Backlit pinhole radiography used with ungated film as a detector creates x-ray radiographs with increased resolution and contrast. Current hydrodynamics experiments on the OMEGA Laser use a three-dimensional sinusoidal pattern as a seed perturbation for the study of instabilities. The structure of this perturbation makes it highly desirable to obtain two simultaneous orthogonal backlighting views. We accomplished this using two backlit pinholes each mounted 12 mm from the target. The pinholes, of varying size and shape, were centered on 5 mm square foils of 50 μm thick Ta. The backlighting is by K-alpha emission from a 500 μm square Ti or Sc foil mounted 500 μm from the Ta on a plastic substrate. Four laser beams overfill the metal foil, so that the expanding plastic provides radial tamping of the expanding metal plasma. The resulting x-rays pass through the target onto ungated direct exposure film DEF. Interference between the two views is reduced by using a nose cone in front of the DEF, typically with a 9 mm Ta aperture and with magnets to deflect electrons. Comparison of varying types of pinholes and film exposures will be presented from recent experiments as well as an analysis of the background noise created using this experimental technique. © 2006 American Institute of Physics. [DOI: 10.1063/1.2351870]
square metal foil. Laser beams irradiate the foil and the surrounding plastic, creating metal plasma, plastic plasma, and the desired Ti or Sc K-alpha x rays of energy 4.51 or 4.09 keV, respectively.

The plastic foil serves three purposes. First, it provides plastic plasma that flows outward with the metal plasma and tamps the radial motion of this plasma. This has proven essential to avoid the exposure of the film by x rays from the metal plasma, seen around the edges of the Ta shield. Second, as the pressure from the laser-irradiated foil drives a shock through the plastic, this distributes the momentum and energy delivered to the metal foil over a larger mass of material, reducing the tendency to create shrapnel when this material strikes the Ta. Third, the plastic can be expected to absorb most of the energetic electrons produced by laser-plasma interactions in the metal plasma. Even so, experience has shown that the irradiance of the metal foil cannot exceed a few times $10^{14}$ W/cm$^2$ without creating greatly increased noise. This particular experiment uses both Ti and Sc foils.

The pinhole in the Ta serves as a filter, only allowing x-rays pointing directly at the target to pass through. These specific experiments used a pinhole aperture of 10 μm or a stepped pinhole with the large side being 50 μm and the smaller opening being 20 μm. The step refers to a large hole on one side of the Ta and a smaller hole on the other. Using a stepped structure (or a tapered pinhole), as opposed to a straight pinhole, produces x rays having a larger cone angle and a more uniform intensity. This reduces the sensitivity of the pinhole backlighters to rotational alignment (though their alignment remains quite demanding). By comparison, the 10 μm straight pinhole allows for better resolution than the 20 μm stepped pinhole achieves, but any tilt in the foil will quickly decrease the source size, limiting the number of photons on the detector. A comparison of intensities from these two pinhole types is shown later in this article.

Accomplishing backlight radiography along two orthogonal lines of sight proved significantly more demanding than using only one line of sight. Using two backlighters is very difficult because any illumination from one will interfere with the other. This cross-talk effect is further complicated when using ungated film. In previous attempts, gated diagnostics were used and fired at different times during the experiment in an effort to prevent interference. However, in some cases, it has been noted that standard microchannel-plate framing cameras provided insufficient extinction of the ungated signals and so this approach generally failed. In order to reduce the cross-talk, the present experiments protected each film holder with a nose cone. The narrow front end of the nose cone was located 1/3 of the (228 mm) distance from the target to the film. At this front end a Ta shield having a 9 mm circular aperture was mounted, and magnetic material was included to deflect any electrons away from the film. With the two pinholes each displaced 12 mm from the target axis along orthogonal lines of sight, the 9 mm aperture was just sufficient to prevent the exposure of a portion of a given film pack by emission from the orthogonal backlighter. There was apparently some remaining exposure, presumably due to scattering of the x rays, but this was small. With these techniques, it is possible to obtain data simultaneously along both lines of sight.

Figure 2 shows the configuration of the experiment using this technique. The hydrodynamics target is placed so that the laser beams that deliver energy to it are focused at the center of the OMEGA chamber. The two backlight pinhole structures are placed 12 mm from the target and 90° from each other. The placement of the film allows for a magnification of about 20 on the radiograph. During the experiment, ten OMEGA laser beams irradiate the target, and the backlighters are irradiated after a delay of 7–40 ns. The group of beams irradiating the rear side of each pinhole structure consists of two to four OMEGA laser beams with a 1 ns pulse, 200–400 J/beam, and 1000–1200 μm spot size. The diagnostic x rays pass through the target and onto direct exposure film (DEF). DEF is well characterized; by using the model of Henke et al. the optical density of the film can be converted to intensity in photons/μm$^2$. The film holder up to three pieces of film are layered on top of one another and behind Be, plastic, and Ti or Sc light shields. The film is ~50 mm in diameter and allows a field of view of about 1500 μm of the target.

RESULTS AND DISCUSSION

Figure 3 shows radiographs from the experiment. These images, taken at 17 ns after the drive beams fired, are from
other experiments, including a comparison between a pinhole with an aperture of 50 μm stepped to 20 μm and a 10 μm straight pinhole.

It is also of interest to estimate the expected number of photons/pixel. Using conclusions made by Kyrkja et al. the conversion efficiency of Ti is $5.66 \times 10^{11}$ photons/J sphere. The laser beams striking the Ti foil have a total energy of 800 J and the area of the foil is $2.5 \times 10^5 \, \mu m^2$. If we estimate that only ~50% of these photons get transmitted through the foil and then pass through the pinhole with an area of $100\pi \, \mu m^2$, the distance to the film is ~230 mm and 1 pixel is equal to 484 μm² on the film, so there are $9.15 \times 10^{15}$ srs/pixel. This gives about 200 photons/pixel or about 0.5 photons/μm², which does not take into account the plastic, Be, or Ti light filters. This is in good agreement with the values of Table I.

To calculate the values in Table I let $N$ be the number of photons/pixel. We find $N$ by multiplying the average number of photons/μm² by the area in 1 pixel, 484 μm². If Poisson noise were the only type of noise in this radiograph then the standard deviation divided by the signal would be $1/\sqrt{N}$. Table I shows this value, and shows for comparison the observed noise obtained by dividing the standard deviation of the values obtained in the line out described above by the mean, background-subtracted signal. The comparison of the expected and observed values is important because it determines whether the majority of noise on the radiograph is from Poisson noise or if there is a larger noise source in the experiment.

The anticipated and observed values agree within a factor of 2 and very closely agree in some cases. It should be noted that the film used in these experiments had been stored over a long period and this increases the fog level of the film. As the fog level increases the film has a lower dynamic range. There is also an area of uncertainty in the difference among the film processing techniques used by Henke et al. and the Laboratory for Laser Energetics. Other possibilities as to the difference between the theoretical and observed Poisson noise include saturation of the film if the actual Poisson noise is lower than the theoretical value. The first layer of film in Fig. 3(a) is presumably close to this point, although the observed noise is reasonably consistent with the expected Poisson noise. In this image, a line out of an area outside the target is flat meaning the film is fully exposed. In this experiment the lasers striking the metal foil had an intensity of $6.4 \times 10^{14}$ W/cm². Compare this to the last line in the table, which is the case of the 20 μm stepped pinhole that had a lower energy/beam as well as a larger spot size to decrease the intensity to $2.2 \times 10^{14}$ W/cm². The experiment using a 10 μm straight pinhole also had an intensity of $2.2 \times 10^{14}$ W/cm²; however, the area of the pinhole was decreased by a factor of 4 making the radiograph dim. In all cases in Table I the observed noise is within a factor of 2 of the Poisson noise, meaning that other sources of noise in the experiment, if present, are not dominant.

**SUMMARY**

This article has discussed the design and geometry needed for dual, orthogonal backlight radiography. Results
from these experiments show that only <1% of the backlighter beam energy exposes the film and the Poisson noise is the dominant source of noise. In future experiments, the backlighter structure will have a Ta foil with 10 μm tapered pinholes. The taper is similar to the step, but has a smoother transition. These pinholes will have a large opening of ~20 μm tapered to 10 μm.

ACKNOWLEDGMENTS

The authors acknowledge useful interactions with and the significant technical contributions to backlit pinhole radiography of J. M. Foster, T. S. Perry, C. Sorce, and S. Sublett. The authors would also like to thank the technical staff at the OMEGA Laser Facility. This work is supported by the National Nuclear Security Agency under DOE Grant No. DE-FG03-99DP00284 and DE-FG03-00SF22021, and by other grants and contracts.