Shigemori *et al*. Reply: Lehmberg *et al.* [1] comment that our previous experiment [2] on the Rayleigh-Taylor (RT) instability should not be defined as an "imprint-free" experiment because of the insufficient spatial resolution. They also comment that the experimental results may not be vital data for the direct-drive laser fusion, because the strong and long foot pulse increases the target adiabat, resulting in decompression of the target.

To examine the validity of the imprint-free condition, we have continued experimental investigation on the laser-imprint problem, using significantly improved diagnostic resolution. In this experiment, a 16-μm thickness polystyrene target with no perturbation was irradiated by partially coherent light. The irradiation condition was the same as that of our previous experiment [2]. We used a face-on x-ray backlighting technique to measure the areal-density perturbation grown from the imprinted perturbations. The modulation transfer function (MTF) of the whole diagnostic system is 0.71 for the perturbation amplitude $\lambda = 60\ \mu$m, 0.45 for $\lambda = 30\ \mu$m, and 0.34 for $\lambda = 20\ \mu$m. (The fitting parameters [1] of the measured MTF are $\sigma_1 = 3.08\ \mu$m, $\sigma_2 = 12.63\ \mu$m, and $\alpha = 0.21$.) The backlit image data were converted to the areal-density perturbation by taking account of the MTF and the measured mass absorption coefficient. The perturbation amplitude at the end of the drive pulse (≈ 2 ns) was approximately $1.0-1.5\ \mu\mathrm{m\,g/cm^3}$ in root mean square (rms) for the perturbation wavelengths of $10-50\ \mu$m. The detection threshold for these wavelengths was evaluated to be $\approx 0.5-0.7\ \mu\mathrm{m\,g/cm^3}$ in rms. Perturbations with wavelength above 50 μm were under the noise level. Since the RT growth factor for these wavelengths (i.e., 10–50 μm) is nearly the same as or slightly larger than that for a 60-μm perturbation wavelength [3], the imprint amplitude can be estimated to be less than $(1.0-1.5)/50 \approx 0.02-0.03\ \mu\mathrm{m\,g/cm^3}$. This value is much smaller than the initial perturbation amplitude of $0.1-0.3\ \mu\mathrm{m\,g/cm^3}$ on the target surface in our previous experiment.

Imprint amplitude of shorter wavelength perturbation is expected to be smaller than this value, because the thermal smoothing is more effective for shorter wavelength perturbations and is calculated from the tested imprint model [3]. The imprint model is based on the equation-of-motion in which the pressure perturbation smoothed by the cloudy day effect causes time derivative of the momentum perturbation of the target per unit surface. This model is coupled with the ILESTA-1D [4] code to predict the imprint amplitude for individual experiments. The model has been tested in two different experiments [3]: a single-mode imprinting experiment, and a dynamic imprinting experiment, where the single-mode nonuniformity moves at a constant velocity. The calculated amplitude of shorter wavelength perturbation ($<10\ \mu$m) is $0.015 \pm 0.008\ \mu$m. This is also much smaller than the initial perturbation amplitude.

Second, they doubt that the experimental data are relevant to direct-drive laser fusion, because the relatively high adiabat in the present experiment decreases the target density which then turns to decrease the RT growth rate. Indeed, our 1D simulation ILESTA-1D predicts that the first shock wave breaks before the onset of the main laser pulse, resulting in moderate decompression of the target. However, calculated growth rate using the reduced density is still larger than the experiments. The decompression by the early shock transit alone is, therefore, insufficient to explain the reduced growth rate. This requires other interpretations, such as, decompression by nonlocal heat transport that may be common physics in future experiments. Furthermore, currently designed ignition targets [5,6] have an adiabat of about three. This is not very far from our parameter.

They also comment that the strong recompression by the main drive would transfer the surface perturbation into the main body of the target in a way that does not realistically simulate a fusion implosion. The surface perturbations are transferred into the target via rippled shock propagation [7] that is expected to occur in most laser-fusion targets.

We have conducted an experiment to test the effect of the shock timing. The foot pulse length was adjusted so that the shock waves each driven by the foot and the main pulse break at nearly the same time, minimizing the increase of isentrope. We have found that the RT growth rate measured in this experiment is almost the same as that in the previous experiment. It appears, therefore, that the early breakout of the first shock is not the dominant factor of reducing the RT growth rate.

In summary, we have evaluated the imprint amplitude for our previous experiment using the improved diagnostic resolution. The measured and calculated imprint amplitude is much smaller than the imposed perturbation on the target. Their doubt about the applicability of our results to direct-drive laser fusion is inappropriate, because the increase of the adiabat is moderate, and the perturbation transfer from the target surface into the target body is common phenomena is most laser-fusion targets.

K. Shigemori, H. Azechi, M. Nakai, H. Takabe, and K. Mima
Institute of Laser Engineering
Osaka University
2-6 Yamada-oka, Suita
Osaka, 565 Japan

Received 12 May 1997 [S0031-9007(98)05760-3]
PACS numbers: 52.35.Py, 52.50.Jm, 52.70.La

[1] R. H. Lehmberg *et al.,* preceding Comment, Phys. Rev. Lett. **80**, 3414 (1998).
[2] K. Shigemori *et al.,* Phys. Rev. Lett. **78**, 250 (1997).
[3] H. Azechi *et al.,* Phys. Plasmas **5**, 4079 (1997).
[4] H. Takabe *et al.,* Jpn. J. Appl. Phys. **32**, 5675 (1993).
[5] C. P. Verdon, Bull. Am. Phys. Soc. **38**, 2010 (1993).
[6] S. V. Weber *et al.,* Phys. Plasmas **4**, 1978 (1997).
[7] T. Endo *et al.,* Phys. Rev. Lett. **74**, 3608 (1995); **75**, 2908(E) (1995).