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A double monochromatization effect in low temperature plasmas

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In a number of previously published papers we presented the monochromatization of the noble gas spectra at the addition of hydrogen or oxygen to the noble gas discharges. As plasma source we used before pulsed or even d .c. low power discharge ($2kV$) peak to peak pulsed with the frequencies up to $10-20kHz$. In the case of the present experimental researcher we report the use of increased power with the voltage pulses up to $25kV$ and a frequency of 25 KHz This increased performance will extend the area of gas mixtures in which the M- effect can be established. Even, in present experiment we report the ignition of multiple gas discharges with one wavelength (monochrome) emission l.

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1. Introduction

The Monochromatization effect (M-effect) was put in evidence over 20 years ago by a research group at the National Institute for Lasers, Plasma and Radiation Physics - Bucharest. The effect consists in the emission of a single spectral line of plasmas ignited in certain gas mixtures. Since then, the effect was continuously studied both for finding new theoretical aspects of physics and also for its great potential for applications [1].

Correlating our experimental results on the M-effect with published data on various types of gas mixture discharges, we also put in evidence the main collision process responsible for the appearance of this effect. A three body collision was found to be the elementary process that generates the monochrome radiation. For a neon-hydrogen mixture discharge, the following three-body equation was found to generate the M-effect:

$$Ne^{+} + H^{-} + H^{*}(n=2) \Rightarrow Ne^{*}(2p^{1}) + H + H^{**}(n=3) \qquad (1)$$

where Ne^+ is the neon ion, H^- is the hydrogen negative ion, H^* is the excited hydrogen atom at the level (n=2), $Ne^*(2p_1)$ is the excited neon atom on the neon energy level $2p_1$, H is the hydrogen atom at the ground level and finally H^{**} is the hydrogen atom excited to the level n=3. Dezexcitation of Ne^*results in the emission of the single spectral line observed experimentally.

On calculation of the energy defect of equation (1), a value of 0.1 eV is obtained. The energy defect represents the difference between the energy-states values of the colliding particles on left side and also on the right side of this equation. Thus, equation (1) is energetically resonant. The energy-state values were taken from references [6-8]. Similar results values of the energy defect were obtained for other electropositive- electronegative gas mixtures also [9]. It was thus proved that the M-effect is due to a resonant recombination of the three body reaction (1).

The main feature of the M-effect is the fact that it can only be obtained in gas mixtures containing at least one electropositive gas and one electronegative gas [2]. Most experiments undertaken until now involved mixtures of a rare gas with either hydrogen or oxygen.

The current paper reports on new research on the simultaneous appearance of two M-effects in a discharge tube containing two rare gases and an electronegative gas, the hydrogen.

2. Experimental arrangement

The experimental setup used for the study of the simultaneous M-effect is shown schematically in Fig. 1. A quartz discharge tube of 16 mm diameter and 200 mm length provided with movable tungsten electrodes was used. The electrodes were electrically insulated using glass, apart from the 20 mm long sharpened ends.

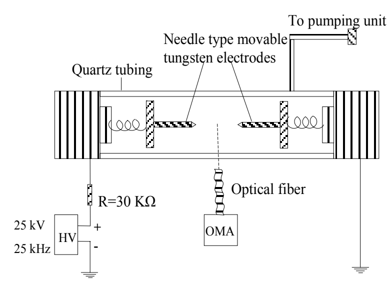


Fig. 1. The experimental device.

A high voltage power supply of 25 kV and 25 kHz frequency was used. A steady gas flow of different compositions was controlled by flow-meters. The spectra were acquired using a computer-controlled Optical Multichannel Analyzer (OMA).

3. Results and discussions

All previous studies of the M-effect contained only one electronegative and one electropositive gas (e.g. Hydrogen and Neon or Hydrogen and Argon). A monochrome radiation was obtained in these two-gas mixtures, as presented in Figs. 2.a.2 and 2.b.2. The wavelengths of the emitted lines are 585.3 nm for the emission spectrum of Ne and 750.4 nm for Ar. For comparison, the spectral lines of the pure electropositive gases (Argon and Neon) are given in Figs. 2.a.1 and 2.b.1, respectively.

The present paper reports on new studies on the simultaneous emission of two spectral lines using simultaneously two electropositive and one electronegative gas, e.g. Argon + Neon + Hydrogen. In this case, the emitted spectra contained both the emission line of Ne at λ_1 = 585.3 nm and that of Ar at λ_2 = 750.4 nm, as can be observed in Fig. 2.c.2.

In order to put in evidence specific features of this simultaneous M-effect, systematic studies of the influence of total pressure and also of concentration of Hydrogen in the mixture of the three gases were undertaken. For simplicity, all gas mixtures studied here contained equal amounts of Ne and Ar.

The ratio of the emission line intensities of Ne and Ar was denoted here with Δ:

$$\Delta = \frac{I_{Ne}(\lambda_1 = 585.3nm)}{I_{Ar}(\lambda_2 = 750.4nm)}$$

1. *Dependence of the simultaneous M-effect on total pressure*

The spectra in Fig. 3 were acquired at different total pressures keeping the Hydrogen concentration constant. As can be observed in this figure, a value of 1 was found for the Δ ratio in all spectra. Table 1 gives the experimental values of the line intensities taken from the spectra given in Fig. 3. This result suggests that the simultaneous M-effect is independent of total gas pressure as long as the relative concentration of the three gases remains unchanged. The concentration of Hydrogen was 50% in this experiment.

Table 1. Calculated Δ ratio using experimental data from Fig. 3. H_2 concentration: 50%.

Pressure [mTorr]	I_{Ne} *[a.u.]*	I_{Ar} *[a.u.]*	*Δ [a.u.]*
40	210	215	0.98
50	222	226	0.98
60	182	197	0.92
70	280	255	1.01

2. *Dependence of the simultaneous M-effect on Hydrogen concentration*

In Fig. 4, a selection of spectra for the study of the dependence of Δ on Hydrogen concentration is presented. As in the previous study, no significant changes of the Δ ratio on H concentration was observed. The total pressure was 70 mT in these experiments. Table 2 gives the intensities of the emission lines presented in Fig. 4.

Table 2. Calculated Δ ratio using experimental data from Fig. 4. Total pressure: 70 Torr.

H2 conc. [%]	I_{Ne} *[a.u.]*	I_{Ar} *[a.u.]*	*Δ [a.u.]*
10			
30	193	212	0.91
50	280	255	1.09
70	196	181	1.08

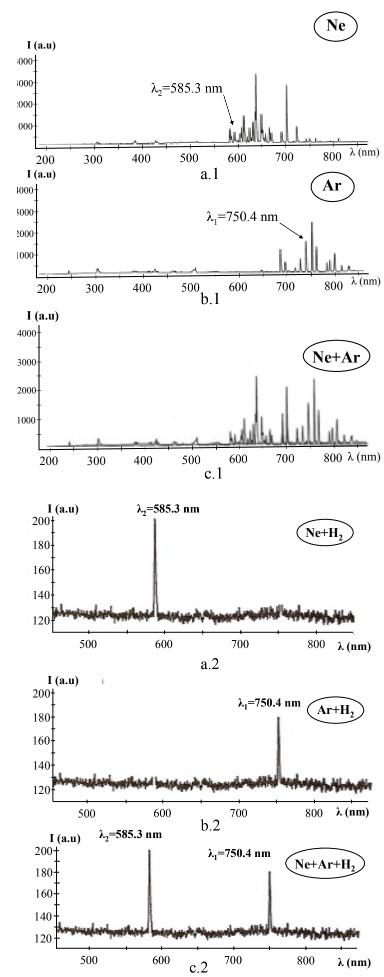
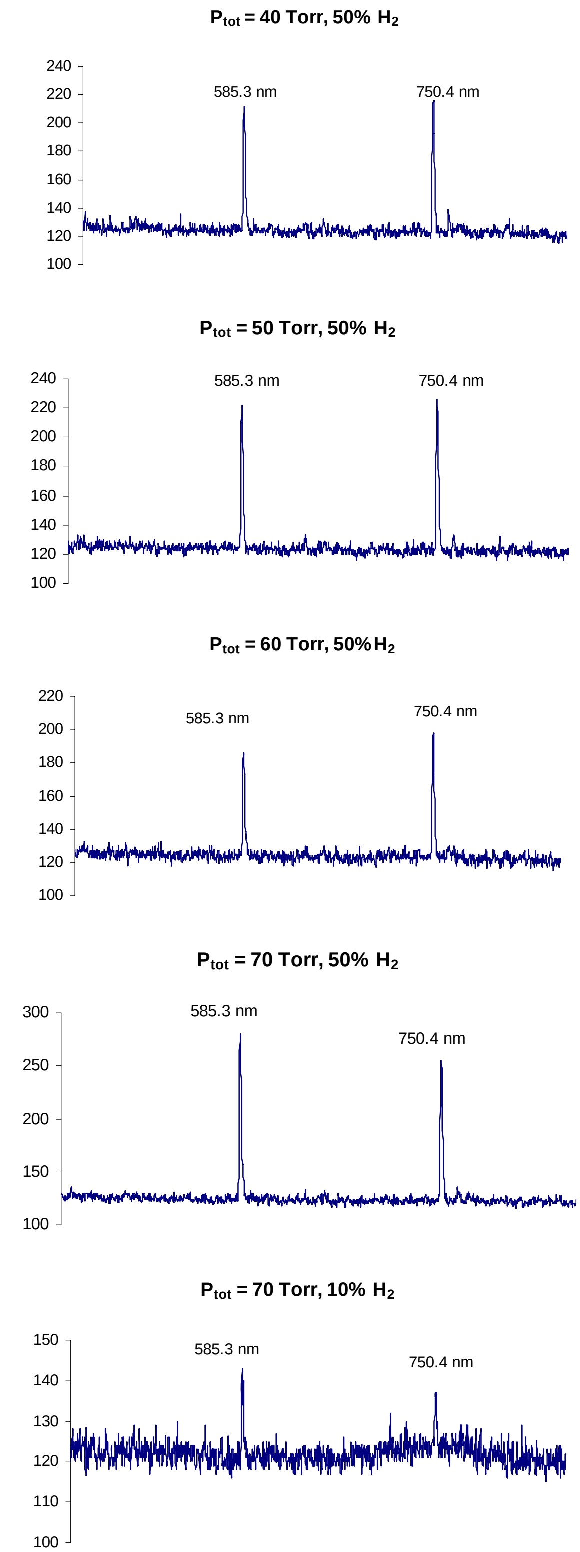


Fig. 2. Emission spectra of a.1 pure Ne, b.1 pure Ar and c.1 Ne + Ar and a.2, b.2, c.2 their mixture with H_2 showing the single M-effect and the double M- effect, respectively.



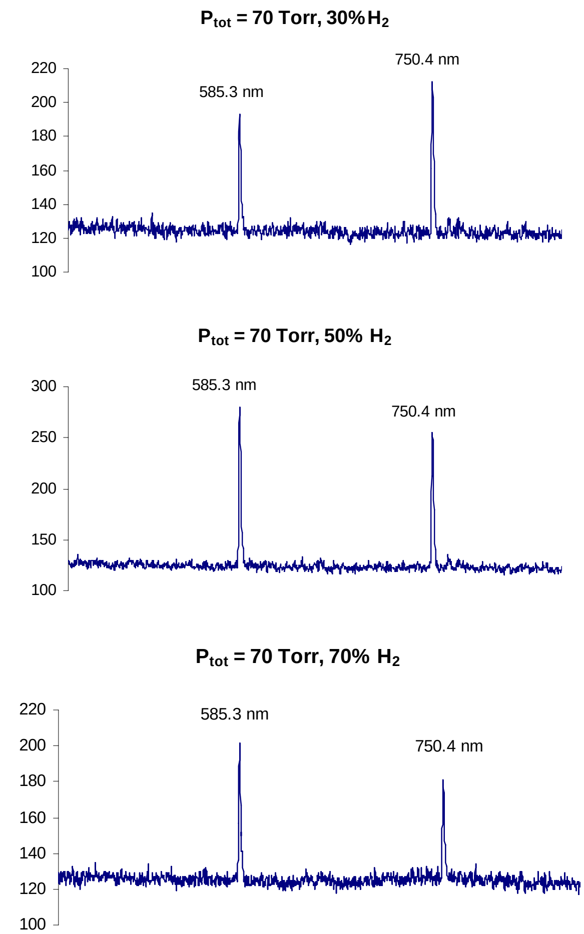


Fig. 3. (continued).

4. Conclusions

The M-effect is a powerful effect which gives monochromatic line spectra of wavelengths dependent on the type of gas used. The main requirement for obtaining this effect is the presence of an electropositive and an electronegative gas. New experiments revealed that this effect can be obtained simultaneously for two different electropositive gases, in the same plasma.

In this paper a mixture of Ne and Ar with H_2 was used to demonstrate the existence of this double effect. The data show a persisting independence of the Δ parameter on both total gas pressure and hydrogen concentration, this phenomenon being put in evidence for a large set of values of the total pressure and concentration.

While the voltage used for the M-effect experiments involving only one electropositive gas at a time was a few keV, the value of the voltage needed to observe the double M-effect was much higher, e.g. 25 kV.

These results have opened a new research area, with tremendous applications involving custom-wavelength emission line sources. Further experiments to put in evidence the dependence of the double M-effect on other experimental parameters are envisaged.

The simultaneous emission of multiple lines is the next obvious step of research into the M-effect.

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