International Journal of Sciences and Techniques of Automatic control & computer engineering
IJ-STA, Volume 3, N° 2, December 2009, pp. 1064–1071.

Electric and spectral characterization of a high pressure mercury lamp used in the photochemical treatment

L.Bouslimi[1], M.Stambouli[1], A.Chammam[1], J.P.Cambronne[2], G.Zissis[2]

[1] Ecole Supérieure des Sciences et Techniques de Tunis,
05. avenue Taha Hussein, 1008 Tunis
[2] LAPLACE-UPS-Bât. 3R2 - 118 route de Narbonne 31062 Toulouse cedex
9 – France

Abstract. *The general objective of this work consists in studying the influence of the current pulses on the electric and photometric behaviour of the gas-discharge high pressure mercury vapour lamps, intended particularly for water treatment. With this intention we carried out a feeding system allowing the providing of the lamp crenels of current with variable amplitude and duration of pulses. In this work we focused on the presentation of the feeding system carried out. We also present experimental measurements (electric and spectral) of a 400W high pressure mercury (HPM) lamp coupled to its electronic power supply in order to evaluate the influence of the current pulses on the radiation production effectiveness in the ultraviolet and the visible part of the spectrum.*

Keywords. *High pressure mercury lamp, pulsed current power supply, ultraviolet-visible radiation, water treatment.*

1. Introduction

The photochemical applications of the radiation develop with a so much accelerated rate in the field of general public technologies (lighting, descriptive, imagery…), and that of advanced technologies (treatment and engraving of surfaces, air and water treatment, agro-alimentary treatment…). The mainly used radiation sources are high, medium and low pressure lamps [1].

Indeed, in the case of high pressure lamps, the significant interactions between particles, it is difficult, with traditional supply (electromagnetic ballasts…) to move the energy distribution of the electronic cloud compared to local thermodynamic balance [2]. However, by using short pulses of current we can hope to obtain such a result and to modify the distribution of the atomic excitation and the spectral distribution of the radiation. The former works showed that the form of the current

This paper was recommended for publication in revised form by the editor Staff.
Edition: CPU of Tunis, Tunisia, ISSN: 1737-7749

wave imposed on the lamp could be selected so as to improve the production of the radiation (mainly visible and ultraviolet). It remains, for these sources, to optimize the parameters of excitation (form, amplitude, frequency, duration of pulses) according to those of the discharge (natural of the mixture gas, energy spectral distribution) [3], [4].

The pulsed light is a source rich in UV which is responsible for its lethal effectiveness. Spectrum UV is continuous and rich in wavelengths higher than 200 nm [5]. There are strong interactions with the biological substances.

UV Light (conventional UV) has been used for a long time for meats treatment with like results of the changes of color and/or of the changes in the oxidations degree of the lipids ascribable to reactions standard "oxydative cascades". Nevertheless, [6] could not measure such changes following the treatment of the meat with the pulsed light.

Many works were completed on the biological effects of the UV. [7], [8] carried out an excellent bibliographical analysis on this subject.

In this work, we present in the first section the structure of the pulsed-power supply designed in our laboratory. The results of time-dependent spectral and elctrical measurements carried out on a high pressure mercury lamp operated in the pulsed mode are discussed and interpreted in the second section. The work reported here has been done to provide a basic understanding of the physical mechanisms resulting in an increase in the ultraviolet and visible radiation efficiency.

2. Structure of the pulsed power supply

The bloc diagram of the lamp circuitry is shown in figure (1). It is composed mainly of two separate power supplies: square wave and pulsed current source.

The square wave operation is achieved using a (DC) constant current source (S1) in conjunction with an electronic full bridge IGBTs (T1, T'1, T2, T'2) and an active protection system allows to protect the IGBTs and the drivers against the over-voltage at the time of starting and the hot restarting of the lamp or by an unexpected opening of the circuit. The pulsed operation is achieved by the second (DC) current source (S2) switched by a pulse switching circuit (IGBT T3). The control signals for the pulse switching circuit and full wave bridge are ensured by a microcontrollor. It permits to obtain a low-frequency square wave with one or more pulses superimposed on each half cycle. The current in each source is controlled. D1 and D2 are anti-return fast diode.

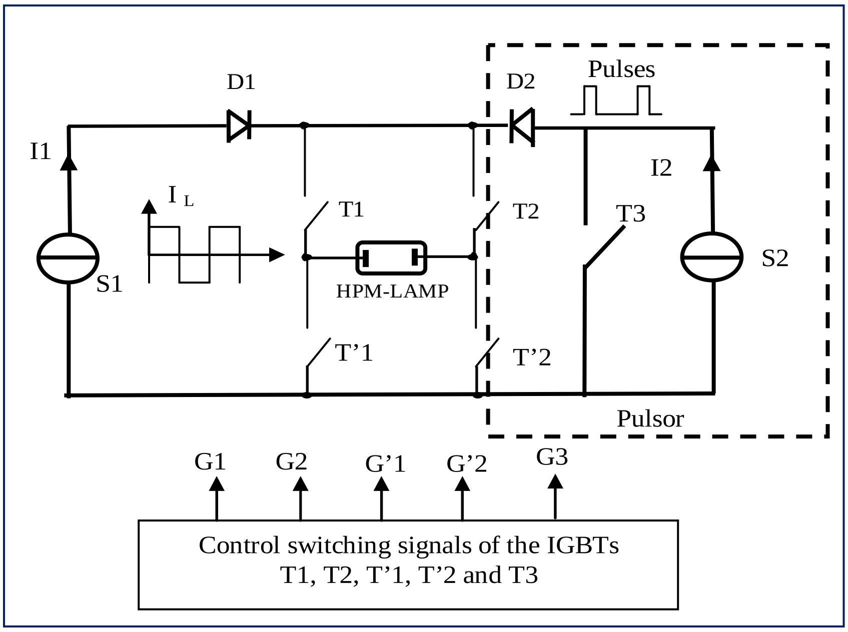

Fig.1. Structure of the pulsed power supply

3. Experimental results

The main characteristics of the discharge lamp used in this investigation are: ballon discharge lamp, inter-electrode length 72.0 mm, internal diameter 18.2 cm, buffer gas (argon) filling at the ambient temperature up to 10 torr and the total mercury mass is 70 mg. the lamp power is 400 W. The lamp operates vertically through a current inverter and all the measurements have been done in a steady state after the flux and circuit stabilization (at least 15 minutes after the start-up) [9], [10].

The current inverter excites the lamp by square waves and the pulsed current. It is designed with the following characteristics: AC input voltage of 230V rms, output lamp current of 3.2A rms, output lamp voltage of 140 Vrms.

Below, we present the results of our electrical and spectral measurements, which allows us to gain a deeper understanding of the dynamic behaviour of the discharge during the pulse.

3.1. Electrical results and discussion

For the low-frequency square wave (the pseudo-continuous mode), the discharge is initiated by applying the pulses of rectangular current with a duty cycle of 1 and a frequency of 50 Hz. The pulses are superimposed on each half- cycle of the square wave. The width of a pulse is about 0.5 ms and the peak of current during the pulse is about 5.5A. The power of the lamp remains the same as in the pseudo-continuous mode. The instantanious current, voltage and power waves of the lamp as well as the equivalent conductance wave and the evolution of the brightness (luminance) of the visible line (577 nm) are shown in figures 2 and 3.

It is also important to emphasize some characteristics of the current, the conductance and the luminance waveforms for the pulsed operation. When a pulse of current is applied to the lamp, both conductance and luminance have a peak and then decrease to stabilize at their constant values. We note that the conductance and the luminance have a clear corelation between both curves.

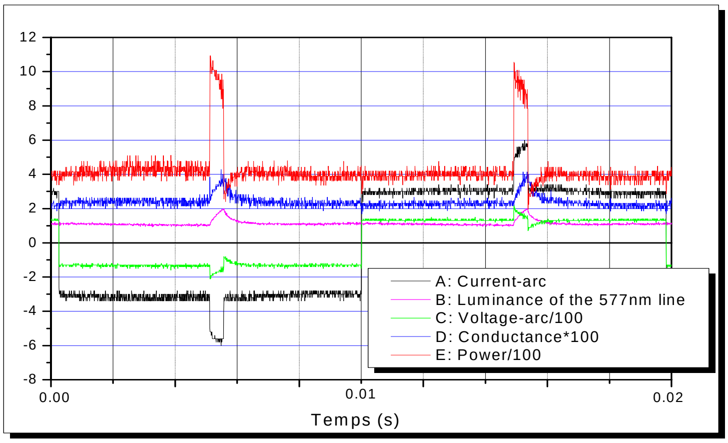

Fig. 2. Curves of the electric parameters of the lamp: A) current lamp (2A/div, 2 ms/div); B) evolution of the visible line 577 nm of mercury (1V/div, 2 ms/div); C) voltage lamp (200 V/div,2 ms/div); D) conductance of the lamp (0.02 V/div, 2 ms/div); E) Power of the lamp (0.02 V/div, 2 ms/div)

In order to explain the evolution of the visible line of mercury (figure 3 / B), we note that, in the first phase, a fast jump of intensity followed of one assembled slower until the establishment of a stationary state. This one depends on the injected current intensity. When the current drops, the same phenomenon is observed in the opposite direction: a fast fall of intensity followed by a relieving [3].

Indeed, we observe, on figures (Fig.2 and Fig.3), that the variation of brightness is spread out over two different phases of time (Te: time of establishment and Tr: relaxation time). When we applied a pulse of current to the discharge which is in local thermodynamic balance (LTE), the electronic density and the densities of excited states also increase with the fast increase in the electronic temperature and brightness increases also quickly.

On the contrary, at the time of the disappearance of the pulse, the excited species, of significant densities, at the metastable levels (6^3P_0 and 63P2) and on the resonance level 6^3P_1 strongly imprisoned, recover energy by collision of second species and the system can cool only as these levels are de-energized.

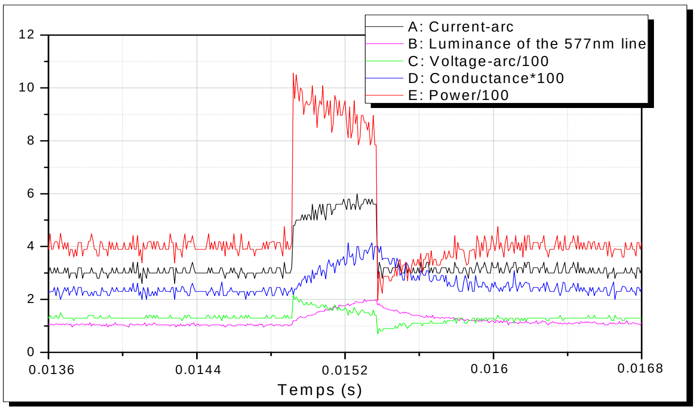

Fig. 3. Curves of the electric parameters of the lamp on zoom scale at the time of the pulse: A) current lamp (2A/div, 2 ms/div); B) evolution of the line 577nm of mercury (1 V/div, 2 ms/div); C) voltage lamp (200 V/div, 2 ms/div); D) conductance of the lamp (0.02 V/div, 2 ms/div); E) Power of the lamp (0.02 V/div, 2 ms/div)

Consequently, the significant number of these species slows down the decrease of the temperature and thus that of the intensity of the line. Therefore, that explains the radiation (brightness) decreases with a relaxation time definitely higher than that of the establishment.

Considering the several pulses and of short durations, they lead the discharge to a state close to the LTE and who slow down gradually the desixcitation. Potentially radiation UV must increase instantaneously but as it is very trapped in plasma, the excitation must be distributed towards the high levels ones, and thus to have more visible radiation.

3.2. Spectral results and discussion

Relative average spectral flux was recorded for a pseudo-continuous current and a pulsed current. In these two modes, the power provided to the lamp was the same one. Thus, it is possible to evaluate the influence of the current pulses on the radiation production effectiveness in the ultraviolet part and the visible part of the spectrum. Theses results are illustrated by figures 4 and 5.

We note a clear increase in all the lines measured in the pulsed mode for the same power as in pseudo continuous mode. However, the increase is particularly clear for bands UVB and UVC of the spectrum. The increases in the UVA and the visible remain more limited.

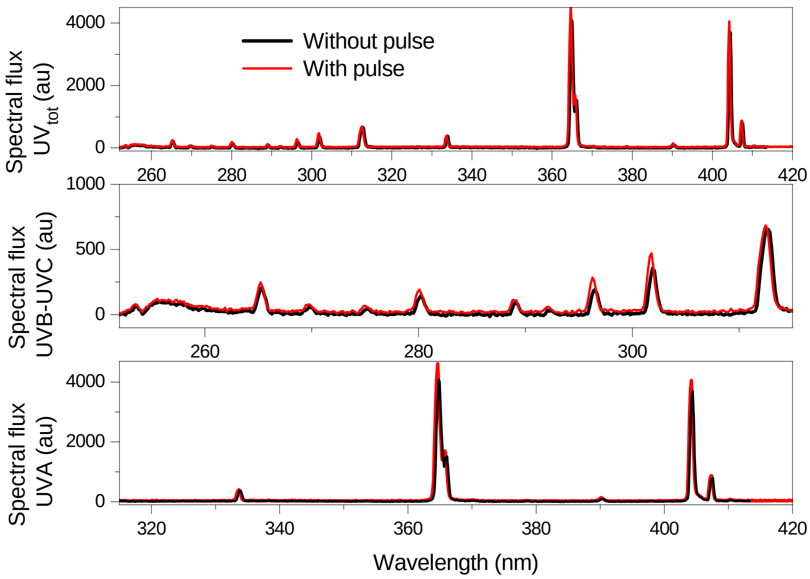

Fig.4. Spectral flux UV with two supplying modes: (—) without pulses; (—) with pulses

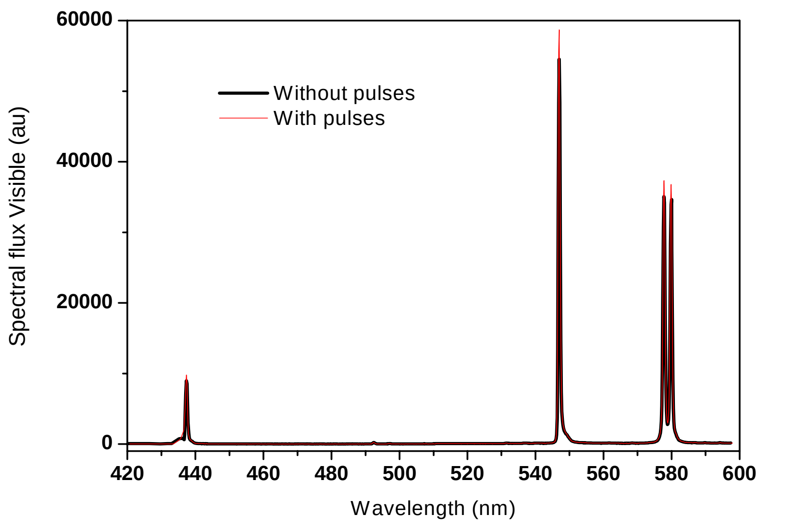

Fig.5. Visible spectral flux with two supplying modes: (—) without pulses; (—) with pulses

4. Conclusion

In this paper we described the structure of the electronic pulsed power supply made in our laboratory, and we presented the exprerimental results (electric and photometric) carried out on the photometric experimental setup using the pulsed operation. A high pressure mercury discharge lamp was used as a lamp producing the ultraviolet and the visible radiation flux.

To conclude, we note a clear increase in all the lines measured (ultraviolet and visible) in pulsed mode for the same power as in pseudo continuous mode. We also noted that the increase in the production radiation considered interests much the photochemical applications and lighting.

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