

## §66. Compact Neutral Particle Analyzer for Wide-Range Passive and Active Charge Exchange Measurements

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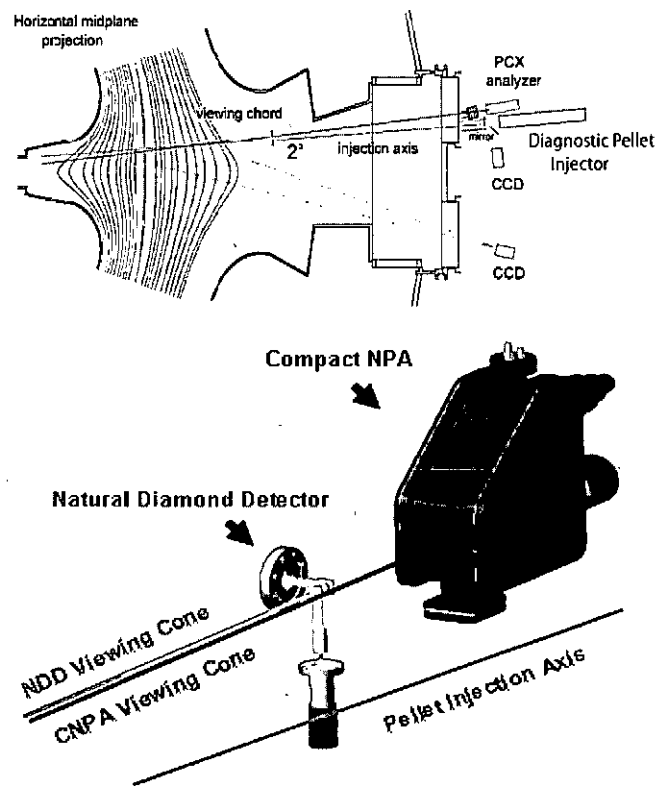
Neutral particle analysis (NPA) technique is used on LHD for studies of suprathreshold ion distribution tail formation from NB and ICRF heating, fast ion confinement properties, and also for routine  $T_i$  measurements. Spatial resolution is required due to the variety of particle orbit classes and complex 3D field geometry of LHD. The correct passive NPA data interpretation for a toroidally non-axisymmetrical plasma and the spatial information retrieval from line-integrated naturally occurring neutral flux observed by a scanning multi-chord passive diagnostic requires a complex numerical modeling [1]. The active probing with an impurity pellet injection, i.e. pellet charge exchange (PCX) diagnostic [2] provides the essential locality of measurements.

Time-resolved spectra of energetic particles neutralized at the pellet ablation cloud moving across the plasma result in radially resolved ion parameter measurements. A natural diamond detector (NDD) is an attractive solution, compared to traditional neutral particle analyzers, due to the wide measurable energy range and compactness, which is essential to have a small angle between the sight line and the pellet injection axis so that the pellet cloud remains within the analyzer's viewing cone during the ablation time. However, the use of solid state detectors in this diagnostic is difficult because of the very high operating speed constraint. As it was demonstrated in [2], the operating count rate should be  $Ct N v_{pel} / \delta l \approx 10^7 s^{-1}$  for the pellet velocity  $v_{pel} \approx 10^3 m/s$ , desired spatial resolution  $\delta l \approx 10^{-1} m$  and the minimum statistically acceptable number of counts per one spectrum  $N \approx 10^3$ . Traditional pulse height analysis (PHA) techniques normally using pulse shaping amplifiers, peak detecting ADCs and digital histogramming modules cannot provide the operating speed high enough for a good spatial resolution in PCX diagnostics. An alternative approach based on the analysis of digitized preamplifier signals directly was discussed in [3]. The signals are treated as a piecewise smooth functions of time due to the fast voltage rise following every incoming particle. The spectra are obtained by regularized detection-estimation of signal increments at discontinuity points proportional to the incoming particles' energies. It was shown that the NDD system may be suitable for the uppermost energies above 100 keV.

For the most of the energy range of interest a conventional (i.e. with ion separation) compact (169x302x326 mm) neutral particle analyzer (CNPA) is planned. CNPA [4] is a unique charge exchange spectrometer to be used on LHD for the energies in the range 1 - 170 keV for  $H_0$ . A high-field-strength (1 T) NdFeB permanent magnet is employed in this analyzer instead of

traditional electromagnets and a thin 100 Å diamond-like carbon stripping foil instead of a gas stripping cell. For PCX measurements CNPA appears to be the most suitable energy analyzer type from the viewpoint of the high operating speed and measurement geometry. Its viewing cone allows to use it simultaneously with NDD, which can be located in the CNPA inlet duct. Thus, the possible measurable energies extend from CNPA upper limit to the MeV range.

An array of channel electron multipliers (CEMs) is used for particle detection. The requirement of a high operating speed necessitates the use of CEMs not only in the counting mode but also in the current mode to be able to work with high fluxes and avoid counting statistics difficulties. This implies the application of special measuring electronics and data acquisition. This analyzer can be used in both ways, i.e. in PCX measurements and also as a passive non-perturbing diagnostic. Comparisons and modeling of complementary measurement results from this diagnostic and the multidirectional passive NPA are planned. CNPA is also planned to be used in a combination with the upgraded cryogenic pellet injection system afterwards. In future experiments this analyzer can also be used for active measurements with a diagnostic neutral beam on LHD.



### References

- 1) P.R. Goncharov et al., J. Plasma Fusion Res. Series, 6 (2003), to be published.
- 2) P.R. Goncharov et al., Rev. Sci. Instrum., 74, 1869 (2003).
- 3) P.R. Goncharov et al., Rev. Sci. Instrum., 76, to be published.
- 4) F.V. Chernyshev et al., Proc. 30<sup>th</sup> EPS Conf. on Contr. Fus. and Pl. Phys., Vol. 27A, P-4.71