LUMINESCENCE OF GASES INDUCED WITH EUV PULSES FROM A LASER PLASMA SOURCE

A. Bartnik *, P. Wachulak, H. Fiedorowicz, R. Jarocki, J. Kostecki, and M. Szczurek

Institute of Optoelectronics, Military University of Technology, Kaliskiego 2, 00–908 Warsaw, Poland

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* *e-mail*: abartnik@wat.edu.pl

Ionization of a gaseous medium can be obtained by an electrical discharge or intense laser pulse irradiation. In both cases the electron collisional ionization is a dominating mechanism leading to plasma creation. In both cases electrons are accelerated by an electric field and some threshold must be exceeded to initialize the discharge or a laser spark. Quite different possibility offers irradiation with X-rays or extreme ultraviolet (EUV). In this case a single photon carries enough energy to ionize any atom or molecule. Thus ionization is possible even with low intensity radiation beams. Some photoionization experiments were performed on high power laser or Z-pinch facilities for laboratory simulation of astrophysical plasmas [1, 2].

In this work different gases were irradiated with a focused EUV beam from a laser-plasma source. In the experiments, a 10-Hz laser-plasma EUV source, based on a double-stream gas-puff target, irradiated with the 3-ns/0.8J Nd:YAG laser pulse, was used. The radiation was focused using a gold-plated grazing incidence ellipsoidal collector, manufactured in Reflex s.r.o., Czech Republic. The collector allowed for effective focusing of radiation emitted from Kr/Xe plasma in the wavelength range $\lambda = 9 \div 70$ nm. The most intense emission was in the relatively narrow spectral region centered at $\lambda = 11 \pm 1$ nm. The spectral intensity at longer wavelength range was much smaller, however, the spectrally integrated intensities in both ranges were comparable. The EUV fluence in the focal plane of the collector exceeded 60 mJ/cm^2 in the center of the focal spot. Detailed description of the source and parameters of the focused EUV radiation can be found elsewhere [3].

Irradiation of gases injected into the interaction region resulted in ionization and excitation of atoms and molecules. Spectra in EUV/VUV range were measured using a grazing incidence, flat-field spectrometer (McPherson Model 251), equipped with a 450 lines/mm toroidal grating. Examples of the spectra for neon and helium gases are shown in Fig. 1.

In both cases the most intense emission lines were assigned to singly charged ions. The other emission lines belong to neutral or doubly ionized atoms. The spectra were excited in low density gases of approximately 2% of atmospheric density, however increase to 10% of atmospheric density, the spectra can be also obtained. Both spectra consist of multiple lines with one dominating line, corresponding to singly ionized atoms. In case of helium ions the line corresponds to 1s-2p radiative transitions, in case of neon to $2s^22p^5 - 2s2p^6$ transitions. The other helium lines correspond to $1s - np$ transitions in He II ions or $1s2 - 1snp$ transitions. These lines are much less intense comparing to the dominating line, thus quasi - monochromatic radiation can be obtained. This is different situation comparing to dense He plasma, where a relative intensity of the $1s - 3p$ is significantly higher. In case of neon spectrum there are multiple Ne II lines corresponding to $2s^22p^5 - 2s^22p^4nl$ transitions. Two very weak lines can be assigned to 2s^{2}2p^4-2s2p^5 transitions in Ne III ions. There are also two lines that correspond to $2s^22p^6 - 2s2p^53s$ of neutral atoms. This spectrum is quite different comparing to neon spectra excited by free electron laser FLASH with a wavelength 32 nm. The dramatic difference corresponds especially to two Ne II lines: $2s^22p^5 - 2s2p^6$ at the wavelength 46.1 nm and $2s^22p^5 - 2s2p^43s$ at 44.6 nm. The intensity ratio of these lines in both

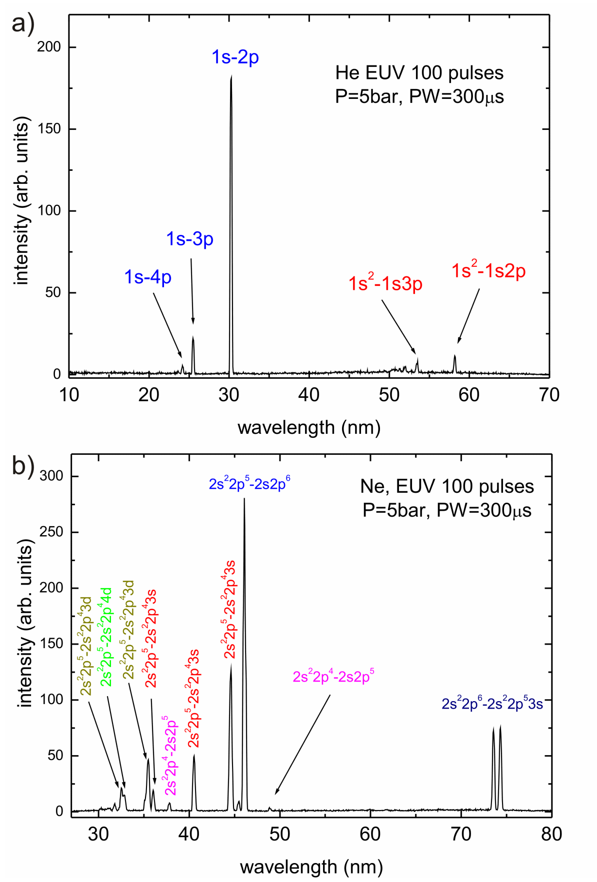

Figure 1: Spectra of gases ionized with EUV radiation pulses from a laser-plasma source: a) helium, b) neon

cases is opposite. These lines come from transitions in the same ion species, thus the difference cannot be referred to different ionization degree. It is thus connected with different excitation mechanism.

Some differences were also observed in case, when the gases were excited with radiation of the laser-plasma EUV source limited to the wavelength range close to the emission maximum at 11 nm. The spectra for helium and neon are presented in Fig. 2. Also in this case some interesting effects can be noticed. Irradiation of helium gas with the short wavelength part of EUV radiation selected with a Zr 140 nm filter results in relative increase of intensity of the $1s^2-1s2p$ line in respect to $1s^2-1s3p$ and He II lines. In case of neon there was an opposite effect: strong decrease of relative intensities of

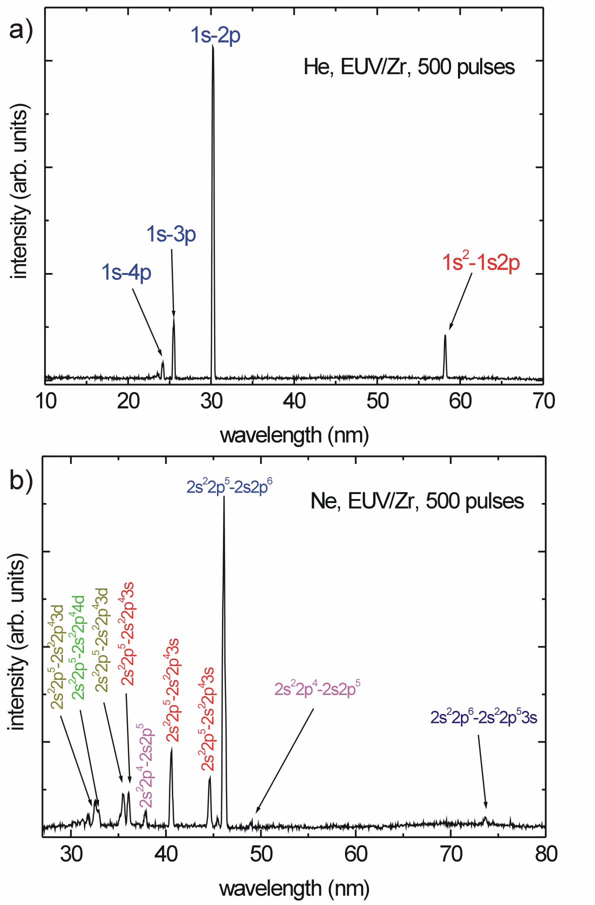

Figure 2: Spectra of gases ionized with radiation of the laser-plasma EUV source limited to the wavelength range close to the emission maximum at 11 nm, selected by Zr filter. EUV radiation pulses from a laser-plasma source: a) helium, b) neon.

Ne I emission lines in respect to Ne II lines. It is probably due to lower excitation probability of the $2s^22p^53s$ states by electron impact comparing to excitation of $2s^2p6$ or $2s^22p^4nl$ states in Ne II ions in case of high energy photoelectrons (about 100 eV). Without the Zr filter photoelectrons can have much smaller energies, because of the long-wavelength tail of the EUV spectrum and the excitation probability of Ne I electronic states is higher. Apart from that irradiation of Ne gas through the Zr filter results in relative decrease of intensity, of an emission line corresponding to the $2s^22p^5-2s^22p^43s$ transition at 44.6 nm. It should be pointed out that in case of the above mentioned experiment with FLASH, intensity of this line was the highest. On the other hand relative intensities of another two spectral lines, corresponding to transitions between the same subshells (with different spin configurations), at the wavelengths 36.0 nm, 40.5 nm respectively, remain almost unaltered.

The Zr filter used for wavelength selection reduces of course the total flux of the EUV radiation from the plasma source. Thus the above mentioned effects can be related both to narrowing of the EUV spectrum and decrease of the irradiation energy. Additional measurements with lower irradiation flux should be performed to clarify this issue.

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