major components of the Shiva prototype alignment system arranged for a typical beam.

Figure 3. Photograph of the Shiva oscillator alignment sensor with its cover removed.

implemented with data obtained from a single pulse. Thus, only a few pulses of the pulsed oscillator or a few samples of the cw oscillators are required to reach and verify proper alignment. Two of the oscillators are mounted on a second table also attached to the spaceframe. Figure 1 shows the locations of various components on these tables schematically and Figure 4 shows a detailed layout.

Centering of the pinholes in the two spatial filters mounted on the pre-amplifier table is monitored by imaging the pinhole planes through a turning mirror and onto a silicon vidicon. The relative (x,y) positions of the beam and pinholes can be determined by alternately inserting and removing a weak lens or a diffuser ahead of the spatial filter to overfill the pinholes.

Main-Chain Input Pointing

To remain centered in the spatial-filter pinholes, the beam must be properly pointed at the input of each amplifier chain. Between the oscillator alignment sensor and the apodizer, most beams reflect off seven mirrors; thus some angular drift may occur. To measure the angular error at the front of each chain and to correct for any drift beyond the tolerances listed in Table 1, a pointing sensor located immediately after the apodizer in each chain drives a servoed chain-input-pointing (CHIP) gimbal in the beam-splitter array.

Spatial-Filter Pinhole Positioning

The relative transverse positions of the focused beams and the pinholes in the main-chain spatial filters are determined as described above by imaging the pinhole planes onto a vidicon. In this case, the vidicon is located either in the incident-beam-diagnostics package which looks through the output pointing gimbal or in the output pointing, focusing, and centering (PFC) sensor, directly across the target chamber from the beam in question. Initially, the video signals are displayed on monitors and the pinholes are positioned in a manual/remote mode. Ultimately, however, these video signals will be digitized and processed in the alignment-system, second-level computer to provide error signals for closed-loop alignment of the pinholes. The

spatial-filter pinhole manipulators are stepping-motor driven and are operated remotely.

Centering on the Focusing Lens

The PFC sensor is located behind the output pointing gimbal in each chain and has several modes of operation. In the centering mode, the centering screen (located ahead of the focusing lens) is imaged onto a lateral-effect detector in the PFC package. This retroreflecting screen is positioned with its center on a line passing through the target position and the nominal center of the focusing lens. During initial setup, the PFC sensor is carefully oriented so that the center of the centering screen is imaged onto the center of the detector. Then, when the alignment beam is on and is reflected back into the PFC sensor, any difference between the present position of the beam centroid and its position at the time of initial set-up generates an error signal.

In the simplest mode of closed-loop operation, this error signal drives the first of two output gimbals until the beam is centered on the screen. With full implementation of the alignment-computer system, this error signal will drive both output gimbals to achieve a pure translation, i.e., no repointing of the beam entering the focusing lens.

Pointing at the Target

In the pointing mode, the centering screen is removed and a spherical surrogate target is positioned in the target chamber (see Figure 5). The PFC sensor continues to image the plane where the centering screen was located. When the beam, which was previously centered on the lens, points directly at the target (its central ray normal to the target surface), the beam reflected back through the lens is centered in the plane being imaged and no error signal is generated. If the beam arrives at the target at any other angle, the back reflection is off-center and the PFC sensor generates error signals. These error signals drive the servos on the output pointing gimbal until they are nulled. This pointing procedure is most accurate when the diameter of the back-reflected beam is small, a condition that occurs for a particular focusing configuration as described below.

Figure 5. Output pointing with the PFC sensor. The sensor has been initially positioned to indicate zero error for beams which are exactly retroreflected from the surrogate. When the focused beam hits the target at other than normal incidence, the back reflection is off-center. This generates an error signal in the PFC sensor.

Focusing on the Target

Moving the focusing lens toward or away from the surrogate target causes the diameter of the reflected beam to vary in the plane being imaged (see Figure 5). The smallest diameter is obtained when the incoming beam is focused at a point about halfway between the center and the front surface of the spherical target. The PFC-sensor optics image the centering-screen plane onto a vidicon as well as onto the detector, so that the operator can visually determine when this focusing condition is achieved. For closed-loop operation, the video signals can be digitized and processed on the alignment-system, second-level computer. This provides a measure of either on-axis intensity or spot diameter that can be maximized or minimized, respectively.

On a given shot, the experimenter specifies the desired offset from the half-radius position. The focusing lens is moved along the beam for that specific amount by the remotely actuated lens drive. The correctness of the final-focus position can be verified by viewing the beam with the opposing PFC sensor.

Target Viewing and Exchange

With a different lens-turret position, the PFC sensor can provide a vidicon image of the target or its silhouette depending on whether the target is illuminated from the same or opposite side. To supplement other target-alignment optics and to provide the capability for viewing the target directly along the beam axis with good image quality, all beams are provided with diffuse target-illumination sources. To accurately replace a surrogate target with the real target, the surrogate's position is referenced on the monitor and the fusion target then is carefully inserted.

Alignment Controls

Shiva will be controlled primarily by a three-level hierarchical-control network of minicomputers. The controls for the alignment system are a part of this network. Each alignment subsystem can be controlled locally in the laser

bay or target room, as well as from the central-control room. In addition, the operator can monitor error signals and gimbal positions for all systems to confirm that the closed-loop functions are being performed correctly.

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