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AR II AND AR III KINETICS IN THE AFTERGLOW OF PULSED HIGH CURRENT DENSITY HOLLOW CATHODE DISCHARGE

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We report a new population mechanism of Ar II energy levels in a high density current hollow cathode pulsed discharge which may be of practical interest in the investigation of population inversion and lasing of Ar II emission lines in the temporal afterglow plasmas.

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Keywords: Population mechanism of atomic and ionic energy levels, Hollow cathode pulsed discharge, Afterglow plasma

1. Introduction

As we have already mentioned in our previous papers [1-2], hollow cathode discharges provide favorable conditions for laser oscillation on atom and ion transitions.

In the present paper we report a new population mechanism of Ar I and Ar II associated to a large hump observed in the temporal profile of their emission lines in pulsed high current density argon hollow cathode discharges.

The detailed mechanism of the processes involved is not yet completely understood. In order to elucidate this mechanism we performed spectroscopic measurements with temporal resolution of atomic and multi-ionized argon ions. Also, we recorded argon spectrum by averaging the light signal acquired through a variable temporal gate during and after the current pulse.

2. Experimental set-up

The experimental set-up is presented in Fig. 1.

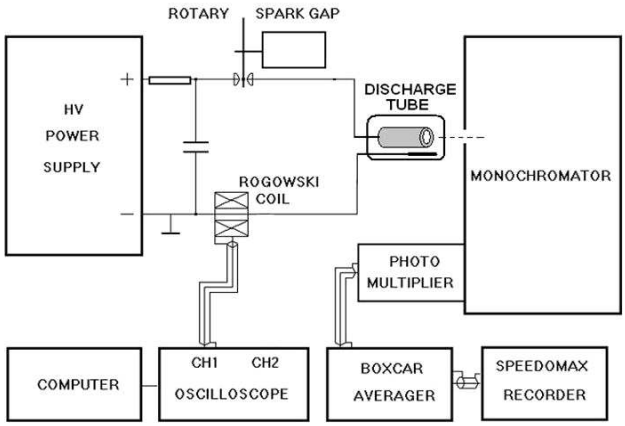

Fig. 1. Experimental setup.

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The glass discharge tube contains a cylindrical hollow cathode made of Lutetium (15 mm length and 4 mm diameter) and a stainless steel wire anode. High current pulses of short duration were obtained by discharging a storage capacitor C through a rotary spark gap with a commutation time below 10 ns [3]. Working at 5 torr filling gas pressure, we obtained peak current pulses with a 60 ns pulse duration in the range of 20-100 A, depending on the charging voltage of the main capacitor. The light emission of the pulsed plasma was filtered with 1-m Jarrell-Ash grating monochromator and detected with an EMI photomultiplier tube. The temporal profiles of the atomic and ionic spectral line in the range of 300 – 500 nm were averaged over 256 discharge pulses and recorded with a TEKTRONIX 2432A oscilloscope connected to computer. Using a boxcar averager with a variable electronic gate, we recorded the emission spectra at various times of the afterglow by opening the temporal gate at certain times.

3. Results and discussions

During the high current discharge pulse a large amount of excited argon atoms, Ar II, Ar III ions and also long-lived atomic and ion metastables are produced. The temporal profile of emission lines of Ar I, Ar II and Ar III during and after the current pulse are presented in Fig. 2.

The big hump observed in the early afterglow of ArI and ArII lines indicate the existence of a complex mechanism of ArI and ArII energy levels population during the afterglow.

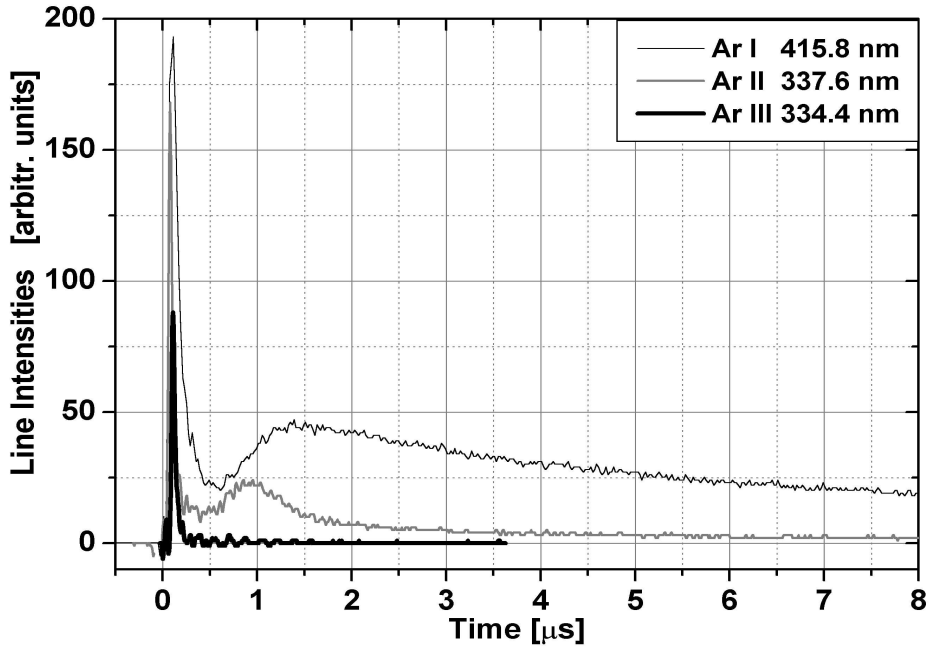

Fig. 2. Time evolution of Ar I, Ar II, Ar III spectral lines.

In order to elucidate this mechanism, we recorded the spectra in the range of 400 - 450 nm, Fig. 3, with a adjustable electronic gate positioned on the current and on the hump duration (see Fig. 3b).

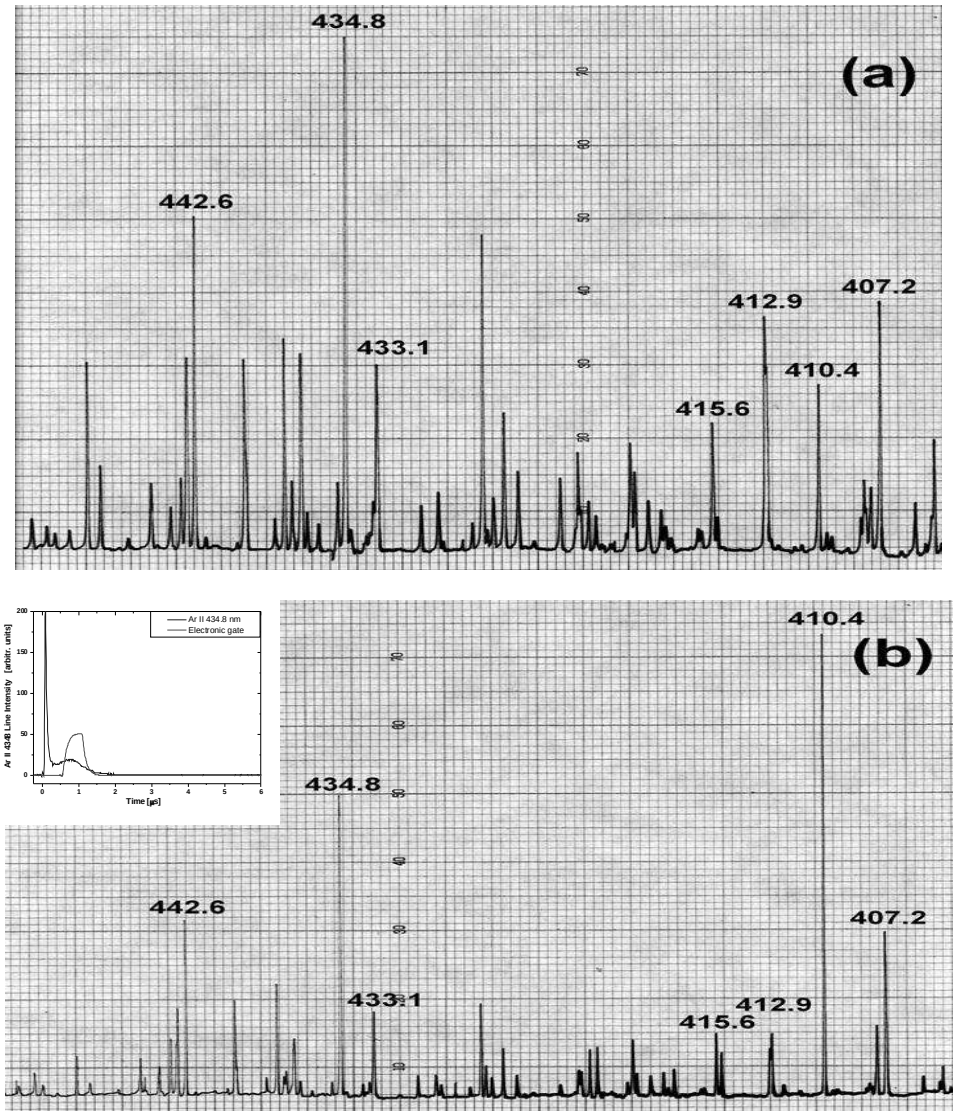

Fig. 3. (a) Emission spectrum during the current pulse; (b) Emission spectrum during the afterglow.

The difference between the Ar I and Ar II line intensities in the spectra recorded during and after current pulse shows that in contrast to the discharge period when the atom and ion excitation is caused mainly by impact with energetic electrons, during the afterglow the recombination processes play a major role in the Ar I and Ar II energy levels population.

Thus we presume that the presence of the hump profile in the temporal afterglow of Ar I and Ar II emission lines is due to recombination processes involving ions generated by metastable - metastable collisions, the atom and ion metastables being as it is already known the only source of excitation and ionization in the temporal afterglow plasma.

Starting from the temporal profile of Ar II transitions 4p $^4D_{7/2}$ (19.49 eV) – 4s $^4P_{5/2}$ (16.64 eV) at 434.8 nm and 5s $^4P_{5/2}$ (22.51 eV) – 4p $^4D_{7/2}$ (19.49 eV) at 410.4 nm, and taking into account their probability of spontaneous emission [4] a population inversion between 4p $^4D_{7/2}$ and 5s $^4P_{5/2}$ of Ar II energy levels occurs during the afterglow of the pulsed high current discharge as it can be seen in the Fig. 4.

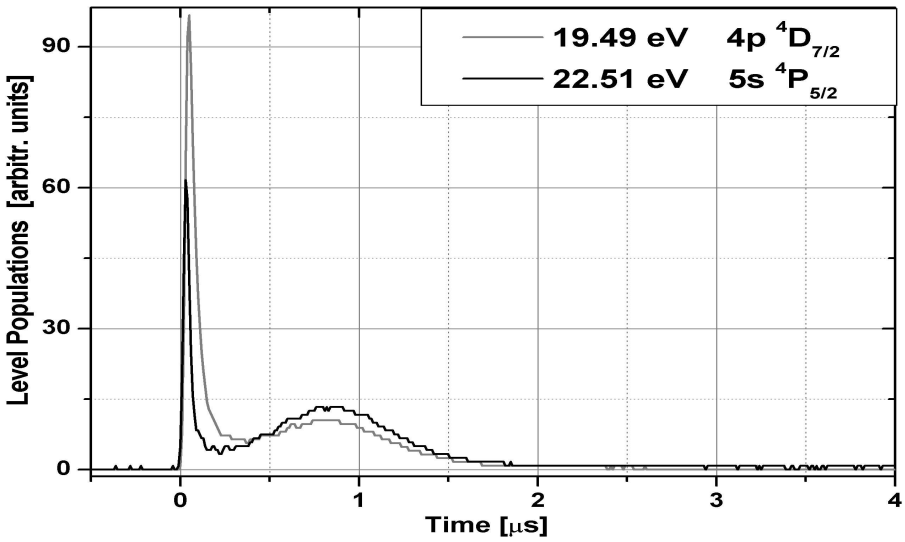

Fig. 4. Relative level populations time evolution.

4. Conclusions

The observed population inversion due to the population mechanism of Ar II energy levels in the temporal afterglow plasma, justify our farther interest for the high density current hollow cathode pulsed discharge as an efficient means of producing inversion and lasing with the argon ion transitions.

References

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