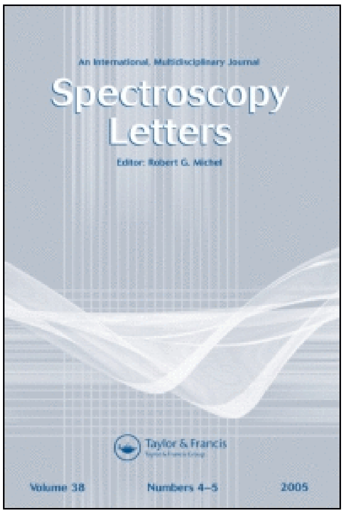

Spectroscopy Letters
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597299

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Online publication date: 01 December 2009

To cite this Article Steflekova, V. , Slavov, D. , Zhechev, D. , Dimova, E. and Todorov, G.(2009) 'Magneto-Galvanic Resonances in Hollow Cathode Discharge Lamps', Spectroscopy Letters, 42: 8, 513 — 517
To link to this Article: DOI: 10.1080/00387010903022426
URL: http://dx.doi.org/10.1080/00387010903022426

Spectroscopy Letters, 42:513–517, 2009

ISSN: 0038-7010 print/1532-2289 online
DOI: 10.1080/00387010903022426

Magneto-Galvanic Resonances in Hollow Cathode Discharge Lamps

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ABSTRACT The galvanic behavior of a hollow cathode discharge versus an external weak magnetic field is investigated. The application of this field leads to disordering of the self-aligned states, which is detected as a resonance in the discharge current, named the magneto-galvanic signal. A correlation magneto-galvanic signal–operating voltage-current point is established and attributed to Penning ionization. The contribution of the metastable Ne I 1 s_5 to the magneto-galvanic resonance is also verified.

KEYWORDS coherence, negative glow discharge, plasma conductivity, self-alignment

INTRODUCTION

Among the interference phenomena, the self-alignment of excited states in the glow discharge is of particular interest.[1] This coherence arises due to the spatial anisotropy of excitation in the discharge and manifests itself by the polarization of the spontaneous emission, which carries diagnostic information. The light emission in the discharge volume is always anisotropic. For example, the axial photon flux in a cylindrical discharge will prevail, if the photon-free path is larger than the tube's cross-section. Both the tensor of (self-) alignment and the angular intensity distribution of the light beams have the same symmetry. After it had been observed in the positive column, the self-alignment has also been detected in a hollow cathode discharge (HCD) and attributed to the spatial anisotropy of the electron gas.[2] Besides the optical effects, the interfering atomic states also generate a specific galvanic effect in the glow discharge. Hannaford and Series[3] observed such a resonant change in the case of a laser-induced galvanic (LIG) signal in a magnetic field, perpendicular to the **E** vector of the optical field. A weak magnetic field (up to 10 Gauss) does not perturb the diffusion of the plasma electrons to the wall, but can split the magnetic sub-levels of the atoms, which is in the order of the natural width of the excited states. Hence, the observed resonance may be attributed to the magnetic destruction of the laser-induced alignment.

Later on galvanic resonances were detected without any irradiation in both HCD[4] and positive column discharges.[5] This phenomenon was considered as a magneto-galvanic (MG) effect. MG resonance arises due to magnetic destruction of all levels self-aligned.

Received 5 December 2008; accepted 20 March 2009.

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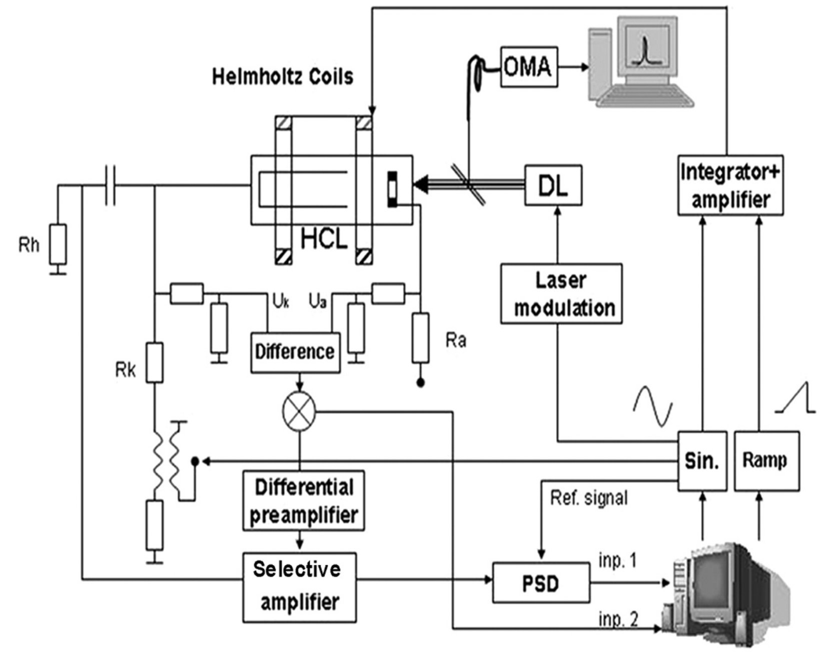

FIGURE 1 **Experimental setup: HCL lamp, DL, R_a—ballast resistance, R_k—cathode resistance, R_h—gauge resistance.**

In the course of previous investigations, this article reports new experimental results obtained for two commercial hollow cathode (HC) lamps and discusses both correlation of MG signals with the plasma parameters and the contribution of Ne I 1 s_5 level to the measured signal.

EXPERIMENTAL

The experimental setup (Fig. 1) is a polyfunctional scheme allowing PC-controlled recording of ΔU ($\mathbf{B_0}$) signals, LIG signals, I–V curves (U/I), and their derivatives dU/dI. Phase sensitive detection (PSD) and laser diode (DL) irradiation in LIG measurements are used. Optical Multichannel Analyzer (OMA) was used to control laser line detuning.

The MG signal is detected as a voltage change ΔU (**B**) across the discharge versus an external magnetic field **B** ⊥ **R**, where **R** is the cathode radius.

In order to improve the *signal-to-noise* ratio, the MG signal ΔU (**B**) is measured with two "Unipan" (Scientific Instruments, Warsaw) nanovoltmeters, one of which (type 237) is a selective one and the other (type 232B) is a lock-in. Due to the magnetic field modulation, the first derivative of the MG signal $\partial U/\partial B\,(\mathbf{B})$ is actually acquired. The frequency of **B**-field modulation is taken as a reference.

The commercial HCD lamps NeCd and NeSi ("Narva") are investigated.

RESULTS AND DISCUSSION

Figure 2 illustrates the shape of the MG signals $\Delta U(\mathbf{B}) = \partial U/\partial B(\mathrm{B})$ under two discharge current I values. Because of the geometry **B** ⊥ **R**, the resonances can be attributed to the magnetic destruction of the radial anisotropy excitation due to the non-thermal (beam-like) electrons in an HCD. The destruction reflects on the plasma conductivity, that is, the latter changes proportionally to the magnetic induction **B**, and it may be measured as a voltage variation ΔU (**B**). It is worth noting that the derivatives of the signals were registered at a constant phase shift, which allows comparison of the corresponding integrated dependences. Then, Fig. 2 illustrates two HCD lamps, with the MG signal distinguished in shape, in sign, and in sensitivity, versus discharge current. In general, the differences above indicate the fact that different processes form and/or destroy the Ne level self-alignment under varying discharge conditions.

The MG effect in the neon positive discharge column was analyzed within the frames of a semi-phenomenological model,[6] based on comparative magneto-optic and MG experiments. In the case of an HCD, some complementary studies are needed to separate the contribution of the competitive processes to self-alignment forming and destruction. The uniform geometry of both NeSi and NeCd

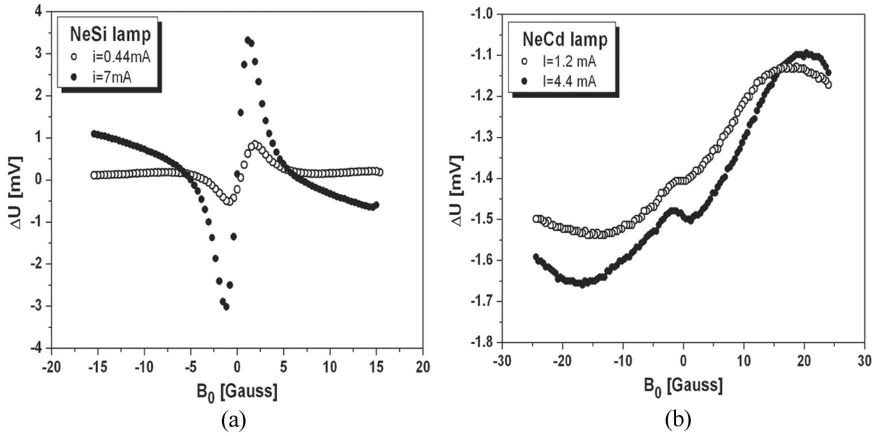

FIGURE 2 MG signal shapes in NeSi and NeCd HC lamps for B $\perp$ R.

HC lamps allows the signal's shape differences to be ascribed to the sputtered cathode component. The latter is known to predetermine the process of Penning ionization specific for an HC discharge.[7,8]

Taken alone, the amplitude of the first-order function ΔU (**B**) characterizes the conductivity difference of the self-aligned and nonaligned ensembles of atoms. Both equal buffer gas neon and differences between MG signal in Fig. 2 provoke a specific correlation between MG signal parameters and operating voltage-current point {U-I} to be looked for. Figure 3 illustrates this correlation for the NeCd HC lamp. The half-widths of the narrow MG resonance, that is, the distance between corresponding extreme points (these values are not extrapolated to zero modulation amplitude) vary practically synchronously with the amplitude change. The half-width is maximum under the {U-I}-region of negative dynamic resistance. This correlation versus the discharge current suggests that one and the same process contributes to both self-alignment and its destruction.

The falling region of the {U-I}-curve may be attributed to Penning ionization of the atom A via the metastable Ne^M:

$$Ne^M(1\,s_5) + A \rightarrow Ne + A^{+*} + e^-; A => Cd,\ Si,\ etc., \quad (1)$$

that is, direct ionization of the sputtered atoms of low ionization potential. If under some {U-I}-point, this process turns out commensurate with the steep ionization the additional electrons decrease the voltage across the HCD.

Earlier, the HCD mode for operation was observed to be unstable to a disturbance in vicinity of the inflection point and for any galvanic perturbation to damp slowly.[7] Thus, the MG effect should be taken as a possible perturbation. Since the self-alignment in a glow discharge is closer to a rule rather than exception, a misidentified alternating sign magnetic field might act on the HCD lamp as a galvanic perturbation via the $1\,s_5$ state at least. The metastable $1\,s_3$ does not contribute to the MG signal

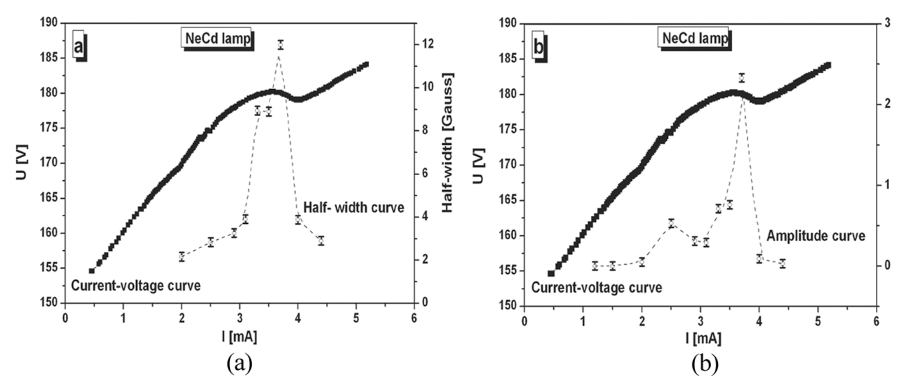

FIGURE 3 Current-voltage (I-U) curve and half-width (a), and (I-U) curve and amplitude (b), dependences in NeCd HCD lamp.

directly because of its zero total moment. As for the NeSi HC lamp, here the amplitude and width of the MG signal change under the narrow I-region (about 0.4 mA).

How does the self-alignment destruction transform into conductivity change Δj? Taking into consideration that j is determined by the electron number density n_e and the electron drift velocity v_e, one can write $\Delta U\ (\mathbf{B}) \propto \Delta j = c_1 \Delta n_e + c_2 \Delta v_e$. The second term can be neglected, because the electron drift velocity v_e is insensitive to weak magnetic induction, pertinent to these experimental conditions. The first term depends on the ionization rate. The sensitivity of the ionisation versus self-alignment destruction has been discussed.[9,10] Reference 9 supposes that the cross-section for collisional ionization from the aligned state must depend on the mutual orientation of the alignment axes and the directional properties of the ionizing particles. Another possible mechanism discussed in reference 10 involves ionization through collisions between aligned metastable neon states (such as $1\,s_5$). Wigner's requirement for conservation of the total spin momentum in such collisions leads to differences in the ionization efficiency from aligned and nonaligned states. The results and discussion above draw attention to the possible contribution of Penning ionization to MG resonance, including via metastable $1\,s_5$.

On the other hand, the metastable Ne I $1\,s_5$ is known to maintain an HCD at low gas discharge parameters.[6] To check the influence of the population and/or alignment of the Ne I $1\,s_5$ level on the formation of the MG signal, an empirical approach based on the selective light perturbation of the transitions $1\,s_5$–$2p_9$ ($\lambda = 640.2$ nm) was applied. The corresponding wavelength λ is synchronously modulated by means of the diode laser current (alternative commutation "on" and "off" the exact transition value) in the successive steps of the B-field ramp. Thus, the measured $\Delta U\ (\mathbf{B})$ signal is recorded in both the irradiated and nonirradiated states. The corresponding maximum LIG signal is an indication of the resonant irradiation. A correlation of MG-LIG signals is of particular interest, since the LIG strongly influences the charge carrier producing levels, and the population of these levels depends on the interaction with different plasma components and on the electron density.

Figure 4 illustrates the decisive contribution of the $1\,s_5$ level to forming the observed MG resonance.

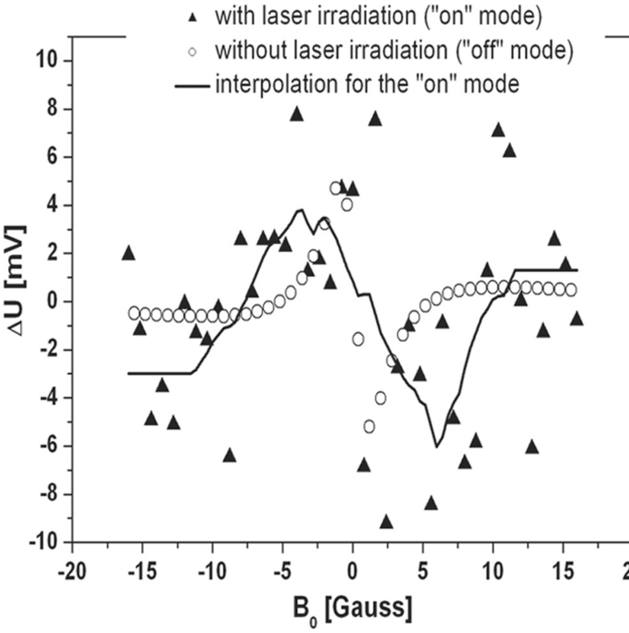

FIGURE 4 **MG signal in NeSi HCD lamp ("Narva") at 640.2 nm irradiating and discharge current 2.6 mA.**

The light perturbation of the metastable dramatic disorders the measured $\Delta U\ (\mathbf{B})$ values and essentially broadens the MG resonance. This result is in concordance with MG measurements in reference 5, where the signal width is found to be close to that of the $1\,s_5$ level at the current discharge parameters.

The same measurements gave another result for the Ne I $1\,s_4$ level. Having been irradiated by $\lambda = 638.3$ nm ($1s_4$–$2p_8$), no change in the MG signal was detected.

CONCLUSIONS

MG signals in NeSi and NeCd HCD lamps contain a local extreme, the amplitude of which depends on the discharge current and reaches the maximum at a current value close to the inflection point of the current-voltage curve. This behavior is attributed to Penning ionization in the HCD.

The metastable Ne I $1\,s_5$ plays a decisive role in the formation of the MG resonance. A misidentified alternating sign magnetic field might act on the stability of an HCD lamp mode for operation via this metastable.

REFERENCES

1. Alexandrov, E. B.; Chajka, M. P.; Hvostenko, G. *Interference of Atomics States*, vol. 7; Springer: Berlin, Heidelberg, New York, 1993; 3.
2. Zhechev, D. Hanle signal formation in the discharge negative glow. *Phys. Scr.* **1991**, *43*, 50–53.

3. Hannaford, P.; Series, G. W. Observation of level-crossing effects in optogalvanic spectroscopy. *J. Phys. B: At. Mol. Phys.* **1981**, *14*, L661–L666.
4. Zhechev, D.; Dulgerova, R. A galvanic replica of the Hanle-signal of self-aligned atomic levels. *Phys. Scr.* **1989**, *40*, 556–557.
5. Zhechev, D.; Lukomskij, N.; Polistchuk, V.; Chajka, M. P. Magneto-galvanic effect in neon discharge. *Opt. Spektrosk.* **1990**, *69*, 474–475 (in Russian).
6. Chaika, M. P. A mechanism of magneto-galvanic effect in neon positive column. *Opt. Spectrosc.* **1995**, *78*(1), 14–19 (in Russian).
7. Zhechev, D.; Atanassova, S. Time dependent optogalvanic reaction and stability to disturbance of an optogalvanic circuit with hollow cathode discharge. *Opt. Commun.* **1998**, *156*, 7400–7408.
8. Tomova, Z. On one type of ionization in tokamak plasma. Proc. of SPIG, 28 August – 1 September Kopaonik, Serbia, 2006, 455–458.
9. Series, G. W. Optogalvanic detection of atomic alignment comments. *At. Mol. Phys.* **1981**, *10*, 199–201.
10. Julien, L.; Pinard, M. Optogalwanic detection of optical pumping. *J. Phys. B: At. Mol. Phys.* **1982**, *15*, 2881–2898.