Influence on gyrotron radiation of the low reflected modulated power. New experiments

N.K. Kharchev[1], Alvaro Cappa[3], M.I. Petelin[2], Yu.F. Bondar[1], V.D. Borzosekov[1], E.M. Konchekov[1], D.V. Malakhov[1], Jose Martinez[3], Yu.V. Novozhilova[2], K.A. Sarksyan[1], A. Tolkachev[3]

[1] *Prokhorov General Physics Institute of Russian Academy of Sciences, Moscow, Russia*

[2] *Applied Physics Institute, Nizhny Novgorod, Russia*

[3] *CIEMAT, Madrid, Spain*

The problem of the gyrotron reflected from plasma radiation influence on the gyrotron direct radiation is significant for the ECRH realization, the use of a gyrotron radiation scattering for plasma diagnostics purposes and for gyrotron radiation electrodynamic calculations. However, until recently, it was neglected that weak reflection from plasma affects a gyrotron. The experiments on L-2M stellarator [1] shown that during ECRH gyrotron power is modulated by reflection and radiation frequency spectrum broadens. For a detailed study of this effect in [2, 3] has been proposed to use as a reflector a metallic plate oscillated with fixed amplitude and frequency. It was confirmed that gyrotron becomes modulated with a period of the reflector oscillations and the modulation character depends on the reflected wave phase, so phase modulation of gyrotron direct radiation takes place. Besides, theoretical assumption that seems to describe effect under consideration was presented.

The main tasks of new experiments were 1) to increase the modulation frequency of reflected power from 200—400 Hz up to 1.2 kHz; 2) to measure with high accuracy the spatial distribution of the gyrotron radiation characteristics in several planes perpendicular to the gyrotron beam in the regime with low reflected power.

To measure the spatial distribution of the gyrotron radiation the new quasi-optical divider and ortho-mode coupler (permitting to measure both linear polarizations of gyrotron beam) were used. Reflector shifting allowed to change the reflected radiation phase. By data of the Gaussian beam modulation and the modulator signal the phase pictures can be obtained. If at all points across the width of the Gaussian beam the modulation phase is the same, the modulation of the gyrotron radiation fundamental mode takes place. If at different points across the width of the Gaussian beam the modulation phase changes to the opposite sign, it should consider the possibility of Gaussian beam deformation. Figure 1 shows the correlation coefficients between the signals of the modulator and the fundamental mode gyrotron radiation of the Gaussian beam for two positions of the reflector at a distance of 1 mm. At the edge of the Gaussian beam gyrotron radiation the correlation coefficient is maximum (curves 46mm and 58mm) and has the opposite sign for different reflector positions. This suggests a possible deformation of the Gaussian beam gyrotron radiation.

The modulator position change leads to changing of the gyrotron radiation modulating phase. On the other hand, for the same position of the phase modulator at different points of the Gaussian beam the gyrotron radiation modulating phase varies. This confirms the influence of the partly backward reflected into the gyrotron own radiation on the shape of the gyrotron output Gaussian beam. Besides of changing of the gyrotron radiation main harmonic output power a saturation of the gyrotron Gaussian beam by higher harmonics is occurred when partly backward reflected own radiation penetrates in the gyrotron. It results to varying diode detector reactions in different points of the Gaussian beam.

Reproducibility of the results is shown in Figure 2. For five different shots the correlation function is the same for the same points in space.

Besides, the use of the ortho-mode coupler shown (Figure 3) a difference in the distribution of the vertical and horizontal field components that indicates the polarization change across the Gaussian beam.

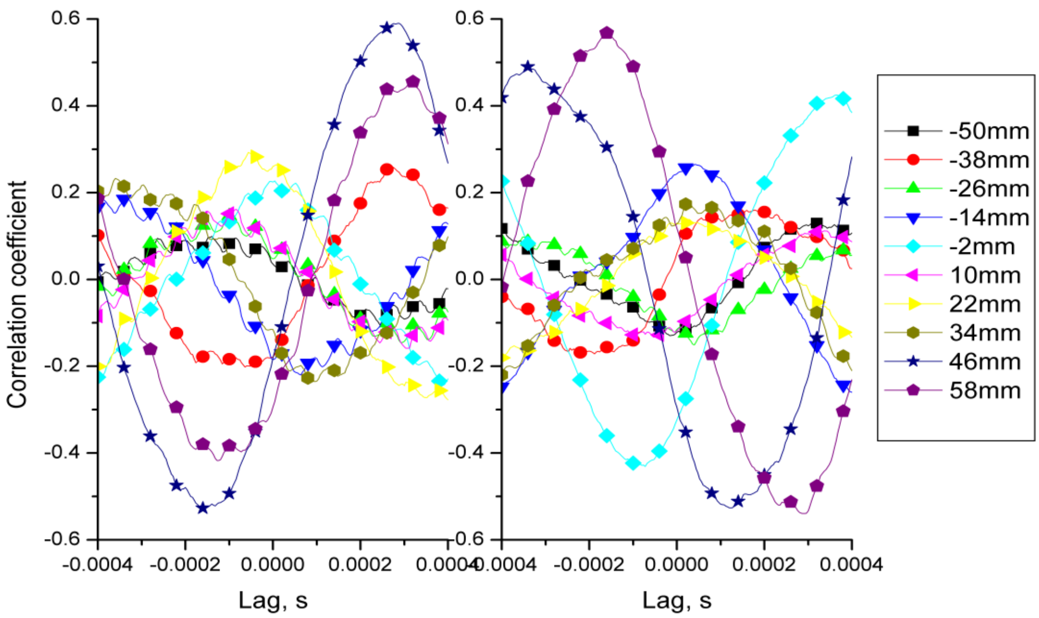

Figure 1. Spatial dependence of correlation coefficient between gyrotron radiation and modulator sygnal at modulator frequency 1200 Hz for two reflector positions shifted from each other by 1 mm. The reflection influence on the gyrotron at the Gaussian beam periphery is sufficient than in the beam center.

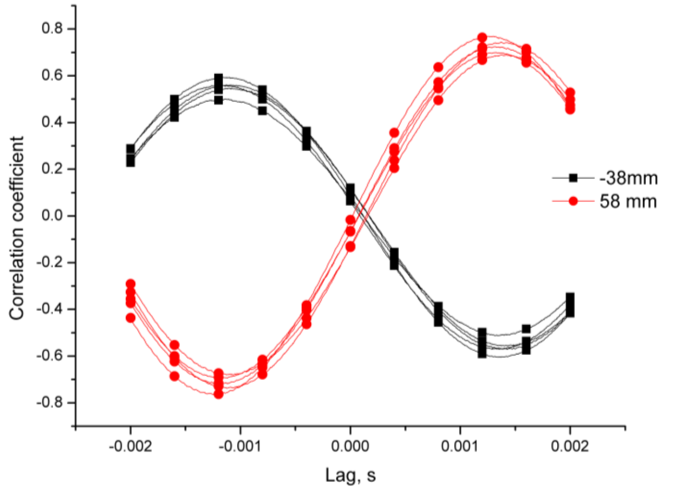

Figure 2. Example of the repeatability of behavior of correlation function.

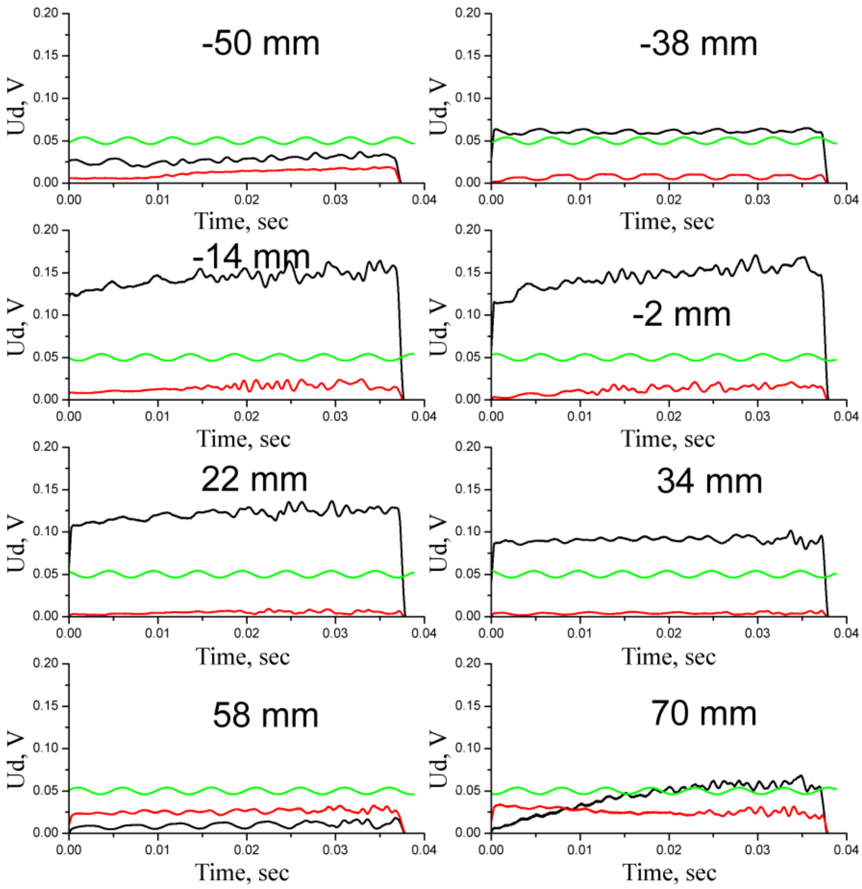

Figure 3. Signals from ortho-mode coupler for 8 points across the Gaussian beam. Black — vertical channel, red — horizontal channel, green — modulator signal.

Two possible mechanisms were considered theoretically for the experiment.

1. A wave reflected from a remote load and returned to the gyrotron cavity has counter-rotate direction and, thus, orthogonal relative to the operative mode. The interaction between this

operated mode and the reflected wave is quadratic to the reflected wave amplitude. This double-reflected wave flow turns scattered in a broad angle of directions on periphery of Gaussian beam due to not-matched to the mode convertor. Thus, the counter-rotating wave influences the central part with “traditional” effects described by common theory for auto-oscillator generator [4-6].

2. In the practical case, the conversion of the operating mode to the Gaussian wave beam is not quite 100% efficient. Accordingly, the part of wave can be reflected from the load and returned to the gyrotron cavity in the form of wave co-rotating to the operating mode [7]. As the resulting, gyrotron-load coupling is linear and due to the non-matched load the influences on gyrotron will depend on the phase of the reflected power.

Summary

It was shown: 1) that maximum influence of reflected modulated signal on gyrotron radiation takes place on periphery of Gaussian beam; 2) the statistical material allows to make conclusions that a good reproduction of experimental results takes place; 3) influence of the small reflected power on the gyrotron radiation is including the deformation of the Gaussian beam too; 4) the possible mechanisms of influence of the small reflected power on the gyrotron radiation are considered too.

The study was supported by The Ministry of education and science of Russia project 8392; Russian Academy of Sciences presidium programme 12 “Fundamental processes in high-temperature plasma with magnetic thermo-insulation” and RFBR project 11-08-01129.

References

1. G.M. Batanov, L.V. Kolik, Yu.V. Novozhilova, et. al. // Technical Physics, 2001, Vol. 46, N5, pp. 595—600.

2. Fernandez A., Tolkachev A., Kharchev N., Bondar Yu., Sarksyan K., Petelin M. // International Journal of Infrared and Millimeter Waves, 2007, T 28, N9.

3. N.K. Kharchev, A. Fernandez, M.I. Petelin, et. al. // Applied Physics, 2009, N6, pp. 158—165.

4. Yu.V.Novozhilova, N.M.Ryskin, S.A.Usacheva. Nonstationary // Technical Physics, 2011, Vol. 56, No. 9, pp. 1235–1242

5. Yu.V.Novozhilova // Izv.vuzov. Applied Nonlinear Dynamics., 2011, V.19, No.2, pp. 112-127.

6. Yu. V. Novozhilova, A.S. Ishenko // Journal of Infrared, Millimeter, and Terahertz Waves: V.32, No 12 (2011), P. 1394-1406.

7. Yu.V.Novozhilova, N.M.Ryskin, Chumakova M.M. // Applied Nonlinear Dynamics., 2011, V.20, N6, pp. 136- 147.