§ 13. Image Reconstruction of LHD Plasma in Bolometer Tomography

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The 2-D distribution measurement of radiation by means of AXUV silicon photodiode arrays [1,2] was developed in adopting a numerical tool of image reconstruction of computed tomography. With respect to the camera system amounted in a semi-tangential cross section of LHD (Fig. 1), the Tikhonov-Phillips regularization method for inversion [3] was applied to detector signals. A square region which covers the triangular plasma region presumed from the magnetic surface configuration was devided to 32x32 pixels, and the projection matrix that was geometrically calculated by taking into account the sight volumes of detectors [1] was used.

Given the projection matrix L and the M-dimensional data vector S (M=40), the image vector estimate E with the Laplacian smoothing operator C is written in a form of series expansion; that is, we have

$$E(\gamma) = \sum_{i=1}^{N} w_i(\gamma)(\sigma_i^{-1} u_i^T S) C^{-1} v_i \ .$$

Here u_i, v_i and σ_i are the singular vectors and the singular values of LC^{-1}, and $w_i(\gamma) = (1 + M\gamma\sigma_i^{-2})^{-1}$ is a lowpass filter function with the regularization parameter γ; we have N=min(M,K) for the pixel number K. In order to neglect the pixels on the outside of the plasma region in numerical processing, the vector E was reduced in dimension, and the corresponding columns of L and the related columns and rows of C were omitted.

A result of analyzing the camera signals is shown in Figs. 2 and 3. The obtained contour map in Fig. 2 exhibits the radiation intensity distribution in an asymmetric radiative collapse of NBI heated plasma [2]. This map was obtained for the γ value that minimized the generalized cross validation (GCV), which is written as

$$GCV(\gamma) = \frac{\varepsilon^2(\gamma)}{\left[1 - \frac{1}{M}\sum_{i=1}^{N} w_i(\gamma)\right]^2}, \quad \varepsilon^2(\gamma) = \frac{1}{M}\| LE(\gamma) - S \|^2 .$$

As a function of γ, the GCV behaved as plotted in Fig. 3 in this example, while the mean square error $\varepsilon^2(\gamma)$ of the chord-integrated value $LE(\gamma)$ in fitting to the detector outputs S was monotonically decreased with γ. This behavior of $\varepsilon^2(\gamma)$ was favorable, endorsed by the good fittings of all the chord-integrated values without large errors.

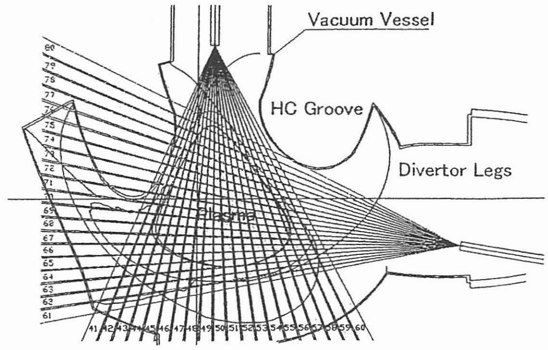

Fig. 1. Layout of two 20-channel fan-beam cameras in the semi-tangential cross section with 3.5U and 4-O ports.

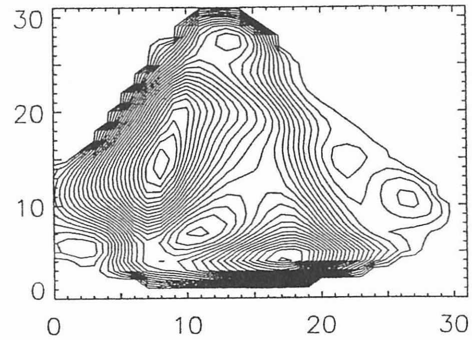

Fig. 2. Reconstructed profile during radiative collapse in the triangular region; Shot 28961, 2.162 sec.

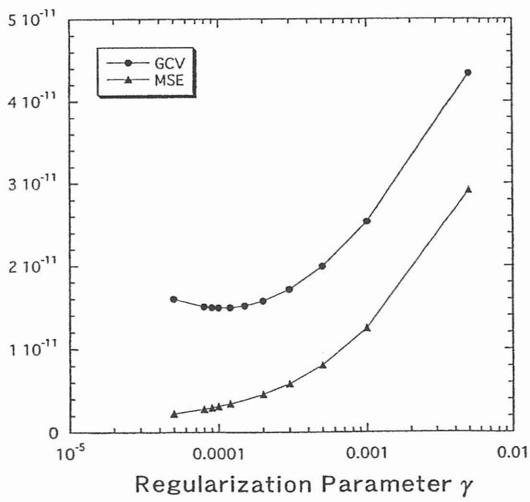

Fig. 3. Changes of $GCV(\gamma)$ and $\varepsilon^2(\gamma)$ (MSE) with γ. $GCV(\gamma)$ was minimized for γ=1.0x10^{-4}.

References
1) Kostriukov, A.Yu., Liu, Y. et al., Ann. Rep. NIFS (2 001-2002) 157.
2) Peterson, B.J. et al., Ann. Rep. NIFS (2001-2002) 55.
3) Terasaki, N., Iwama, N. and Hosoda, Y., Trans. IEICE **J81-D-II**, (1998) 93.