THE ESTABLISHMENT OF THE SYNTHETIC DIAGNOSTIC MODELING SPECIFICALLY FOR THE IMAGING NEUTRAL PARTICLE ANALYZER ON THE EAST

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In fusion research, the diagnostics of key information of fuel particles are various and intersecting. To obtain the information of particles more accurately and thoroughly, we applied Synthetic Diagnostic method to establish a physical diagnostic model and develop a complete forward simulation for Imaging Neutral Particle Analyzer (INPA)[1] on the Experimental Advanced Superconducting Tokamak (EAST). Correspondingly, the results are compared and analysed with the experimental data, and it is proved that the active signals of the numerical simulations of this diagnostic can be obtained by this method. The establishment of this Synthetic Diagnostic greatly promotes the analysis of INPA signals and provides a powerful help for further study of the behaviours of fuel particles by obtaining more information such as fast ion distributions through INPA.

1. INTRODUCTION

A series of diagnostic technologies for critical information of fuel particles, mainly including Neutron Emission Spectroscopy (NES), γ-ray Spectroscopy (GRS), Collective Thomson Scattering (CTS), Fast-ion D_α Spectroscopy (FIDA), and Neutral Particle Analyzers (NPA), cover different physical quantities and sensitive intervals of parameters, but there are overlapping. The Integrated Analysis of multiple diagnostic data makes it effective to combine different diagnostics to obtain comprehensive information of fuel particles accurately. Synthetic Diagnostic method is the basis to achieve it, being a forward simulation analysis method that synthesizes diagnostic data by combining predictive numerical simulation of plasma with diagnostic physical models. The range of parameters sensitive to diagnosis and the distribution function information of particles can be estimated through this method. For INPA, the fast ions in the specific area of phase space, after the charge exchange with the neutral particles in the tokamak, are neutralized and may enter the sightlines of the INPA and thus be detected. Then, inside the INPA diagnostic device, the particles undergo a series of events, such as being reionized by the carbon foils, being deflected by the magnetic field, and hitting the scintillator screens. For this whole process, a physical diagnostic model is established and a complete forward simulation is developed.

2. MODELING AND SIMULATION

Based on the processes described above (the detailed setup of the INPA are elaborated in Ref. [1]), the physical model of this diagnostic is established similar to the simulation idea of the INPA on the DIII-D[2]. Detailed, as shown in Fig. 1, first, with the measured temperature and density profiles, the fast ion distribution functions under neutral beam injection (NBI) heating are calculated by NUBEAM module of TRANSP; then, according to the obtained fast ion distribution functions, combined with the specific data of NBI, the geometry of INPA, and the magnetic field, FIDASIM[3-5] (a Monte Carlo code used to calculate the signals generated by the charge exchange of ions and neutrals, mainly for FIDA and NPA diagnostics) is applied to calculate the neutral flux reaching the INPA head; finally, a newly developed programme describes the INPA instrument response, including the interaction of the particles with the foils, the full orbit path of the particles when deflected by the magnetic field, and the luminescence and camera response, so the striking points and the final synthetic image are obtained. It is worth noting that the model only includes the process of active charge exchange (the charge exchange between ions and neutral beams), and does not consider the process of passive charge exchange (the charge exchange between ions and other neutral particles), but actually the active signals are the dominant ones.

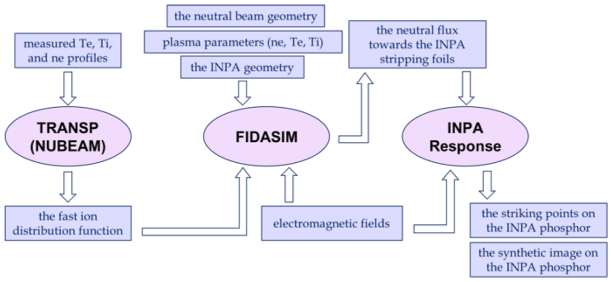

Fig 1. The flow chart of the forward simulation for INPA on the EAST.

3. RESULTS AND CONCLUSIONS

As mentioned in the previous section, the diagnostic physical model is established, thus a complete forward simulation method is developed. Take EAST shot 136376 as an example. In this shot, NBI 1L, 2L, and 2R are turned on, where 1L is the active beam (see details in Ref. [1]). The selected time is 3500ms, which is approximately a few hundred milliseconds after the three beams are turned on in turn. The results are shown in Fig. 2. It shows the INPA experimental image (a) and the image simulated by the Synthetic Diagnostic method (b), both of which are two-dimensional distribution maps, taking Tokamak radius R and particle energy E as horizontal and vertical axes, and fluxes under specific R values are fluxes of different sightlines. The particle distribution at $R = 1.8 - 2.1$ m is in good agreement with the experimental situation, and the two sightlines between $R = 1.6 - 1.7$ m showed obvious signal spots that do not appear in the simulation. So a preliminary simulation is conducted and it is confirmed that these signals may come from the first orbit loss with a ring asymmetry. Through the simulation of the first orbit loss of 1L, the loss location was close to the sightlines of the INPA head, and this phenomenon has also been observed in the experiments of other discharge shots.

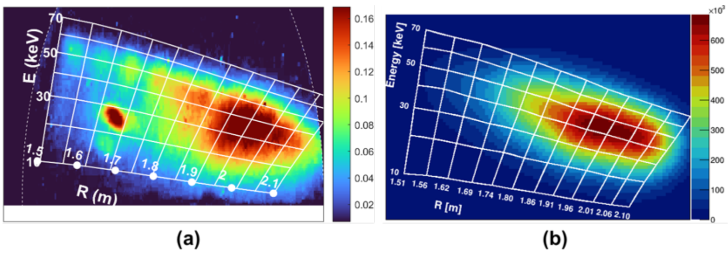

Fig 2. The INPA experimental image (a) and the synthetic result (b) for EAST shot 136376 at time of 3500ms.

In summary, it is proved that the Synthetic Diagnostic method and modeling can obtain the numerical simulation signals of the active charge exchange of INPA, which are consistent with the experimental results. The completion of this work provides ideas and basis for analysing INPA data and obtaining more information through INPA. Further, it will help to solve the key problems for fusion reactor fuel particle diagnostics, that is, how to scientifically design the diagnostic systems to better cover the intervals of key parameters and how to integrally analyse the interrelated complex diagnostic signals.

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