Ion and electron temperature fluctuations measurements using a retarding field analyzer

I. Nedzelski*, C. Silva, P. Duarte and H. Fernandes
Associação Euratom/IST, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico,
1049-001 Lisboa, Portugal
* igorz@ipfn.ist.utl.pt

EFDA TASK: WP10-TRA-05/IST

Introduction
- The local measurement of the radial ion transport is an important issue in magnetically confinement plasma experiments.
- The retarding field analyzer (RFA) is known as the most appropriate diagnostic tool for the ion temperature measurement in the edge plasma of the fusion devices.
- The temporal resolution in the standard RFA application is, as a rule, restricted to a few milliseconds.
- In this contribution a DC operation of the RFA is considered, which allows for instantaneous measurement of the plasma ion and electron temperatures. The method is based on two point measurements on the RFA I-V characteristic with two differently DC biased RFA electrodes. The results obtained in the ISTTOK boundary plasma are presented and the limitations of the method discussed.

Experimental set-up
- The RFA used in this work includes an input stainless still aperture (diameter = 0.4 mm, thickness = 0.1 mm, covered with a fine Nickel grid), three similar grids and a copper collector plate; all separated by MICA insulators (1 mm of distance between the grids) [1].
- The grids and collector stack are assembled inside a boron nitride housing attached to a probe shaft allowing for radial movement.
- The current collected by the RFA is measured across a 100 kOhm resistor via an isolation circuit and acquired by the ISTTOK data acquisition system with 2 MHz sampling rate.
- The experiments have been performed on the ISTTOK tokamak (R = 0.45 m, a = 0.085 m, B0 = 0.5 T, ncm> = 4x1019 m⁻³, j = 4 kA) edge plasma.

Applicability to ISTTOK operation conditions
The time evolution of the low pass filtered (10 kHz) ratio Ic/I0 during the discharge is shown for three equipotential biasing of G2 and C [Vc/G2 = Vc/C = 0, 12, 24 V] and for Vc/G2 = 12 V, Vc/C = 24 V.
- A strong variation of the currents ratio for Vc/G2 = 12 V, Vc/C = 24 V is measured, contrary to the observed for the equipotential cases.
- With an assumption of ξc ~ ξc ≈ ξ, the grids absorption coefficient for the ions is estimated to be ~0.54 (12 V on G2/C) and ~0.51 (24 V on G2/C). These values are ~2 lower than the optical transparency, 0.8.
- The effect of the backward current on grid G2 is small, ~ 6%. This is confirmed measuring the current on G2 when a ramping voltage is applied to the collector; the expected current modulation is undistinguishable.

Method
- The considered method is based on the conventional RFA operational relations for Maxwellian distribution of the analyzed ions:

  \[ I(V) = \frac{I = \exp\left[q(V - V_{\text{shift}}/kT)\right]}{\exp\left[q(V - V_{\text{shift}}/kT)\right]} \]

- For any two points on retarding curve in the range of \( V_{\text{ini}} \leq V < V_{\text{shift}} \), the ratio of the respective currents is:

  \[ \frac{I(V_i)}{I(V_j)} = \exp\left[q(V_i - V_j)/kT\right] \]

  suggesting that instantaneous ion temperature measurements can be obtained via the inverted relation:

  \[ kT_i = q \alpha \ln\left[\frac{I(V_i)}{I(V_j)}\right] \]

  where the coefficients \( \alpha \) and \( \beta \) are:

  \[ \alpha = \frac{\xi_c}{\left(1 - \xi_c\right)} \quad \beta = \frac{\xi_c}{\left(1 - \xi_c\right)} \quad \gamma = \frac{\xi_c}{\left(1 - \xi_c\right)} \]

  and \( \xi_c \) is the attenuation/absorption factors/coefficients of the grids G2 and G3 for the ions.

Ion temperature measurements
The temporal evolution of the ion temperature (with and without a low-pass filterer @ 10 kHz) for Vc/G2 = 12 V, Vc/C = 24 V. For comparison, \( T_i \) measured with RFA operated in conventional ramping ion mode is also shown (full points).

Electron temperature measurements
RFA operation in the electron mode has been tested, where the electron current on the biased grid G3 and the collector C has been measured.

Summary and discussion
- A simple method is considered that allows instantaneous and very localized monitoring of the ion and electron temperatures based on the simultaneous measurement of two points on the RFA I-V characteristic with two differently DC biased RFA electrodes.
- The method has been tested in the ISTTOK SOL plasma and compared with conventional RFA measurements of the ion and electron temperatures. The fluctuations attributed to \( T_i \) are quite large (~30%) with frequencies up to 100 kHz. The fluctuations attributed to \( T_e \) are ~2 × smaller.
- One clear restriction in the implementation of the method is the secondary electron emission from RFA electrodes that is being investigated.

References