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기체 방전관의 색상 제어에 관한 연구

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A Study on Color Control in Gas Discharge Tube

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Abstract

The electronic operation of the gas discharge tube is controlled by the electrical energy as sinusoidal waveform in arbitrary frequency range, or as a sequence of pulses at a wide range of duty cycle, the gas composition, the kind of electrode and the vessel geometry. In this paper, the pulsed mode operated gas discharge tube is composed with mixed gas of Hg-Ne (10 Torr), in the tube of 15.0 mm outer diameter and has variable color from red to blue with changing frequency and pulse width in high voltage. As increasing pulse width and frequency in the gas discharge tube, the phenomenons that the electron temperature in the positive column increases and the radiation from atoms of higher upper state energy levels increases, exist. The color have the locus from red (0.4972, 0.3128) to blue (0.2736, 0.2619) in CIE chromacity diagram with increasing pulse width and frequency. The changing method of pulse width and frequency has been shown to be suitable for the luminous color control.

1. INTRODUCTION

Since the first incandescent lamp was developed by T. Edison in 1879, the efficiency of light sources have ceaseless enriched through many kinds of light emitting systems till up to now. The crisis of energy and the requirement of the better visual environment have been driving in great force to develop lamps with higher efficiency and better color performance[1]. The progress of new materials and process technology have also contributed to the development of new lamps[2].

The electrical power as sinusoidal waveform in arbitrary frequency range or as a sequence of pulses at a wide range of duty cycle and peak energies manage the electric operation of the gas discharge tube. The responses of the tube depend on the gas composition, on the kind of electrode and on the geometry of the arc and the discharge vessel. To keep constant one of the electrical quantities or a composition of them to stabilize the tube power, the arc position, or an other feature of importance is possible. The basic problem to do so is to find an information which is representative for the actual condition of the tube, and to translate it into an electrical signal which can be introduced by the electronic power supply. As a example, recently the fluorescent discharge lamps which discharge the mixed Hg-Ar gases in the A.C. or D.C., use the ultraviolet radiation with the Hg resonant wavelength of 253.7 nm[1]. The color of the tubes are controlled by the kind of phosphor and the spectroscopic properties of the ultraviolet radiations[5]. In this paper, the pulsed mode operated discharge tube is introduced, which is possible to modify the color and the color rendering index independently by means of controlling the spectroscopic properties of the radiations in the discharge, just as the variable peak power and the variable repetition frequency of the pulse series[3~5].

2. EXPERIMENTS

In the experiment, the discharge driving circuit, the gas discharge tube and the optical measuring instruments are respectively important parts as follows. The function of the discharge driving circuit switches D.C. with pulse as well as properly applies power. In the Fig. 1. during the transistor Tr (2SC1325A) is off time, the applied voltage E (2 kV, 1 A NIPPON STABILIZER HVF-200R) charge to capacitor C (1.0 μF). When the charged energy to C, the bias starts to cathode in the gas discharge tube as a negative voltage, which means operating instant of Tr, the discharge will be started. As the pulse width is limited by base of Tr, the voltage in the discharge tube decrease slowly with discharging the charged energy to C. The limitation of pulse width regulation with the capacitor C obviously exist. As the high frequency is generated by repetition of pulse, which has a phenomenon that does not enough charge to capacitor C in discharge time, the repeating frequency is restricted by applied voltage E. The applied voltage E is restricted by the maximum voltage 1500 V between collector and base of Tr, and the maximum collector current 10 A. Then, to obtain the high current, Tr are connected by 4 parallels. The R and R_i, which are summed about 2.5 to 12.5 kΩ in the experiment, to restrict the peak current. To use the R and R_i resistor intimately to contact of the electrode with the gas discharge are reprehensive means.

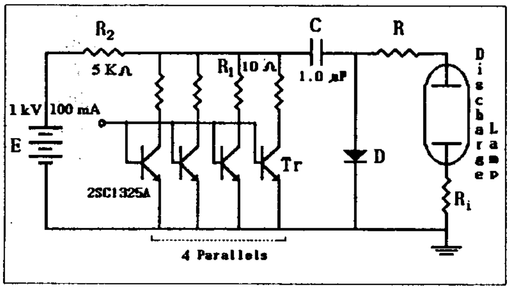


Fig. 1. The discharge driving circuit

The gas discharge tube is as follows Fig. 2. The electrode is coated inside of the gas discharge tube, which is constructed by the inner diameter, the electrode and the electrode interval are 12.9, 10.0 and 128.0 mm respectively. In the discharge tube, Hg-Ne (1 : 9, 10 Torr) are filled with mixed gas.

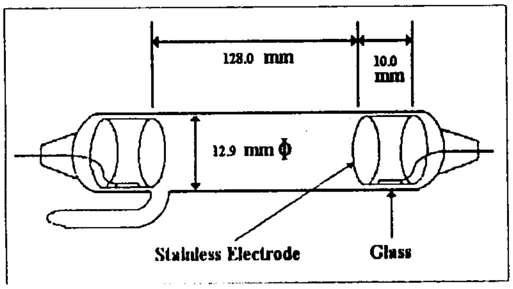


Fig. 2. The discharge tube structure

The optical measuring instruments are following Fig. 3. The radiations of the gas discharge tube through the slit are derived to the monochrometer (Nikon P250). The photomultiplier (Hamamatsu C659) converts optical to electrical signal and then the radiations are amplified. To measure the distributions of the radiations, the amplified signals are averaged with Boxcar Averager (EG&G PAR 162) and amplified signals are output to the pen recorder. To obtain the radiations with time domain variable, the amplified signals are compared with applied signals on the digital oscilloscope (Tektronix 2430A) and are stored to the personal computer. And to plot the CIE chromaticity chart, which has a brief reference, luminance colormeter (BM-7, TOPCON) is used.

At first, to measure the radiations of the gas discharge tube, the controlling of the discharge driving signal is needed with observing the tube color by the change of the pulse width, which means the variation of the spectroscopic property in the radiations. The red to blue color of the tube are existed in the 25 to 100 µs variation of the pulse width at 100, 500, 1000 Hz in this paper. The distributions of the radiations are plotted to the pen recorder through the Boxcar Averager at their tube color and then checked the peak energy with the wavelength. The each intensities are compared with the biased signals at the checked wavelength.

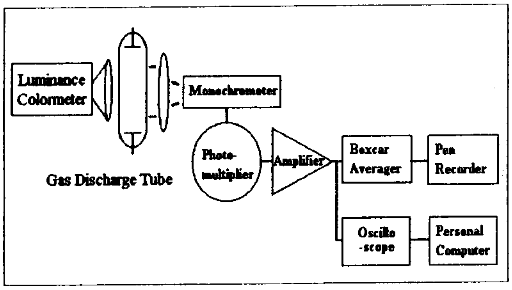


Fig. 3. The schematic of the optical measuring instruments

3. RESULTS

The radiations in the gas discharge tube have lights with the variable wavelengths. In the paper, the color of the lights are changed with variable pulse width and frequency. The mixed gases of Hg and Ne make a lot of related distributions, which means that their gas have a lot of excitations at distinct wavelength, but especially the wavelengths of 365.0 ㎚(Hg), 435.8 ㎚(Hg), 585.2 ㎚(Ne) and 640.0 ㎚(Ne) in visible region are chosen. But the pulse widths of each frequency are restricted by stability of gas discharge driving circuit, as 25 ㎛, 50 ㎛ in 500 Hz and 25 ㎛ in 1000 Hz. As increasing pulse width and frequency in gas discharge tube, the electron temperature in the positive column increases. Hg radiated intensities of 365.0 ㎚ and 435.8 ㎚ are increased with pulse width and frequency but Ne radiated intensities of 585.2 ㎚ and 640 ㎚ are decreased with the pulse width and frequency particularly in Fig. 4.

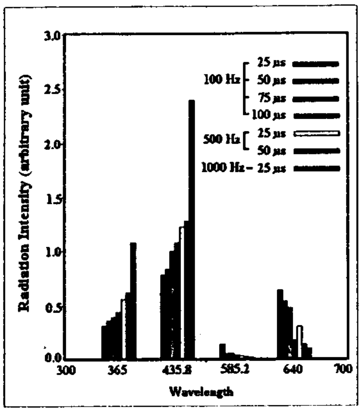
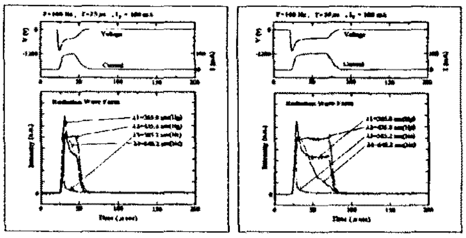


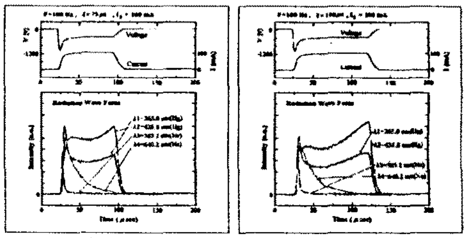
Fig. 4. The distribution of radiated intensity with wavelengths

The intensity of radiations which are described as pulse width of 25 μs, 50 μs, 75 μs and 100 μs, are respectively obtained at 100 Hz, 500 Hz and 1000 Hz in the Fig. 5. The one of Hg radiation on 365.0 ㎚ rapidly increases to the peak energy in first stage and exponentially decreases to the stable state and then is disappeared in the time domain. At 435.8 ㎚, the Hg radiation are similar to current below the 50 μs and have the most high intensities in the visible region, which is related with Fig. 4. Hg radiations at 365.0 ㎚ and 435.8 ㎚ are augmented with increasing of pulse width and frequency. The Ne radiations of 585.2 ㎚ in low frequency (100 Hz) just have intensities at first stage but in high frequency have very small intensities. At 640.0 ㎚, the Ne radiation which have also small intensities in high frequency, increase and slowly dwindle to end of current.



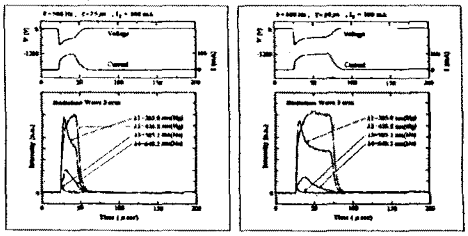
Ⅰ. In the 100Hz and 25μs

Ⅱ. In the 100Hz and 50μs



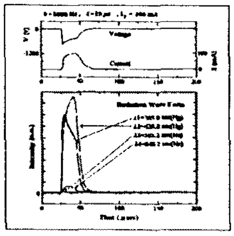
Ⅲ. In the 100Hz and 75μs

Ⅳ. In the 100Hz and 100μs



Ⅴ. In the 500Hz and 25μs

Ⅵ. In the 500Hz and 50μs



Ⅶ. In the 1000Hz and 25μs

Fig. 5. Radiation wave forms in 25 μs, 50 μs, 75 μs and 100 μs with 100 Hz, 500 Hz, and 1000 Hz

When the pulses is changed from 25 μs to 100 μs and frequency is varied 100 Hz to 1000 Hz, the luminous color changes from red which is restricted (0.4972, 0.3128) by CIE chromaticity coordinates to blue (0.2736, 0.2619) as shown in Fig. 6. and table 1. The luminous colors of Hg and Ne are shown by the points Hg (0.217, 0.198) and Ne (0.705, 0.295) respectively. Increasing the pulse width and frequency, the color of the gas discharge tube varies from the red which is close to that of Ne toward the blue of Hg. In the method of changing the pulse with and frequency, increasing the repetition frequency of pulses, the color varies from red to blue. Whenever Ne with high excitation levels is excited, Hg with low excitation levels is excited and emits radiation, because of the spread of the distribution of electron energy.

		X	Y
100 Hz	25 μs	0.4972	0.3128
	50 μs	0.4542	0.3025
	75 μs	0.4142	0.2960
	100 μs	0.3718	0.2857
500 Hz	25 μs	0.3609	0.2826
	50 μs	0.2970	0.2633
1000 Hz	25 μs	0.2736	0.2619

Table 1. Variation of the CIE chromaticity values

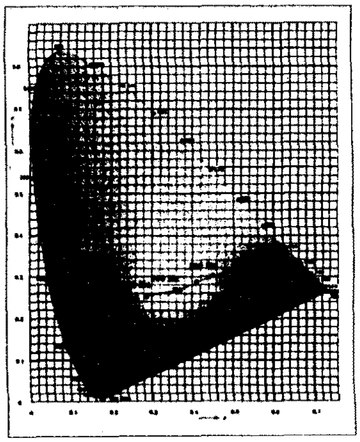


Fig. 6. CIE chromaticity diagram for luminous color in the Hg-Ne gas discharge tube

4. CONCLUSIONS

Practically the electronic operation is controlled by the sequence of pulses at a wide range of duty cycle and peak energies in the gas discharge tube. The gas composition in the gas discharge tube are composed with Hg-Ne (10 Torr).

1) The electron temperature in the transient plasma

resulted from the sudden increase of current rises much higher than that of the steady state. In the transient plasma, not only the atoms having low excitation levels (Hg : 10.43 eV) but also the atoms having high excitation levels (Ne : 21.56 eV) emit radiations. Especially, with changing of pulse width and frequency, the electron temperature in the transient period is affected by the changes of the residual ion and metastable atom densities.

2) The intensity of Hg which have high intensity and small distribution, more affects to the color of blue in the high pulse width and frequency. But Ne which have low intensity and large distribution, affects to the color of red.

3) In the mixed gases of Hg-Ne (10 Torr) discharge tube, the color have the locus from red (0.4972, 0.3128) to blue (0.2736, 0.2619) in CIE chromacity diagram with increasing pulse width and frequency.

By above things in the gas discharge tube, the changing method of pulse width and frequency has been shown to be suitable for the luminous color control.

REFERENCES

[1] 渡辺良男 他, " Ar-Hg放電における253.7nm光學光效率の直管依存性" 照明學會誌 Vol.11, No.11, pp. 762~677, 1995

[2] 加納忠男, "光源システムの技術動向と展望", 照明學會 調査報告書, pp. 147~155, 1993. 3.

[3] T. Hanada, "Lighting Industries In Japan", Symp. Proc. of The 7th Inte. Symp.Scie. & Tech. of Light Sour., Japan, pp. 17~25 ,1995

[4] K. Günther, "Electronic Optimization of HID Lamps ", ibid., p.93~100 ,1995

[5] M. Aono, et al., "Color Control of Fluorescent Lamps", ibid., p.81~82 ,1995

[6] G. Chodil, "Gas Discharge Displays for Flat-Panel", Proc. SID, Vol. 17, p.14~22, 1976

[7] L. F. Weber, "Plasma Displays", L. E. Tannas Jr., Ed., New York: Van Nostrand Reinhold, p.332~414 ,1985