STUDY OF THE LINEAR AND PARAMETRIC ABSORPTION OF LOWER HYBRID WAVES IN PLASMA ON THE FT-2 TOKAMAK

V.N. Budnikov, E.O. Chechik[†], V.V. Dyachenko, P.R. Goncharov[†], L.A. Esipov, E.R. Its, S.I. Lashkul, M.Yu. Kantor, D.V. Kouprienko, I.E. Sackharov[†], S.V. Shatalin[†], A.P. Sharpionok[†] and V.B.Yermolaev[†]

Ioffe Institute, Saint-Petersburg, Russia
[†] Technical University, Saint-Petersburg, Russia

Absorption mechanisms of LH waves in tokamak plasmas: stochastic absorption, Landau damping and mechanism associated with parametric decay instability have been understood in early 80’s. The interest to the LH heating was lost due to the contradictory, unstable or irreproducible results and to the absence of heating. The main goal of FT-2 studies was to investigate the mechanisms of LH power absorption and electron and ion heating.

The experiments in FT-2 demonstrate that one may provide the condition for either parametric or linear absorption of LH wave in plasma at the same launching auxiliary RF power. This was found during controlled shift of plasma column along major radius. Outward shift of plasma for 0.5 cm results in L-H transition and, hence, higher electron temperature both in plasma center and periphery. The electron temperature affects substantially on plasma-wave interaction [1,2]. Outward shift of plasma column increases the electron temperature in the discharge respect to inward shifted plasma. The strong parametric instabilities are excited in lower temperature plasma.

This paper deals with an observation of spectra of scattered radiation near the pump frequency f_0=920 MHz by 4, 5-electrode Langmuir probes [3, 4] operated as RF antennas located in the limiter shadow. The design of the chamber and diagnostic ports of the FT-2 tokamak gives a unique possibility to investigate the peripheral plasma practically at any poloidal angle. Three movable multielectrode Langmuir probes enable measure the time dependence of local values of the electron temperature, plasma density, space potential, electric field, quasistationary and fluctuation-induced **E**x**B** drift flux densities.

The lower hybrid wave parametric decay with generation of the ion cyclotron frequency harmonics has been studied using the same probes. In these experiments the RF signal from one of the electrodes which acted as an antenna was fed after a blocking capacitor to the RF circuit developed for measurements. This allowed to study the RF spectrum and plasma parameters simultaneously. The circuit consists of an inductive galvanic uncoupler, voltage controlled generator, heterodyne, low frequency amplifier, detector, oscilloscope and digital data acquisition system. Heterodyne frequency was controlled by an external single sawtooth pulse of 1 ms duration. The spectrum in 190 MHz frequency band (760 - 950 Mhz) was registered during this period of time. The location of the movable probes in diagnostic ports and a schematic of the RF circuit are shown in Fig. 1. The 920 MHz, 100 kW LH wave was launching by two-waveguides grill, launched the wave from the low field side. Diagnostic ports with movable probes are shifted by 90^0 from the grill in toroidal direction. There are also two fixed probes near the grill.

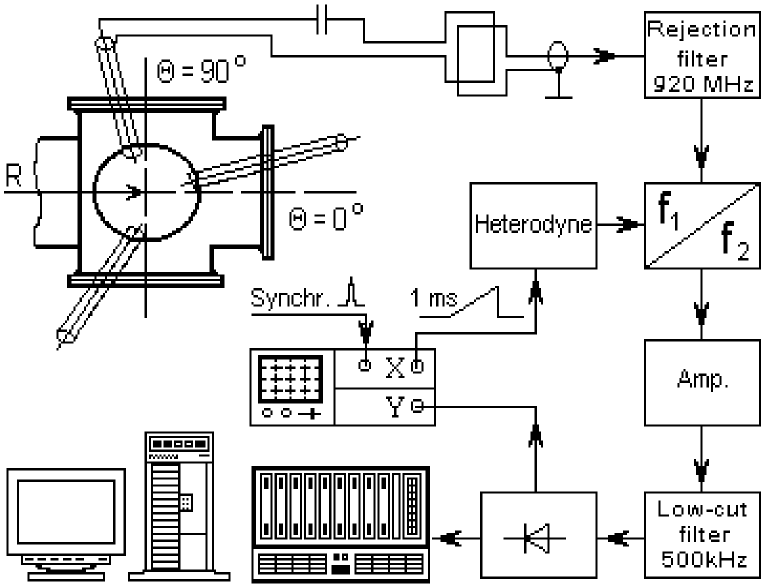

Fig. 1

Red satellites with frequency $f_n=f_0$ - $n*f_{ci}$ (n=1,2,3,4), where f_{ci} is the ion cyclotron frequency, f_0 - the pumping wave frequency, were detected by movable and fixed probes as well. Blue satellites $f_n = f_0 + n*f_{ci}$ were not detected in both cases. This fact confirms an assumption that the observed spectra represent the LH wave decay, but not the combination frequencies $f_0 \pm n*f_{ci}$ where f_{ci} is the frequency of an ion cyclotron wave, excited by an independent mechanism.

Poloidal distribution of wave power at f_0 registered by movable probes is shown in Fig.2. Band-elimination filter was excluded from the RF circuit during these measurements. The most efficient decay was observed in the same region. One can see that there is a sharp peak at the poloidal angle of about 0^0. Fig. 2 also depicts the first satellite ($f_1=f_0$ - f_{ci}) power to the f_0 power ratio. It is necessary to emphasize that the first satellite power is a quarter of the pumping wave power. Higher harmonics of f_{ci} power have maximum at poloidal angle of about 0^0 too (Fig. 3). The satellites power in most experiments has additional maximum at poloidal angles from 100^0 to 140^0. Notice that the peripheral plasma param-

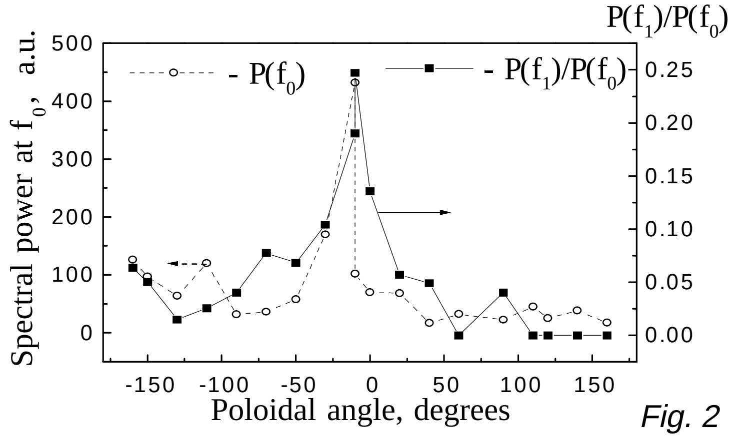

Fig. 2

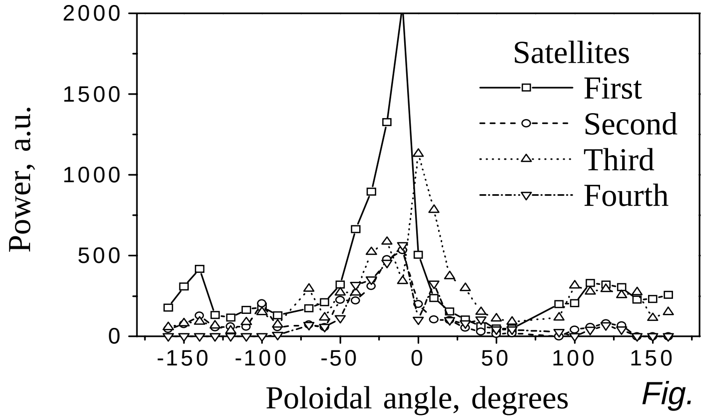

Fig. 3

eters have peculiarities in the same range of angles. Variations in frequencies of the satellites observed at different poloidal angles show that there is a connection between the frequency $f_0 - f_{ci}$ and the local value of magnetic field. For the frequencies $f_n=f_0 - n * f_{ci}$, where $n \geq 2$ this connection is not so obvious. It could be account for cascade decay character.

Plasma column shift caused significant changes in the character of spectra. Outward shift of plasma column (when it is closer to the grill) was followed by the abrupt suppression of ion cyclotron harmonics. This case is illustrated in Fig. 4. Spectrum of central plasma column central position is shown by dashed line. (The same spectrum was observed in inward shifted plasma.) It is clear that $f_n=f_0 - n*f_{ci}$ frequency waves power is comparable to pumping wave power. Solid line in Fig. 4 refers to outward shifted plasma. Power of f_n wave is very small, so we could conclude that parametric decay is suppressed.

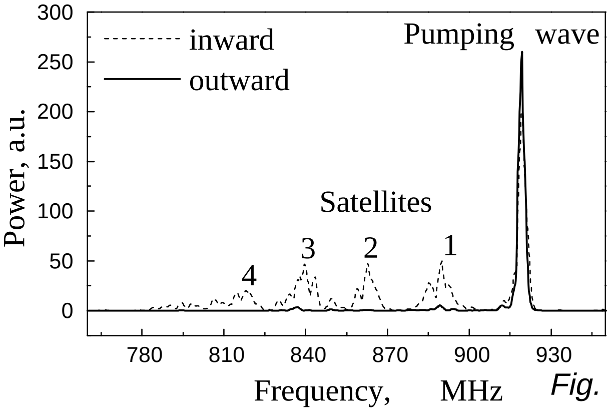

Fig. 4

It was shown that parametric instability process essentially depends on the edge plasma parameters near the grill. Fast ion generation, electron temperature and density rise observed at r=5-6 ($n_e = 2*10^{13}$ cm^{-3}) evidence that non-central absorption of RF power takes place in case of central and inward shifted plasmas. Outward shift of plasma column increases the electron temperature above the threshold of parametric instabilities [5]. They are not observed in these conditions and the wave seems to penetrate to the plasma center and absorbed by ions at LH resonance. This is proofed by that fact that ion temperature grows linearly during whole RF 4 ms pulse and the increase of ion temperature from 90 up to 350 eV, 4-fold increase of energy lifetime and the absence of the direct interaction of the wave with electrons [2].

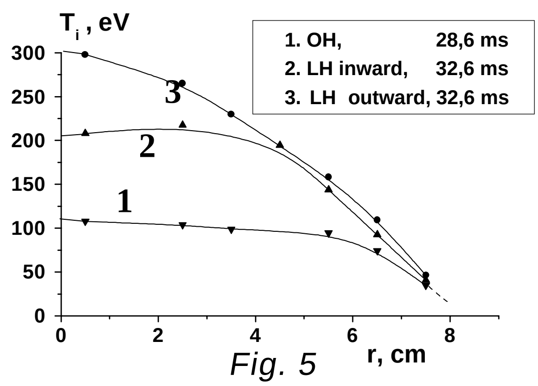

Fig. 5

Ion heating was very different also. In inward shifted plasma the increase of ion temperature $\Delta T_i(0)$ is equal to 100 eV and occurs only for 1 ms. Fig. 5 presents a chord distribution of the ion temperature measured by CX diagnostics. The distribution in outward case is typical for the central power deposition and in inward is typical for the non-central one. An analysis using ion energy balance equation shows that really the RF power absorbed in the

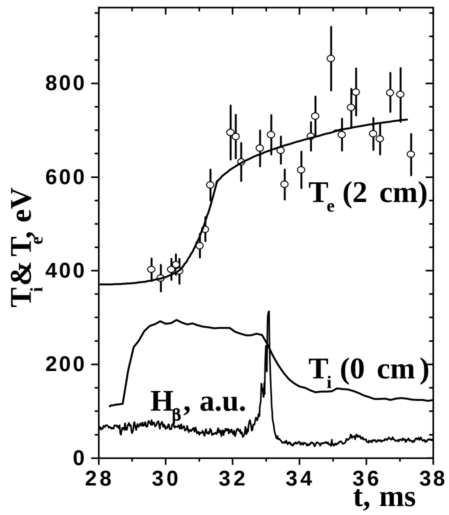

Fig. 6

center in the outward shifted plasma is equal to P_{RF} = 28 kW and in other case, absorbed RF equal to 37 kW and absorbs at on the middle and periphery at r=4÷6 cm. It is necessary to note that in the experiment without shifting plasma column but when the higher electron temperature is realized, the high ion heating in center is observed. Such plasma parameters $T_i(0)$, $T_e(2$ cm) and H_β are shown in Fig. 6. The ion temperature profiles for different moments of LH experiment in this case are shown in Fig. 7. One can see the central increase of the ion temperature from 100 eV up to 300 eV. The increase of the T_e can be connected with L - H transition during LH heating. This fact can explain the conservation and increase of the electron temperature in post heating (PLH) phase. With this seems the large gradient of ion temperature is connected at the periphery in PLH.

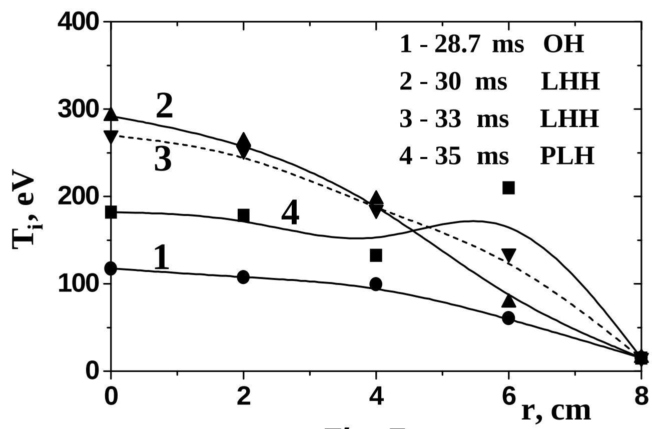

Fig. 7

So, there is a correlation between the excitation of the parametric instability and the absorption of the LH waves. More slowed-down daughter waves are absorbed not reaching the plasma center.

Acknowledgement

The research described in this publication was possible partly by INTAS-RFBR 95 -1351, RFBR 97-02-18084 and RFBR 98-02-18346 Grants.

References

[1] V.N. Budnikov et al.: *24th EPS Conf. on Cont.Fus. and Pl.Phys* , Berchesgaden, 1997, II 681

[2] V.N. Budnikov et al.: Tech. Phys. Lett. **23** (1) 1997, 32 - 34

[3] L.A. Esipov et al.: Tech. Phys. **42** (4) 1997, 367 - 373

[4] A.N. Levitskii, I.E. Sakharov and S.V. Shatalin: Prib. Tekh. Eksp.**5**, 1992, 153 - 157

[5] V.N. Budnikov et al.: *2nd EPS RF Heating and CD of Fus. Dev* , Brussels, 1998, 161 - 164