§39. X-ray Penumbral Imaging for Laser-Produced Plasma —Blind Reconstruction Based on a Heuristic Method—

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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

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

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 flowchart of SA for reconstruction of penumbral images is shown in Fig.1.

The simulation results are shown in Fig.2. Both radius of PSF and source image are reconstructed well. The proposed heuristic based reconstruction method has also been applied to real laser-produced plasma experiments.

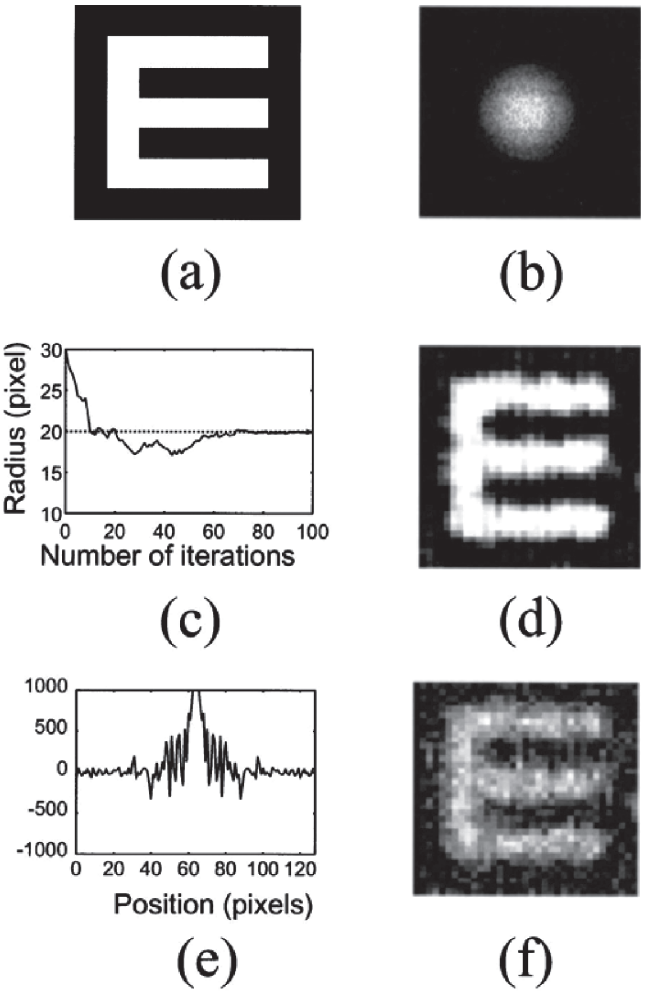

Fig.2 (a) a phantom "E" image; (b) its penumbral image (we only know the penumbral image); (c) estimated radius of PSF; (d) estimated source image; (e) estimated cepstrum of the penumbral image; (f) reconstructed image by capstrum based method.

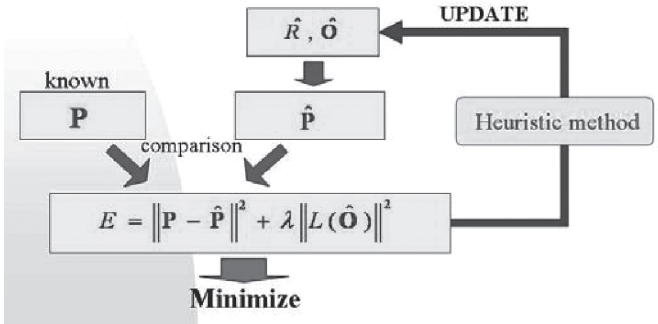

Fig.1 Blind reconstruction based on SA