§50. Semiconductor Detector-Based Neutral Particle Energy Analyzer with 2D Plama Scan

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The ion-implanted silicon detector-based neutral particle analyzer (SDNPA) proposed in [1] represents a passive corpuscular diagnostic technique offering an advanced approach to studies of fast ion physics on LHD. The characteristic features of this diagnostic are the extremely high energy resolution, wide range of energies that can be measured and the capability of performing a two-dimensional scan of the non-axisymmetric plasma column.

The measured atomic flux is given by the following general formulae:

$$\Gamma(E)dE = \frac{\Omega S}{4\pi}\int_0^L g(E)dE e^{-\tau(E,r)}dr \quad [\mathrm{s^{-1}}]$$

$$g(E)dE = \left(n_0\langle\sigma v\rangle_{cx} + n_e\langle\sigma v\rangle_{rec}\right)n_i f_i(E,\mathbf{r})dE\,, \quad [\mathrm{cm^{-3}s^{-1}}]$$

Here Ω is the visible solid angle, S is the analyzer's collimating slot area, the viewing chord is supposed to extend from $r = 0$ to $r = L$; n_0 is the density of targets for charge exchange (background neutrals, impurity ions), n_e – electron density, n_i and $f_i(E,\mathbf{r})$ – main species ion density and energy distribution function, $\langle\sigma v\rangle_{cx}$ and $\langle\sigma v\rangle_{rec}$ – rates of charge exchange and radiative recombination processes; $\tau(E, r)$ is the "optical depth" of the plasma determined by the mean number of atomic collisions per unit path length $\lambda^{-1}_{mfp}(E)$. The expressions above underlie the passive NPA data interpretation. However, in practice numerous assumptions and simplifications are often required.

The design philosophy allowing the two-dimensional scan is to employ the detectors' moderate size to build a compact array for simultaneous measurements along several lines of sight. This is depicted in the Fig. 1b.. SDNPA uses a six-detector array. The collimating slot of the analyzer is movable to provide a scan in the orthogonal direction (Fig. 1a). The collimating aperture size is adjustable.

The lowest particles' energy that can be measured is about 5 keV taking into account the so-called dead layer consisting of the 500Å thick front electrode and the 40 μg/cm^2 aluminium coating eliminating the light from the plasma. The maximum measurable energy about 4 MeV is determined mostly by the range of the particles in silicon and the depletion layer thickness which is 300 μm at the standard detector bias voltage of 50V.

In order to minimize the thermally dependent leakage current the detectors themselves and the input stages of the preamplifiers are mounted on liquid nitrogen cooled substrates. This results in noticeably better parameters compared to other NPAs utilizing semiconductor detectors. The preamplifiers are located close to the detectors for noise reduction purposes.

The diagnostic has been tested and calibrated with the internal radioactive source ($^{55}Fe_{26}$ 5.9 keV X-ray). The example of measured spectra is in the Fig. 2. The full width at half-maximum of the test X-ray spectral line is demonstrated not to exceed 1 keV. The lowest energy part of the spectrum attributed to the background noise is measured not to extend further than 3 keV.

The diagnostic consists of several subsystems, *viz.* detectors and detector electronics, digital data acquisition system (NIFS LABCOM based), electromechanical system for plasma scan, and local vacuum system. All these subsystems have been tested and proved to operate properly in the fourth experimental cycle.

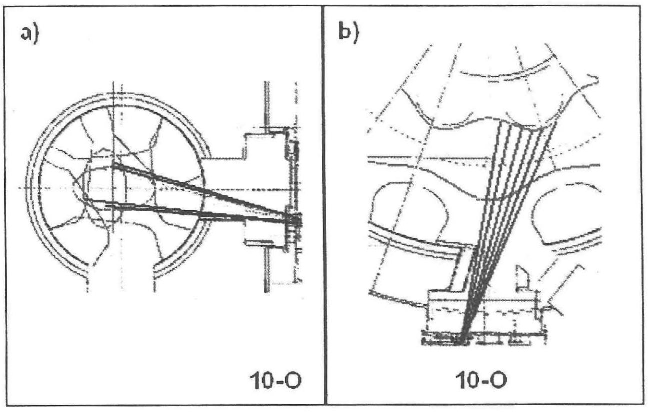

Fig.1. a) Extreme positions for vertical scan (radial cross-sectional plane projection)
b) Lines of sight of the six detectors (midplane projection)

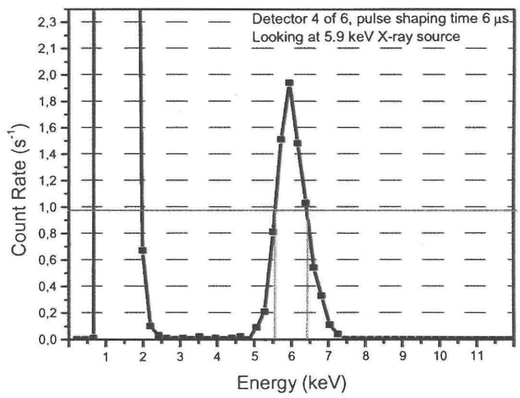

Fig.2. $^{55}Fe_{26}$ 5.9 keV spectral line measured for SDNPA testing and calibration

References
1) Lyon, J.F. et al.: J. Plasma Fus. Res. SER., 1(1998)358.