Tomographic Reconstruction of Plasma Radiation Distribution at GOLEM Tokamak Plasma Using Fast Visible Cameras

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Abstract

The tomographic inversion [1] of plasma radiation distribution at the GOLEM tokamak is performed based on the Minimum Fisher Regularization (MFR) algorithm implemented in the Tomotok package [2]. For measurements of the line integrated plasma projections data, the diagnostic system consisting of two crossed fast visible color cameras Photron FASTCAM MINI UX100 with the frame rate of 40,000 fps (1280×56 pixels) [3] was used.

Introduction

Radiation intensity distribution can reveal valuable information to identify the spatially varying impurity concentration, development of MagnetoHydroDynamic (MHD) instabilities and dynamics of runaway electrons (REs) in tokamaks. Tomographic inversion determines the spatial distribution of tokamak plasma radiation sources by implementing Special methods and using line integrated plasma projections data [1]. For measurements of the projections, fast visible radiation matrix cameras became broadly applied on tokamaks in recent past [4]. In present work, the tomographic reconstruction of radiation distribution at GOLEM tokamak plasma is performed by implementing the line integrated date recorded by fast visible cameras.

The GOLEM Tokamak and Diagnostics

The tokamak GOLEM is located at the faculty of Nuclear Physics an Physical Engineering (Czech Technical University in Prague). The diagnostic system to detect the visible radiation is composed of two crossed color model cameras (Vertical (V) and Radial (R)) placed in the same poloidal cross-section. The cameras are with a maximum frame rate of 204,800 fps (1280×8 pixels) in 12-bit ADC dynamic range [3] with detector size $10\,\mu\text{m} \times 10\,\mu\text{m}$. Fig. 1 from left to right shows respectively the GOLEM tokamak with the installed R and V cameras (Left), the visible camera (Photron FASTCAM MINI UX100) (Middle) and the schematic figure of the poloidal GOLEM tokamak cross-section with the geometry of the lines of sight of two V and R cameras respectively, in red and purple (Right) resulting in vertical and radial line integrated visible light data. Furthermore, perspectives of implementing other methods of light

Figure 1: The GOLEM tokamak and diagnostics.

and radiation detection to support the cameras' data analyses are under consideration at present.

Tomographic Inversion and Line of Sight Layout

Tomographic inversion determines two dimensional plasma emissivity profile (g) by using line integrated data recorded by detector–pinhole cameras. The plasma region observed by the detector pinhole camera is discretized into N plasma pixels (plasma emissivity distribution with value g_j in the j-th pixel). The small pinhole consists of a fan of narrow cones approximated a single Line of Sight (LoS) by considering the smooth variation of the emission function over the view cone. Fig. 2 shows the layout of discretization of a circular cross section of plasma region and the LoS of one detector in the tomographic system. The measured signal intensity f_i corresponding to the incident light radiation on the i-ith detector is given by $\mathbf{f_i} = \sum_\mathrm{j} \mathbf{T_{ij}}\, \mathbf{g_j}$, where T_{ij} relates the weight of the radiation emitted from the plasma located in j-th pixel. The function g_j is reconstructed from the sparse measured signal f_i by implementing some regularisation methods (including, in particular, the MFR method).

Figure 2: Layout of the LoS of one detector.

Inversion Reconstruction (GOLEM - Shot Database - #41883)

The two-dimensional tomographic reconstructions of the line integrated data was performed on a square rectilinear grid of size 60×60 pixels with a total size of $17\,\mathrm{cm} \times 17\,\mathrm{cm}$ by implementing the Tomotok package [2] based on the MFR method. The line integrated data was acquired by two R and V visible cameras viewing one GOLEM tokamak poloidal cross section with spatial resolution of 1280×56 pixels at 40,000 fps (frame per second). The smoothness of the result was enforced anisotropically in relation to the magnetic flux surface. Table 1 shows the tokamak and plasma parameters corresponding to the GOLEM shot used for reconstruction (GOLEM - Shot Database - #41883) [5]. Fig. 3 shows the images captured by V