A new neutral particle analyzer diagnostic and its first commissioning on HL-2A\textsuperscript{a)}

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A new neutral particle analyzer diagnostic has been developed for HuanLiuqi-2A (commonly referred to as HL-2A), which can provide the neutral particle flux measurement along 11 separate sightlines, simultaneously, within a wider energy range (1—70 keV). It is an electrostatic type analyzer with a removable pinhole and special-shape condenser. The energy analysis can be flexibly achieved by controlling a preset stepwise high voltage on the condenser. It is compact and its field of view covers HL-2A cross section from −33 cm to 33 cm without “cross-talk.” The energy spectra and ion temperature profile have been obtained during its commissioning. © 2012 American Institute of Physics.

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I. INTRODUCTION

Neutral particle analyzer (NPA) is an instrument, which is specially designed for the energy spectra measurement of fast neutral particles that escape directly from plasma.\textsuperscript{1–8} Through the energy spectra analysis, the ion temperature and energetic particle spectra excited by auxiliary heating can be obtained, and neutral density, hydrogen isotopic composition, and impurity content in fuelling plasma can be deduced.\textsuperscript{3} Therefore, NPA normally serves as one of the principal diagnostic tools to study the ion heating mechanism and the effect of macro- or micro-instability, hydrogen isotopic composition to transport,\textsuperscript{9} and ion confinement time in plasma.

HL-2A is a midsize divertor tokamak device with auxiliary heating from neutral beam injection (NBI) and electron cyclotron resonance heating (ECRH).\textsuperscript{10} Its typical parameters are as follows: major radius \( R = 1.65 \) m, minor radius \( a = 40 \) cm, plasma current \( I_p = 200-400 \) kA, and toroidal field \( B_t = 1.4-2.5 \) T. One tangential deuterium neutral beam has an injected power up to 1.5 MW at full energies up to 50 keV. The ECRH, at 68 GHz, can deliver the power up to ∼3 MW to deuterium plasma.

In order to provide the capability of the ion temperature profile and fast particle energy spectra measurement, a new neutral particle analyzer diagnostic is developed for the HL-2A tokamak and manufactured in the Ioffe Physical-Technical Institute. It could provide the spatial measurement of escaped neutral flux within the energy range of 1—70 keV, simultaneously, and its field of view covers HL-2A cross section from −33 cm to 33 cm without “cross-talk.”

In the paper, the description of this new NPA diagnostic is illustrated in Sec. II and some results are briefly introduced in Sec. III. Finally, a short summary is given.

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II. DIAGNOSTIC DESCRIPTION

This new NPA diagnostic, called after CP-NPA, is an electrostatic type NPA with a removable pinhole. It is also the first NPA diagnostic to provide the spatial measurement of energy spectra within the energy range of 1—70 keV or ion temperature, simultaneously. The schematic setup of the CP-NPA diagnostic is shown in Figure 1. It mainly includes the CP-NPA analyzer, high voltage power supply, and modulator modules, counter module, auxiliary pumping sub-system, and so on.

The CP-NPA analyzer is compact and its internal layout is presented in Figure 2. Input neutral flux enters the analyzer through the block of entrance removable diaphragms. The diameter of input diaphragm can be 0.3, 1.0, and 3.0 mm, which corresponds to the solid angle of the analyzer equal to \( 2 \times 10^{-8}, 2.2 \times 10^{-7}, \) and \( 2 \times 10^{-6} \) cm\(^2\)st, respectively. Then the angle formed by the neutral flux comes to the stripping unit, which cuts the flux according to the 11 angle directions with an angle step 2°06′. Two kinds of stripping units can be used. One is the diamond-like-carbon (DLC) foils unit in which 11 stripping DLC foils of ∼50 Å thickness, individual for each angle channel, are installed (as shown in Figure 2). Another is a special designed gas-stripping cell. These two stripping units can be replaceable. Which one is installed depends on the energy of particles to be measured.

The gas-stripping cell is suitable for thermal particles and the DLC foils unit is suitable for high-energy particles. Neutral atoms are ionized in the stripping unit and secondary ions enter a special designed electrostatic condenser via a set of internal diaphragms to avoid the “flux cross-talk” between neighbor channels. Further, the secondary ion beams are analyzed for the energy in the electrostatic condenser and measured by the detection array, which consists of 11 channel electron multipliers of KBL1010IPP type (“Sjuts” production, Germany). Flexible energy analysis is a feature of CP-NPA analyzer. The stepwise voltage supplied to the electrostatic condenser is easily programmed. The number, duration, and value of the voltage steps can be changed to provide the energy spectrum measurement of the secondary