Photoemission optogalvanic effect studies in N$_2$, NO$_2$ and Ar discharges under pulsed laser excitation

This article has been downloaded from IOPscience. Please scroll down to see the full text article.

(http://iopscience.iop.org/0022-3727/26/1/001)

View the table of contents for this issue, or go to the journal homepage for more

Download details:
IP Address: 117.211.83.202
The article was downloaded on 29/10/2011 at 07:25

Please note that terms and conditions apply.
Photoemission optogalvanic effect studies in N₂, NO₂ and Ar discharges under pulsed laser excitation

P R Sasi Kumar, V P N Nampoori and C P G Vallabhan
Laser Division, Department of Physics, Cochin University of Science and Technology, Cochin 682 022, India

Received 11 November 1991, in final form 2 March 1992

Abstract. A two-photon induced photoemission optogalvanic effect which brings about a change in the discharge voltage when a pulsed dye laser beam is focused on a tungsten electrode has been described. The experiment is performed with N₂, NO₂ and Ar discharges. The magnitude of the signal voltage is studied as a function of laser energy and discharge current. The effective quantum efficiency in the discharge is found to be larger than that in the vacuum condition.

1. Introduction

The optogalvanic (OG) effect is the change in the electrical properties of a gas discharge caused by illuminating the discharge with radiation (Green et al 1976). The OG effect is a sensitive technique for studying the spectra of atoms and molecules in a discharge plasma. The energy absorbed by the species perturbs the plasma characteristics and produces a measurable impedance change in the discharge. OG effects can also be produced by injecting electrons into the discharge via photoelectric emission from the electrode surface by laser irradiation (Downey et al 1988). Photoelectrons emitted may excite or ionize the atoms or molecules on their way to the anode and produce more secondary electrons by collision. This non-resonant phenomenon is called the photoemission optogalvanic (POG) effect. The magnitude of the POG signal depends on the work function of the electrode material, nature of the discharge medium, discharge conditions and the intensity of the laser beam. The effect of the discharge current and the laser energy on the magnitude of the POG signal is studied in this paper.

2. Experimental set-up

The experimental set-up used to observe the POG signal (Sasi Kumar et al 1991) is shown in figure 1. Radiation from a pulsed dye laser (Quanta Ray PDL-2), pumped by the second harmonic of a Q-switched Nd:YAG laser (Quanta Ray DCR-11), was used as the excitation source. The discharge cell was made of glass, had an inner diameter of 1 cm and tungsten electrodes at an inter-electrode separation of ~1 cm. The discharge was produced by DC excitation in the cell with a ballast resistance in series with the tungsten electrodes. Continuous flow of the sample gases N₂, NO₂ and Ar was maintained in the cell at low pressure. The pulsed dye laser beam was focused on the cathode using a lens. The POG signal taken through a capacitor can be displayed on a CRO. The amplitude of the signal was measured for different laser energies at 564 nm and discharge currents.

3. Results and discussion

The variation of the POG signal amplitudes at 564 nm wavelength for N₂, NO₂ and Ar are studied as a function of laser energy for different discharge currents. The work function of the electrode material (tungsten) is 4.3 eV (Weast 1974-75) which approximately coincides with twice the photon energy at 564 nm. It has been found that the dependence of the observed signal amplitude S on the laser pulse energy I can be fitted into a quadratic expression

\[ S = AI + BI^2 \]  

where A and B are constants which depend on the discharge conditions. Figure 2 shows the above curve fitted to experimental observations. The first term can be interpreted as a one-photon process which is due to the direct absorption of radiation by the discharge
plasma (the OG effect) while the second term corresponds to the two-photon process due to photo-emission from the electrode surface.

The magnitude of the POG signal in the case of the N₂ discharge is very much larger than that in NO₂ and Ar discharges. The first term in equation (1) results from the resonant absorption of laser radiation at 564 nm. It is noted that the N₂ molecule has absorption bands (Gaydon and Pearse 1965) in the spectral regions 700–500 nm (5,0 band of the first positive system) and at 640–500 nm (3,4 band of Gaydon’s green system). One-photon-like signals can also arise due to thermionic emission from the target surface due to large temperature increases resulting from the laser irradiation. The second term arises as a result of the two-photon induced photoemission optogalvanic effect.

Figure 3 shows the variation of coefficients A and B as a function of discharge current. In the case of the N₂ discharge, coefficient A is initially negative and increases with current while for the discharge in Ar gas it decreases. For the NO₂ discharge the variation of A with the discharge current is nonlinear. The coefficient B for N₂ and NO₂ discharges decreases while for Ar it decreases.

**Figure 1.** Block diagram of experimental set-up.

**Figure 2.** Curve for \( S = A + B \) for N₂ at 15 mA (\( A = 31.2, B = 10688 \)), Ar at 15.5 mA (\( A = 57.8, B = 3423 \)) and NO₂ at 15.4 mA (\( A = 43.43, B = 4144.5 \)). A is measured in \( \text{VJ}^{-1} \) and \( B \) in \( \text{VJ}^{-2} \). The points correspond to experimental observations.

**Figure 3.** Dependence of A and B on discharge current for Ar ((a) and (b)), N₂ ((c) and (d)) and NO₂ ((e) and (f)).
increases with discharge current. This shows that at low currents the two-photon process in \( \text{N}_2 \) and \( \text{NO}_2 \) is more predominant than that in the \( \text{Ar} \) discharge.

4. Calculation of effective quantum efficiency

The quantum efficiency (photoelectrons emitted per photon) in the plasma is two to three times larger than that in the vacuum as a result of secondary electrons produced via collisions in the plasma. The effective quantum efficiency of the POG effect \( \Phi_p \) in the gas discharge is

\[
\Phi_p = \alpha \Phi
\]

(2)

where \( \Phi \) is the quantum efficiency in vacuum (\( \sim 10^{-4} \)) and \( \alpha \) is the number of secondary electrons produced per collision and can be written as

\[
\alpha = iS/I
\]

(3)

where \( i \) is the discharge current, \( I \) the laser energy per pulse and \( S \) is given by equation (1). Then,

\[
\alpha = i(A + BI).
\]

(4)

Figure 4 shows the variation of \( \alpha \) as a function of the laser pulse energy. \( \alpha \) is found to be greater than one which means that effective quantum efficiency in the discharge is at least \( \alpha \) times that in vacuum. However, for low laser pulse energy \( \alpha \) is less than one—this is due to the predominance of recombination processes between electrons and positive ions in the discharge.

5. Conclusions

The change in the discharge characteristics as a result of the photoemission POG effect using tungsten electrodes in \( \text{N}_2, \text{NO}_2 \) and \( \text{Ar} \) discharge was studied. The effective quantum efficiency of the process in the discharge is found to be at least \( \alpha \) (number of secondary electrons produced per collision) times that in vacuum.

Acknowledgments

We thank the Department of Science and Technology (India) and the Ministry of Human Resource Development (India) for financial assistance. Technical help from A V Ravi Kumar and G Padmaja is also gratefully acknowledged. One of the authors (PRS) is thankful to the University Grants Commission of India for a research fellowship.

References