X-ray Spectroscopy of the Megaamper Z-pinches

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Influence of the plasma material on radiation spectra of the high current Z-pinch is investigated. Two different diagnostics (transmitting grid and reflection crystal) for spectroscopy in to the whole of spectral diapason E_{hv} = (50 – 5000 eV) are used. Experimental and calculation results are compared.

1. Introduction

The investigation results of the plasma radiation in Z-pinches at Angara-5-1 facility (currents up to 5 MA) are presented. Multiwires cylindrical W and Al arrays with diameter 12 – 20 mm and the wires diameter 5 –20 μm are used as starting base of the pinch. The column of the dense high temperature plasma with diameter ~1 mm is formed at the final stage of the pinch compression. This plasma radiates soft X-ray (E_{hv} = 50 – 5000 eV) with total issue up to 50 kJ during 5 – 10 ns. To use this X-ray source for different applications it is necessary to know and to control the spectral characteristics.

2. Methods

There are two X-ray spectroscopy diagnostics used for this goal. Diagnostics on the base transmitting diffraction grid is used for analysis of the pinch radiation into very soft spectral region ($E_{hv} \leq 1000$ eV). Parameters of the grid are the following: material – Au, thickness – 0.6 μm, grid period – 1.4 μm, number of lines is 50. The special film is used as detector of X-ray spectra. To protect the grid from hard electrodes products valve is applied with the time closing ~ 500 μs. Spectrograph with convex mica crystal (2d = 19.9 A) measure the radiation spectra by energy quanta more than 1000 eV. The linear CCD (2048 cells with dimensions 15×15 μm^2) is used for the detection spectral distribution in this device. CCD interface and software provides online processing and presentation spectral picture.

The theoretical model of nonequilibrium radiating multicharge ion plasma, which takes into account the radiation transport and level kinetics of electrons, is used for analysis the experimental data.

3. Results

It was shown that with optimal parameters of the liner (weight, diameter) for current generator the radiation spectrum is determined by atomic weight of wires.

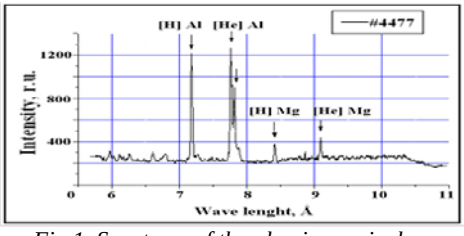

Fig.1. Spectrum of the aluminum pinch.

The pinch radiation of aluminum liners has typical line spectrum (see Fig.1.) which is in agreement with calculations. The [H] and [He]-like lines of aluminum ions are the most intensive. Also one can see K-lines of magnesium that is presented in the using wires (several per cents). The analysis by means comparison of these line intensities gives the following plasma parameters: $T_e \sim 550$ эВ, $n_e \sim 3 \cdot 10^{20}$ см$^{-3}$ [1]. The increase in the atomic number of substance gives a very high reduction in the intensity of spectral lines. For example, the including small quantity of tungsten wires (about 10%) in to aluminum liner gives decreasing the spectrum line intensity more than one order. The subsequent increasing of tungsten wires transforms the line spectrum into quasi-continuous.

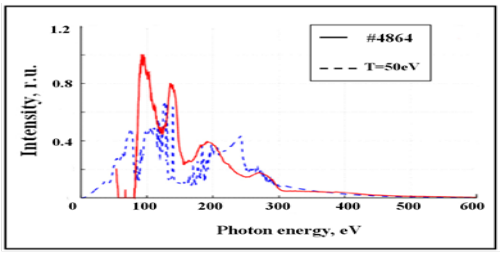

Fig.2. Experimental and calculated spectra of the tungsten pinch.

The large-scale computations were carried out for parameters close to those of the experiment. The atlas spectra form for wide W-plasma parameters (T_e, n_e) was made. The comparison shows that the closest modeled spectra to the experimental data (fig.2) correspond to the following parameters of tungsten plasma: $T_e \sim 60$ eV, $n_e \sim 10^{21}$ cm^{-3}[2]. Some differences in the shape of the spectra can be explained by the simplifying details of the model.

These researches are supported by the RFBR grant 11-02-01027-a.

References

[1] G.S.Volkov, V.I.Zaitsev, E.V.Grabovski et al., Plasma Physics Reports, v.36, N.3, pp. 191-215, 2010

[2] Vichev I. Yu., Novikov V. G., Solomyannaya A. D. plasma//Mathematical Models and Computer Simulations, 2009, v. 1, N.4, pp.470–481