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IMPURITY CONCENTRATION IN THE ATC

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Impurity Concentration in the ATC

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ABSTRACT

The impurity level in the ATC before compression has been investigated by spectroscopic measurements. The first experimental results concerning the concentrations and the influence of impurities on some discharge characteristics are given.

INTRODUCTION

In this set of spectroscopic measures we looked at the time behavior and the intensities of various lines of impurity ions in order to obtain the composition of the discharge and the influence of the impurities on some main parameters of the discharge like the resistivity and the confinement times.

We have used a calibrated grazing incidence monochromator looking horizontally along the major radius at 135° from the limiter. In this way only quantities averaged along the line of sight are obtained and the measured intensity is given by

$$I(p,q) = \frac{A(p,q)}{\sum_{r<p} A(p,r)} \frac{1}{4\pi} \int n_e(r) n_i(g,r) X[T_e(r),g,p] dr \qquad (1)$$

photons s^{-1} cm^{-2} sr^{-1}

where $n_e(r)$ is the electron density in cm^{-3}, $n(g)$ is the density of the particular ion species in its ground state in cm^{-3}, $X[T_e(r),g,p]$ is the excitation coefficient from the ground state g to the p level (in cm^3 s^{-1}), $A(p,q)$ is the spontaneous radiative transition probability from the p to the q level (in sec^{-1}). This is of course an unsatisfactory condition. In fact, if the ion distribution is very peaked or hollow, this can affect the discharge deeply and little information in respect to this can be drawn from the average of Eq. 1. These measures have been made during the months of July and September so no long time variation of the impurity level could have been measured. Moreover, only the uncompressed plasma has been studied.

CALIBRATION

The calibration has been done with the branching ratio method. This gives directly the brightness of the source, so no knowledge of the geometrical factors is needed.

In the following table we give a list of the transisitons used in the calibration.

	Calibration	
Element	λ UV in A	λ V in A
1. H	1025.7(L_β)	6562.8
2. H	1215.7($L\alpha$)	6562.8
3. He II	303.8	4685.6
4. He II	256.3	4685.6
5. He II	243	4685.6
6. He I	537	5015.7

In cases 2, 3 and 4 the upper levels are not the same so the intensity ratios are functions of plasma electron density and temperature. They have been calculated by Johnson and Hinnov[1]; if KTe is higher than the transtion energies, they are a very slowly varying function of temperature and the error should not be large

IMPURITIES

In the following table is a list of ions and of the corresponding transtions we have used most:

Element	Wavelength in A	Transition
O IV	554.5	$2p\ ^2P^o-2p^2\ ^2P$
O V	629.7	$2s^2\ ^1S-2p\ ^1P^o$
O VI	1032	$2s\ ^2S-2p^2P$
C III	977	$2s^2\ ^1S-2p^1P$
N V	1239	$2s\ ^2S-2p^2P$
Fe XV	284	$3s^2\ ^1S-3s3p^1P$
Mo XIII	341	$4s^2\ ^1S-4s4p^1P$

Figure 1 shows the time behavior of current and electron density in a typical discharge. The arrows indicate the time when the lines of the various ions peak. Figure 2 shows a typical time behavior of the impurity line radiation. The O VI light begins to appear somewhat later with respect to the beginning for the current namely when the electron temperature is so high that an appreciable ionization O V → O VI takes place. The lowering of the light intensity indicates a passage to the O VII ion. Of course the light distributions are not known; but the measure of the evolution of the temperature profile shows that in the first milliseconds the temperature is flat and reaches values of hundreds of eV very quickly (2-3 ms); then we can assume with confidence that the light distribution at peak is quite uniformly distributed. During the plateau the light comes from a cylindrical shell in the outer region of plasma.

To get the ion concentration from Eq. 1, one has to know the radiative transition probabilities and the collisional excitation coefficient. For the former we have used the tables of Wiese, Smith and Glennon[2] while for the latter the problem is much more difficult. For lithium-like ions, the excitation coefficients derived from the cross section of Bely[3] have been verified experimentally to be accurate by Kunze and Johnston[4], Boland et al.[5] For other ions experimental checks are or lacking or unconclusive. We have used the $\bar{g}$ approximation of Van Regemorter[6] and Seaton[7] which is very simple and is supposed to be correct in a factor 2.

The impurity concentration is reliable only at the peak. But the electron density and the light signal are constant or increase slightly after the first few milliseconds of the current pulse. So we can assume that the concentrations are quite constant (the whole discharge does not last longer than 40 milliseconds). Only the concentration of the heavy elements grows in many cases during the discharge.

RESULTS AND DISCUSSION

A summary of the results is given below

$$8 \times 10^{10}\ \text{cm}^{-3} < \text{O} < 4.5 \times 10^{11}\ \text{cm}^{-3}$$

$$\text{C} < 10^{10}\ \text{cm}^{-3}$$

$$\text{Mo} < 10^{10}\ \text{cm}^{-3}$$

$$3 \times 10^{9}\ \text{cm}^{-3} < \text{Fe} < 1.5 \times 10^{10}\ \text{cm}^{-3}$$

Nitrogen was negligible in the first period of the experiment but grew to a few units x 10^{10} after a major opening in the machine. Given the short time it has not been possible to find which is the source of the these impurities if the liner or the limiter neither to study the long time variations. In the following we give in detail the results regarding some typical discharges. The accuracy in the oxygen concentration is the accuracy of the calibration and can be put about $\pm$ 40 per cent. The accuracy in the iron concentration is given by the uncertainty of the excitation coefficient. The other quantities have been evaluated quite late in the discharge after 25-30 ms from the beginning of the current pulse. For the evaluation of

$$Zeff = \sum n_i z_i^2 / \sum n_i z_i$$

we have considered the light atoms fully stripped and the Fe in the Fe XVI state. The main contribution to the enhancement of the Zeff comes from the O nucleus. The accuracy for Zeff is given by the formula

$$\frac{\Delta Zeff}{Zeff} = \frac{\Sigma_i \Delta n_i z_i^2}{n_e Zeff} + \frac{\Delta n_e}{n_e} \qquad (2)$$

and results to be about $\pm$ 30-40 percent. τ is the particle confinement time calculated for a pure hydrogen plasma, while τ^1 takes in account the effect of oxygen. The ionization rate of oxygen has been taken as 7 times the one of O VI at a temperature of 120 eV; this temperature is between the ionization potential of O V (114 eV) and O VI (138 eV). Given the assumption τ^1 can

give only a rough idea of the influence of impurities on the particle confinement.

$n_e(cm^{-3})$	$O(cm^{-3})$	$Fe\ (cm^{-3})$	Zeff	τms	$\tau^1 ms$
10^{13}	1.5×10^{11}	10^{10}	2.1	57	21
1.7×10^{13}	2×10^{11}	10^{10}	1.7	57	21
2×10^{13}	3×10^{11}	2×10^{10}	2	67	25
1.3×10^{13}	4×10^{11}	10^{10}	3		
2×10^{13}	4×10^{11}	10^{10}	2.2		
8×10^{12}	6×10^{11}	3×10^{9}	4.6	25	8.5

Power radiated in the lines is mostly O V and O VI resonance radiation. It results to be small respect to the power input (less than or equal to 10%) in all the cases shown.

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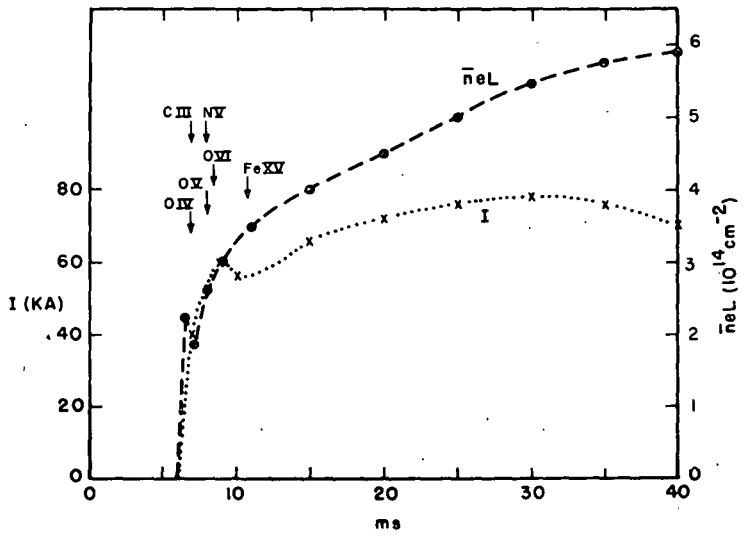

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Fig. 1. Time behavior of ohmic heating current and average electron density. Arrows indicate the time of peaking of the emission of various ions.

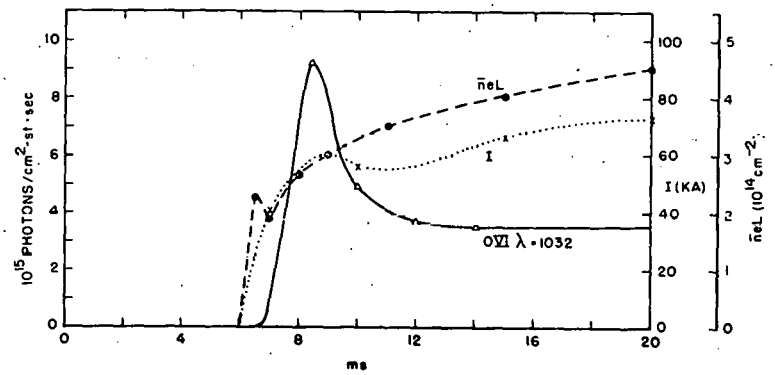

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Fig. 2. Detailed behavior of the λ = 1032 O VI line compared with the evolution of current and electron density.