§18. Image Processing Study for Bolometer Tomography of LHD Plasma

Iwama, N. (School of Informatics, Daido Institute of Technology)
Hosoda, Y. (Dept. of Information Science, Fukui Univ.)
Peterson, B.J.

For the purpose of tomographic imaging of LHD plasmas, a system of two 20-channel fan-beam cameras with AXUVD silicon photodiodes has been arranged in a semi-tangential cross section by using 3.5-U and 4-O ports [1,2]. This imaging system is examined by applying numerical methods of image reconstruction to the camera signals. One method is the linear regularization method of Tikhonov-Phillips [3], which synthesizes a plasma image with an orthogonal basis function system that is numerically generated by the singular value decomposition of the projection matrix in an imaging system layout. Another method is the nonlinear regularization method of maximum entropy which gives a plasma image as the result of minimizing an entropy-involved Lagrangian function with a new fast algorithm.

The two algorithms worked well. Plasma image reconstruction from typical data of LHD experiment was investigated. One of the results is shown in Figs. 1 (a) and (b) and Fig. 2. The analyzed signal data was acquired during an asymmetric radiative collapse of NBI heated plasma. In the numerical processing, a square region of image reconstruction was set so as to cover the triangular region of the magnetic surface configuration and divided into 32x32 pixels. In the Tikhonov-Phillips analysis, the pixels outside of the triangular region were given zero values and omitted in the image calculation in order to avoid the appearance of negative values and the related distortion of the objective plasma image.

The Tikhonov-Phillips method, with the La placian operator for profile smoothing and with the criterion of minimum GCV for choosing the regularization parameter γ, gave a reasonable behavior of image estimate concerning this signal data. However, it is seen in Fig. 1(b) that bias errors in fitting to the signals were non-negligible over most channels of the horizontal camera and hardly diminished even when γ was decreased below the value that minimized the GCV. Rather, the misfit tended to disappear when the reconstruction region was widened with a broadening of plasma image in the top of the triangular region.

The disappearance was quite clear in the maximum entropy analysis, which could deal with the whole reconstruction region of 32x32 pixels owing to the property of positive-definite imaging. When the value of γ was decreased, fitting to the signals was improved to get a precise approximation for all of the channels. Correspondingly, the image estimate had a very high peak in the top region as seen in Fig. 2. As all the sight-lines of the vertical camera of fan-beam type pass through this region, this peak in emissivity is consistent, numerically at least, with signal magnitudes which are larger in the vertical camera by a factor of 2~3. This problem was also seen on the signal data in the stable state of plasma. Another problem in the plasma collapse observation was found in the bottom of the triangular region; misfit to signals can be large in the lower channels of the horizontal camera and may suggest the existence of plasma on the outside. Investigation is needed on the plasma boundary.

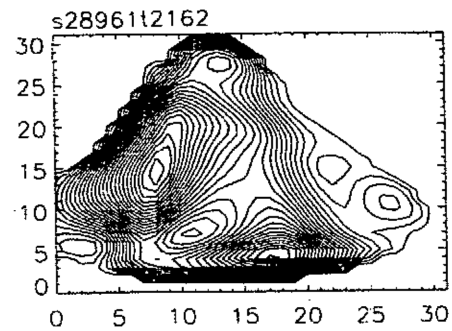

Fig. 1(a). Tikhonov-Phillips image of plasma (contour plot on 32x32 pixels); Shot 28961, 2.162 sec; $\gamma=1.0\times10^{-4}$ (min. GCV).

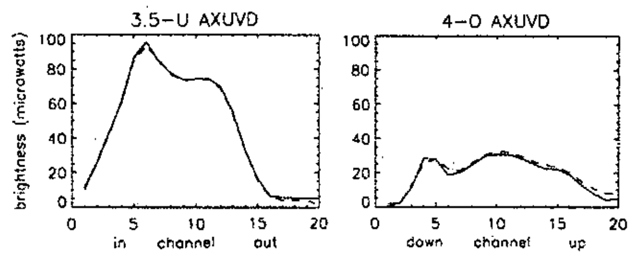

Fig. 1(b). Signals (solid lines) of the vertical camera (left) and the horizontal camera (right), and the projections (dotted lines) of the image shown in Fig. 1(a).

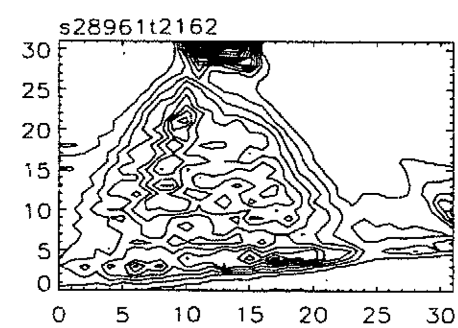

Fig. 2. Maximum entropy image of plasma (contour plot on 32x32 pixels); Shot 98261, 2.162 sec; $\gamma=0.1\times10^{-4}$.

References
1) Y. Liu, A. Yu. Kostrioukov, B. J. Peterson, et al., *Rev. Sci. Instrum.* 74(4) (2003) pp. 2312-2317.
2) B.J. Peterson et al., *Plasma Phys. Contr. Fusion* **45(7)** (2003) pp. 1167-1182.
3) Iwama, N., Hosoda, Y. and Peterson, B.J., Ann. Rep. NIFS (2002-2003) 162.