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Particularities of formation of multiply charged ions at the interaction of laser radiation with two-element PbMg targets

R.T. Khaydarov, S.A. Kondrashev[1], D.H.H. Hoffmann[2], M.G. Khalmuratov,
E. Tojikhonov, G.R. Berdiyorov, B.Yu. Sharkov[1]

Research Institute of Applied Physics at the National University of Uzbekistan, Tashkent,
[1]Institute for Theoretical and Experimental Physics, Moscow, Russia,
[2]Gesellschaft fuer Schwerionenfprschung (GSI). Darmstadt, Germany.

e-mail: ragab@iaph.tkt.uz

Laser source of ions enables one to get larger intensity for multiply charged ions in a single injection, practically in any elements of synchrotrons. For its practical use, one needs to enlarge ions' impulse, keeping the intensity and charge of ions the same. This effect can be realized using multielement targets. It was shown [1,2] that the energy spectra of ions obtained at the interaction of the laser radiation with multielement targets appreciably differ from the spectra of ions obtained from single element targets. In the case of multielement targets the exchange of energy between ions of different mass is observed, which leads to the widening of energy spectra of both light and heave ions. Authors of Ref. [3] investigated the ionization process and expansion of laser-produced plasma when the target consists of two elements with different masses (NaF, NaCl, NaBr, $CuCl_2$, Cu Br_2, $PbCl_2$, PbI_2). It was shown that the presence of these two kinds of elements influences to the formation of energy spectra and to the charge composition of plasma.

In previous experiments they normally used either multicomponent targets with complex structure or single component targets, which makes it difficult to change fluently concentration of different elements and also to describe experimental results. In the present work we investigate physical properties of multiply charged plasma ions, formed under the action of laser radiation on two element (PbMg) targets at different concentration of Mg (n =15%, 25% and 35 % of the total target mass).

Experiments were carried out in a laser mass-spectrometer with mass resolution of $m/\Delta m$ ~100 and time-of-flight distance L=100 cm, which was described in detail in Ref. [4]. The Neodymium glass laser, working in the frequency mode was used in experiments and the laser beam was directed normal to the surface of the target. The duration of the laser impulse is 15 ns and the power density of the laser radiation at the target surface is $q=5\ 10^{10}$ W/cm^2. The peak power of laser radiation varied within 5 % and the experimental

value are average over five impulses of a laser radiation. All experiments were carried out at the same inertial conditions (vacuum (10^{-6} Tor.), focusing condition of laser radiation, parameters of electrostatic mass-spectrometer, etc). The construction of the target chamber allows one to put 10 targets with diameter 10 mm and change the place of interaction of laser radiation with target. Experiments were carried out at $q=5\cdot10^{10}$ W/cm^2.

Experimentally observed mass-charge spectra of PbMg plasma ions for the different concentration of light element (n=15%-35%) shows that the plasma consists of Pb and Mg ions and the increase of n leads to the change of mass composition of plasma and intensity of ions. These changes are clearly seen at relatively low energy of ions E/Z ≤ 80 eV. Figs. 1(a,b) show the mass-charge spectra of multicharge ions from mono-(Pb) and two-element (PbMg) plasma. It is seen from this figure that the inclusion of light element into the plasam leads to decrease of the charge of Pb ions and to the increase of speed of these ions. The maximal charge of ions of monoelement Pb (Mg) plasma equals Z_{max}= 5 (4), while

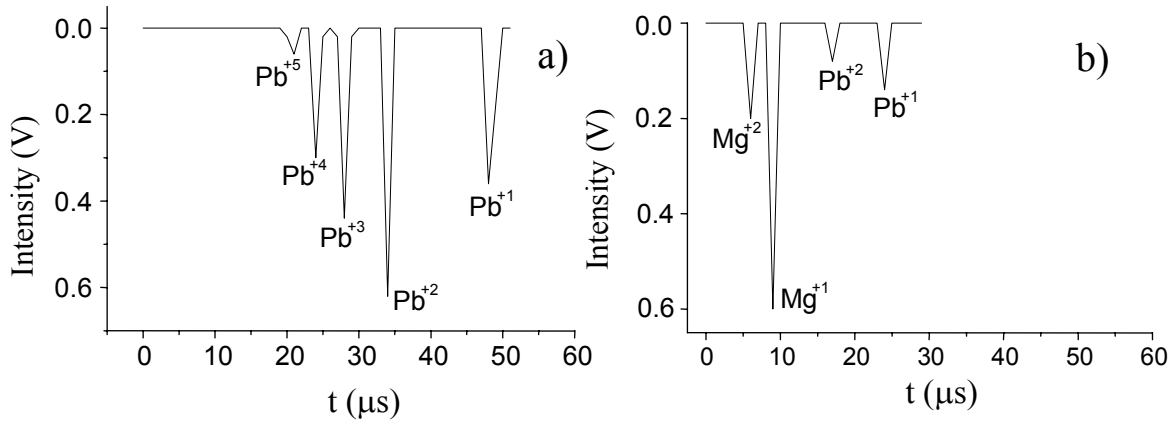

Fig. 1. Mass-charge spectra of two-element PbMg plasma for the concentration of Mg 0% (a) and 35% (b). The energy of ions is E/Z= 80 eV.

the maximal charge of Pb (Mg) ions from two-element PbMg plasma is Z_{max}=4 (3). It is possible to detect Mg ions with maximal charge Z_{max}=3 together with Pb ions with charge Z_{max}=4 at the energy intervals 800-2500 eV for Pb ions and 250-800 eV for Mg ions. For relatively higher energies of ions (E≤1000 eV) peaks of Mg ions disappears, and peaks of Pb ions are clearly seen.

On the base obtained mass-charge spectra of ions of mono- and two-element plasma we plotted energy spectra of ions for different n. Typical energy spectra of ions from mono-(Pb) and two-element plasma for n=0%, 35%, and 100% are given in Figs. 2(a-c), which show that ions of mono element plasma have energy range (0-2000 eV for Pb ions and

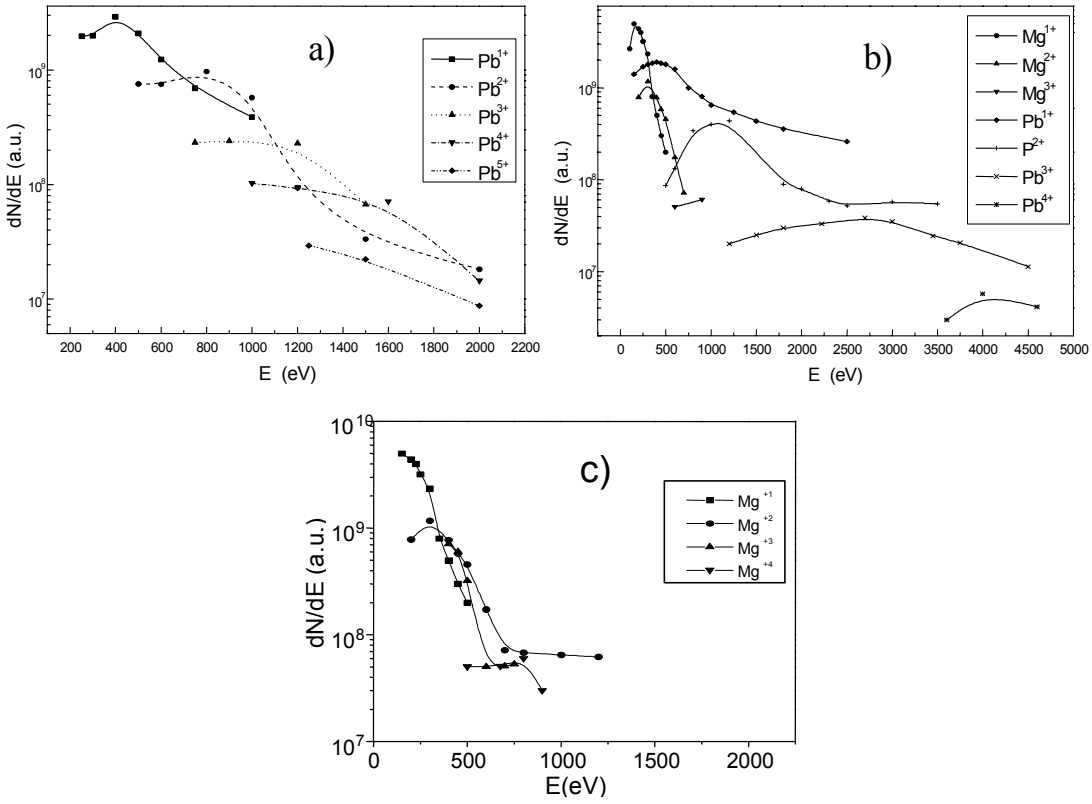

Fig. 2. The energy spectra of ions from mono (Pb and Mg) and two-element plasma for the concentration of Mg 0% (a), 35% (b) and 100% (c).

0-1000 eV for Mg ions) with a maximum of energy distribution. This maximum is shifted for larger energy values with increasing the charge of ions. The energy spectra of two-element plasma ions also have such a tendency but in this case energy diapason of Pb ions increase up to 4500 eV, while energy diapason of Mg ions decreases and equals to 650 eV. With increasing the concentration of Mg ions from 15% to 35% the energy spectra of Mg ions decreases essentially and energy spectra of Pb ions enlarge to higher energies. To our knowledge, the increase of energy range of two-element plasma ions in comparison with mono-element plasma is due to the change of recombination processes and this effect can be used to control the charge and intensity of ions.

Fig. 3 shows the intensity of Pb ions as a function of the concentration of Mg ions. It is seen that the intensity of Pb ions with charge $Z \leq 3$ increases with increasing n, while the intensity of Pb ions with charge $Z=4$ does not depend on n.

The enlargement of energy spectra to high energies and the presence of the maximum in spectra show that, processes in two-element plasma can be considered in two stages. In the first stage (up to the maximum of distribution) intense ionization takes place entailing the

increase of multiply charged Mg and Pb ions, included into the target at different concentrations. The second phase (after the maximum) is characterized with increase of recombination processes, i.e. with energy exchange between light (Mg) and heave (Pb) ions of plasma.

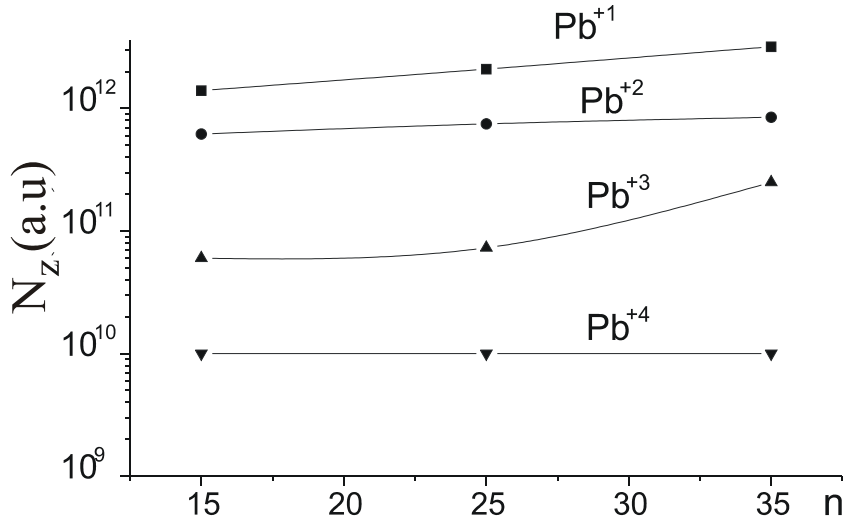

Fig.3. Intensity of Pb ions N_z as a function of the concentration *n* of Mg.

Our experimental results can be described by the theoretical calculations given in Ref. [5], which show that in such cases collisional limit of speed of all components of plasma becomes equal, energy does not depend on the charge it becomes proportional to the mass, i.e. $E_k \sim M_k$. We can conclude that the formation of charge and energy spectra of multiply charged Pb and Mg ions from two-element plasma depends on not only ionization, recombination processes, but on the interaction of light and heave ions of the plasma.

To summarize, we have shown experimentally that with increasing the concentration of Mg the energy spectrum of ions enlarges more than two times due to the exchange of energy between light and heave ions. The intensity of Pb ions of all charge increases with increasing the concentration of Mg, though character of change of intensity does not depend on the concentration.

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