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# Density profile evolution on EAST tokamak by the polarimeter/ interferometer system

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ABSTRACT

An 11-channel POlarimeter/INTerferometer (POINT) system with high time resolution (1 μs) was built in 2015 to measure the accurate line-integrated electron density and Faraday rotation angle on the EAST tokamak. An improved density profile reconstruction method was developed based on the POINT measurements to provide accurate density profiles. Furthermore, the pedestal factor from reflectometry data statistics was also introduced. The accuracy of this method is discussed thoroughly. Based on this method, the evolution of the density profile with much higher time resolution than Thomson scattering system can be obtained. These will make for a better understanding of the formation of the internal transport barrier (ITB) on the EAST tokamak.

## 1. Introduction

Electron density is an important parameter for understanding and controlling tokamak plasmas. The Far-InfraRed (FIR) laser diagnostics are common ways to get the line-integrated electron density. The polarimeter/interferometer is an important instrument for tokamak diagnostics [1–3], as it can be used to measure the line-integrated density and the Faraday rotation simultaneously [4,5]. Some reconstruction methods of local electron density based on FIR measurements have been studied extensively in the past several decades in order to get an accurate electron density profile [6,7]. Several examples and their advantages and disadvantages are as follows: The Abel-inversion method [8,9] is the simplest method but hard to apply to the cases of non-circular cross sections. The Separation- of-variables method [10] can be applied to the asymmetric situations but it's not suitable for a plasma with a large Shafranov shift. Because the plasma shape is not symmetrical about the origin and this is one condition the method uses to calculate the asymmetric adjustments. The Slice-and-stack method [11], which is just like tomography, has a high accuracy but needs much more measurement data to guarantee the accurate result, and 11-channel POINT data does not satisfy this requirement.

All these methods are not applicable directly and/or are unsuitable for some reasons on the POINT system on the EAST tokamak [12,13]. However, the Park-matrix method [14,15], which meets the requirements of EAST, can provide high accuracy results and so is considered in this paper. Here, "meets the requirements" means the principle is can be applied to the plasma configuration and the 11-channel data is sufficient for interpolation calculations. In order to improve the accuracy of this method according to the diagnostic systems on EAST and compensate for the small number of measuring chords of the POINT system at the edge of plasma, pedestal factors are introduced by the statistics of coefficients between reflectometry data with POINT_1 and POINT_11, the details will be shown in the Section 2.2.

In the 2015 campaign, an internal transport barrier (ITB) [16,17] was observed on EAST. Accurate density profiles with high time resolution can more clearly show the formation of this ITB and hopefully help to deduce its origins. The improved density profile reconstruction method is applied to the data processing, and the error analysis of this method is presented. Based on this method, the density profile evolution with the ITB formation is shown and the results compared with the experimental phenomena are discussed. Section 2 gives a brief introduction of the POINT system and the details of density reconstruction method. The application of this method to experimental examples is shown in Sections 3 and Section 4 is a short summary.

## 2. The POINT system and improved density reconstruction method

### 2.1. The POINT system

The POINT system on EAST was first built in 2014 with 5 channels [18] and just a year later it was updated to 11 [19], giving the system higher spatial resolution. The optical paths of the 11-channel POINT system are shown in Fig. 1 where the red solid lines represent the

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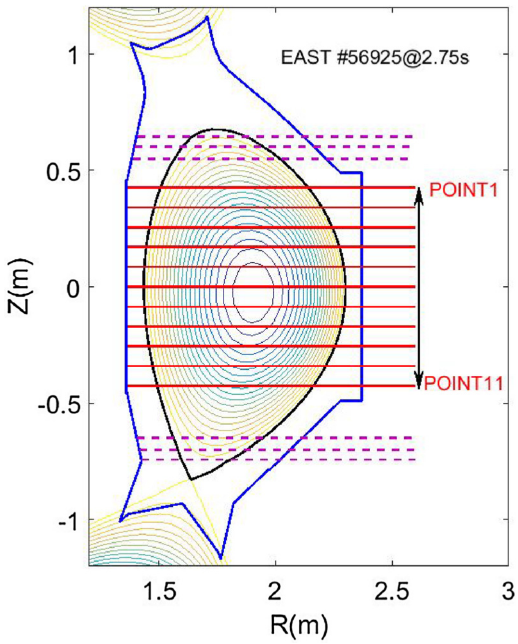



**Fig. 1.** The optical layout of the POINT system on EAST and the poloidal flux information of EAST shot 56925 at 2.75 s. The red solid lines represent the POINT channels, and the purple dotted lines are virtual channels related to pedestal factors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

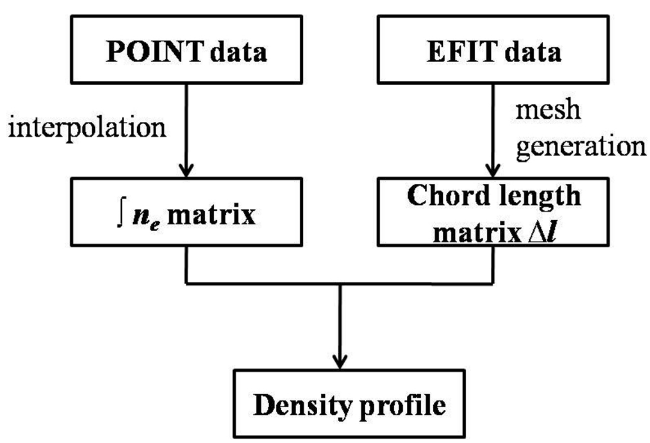



**Fig. 2.** The flow chart of the density reconstruction principle.

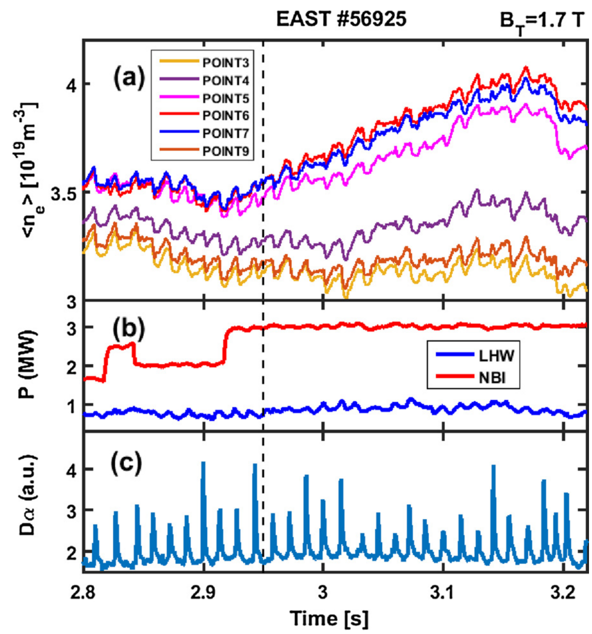


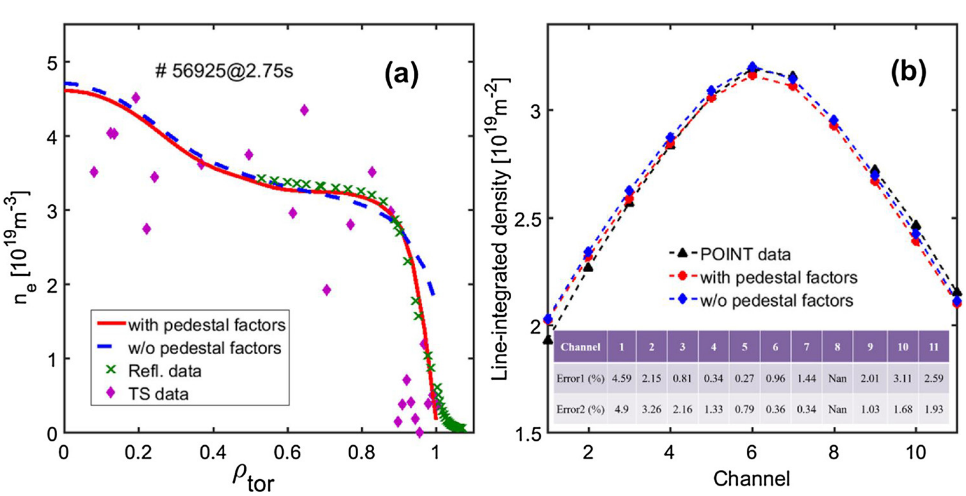

**Fig. 4.** Main parameters of EAST shot 56925. (a) shows multi-channel POINT data, the density of core channels (POINT_5, 6, 7) obviously increases from about t = 2.95 s, while that of the edge channels do not; (b) shows the heating power of the lower hybrid system and neutral beam injection system; (c) is the signal of Dα, indicating an H-mode plasma.

measuring channels. Some parameters of the system are designed as follows: laser wavelength: 432.5 μm; time resolution: 1 μs; spatial resolution: 11 horizontal chords from Z = 0.425 m to Z = −0.425 m with 0.085 m between two adjacent chords; measuring accuracy of electron density: $1 \times 10^{16}\,m^{-2}$ and 0.1° of the Faraday rotation angle.

### 2.2. Improved density reconstruction method

Assuming that the electron density on the same poloidal flux surface is constant, then the plasma cross section can be divided into a sufficiently dense grid, and a matrix of chord length *Δl* can be obtained. The matrix of line-integrated density ∫*ne* is taken from the POINT measurements. Solving the chord length matrix and the line-integrated density matrix, the density of each grid point can be determined and the density profile is also identified. Fig. 2 shows the flow chart of this progress.

A density profile reconstruction method [20] was performed with 5-channel POINT system in the 2014 campaign, and this method was




| Channel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Error1 (%) | 4.59 | 2.15 | 0.81 | 0.34 | 0.27 | 0.96 | 1.44 | Nan | 2.01 | 3.11 | 2.59 |
| Error2 (%) | 4.9 | 3.26 | 2.16 | 1.33 | 0.79 | 0.36 | 0.34 | Nan | 1.03 | 1.68 | 1.93 |

**Fig. 3.** (a) Comparison of the reconstructed density profile by POINT data. The red solid line is the result with pedestal factors while the blue dotted line is without. That means the profile of the blue one is calculated without constraint of the virtual chords, which are shown in Fig. 1 by the purple dotted lines. The green X's are the reflectometry data and the purple diamonds represent the data of Thomson scattering system; (b) comparison results of measured values by POINT system and calculated values by the red solid line and the blue dotted line in (a), "Error1" and "Error2" represent the errors of these two results, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)