§31. A Novel Electron Density Reconstruction Method in Heliotron J

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The electron density profile is one of the most important information in magnetically confined plasmas. Far-infrared (FIR) laser interferometry is a routine diagnostic technique for measuring the electron density in thermonuclear fusion devices with a high time resolution. However, it can only provide the line-integrated density based on the phase shift of the laser beam along the plasma cross section. Thus, algorithmic methods for reconstructing the density profile from line-integrated signals are important. For the Heliotron J device at the Institute of Advanced Energy in Kyoto University, which is a flexible helical-axis heliotron[1,2] with a highly asymmetrical poloidal cross section, a multi-channel FIR interferometer is currently being developed, and the local density profile is more difficult to reconstruct. A novel reconstruction method, SVD-GCV method, which gives a physically reasonable solution, is investigated. The generalized cross-validation (GCV) function[3,4] is used together with singular value decomposition (SVD) in order to optimize the regularization parameter.

Figure 1 shows comparison of SVD-GCV method and a conventional method based on the well-known onion-slice technique. Using the conventional method, the reconstructed profile is found to be close to the true one in the case of the peaked density profile; in the case of the hollow profile, the reconstructed profile strongly deviates from the true one. On the other hand, using the SVD-GCV method, a good fit is obtained in both situations.

Figure 2 shows the typical magnetic configuration of the Heliotron J. The horizontal lines show examples of measurement channel positions. The effect of the shape of the electron density profile, the number of channels, and the channel spacing on the accuracy of the proposed reconstruction method was investigated, and the results are shown in Fig. 3. It can be seen that for the peaked profiles, good reconstruction results are obtained regardless of the number of channels used. In addition, for the hollow profiles, the results are significantly improved for the case of using five or six channels, although they are still poor for four channels. The main reason for the failure in the four channels case is that this number is insufficient to follow the changes in the density profile. The results clearly show that for an intermediate number of channels, significant improvements in reconstruction accuracy can be achieved by careful choice of the channel position.

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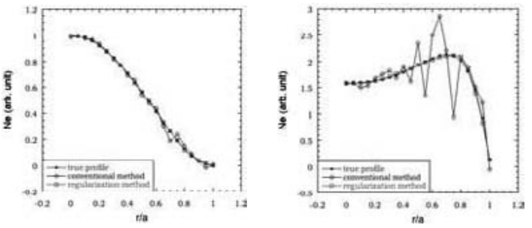

Fig. 1 Comparison of conventional and SVD-GCV method for reconstructing peaked and hollow profiles generated in helical device.

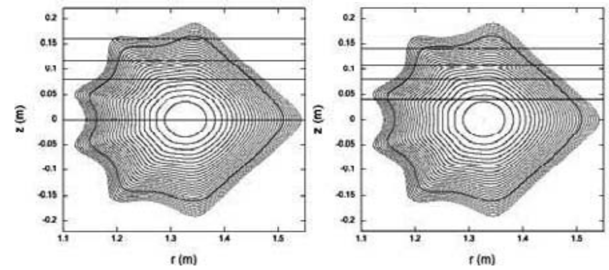

Fig. 2 Magnetic field topology of typical configuration in Heliotron J. In the left one, the channels are equally spaced. In the right one, the channels are unequally spaced.

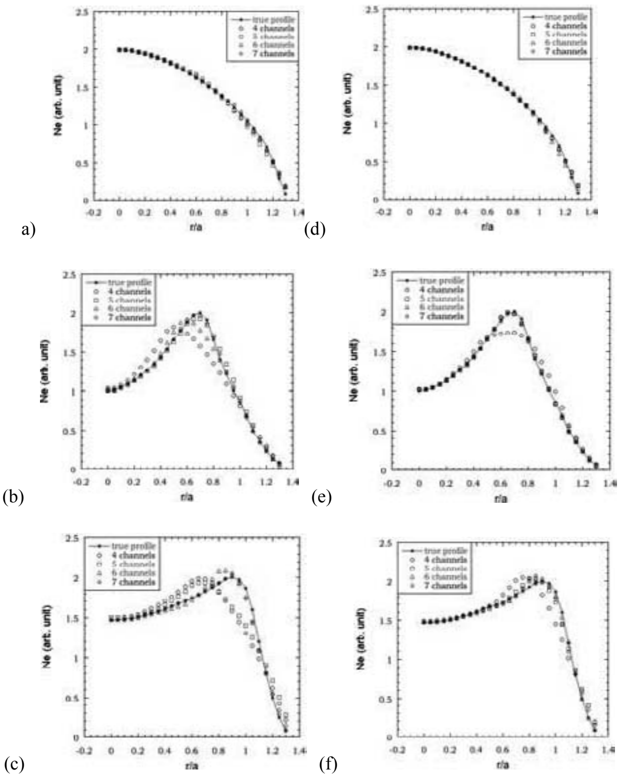

Fig. 3 Reconstruction results for four, five, six and seven channels. For (a)-(c), the channels are equally spaced, and for (d)-(f), they are unequally spaced.