3.D Real-Time Interactive Spectroscopy

In Sections 2.A and 2.B of this issue it is described how the spectroscopic analysis of light originating in the corona of laser-fusion targets provides information about important plasma processes. In particular, the 1/2-, 3/2-, 2-, and 5/2-harmonic multiples of the fundamental laser frequency ω_0 have been spectrally resolved in experiments on OMEGA.

Earlier experimental work at LLE on harmonic emission by Rizzo *et al.*[1] and Tanaka *et al.*[2] involved recording information on film; subsequent film handling, and in the latter case digitizing, took several hours. Here we describe an alternative to film: we use an automated optical multichannel analyzer (OMA), which is capable of yielding quantitative spectroscopic measurements within a few seconds of a laser shot. This OMA-based system was used to obtain some of the data discussed in Section 2.A of this issue.

Early Work with OMA's at LLE

For several years the Laboratory has used OMA's manufactured by Princeton Applied Research (PAR). Our OMA's are silicon vidicons suitable for imaging infrared and visible light. Most recently, we have used a configuration consisting of an OMA, a controller and a computer for 2-D imaging of x-ray diffraction patterns,[3] imaging of streak cameras to temporally resolve laser pulses, and temporally resolving weak-fluorescence measurements.[4]

Two computer configurations have been employed. The first involves interfacing the OMA directly to a DEC LSI-11/23 computer, as used in Ref. 3. The second uses a packaged system from PAR called the OMA II, consisting of a DEC LSI-11 computer, memory-mapped graphics, and a direct-memory controller for up to four OMA's. As with many of our real-time automated diagnostics, this system was written in the Forth programming language.[5-7]

A recent application involved monitoring the lasing wavelength of the phosphate-glass oscillator on GDL. It was found that this wavelength could change under certain conditions when the oscillator was being serviced, thus significantly affecting the third-harmonic conversion efficiency of the GDL system. For this purpose the streak-camera acquisition and reduction system was modified to monitor instead a one-meter spectrometer with an overall spectral resolution of 1 Å. Although the dynamic range of the OMA was less than that of film, it was sufficient for this application. Using additionally an OMA-equipped streak camera, we are thus able to measure simultaneously the spectral and temporal shape of each oscillator pulse.

Harmonic-Emission Spectroscopy on OMEGA

This rapid turnaround of quantitative spectral information was seen as an advantage for the OMEGA coronal-physics experiments which began in early 1983. An OMA was therefore installed

on OMEGA, with the OMA head positioned at the output plane of a spectrometer as shown in Fig. 32. The OMA-head controller was connected by cable to a computer located in the control room. Noise arising from the electromagnetic pulse generated by target disassembly contributed fewer than 40 OMA counts to a background of about 2,000 counts; for comparison, typical data had up to 10,000 counts. The OMA was spectrally calibrated using a Cd lamp for $3\omega_0/2$ and a Th lamp for $5\omega_0/2$. Changes in spectrometer alignment were corrected using stored reference spectra.

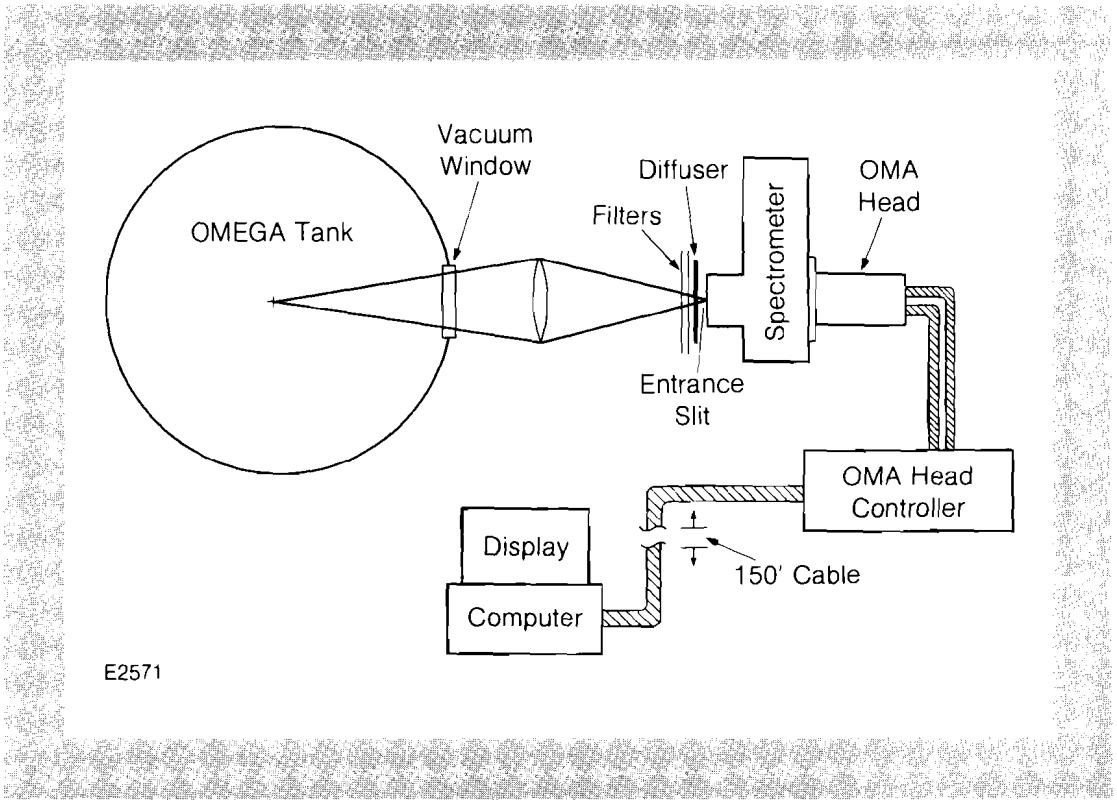

Fig. 32
Typical instrumentation configuration including the target chamber, spectrometer, OMA head and controller, computer and console.

Raw data was displayed on the OMA graphics screen immediately after each shot. A $3\omega_0/2$ spectrum taken at low intensity is shown in Fig. 33a, after background subtraction. The spectrum was then fitted using a third-order polynomial routine to yield the smooth curve of Fig. 33b. Even though the spectrum after background subtraction is dominated by noise, the resulting spectrum (Fig. 33b) clearly reveals the double-peaked structure characteristic of $3\omega_0/2$ spectra; for comparison, a more typical $3\omega_0/2$ spectrum is shown in Fig. 34. The computer system identified the various peaks by wavelength (see Fig. 34), and the scaled and labeled spectrum was plotted on an analog plotter. The system contained several interactive features; for example, data from two different shots could be superimposed and shifted with respect to wavelength; this was useful for identifying structural changes such as frequency shifting, broadening, and line splitting. A total of 120 spectra were recorded using the OMA in the course of the OMEGA coronal experiments, along with reference and background spectra.

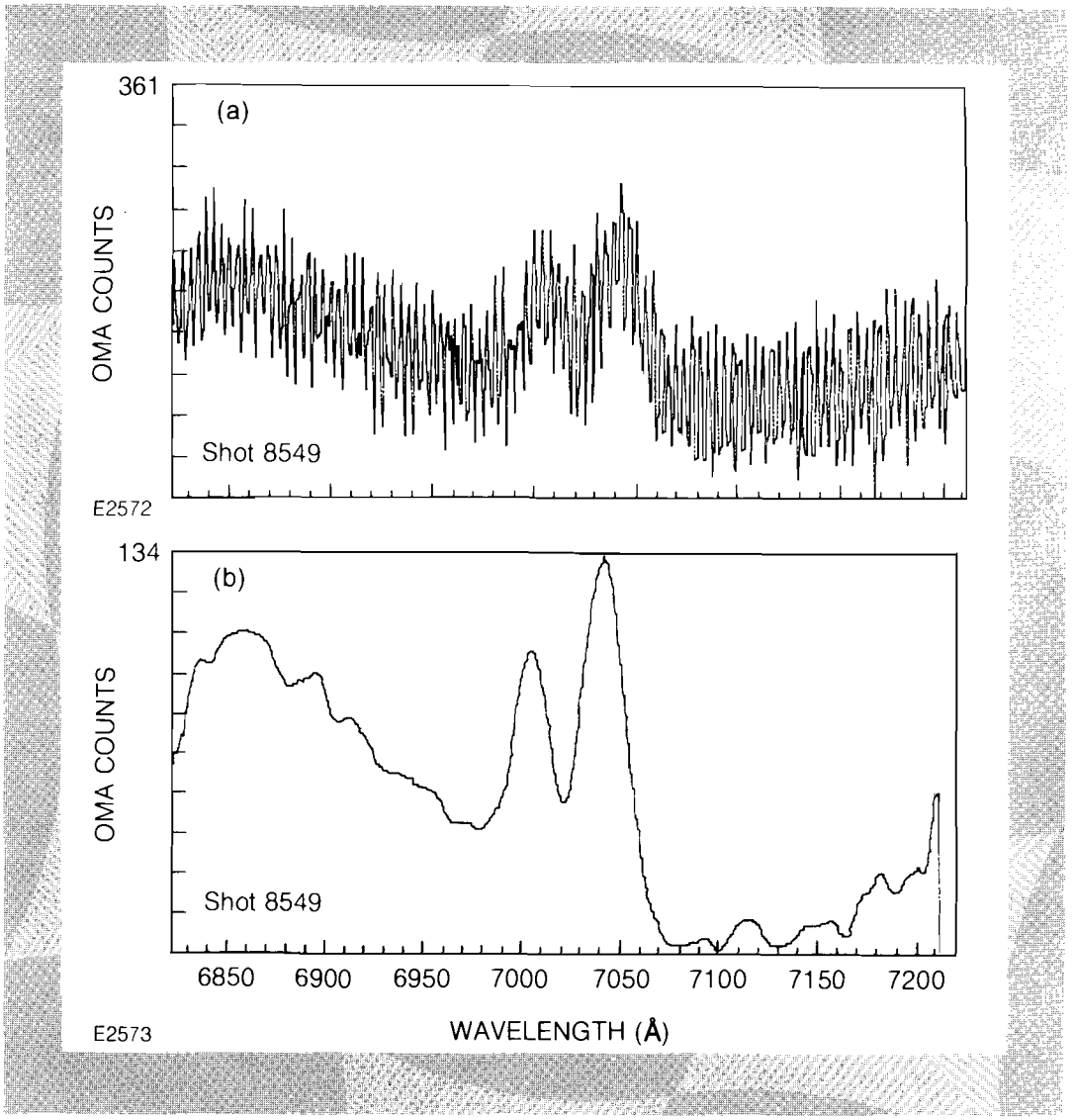

Fig. 33
Removal of noise from data. In this shot the signal on the spectrometer was attenuated to about 1% of normal, but the distinctive double-peaked $3\omega_o/2$ spectrum was extracted.
a) raw data after background subtraction.
b) after smoothing with a third-order-polynomial routine.

The flexibility and tradeoffs with regard to film become most apparent in Fig. 35, where $2\omega_o$ spectra taken on similar shots with the OMA and with film are compared. In comparison with film data, the OMA is seen to have a dynamic range of more than 100 (for these light pulses of nanosecond duration). Although many of the smaller peaks on these shots were lost with the OMA, the data were available less than 30 seconds after the shot, whereas data from film were not normally available until the following day. Clearly, the two approaches can complement one another.

Summary

Real-time interactive spectroscopy has evolved from automated systems developed to acquire and reduce streak-camera data. The flexibility of the silicon vidicon, the controllers, and the Forth-based software have allowed successive adaptations to very different experiments. Thus, we now have a system which complements the use of film in spectroscopy, allowing us to

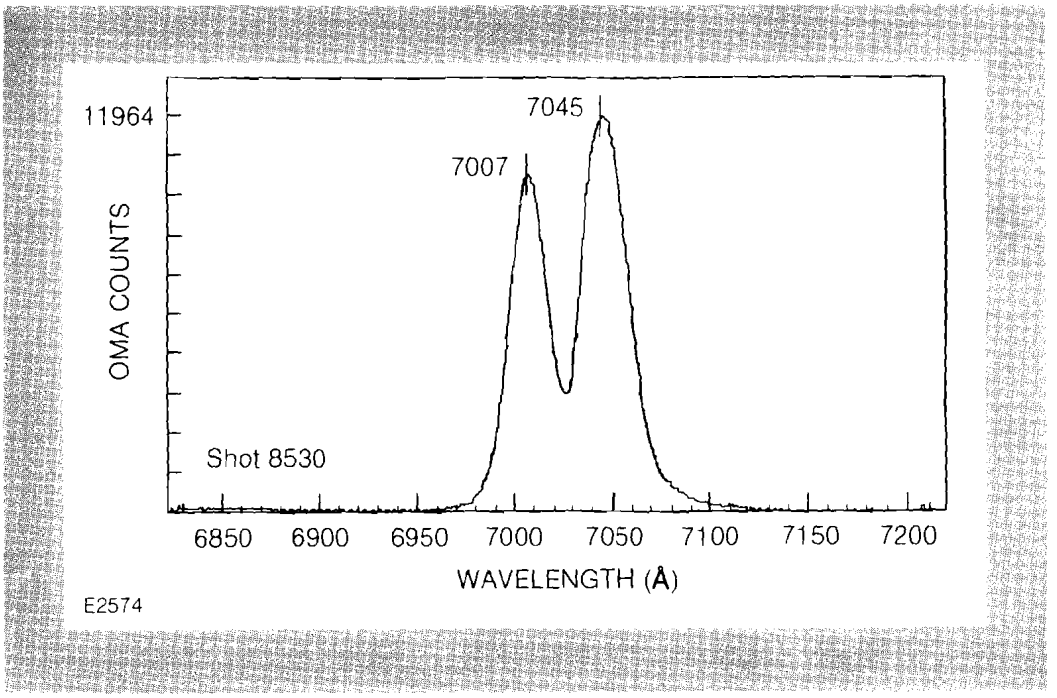

Fig. 34
Typical $3\omega_o/2$ spectrum from an OMEGA coronal-physics experiment, as obtained within a few seconds of the shot.

collect, reduce, and present data in a few seconds rather than after several hours. Although the reduced dynamic range and spatial resolution of our detector could in some circumstances be a disadvantage as compared with film, the rapid turnaround of data allows a tuning of experiments from shot to shot not otherwise possible.

REFERENCES

1. J. Rizzo, S. Letzring, D. Villeneuve, M. C. Richardson, G. Gregory, R. S. Craxton, J. Delettrez, K. Lee, and R. Hutchison, *Proceedings of the Second Conference on Lasers and Electro-Optics (CLEO)*, Phoenix, AZ (1982).
2. K. Tanaka, L. M. Goldman, W. Seka, M. C. Richardson, J. M. Soures, and E. A. Williams, *Phys. Rev. Lett.* **48,** 1179 (1982). See also Section 2.A of this issue.
3. LLE Review **8,** 17 (1981).
4. W. Knox and L. Forsley, "Data Acquisition for a Jitter-Free Streak Camera," submitted to the American Chemical Society, Symposium on Multichannel Detectors.
5. J. Boles, D. Pessel, and L. Forsley, *IEEE J. Quantum. Electron.* **QE-17,** 1903 (1981).
6. Princeton Applied Research, Inc., Princeton, NJ, OMA II Open System Programming Manual.
7. C. Moore and E. Rather, *Proc. IEEE* **61** (9), 1346 (1975).

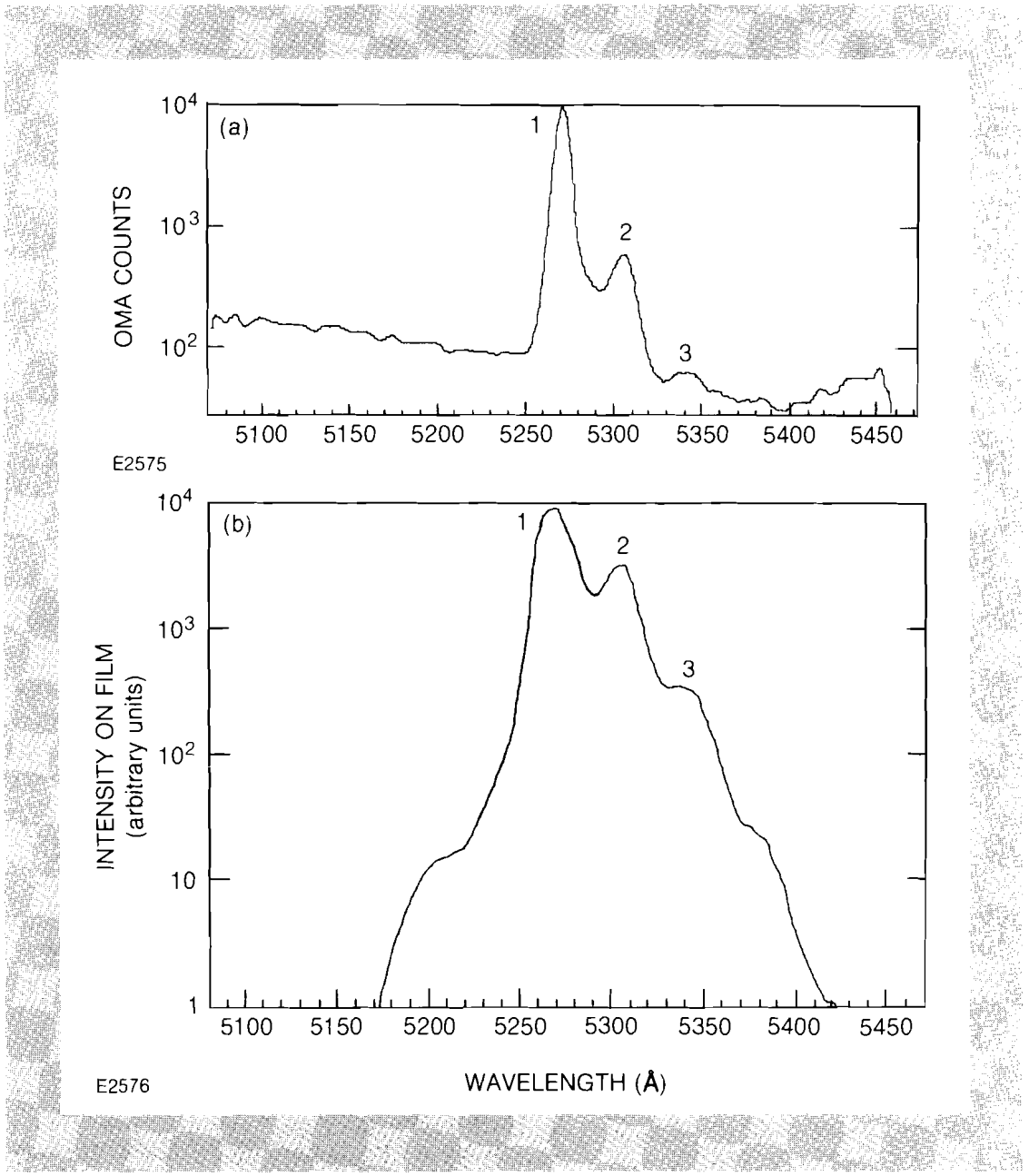

Fig. 35
Comparison of the OMA- and film-collected $2\omega_0$ spectra:

a) Data taken with the OMA, using a logarithmic scale. Note peaks 1, 2, and 3.

b) Film-digitized spectrum from a similar shot with a logarithmic intensity scale. Note that there are resolvable peaks in addition to the three peaks found with the OMA, illustrating the higher dynamic range of film.