§42. X-ray Penumbral Imaging for Laser-Produced Plasma — Heuristic Blind Reconstruction —

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Penumbral imaging is a technique which uses the fact that spatial information can be recovered from the shadow or penumbra that an unknown source casts through a simple large circular aperture. Since such an aperture can be ''drilled'' through a substrate of almost any thickness, the technique can be easily applied to highly penetrating radiation such as neutrons and γ rays.

The penumbral image **P** can be expressed as a convolution of source image **O** and aperture function or point spread function **A**. If the exact point spread function (PSF) **A** is *a priori* known, the source image **O** may be deconvolved. Usually a Wiener filter is used for deconvolution. But in many experiments, the PSF is unknown or known with some error, yielding erroneous results. In this paper, we propose a heuristic method to deconvolve **O** from **P** alone, which is known as a blind deconvolution problem.

Since the penumbral aperture is a circular one, the PSF of the aperture can be approximated by a cylinder as

$$\hat{A}(r)=\begin{cases}0 & |r|>\hat{R}\\ \frac{1}{2}(2\hat{R}) & |r|\le \hat{R}\end{cases} \qquad (1)$$

where $\hat{R}$ is the radius of cylinder, which is determined by the aperture radius r and magnification of the camera. Estimation of PSF (**A**) can be simplified to that of $\hat{R}$.

The reconstruction of penumbral images can be viewed as an optimization problem. We estimate the optimal reconstructed image by minimizing the distance between the obtained penumbral image P and the estimated penumbral image $\hat{P}$. In this research, we use simulated annealing (SA), which is one of heuristic methods, as an optimization tool. The details about SA for blind reconstruction of penumbral images have been presented in the last annual report.

The proposed method has been applied to the experiments of real laser plasma. The experiments were carried out with GEKKO XII at ILE, Osaka University and the experimental setup is shown in Fig.1. The penumbral aperture used a hole drilled in a 25μm thick tantalum substrate. The radius of the hole was measured as 125μm. A x-ray CCD camera is used as a detector and it has 1242x1152 pixels with a pixel size of 22.5μm x 22.5μm. The pixel resolution is 2.6μm on target. The penumbral image recorded by X-ray CCD camera is shown in Fig.2. As a demonstration experiment, we use a Ti target with a cross shape, which is shown in Fig.3(a). The pinhole image taken in the same direction is also shown in Fig.3(b). The reconstructed image by the proposed blind method (without any information about aperture size) is shown in Fig.3(c) and the reconstruction by the conventional Wiener filter with an exactly known PSF (not blind reconstruction) is shown in Fig.3(d). It is evident that the reconstructed image by the proposed method without PSF is much superior to that of the conventional Wiener filter with exact PSF.

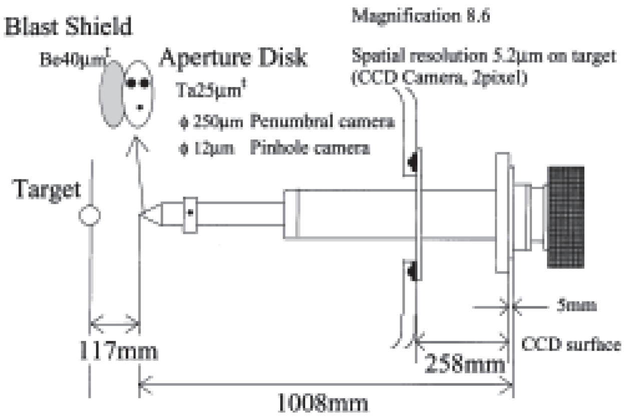

Fig.1 Experimental setup for laser plasma experiments

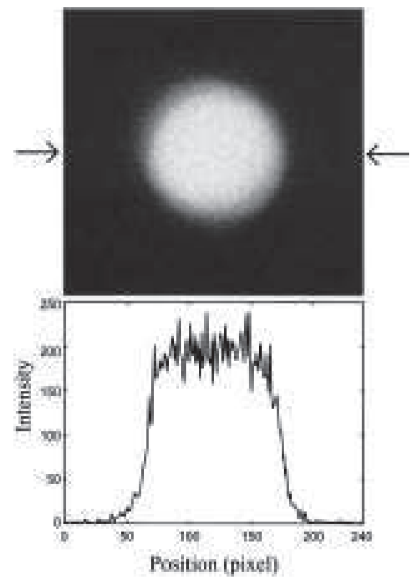

Fig.2 Penumbral image obtained from the experiment

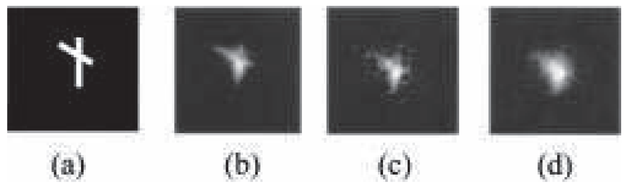

Fig.3 (a) desired image; (b) pinhole image; (c) the reconstructed image by the proposed blind method; (d) the reconstruction by the conventional Wiener filter with an exactly known PSF.