Section 1
LASER SYSTEM REPORT

1.A GDL Facility Report

During the fourth quarter of fiscal year 1983 (July through September) we continued to operate GDL as a 3ω (351-nm) interaction facility. Shots were taken in support of interaction, shell hydrodynamics, 3ω holography, and x-ray biophysics experiments; the continuing optical-coating damage-testing program; and several NLUF users. A highlight of the quarter was the smooth, efficient running of the facility, with minimal downtime owing to system problems.

A summary of operations in the GDL facility follows:

Interaction Experiments	163
X-Ray Biophysics	44
Damage Testing	139
NLUF Users	69*
System Pointing, Alignment	56
Miscellaneous	9
TOTAL	480

*Included 20 UCLA and Yale shots, 14 Naval Research Laboratory shots, and 35 University of Pennsylvania and University of Connecticut shots.

1.B OMEGA Facility Report

OMEGA operations this quarter consisted of (a) completion of the wavelength conversion of the six-beam "D group" of OMEGA, from an infrared (1054-nm) output to an ultraviolet (351-nm) output, (b) activation of the frequency-converted beams, and (c) target irradiation experiments with 351-nm beams.

By the beginning of the quarter, only the spatial filter modifications had been completed. We spent the month of July assembling crystals into conversion cells and mounting and aligning the beamsplitters, integrating spheres, calorimeters, and photodiodes which comprise the multi-wavelength emission-sensing system (MESS). The MESS system provides the capability of measuring the total IR beam energy, the crystal output energy, and the fractional composition of the output, in terms of first, second, and third harmonics. A block diagram of the MESS system is illustrated in Fig. 1. Further accomplishments during

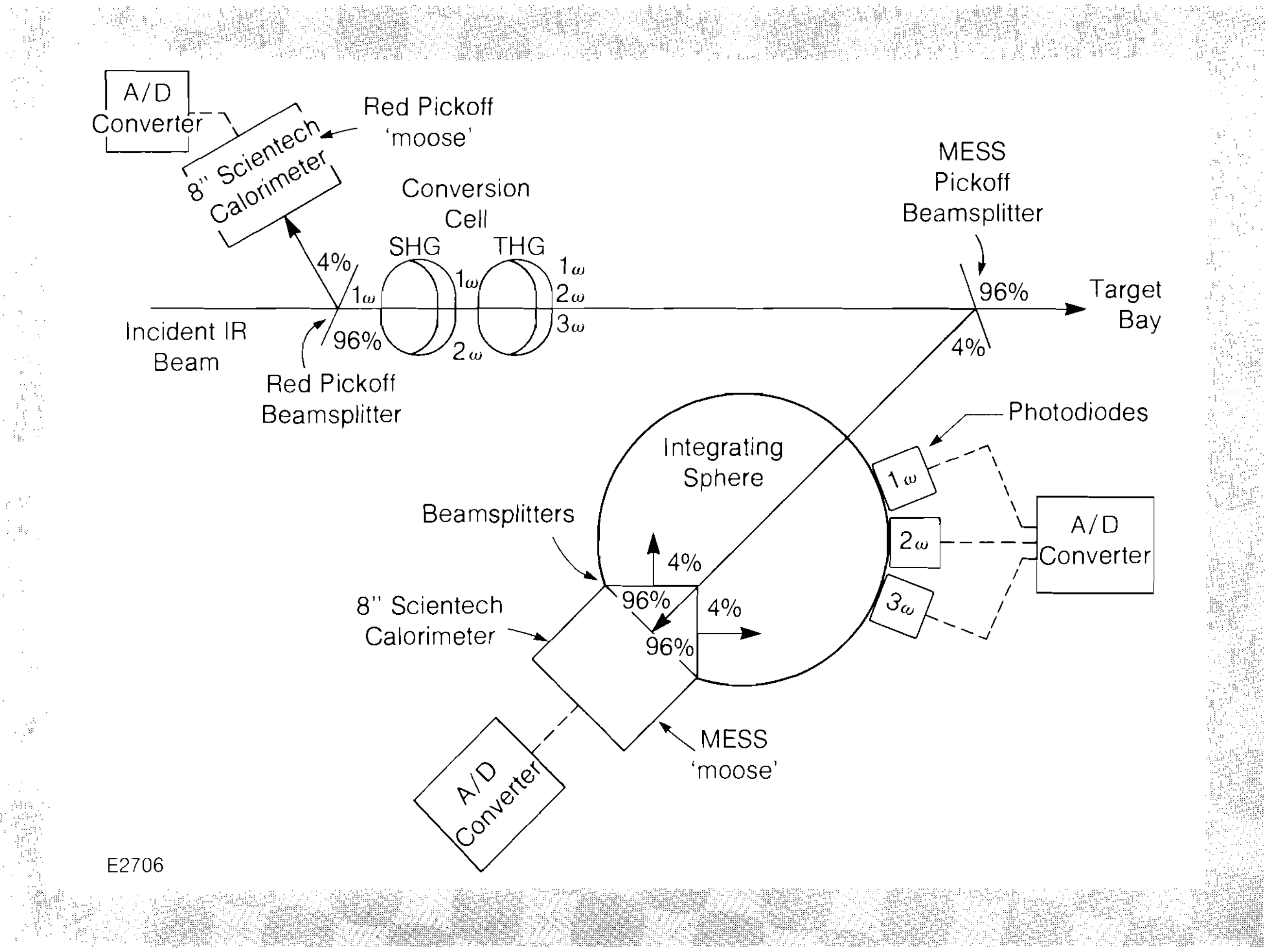

Fig. 1
Multi-wavelength emission-sensing system (MESS) block diagram. The second-harmonic generator (SHG) and third-harmonic generator (THG) crystals are contained within a single cell. The first-, second-, and third-harmonic energy components (1ω, 2ω, and 3ω) of the converted beam are measured individually by photodiodes on an integrating sphere. Total beam energies are measured by calorimeters.

July were the addition of flip-in wave plates in the Pockels-cell structures, to facilitate alignment, and the completion of the thermal control system designed to maintain the crystal cell temperature at ±0.1°C. A majority of the laser system maintenance scheduled for this quarter was completed during July.

In August, we completed the conversion-cell assembly. During the filling of the cells with index-matching fluid, many attempts were required to find a filling technique that would leave no air bubbles remaining in the fluid. As they were completed, the cells were placed

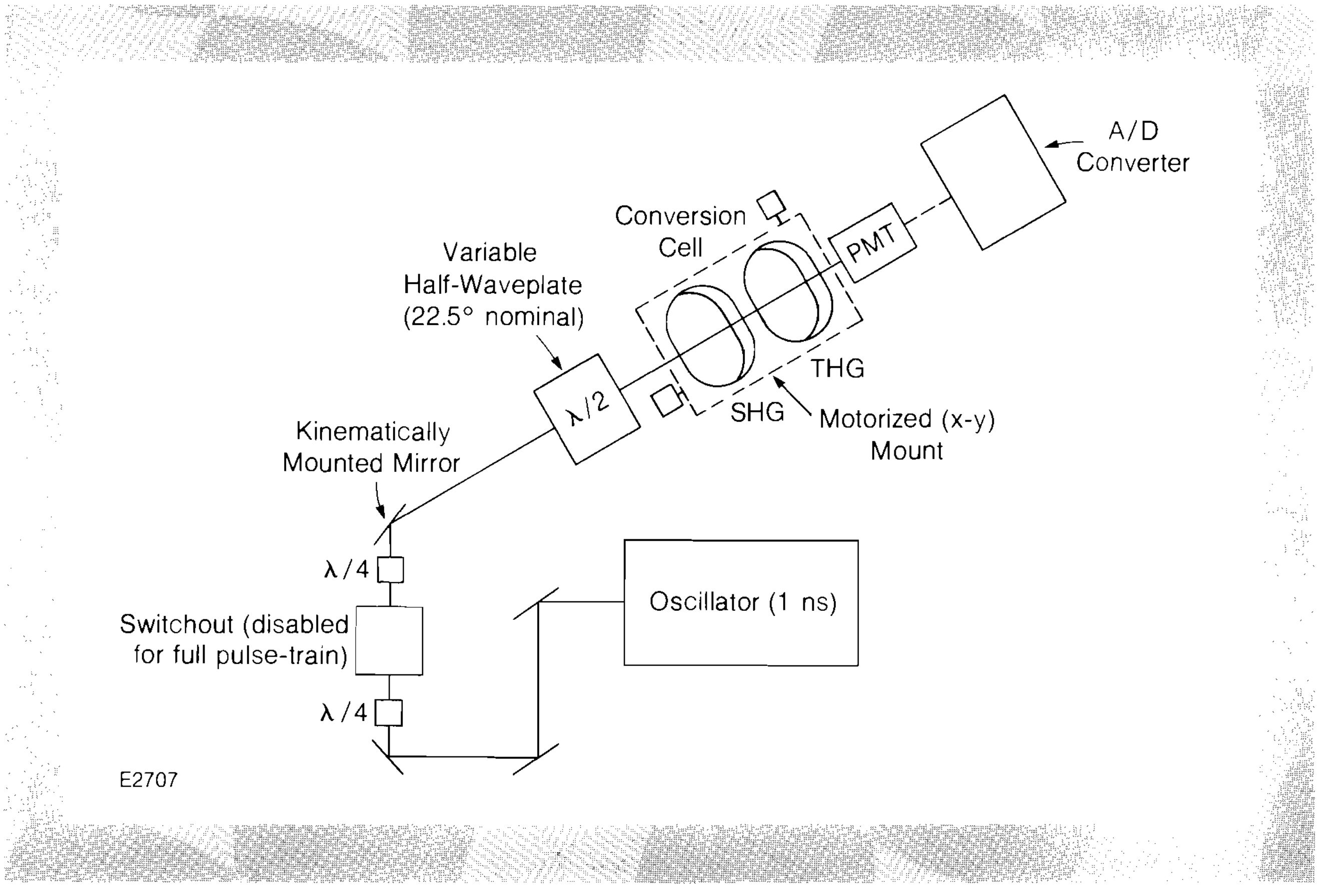

Fig. 2
Driver conversion-cell small-signal tuning setup.

into the small-signal tuning system in the driverline area. Figure 2 shows a schematic of the tuning system. A more complete report describing the automated tuning system is given in the following article. During August, the transport optics were also delivered, and interferometric testing and angular characterization of coatings were performed.

By the end of August, we had completed assembly of the system up to the turning mirrors, and we began activation of the ultraviolet beams. The MESS system was calibrated, using a well-characterized 8-inch Scientech calorimeter, or "moose," as a reference in each beam, and using a subtractive procedure to calibrate the photodiodes. The first ultraviolet energy out of the six beams was measured on 2 September, at a level of approximately 50 J.

During September, we began final preparation for target shots. The first tasks were system maintenance and large-signal tuning of the conversion cells. After the cells were tuned, the energy of the system was increased to measure the maximum energy available in the ultraviolet. Target shots were then taken with the infrared beams, for diagnostic shakedown, and the conversion cells were adjusted for maximum third-harmonic output. By 21 September, the ultraviolet output of OMEGA had been increased to 305 J. Even higher performance is expected as we gain confidence in the performance of the system. Figure 3 shows the performance of the beams, during the activation shots, compared to MIXER[1] code predictions of the conversion.

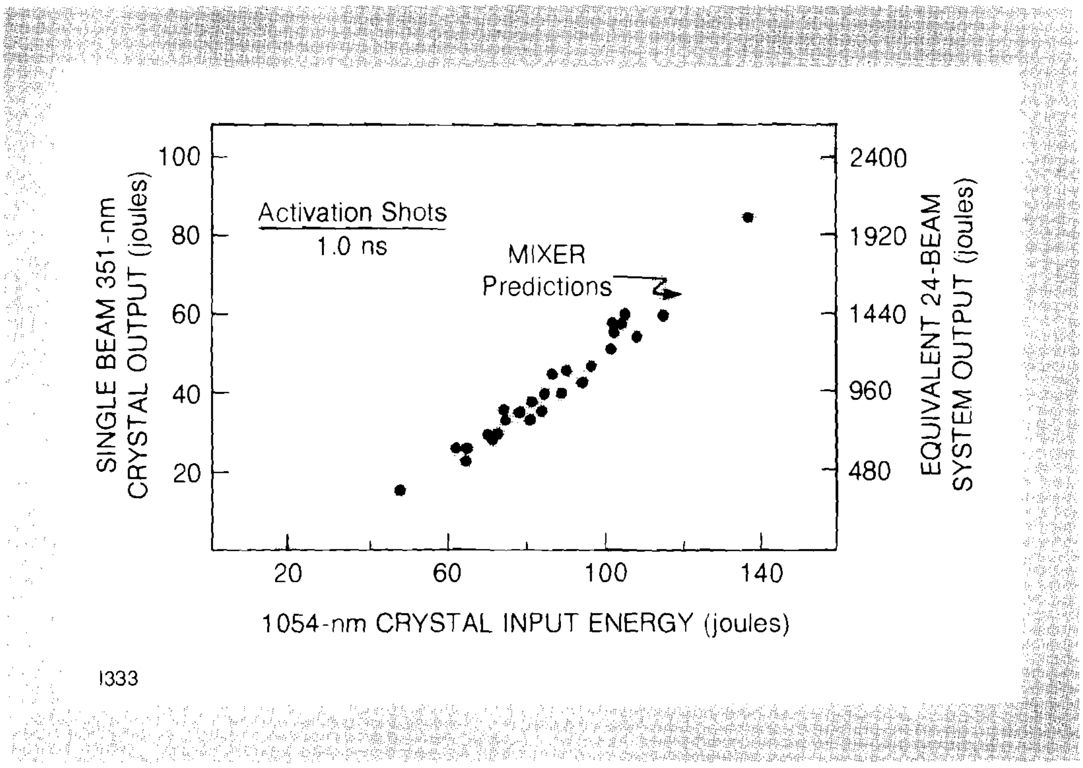

Fig. 3
Ultraviolet conversion efficiency measurements demonstrated close agreement between OMEGA single-beam performance and predictions of calculations using the frequency-conversion code MIXER.[1]

The final weekend of September was spent on (a) installation and alignment of focus lenses, (b) adjustment and check-out of the focus-lens pneumatic-ram system, which rapidly translates the focus lenses from the red focal position along the 33.2-mm distance to the ultraviolet focus position, and (c) realignment of all six beams. Substantial diagnostic activation and checkout work was accomplished during this period, and by the beginning of the final week of this quarter, the first six-beam pointing/focusing target shots on OMEGA had been accomplished. During this final week, one day was devoted to target shots and to the characterization of the transport-optics losses, followed by two days of target shots for absorption, thermal-transport, and fast-electron generation experiments.

A summary of OMEGA operations during this quarter is as follows:

Target Shots	19 @ 3ω
	10 @ 1ω
Ultraviolet Calibration and Tuning Shots	93
Driver Alignment	88
Software Tests, Misfires, Miscellaneous	111
TOTAL	321

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1.C Automated Crystal Tuning for OMEGA Frequency Conversion

The initial phase of the ultraviolet conversion of OMEGA includes adding monolithic frequency-tripling cells[1] to six beams of the laser system. To obtain the maximum ultraviolet conversion efficiency, these cells must be aligned, or "tuned", to within a fraction of a milliradian of their optimum orientation.[2] In previous applications at LLE,[3] this tuning was done manually. We have developed an automated tuning system for the OMEGA system that significantly reduces the time and effort required to perform the initial tuning of the conversion cells. The tripling cells are tuned using pulses from the OMEGA oscillator, which are available at a high repetition rate, before being installed in the OMEGA system.

The Monolithic Frequency-Tripling Cell

The monolithic frequency-tripling cell consists of two type-II-cut KDP crystals mounted within a single fluid-filled cell.[1] The two crystals are oriented with their "ordinary" axes perpendicular to one another, according to the "polarization-mismatch" scheme.[2,4] The first crystal, the "doubler," converts the incident infrared (1054-nm) beam into a beam containing nearly equal photon-number fluxes of infrared and green second-harmonic (527-nm) photons. The second crystal, the "tripler," converts this composite beam into an ultraviolet third-harmonic (351-nm) beam.

Since the indices of refraction of KDP crystals are dependent on propagation direction, the phase-matching or wave-vector conservation condition required for efficient harmonic generation is satisfied only if the input light is incident at a specific phase-matching angle, relative to the optic axis of the crystal. In the weak-signal limit, the conversion efficiency of a crystal falls off with the phase mismatch Ψ as $(\sin\Psi/\Psi)^2$. This phase mismatch is proportional to the angular deviation of the incident beam direction from the phase-matching direction. At the low pulse energies used for tuning, the efficiency of the tripler is halved if this mismatch angle is 0.5 mrad. The doubler is half as sensitive to this separation angle.[5]

The tripling cell is tuned as a unit to its maximum conversion efficiency by rotating the doubler and tripler crystals to their respective phase-matching angles. For a single crystal, this adjustment is made by rotating the crystal about its ordinary axis. Since the two crystals in the tripling cell are mounted with their ordinary axes orthogonal to each other, each crystal in the cell can be tuned independently, without disrupting the tuning of the other crystal.

The Tuning System

In the tuning system, unamplified 1054-nm pulses are fired from the oscillator at a rate of 0.3 Hz through the tripling cell being tested. The second- and third-harmonic outputs from the cell are monitored and recorded through a computer interface. The computer automatically scans the cell alignment angles by driving two stepping motors on the gimbaled mounting of the tripling cell. A schematic diagram of the tuning system is shown in Fig. 4. Plots of the second-and third-harmonic outputs as functions of the alignment angles are displayed on a screen immediately after the outputs are measured. The convenience of this real-time display and the ability of the tuning system to use information from every oscillator pulse allow the operator to optimize the alignment quickly and efficiently. The speed of this operation is limited only by the pulse rate of the oscillator.

The optimum orientation of the tripling cell is specified relative to a "retro" position where a reference surface on the cell is set normal to the oscillator beam axis. This reference orientation can be reproduced in each converted beam in the OMEGA laser. Once the optimum tuning orientation of a tripling cell has been determined using the tuning system, the cell can be placed in the laser system and rotated directly from the retro position to its phase-matched orientation. A final manual adjustment of the installed tripling cells is performed using the OMEGA beam calorimetry and amplified pulses. Once the optimum angles of a given cell are determined, the tuning process need not be repeated, except as a check on the long-term mechanical stability of the cell.

Operation of the Tuning System

The converted green and ultraviolet tripling-cell outputs are monitored by a photomultiplier which is read with a LeCroy 2249 integrating analog-to-digital converter. The stepper motors and photomultipler are interfaced to a DEC LSI 11 computer using the CAMAC[6] instrumentation standard. The computer includes a floppy disk and a color graphics terminal. A stand-alone Forth software[7] system is used to collect, reduce, display, and store the data.

The tripling cell is tuned by first performing a scan about the ordinary axis of the doubler crystal to locate the second-harmonic conversion maximum, and then by scanning the tripling-cell orientation about the ordinary axis of the tripler crystal while monitoring the ultraviolet output. The automated tuning system allows the operator to select the angular step size of the tuning scans and to select the number of pulse readings to be averaged per plotted point. A file system saves the tuning scan results on floppy disk for later

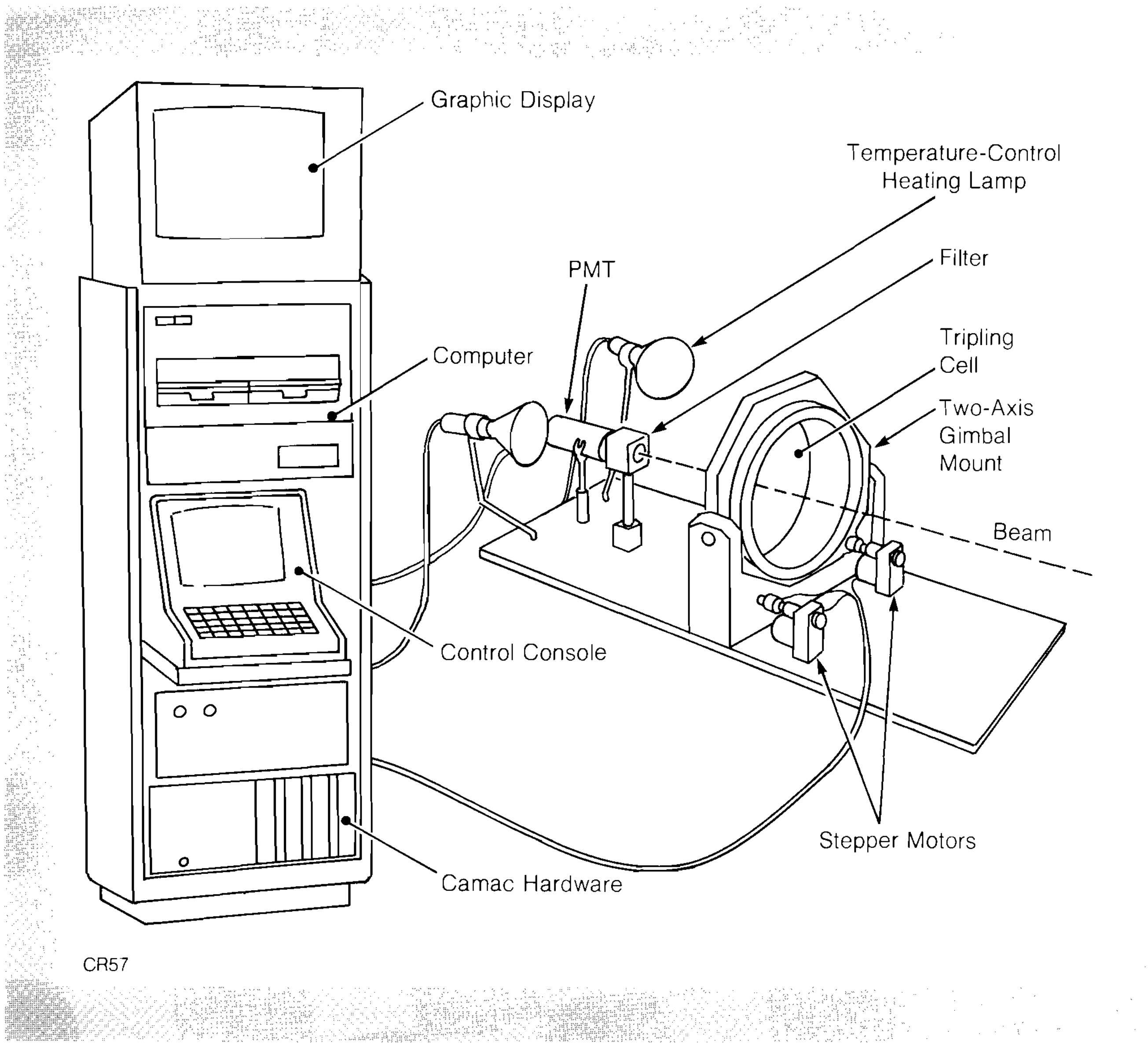

Fig. 4
Diagram of the tuning system showing the basic components.

comparisons or analysis. This allows the triplers to be returned to the testbed to be checked against earlier readings.

Figure 5 shows a typical data display with the color represented as a grey scale. The horizontal graph shows the most recent green scan, and the vertical graph shows the most recent ultraviolet scan. The display includes a color-coded two-dimensional photomultiplier intensity map of the scanning grid, where the two orthogonal rotation axes are represented by a Cartesian grid. This map allows the results of current scans and the stored results of earlier scans to be compared.

For any alignment position, both the green and ultraviolet photomultiplier data can be recorded, but the display shows only the intensities of the harmonic associated with the current scanning angle. Although the computer can be programmed to locate the blue and green maxima, the maxima are currently determined visually by the operator. The tuning scans must be broad enough to distinguish true maxima from the side lobes of the $(\sin\Psi/\Psi)^2$ modulation of the conversion efficiencies (see Fig. 5).

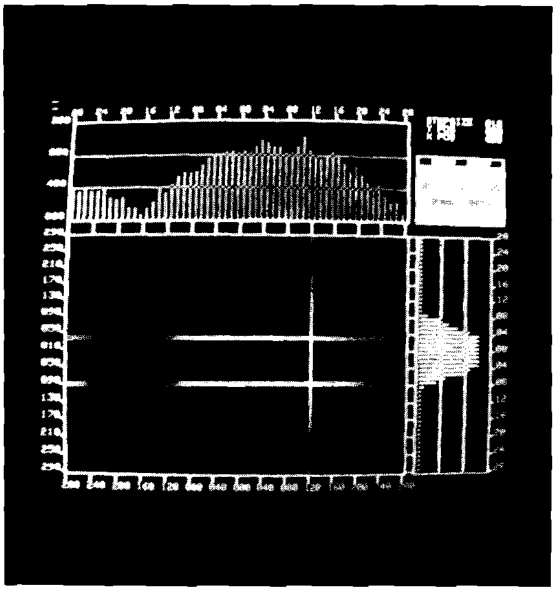

Fig. 5
Typical scanning display produced by the tuning system. The horizontal and vertical graphs show the results of the current green and ultraviolet tuning-angle scans. The two-dimensional grid (color reproduced as a gray scale) provides a convenient display of both current and stored scan data.

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Since the phase-matching angle is strongly wavelength-dependent, one advantage of tuning the tripling cells with the OMEGA oscillator is that both the tuning and operation of the tripling cells are done at the same input wavelength. The phase-matching angle is also strongly temperature-dependent, and, consequently, the temperature of the tripling cells is kept constant to within approximately 0.2°C.

The tuning of all six tripling cells is checked using the OMEGA beam calorimetry after the cells are installed. The conversion efficiencies of the tripling cells are somewhat more sensitive to changes in their tuning angles at the higher powers of the amplified OMEGA pulses than at the lower power used in operating the tuning system. At full power, the peaks can be narrower by nearly a factor of 2.[2] This increased tuning sensitivity, random errors in identifying the initial conversion-efficiency maxima, and errors in reconstructing the tuning-system retro orientation on the OMEGA system are sufficient to require final orientation adjustments of up to a milliradian. The distribution of final angle adjustments shows no evidence of systematic disagreement between the tuning system results and the final tuning angles. The final adjustments of the tripling cells can be expected to require about ten laser shots. In the initial activation of the ultraviolet OMEGA system, the final tuning was completed in the diagnostic-activation shot series.

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