Spectroscopic study of radiation from Low-inductance vacuum spark

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Abstract. A research of radiation spectra of a low inductance vacuum spark in visible and ultraviolet regions was realized. Time dependences for hydrogen atom lines, and so for iron atom lines and iron ion lines were obtained. Temperature of an external plasma cover was determined.

1. Introduction
The study of low-inductance vacuum spark is performed to simulate characteristic high-temperature plasma processes. X-rays are widely used to analyze behavior of z-pinch plasma[1]. To study the more rarefied peripheral areas of plasma visible and ultraviolet spectra radiation can be used.

2. Experimental setup
We used an electrode system consisted of an anode (3 mm in diameter, made of steel and copper) and a steel cathode (20 mm in diameter) in our experiments. The electrodes are 4-5 mm away from each other. Operating pressure in a chamber is within 10⁻⁴-10⁻⁵ Torr range. The initial voltage is 5-15 kV. The discharge is driven by triggered ignition. The discharge current is within 100-150 kA range with period of 8.5 μs. A 1-2 mm-diameter pinch is formed under the influence of high current. The pinch is surrounded by a more rarefied plasma shell. Furthermore generation of micropinches can be observed in anode’s vicinity. The concentration of plasma in pinch area was measured (n_e=10¹⁷-10¹⁹ sm⁻³) by laser interferometry [2]. X-ray radiation spectrum of pinch and micropinches is comprised of lines of multicharged Fe and Cu ions.

Spectra of vacuum spark in ultraviolet and visible ranges was obtained by Ava Spec 2048 spectrometer (operating range of 200-1000 nm, spectral resolution of 0.3 nm). Monochromator MUM (operating range of 200-800 nm, spectral resolution of 0.2 nm) and photomultiplier PMT-85 (time resolution of 5ns) were used to record temporal dependences.

Steel electrodes were used in the experiments. Radiation was registered from plasma shell of 8-10 mm in diameter. Discharge spectrum in ultraviolet and visible ranges contained a number of intense spectral lines and had a considerable continuous component. Radiation of H, 434 nm, Hα 656 nm and Hβ 486 nm hydrogen lines was observed (figure 1(a)). These lines are apparently a result of presence of water vapor in residual gas in the facility. Besides that, intense lines of Fe were observed (see figure 1(b)).

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3. Discussion

The panoramic spectrum of vacuum spark allowed us to obtain general information on basic elemental composition of plasma and integral intensities of the corresponding lines of elements. Temporal dependencies of separate spectral lines were studied to figure out evolution of discharge radiation in time. Figure 1(a) shows typical temporal dependences of Hα 656 nm and Hγ 434 nm. Radiation pulses of these lines have a leading edge of 0.4-0.6 μs at pulse durations of 2.0-2.5 μs. Maximum of intensities of these lines correlate with discharge current maximum. The presence of these hydrogen lines in all the peripheral area of pinch allows diagnostics by relative intensities of spectral lines. It was supposed that pinch shell was in local thermal equilibrium. Calibration of intensities of studied lines was carried out by calibration lamp SIRSH6-100. Using relative intensity method [3] and H lines data, plasma temperature at applied voltage $U=14$ kV was measured ($T=3600\pm 300$ K). Radiation of Hα and Hγ lines after decreasing the current to a minimum value may occur due to the presence and radiation of excited hydrogen in the vicinity of the electrodes.

Figure 1(b) shows typical time dependences of spectral lines of atoms and ions of Fe: Fe I 382 nm and Fe II 523 nm. Compared to H lines radiation pulses of Fe lines have steeper leading edge with duration of 0.2-0.3 μs at pulse duration 2.5-3.5 μs. Thus, we can assume that at the initial stage of pinch formation plasma shell is sufficiently transparent for wavelengths of Fe spectral lines. Maximum of Fe lines intensities coincides with the moment of maximal plasma compression which was determined from the discharge current signal.

The spectral measurements of radiation of low-inductance vacuum spark in visible and ultraviolet spectrum ranges carried out in our experiments allow us to determine the composition of plasma shell. Radiation evolution of spectral lines of atoms and single-charge ions was registered. The study of the initial stage of discharge development and plasma shell properties was performed at the moment of pinch formation.

References

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