A tangentially viewing camera [1] is suitable to study the MHD activities, especially the dynamics of the magnetic islands. Since the magnetic islands extend toroidally along the magnetic field lines, they can be visualized better when they are observed tangentially. Here, we present a method for the reconstruction of the radiation profile using images obtained from TEXTOR experiments.

From one tangential view, it is not possible to reconstruct a 3-D radiation profile. We assume that radiation along the magnetic field lines is constant and try to reconstruct a 2-D profile on a poloidal plane. A column vector $S(S_j = 1, 2, \ldots , M)$ representing measured signals can be expressed as a linear combination of the radiation profile $E(E_j = 1, 2, \ldots , K)$ and the residual error vector $e$, $S = LE + e$. The geometrical weight matrix $L (M \times K)$ can be determined from integration along the line of sight (Fig. 1). We assume that the magnetic flux surfaces are circular and are shifted. Thereby all elements along a line of sight can be connected to elements in the reference poloidal plane ($P2$ in Fig. 1) by magnetic field lines (Dotted / Dashed lines in Fig. 1). We assume the $q$-profile to be, $q(p) = p^2/(1 - p^2(q_{+1})) q_{-1}$. In this study, $M \sim 2500$ (effective channels within 64 x 64 pixels) and $K = 1024$ (poloidal cross section is divided by 32 x 32). Since this is an ill-posed problem, the least square solution is rather unstable; we need some smoothing mechanism. We adopt two methods. One is Fourier-Bessel (FB) expansion [2]. The radiation profile $E$ is assumed to be in the form $\sum_{m=0}^{\infty} \sum_{l=0}^{\infty} a_{ml} \exp(i m \theta) J_m(\lambda_m \rho)$. The coefficients $a_{ml}$ will be determined by a least square fit. Here, $J_m$ is the $m$th order Bessel function and $\lambda_m$ is the $l$th zero-point of $J_m$. If we cut higher modes, this fitting will act as smoothing. The other method is Phillips-Tikhonov (PT) regularization [3,4]. In this scheme, minimization of $Q = \gamma \sum |CE|^2 + \frac{1}{M} \sum |S - LE|^2$ is considered rather than minimizing $\sum |S - LE|^2$ itself. The matrix $C$ is the Laplacian operator. The first term of the $Q$ decreases when the radiation profile is smoothed; parameter $\gamma$ acts as the control parameter of the smoothness. After the matrix $C^{-1}L$ is SV decomposed as $UWV^*$, $E(y) = \sum_{j=1}^{\rho} w_j(y) \frac{u_j^*}{\sigma_j} (C^{-1}v_j)$, $E$ is now written as combination of orthogonal patterns $C^{-1}v_j$ with weighing factors $w_j(y) = 1/(1 + M y/\sigma_j^2)$. $w_j$ is a decreasing function of $j$ and the destabilizing effect from the small-scale structure is suppressed by proper choice of $\gamma$. The reconstructions by both methods are shown in Fig. 2. In FB inversion, poloidal mode $0 \leq m \leq 6$ and radial mode $0 \leq l \leq 9$ are included. In PT inversion, $\gamma = 1.0$ is used. Quite similar radiation profiles are obtained. Both methods are fast enough and stable. Reconstruction of images in LHD experiments are being developed based on these schemes.

References:

Fig.1: Geometry of the tangentially viewing camera system. On the equatorial plane (A) and the bird-view diagram (B) are shown. To project images on the plane ($p2$) we assume a magnetic flux shifted by $\Delta(p) = \Delta_0 (1 - p^2)$ shown in (C).

Fig.2: Tomographic reconstruction using two methods. (A) measured data. (B1) and (B2) reconstructed radiation profiles by FB and PT, respectively, (C1) and (C2) tangentially viewing image assuming radiation profile (B1) and (B2). (D) gives the residual error obtained by (A) and (C2).