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A Simple Method for the Optogalvanic Detection of Argon Ion Transitions in Hollow-Cathode Lamps (*).

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Summary. — We describe a simple method for the observation of argon ion transitions in hollow-cathode lamps, using the optogalvanic effect, and report the first optogalvanic detection of the six ArII transitions: 457.9 nm, 476.5 nm, 488.0 nm, 496.5 nm, 501.7 nm and 514.5 nm. We also study the optogalvanic signal as a function of the incident laser power and the lamp current.

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1. – Introduction.

The optogalvanic effect is the photoinduced change in a plasma impedance and has become of wide application in atomic and molecular spectroscopy [1, 2]. Using hollow-cathode lamps (HCL) it is possible to obtain optogalvanic signals (OGS) not only for the buffer gas but also for the cathode species, that are sputtered into the discharge. The lamp is at the same time sample and detector, provided one measures the voltage or current changes, synchronous with the incident radiation.

The measurement of the OGS for the cathode ions Eu II, Ba II [3], U II [4] and even U III [5] has been reported, but at the early stages of the laser-induced optogalvanic studies the signals of the ions from rare gases, like neon [3, 6], argon or xenon [6], were not successfully detected. Using a special «planar hollow cathode» geometry Pfaff *et al.* [7] measured, for the first time, the OGS of ionized rare gases: one transition of the He II (at 650.0 nm) and 8 transitions $3d$-$4p$ of the Ar II (between 610 and 670 nm).

In the present work, we describe a very simple experimental set-up to detect optogalvanic signals of some argon ion lines, in a «standard» hollow-cathode lamp, inducing the absorptions with the intrinsically resonant argon ion laser. By this procedure we measured the OGS as a function of the laser intensity, for the

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six available wavelengths. Selecting the two most intense ones, we also observed the OGS as a function of the lamp current.

2. – Experimental.

One of the most attractive features of the optogalvanic spectroscopy, using a dye laser as a tunable source of radiation, is the simplicity of the experimental set-up, avoiding the use of optical detection measurements and giving rise to an excellent signal-to-noise ratio.

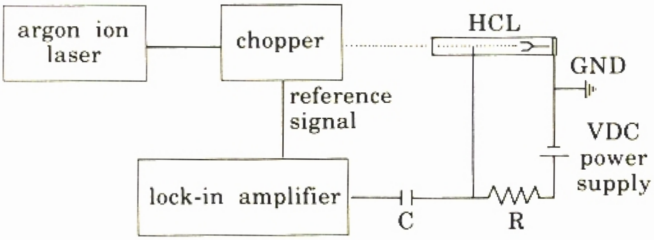

Fig. 1. – Experimental set-up for the optogalvanic spectroscopy of the argon ions in hollow-cathode lamps (HCL, hollow-cathode lamp; R, resistor; C, capacitor).

Looking for the argon ion transitions we have used an even simpler scheme, putting aside the dye laser and directing the argon ion laser beam right into the HCL (fig. 1). The sample was manufactured with the conventional cilindrical hollow-cathode geometry, made of copper and was sealed with a 7.9 Torr ultrapure argon atmosphere. The hollow-cathode discharge was maintained by a stabilized voltage power supply, working in the range of $(200 \div 300)$ VDC, connected to the lamp by a ballast resistor ($R = 1\ \text{k}\Omega$). When the incident radiation frequency is resonant to some transition of the species within the discharge, the resultant changes in the ionization rates are detectable by the lock-in amplifier. The capacitor ($C = 0.1\ \mu\text{F}$) suppresses the DC component of the measured signals and the mechanical chopper modulates the laser amplitude, generating a reference code to the lock-in, that enables the synchronous detection. The incident radiation intensity is regulated simply by changing the laser tube current and the different laser spectral lines are tuned by an intracavity mounted prisma.

3. – Results and discussion.

Even at such low currents in the HCL ($(5 \div 20)$ mA) it was possible to measure, for the first time, the OGS of the six argon ion transitions: 457.9 nm, 476.5 nm, 488.0 nm, 496.5 nm, 501.7 nm and 514.5 nm. All the detected signals showed negative polarities, despite the lamp current, indicating a photoinduced decrease in the plasma impedance, as it was expected [6, 8], once the lower levels ($4s\,{}^2P$ and $3d\,{}^2D$) of the transitions are nonmetastable ones. The mechanism for rare-gas ions to be actually observed by optogalvanic detection was discussed in ref. [7]. The explanation is that the induced excitation of the argon ions alters not the ionization rates, but rather the electron-ion recombination rates.

Setting a constant current in the HCL (15 mA) and ranging the argon laser power from 100 to 400 mW we measured the behaviour of the OGS, in absolute values, as a

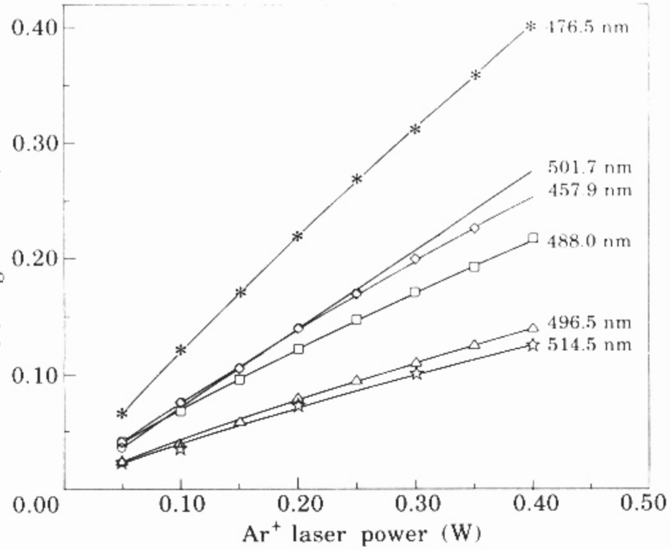

Fig. 2. – Dependence of the argon ion OGS with the incident argon ion laser power, for the six observed transitions (HCL current = 15 mA).

function of the radiation intensity, for all observed transitions (fig. 2). We see that a linear dependence showed here to be valid also for argon ion transitions, at low laser power intensities, as was verified for neutral atoms [9].

To measure the behaviour of the OGS as a function of the HCL current it was necessary to change the lamp voltage very carefully, as to prevent discharge instabilities. Figure 3 shows the evolution of the OGS, in absolute values, with respect to the lamp current, for the 514.5 nm line, ranging laser power intensities up to 1.0 W. Also the 488.0 nm transition showed the same complex pattern. Besides its

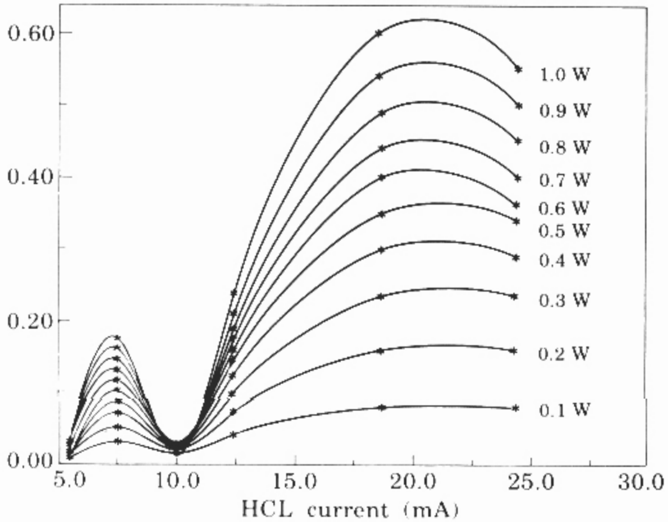

Fig. 3. – Dependence of the 514.5 nm argon ion transition OGS with the HCL current, for several values of the incident argon ion laser power.

«capricious behaviour»[10] and a «somewhat irregular» dependence[7] in a continuous-wave experiment as ours, this evolution can be understood qualitatively, taking into account known mechanisms that are most likely to occur in the discharge, for each range of the lamp current: *a*) at the beginning ($I < 5$ mA), the lower level of the absorption transition is weakly populated, being progressively fulfilled as the current increases, favouring the absorption of radiation and so giving rise to the first maximum of the OGS; *b*) next, for intermediate values of current, the several collision processes of the discharge plasma start to disturb the level occupation, leading to a decrease in the magnitude of the signals[11]; and at last, *c*) as the current increases progressively, so does the electronic density in the plasma, turning back the electron-ion recombination competitive again, thus the OGS will grow up until a new maximum. Once the recombination has become the most important channel of charge losses and the laser absorption by the gas ions diminishes the recombination, whenever this absorption occurs, it will affect drastically the dynamical equilibrium of the discharge voltage and, as a consequence, we observe this maximum with a magnitude still greater than the previous one (cf. fig. 3).

4. – Conclusions.

With this brief study of the argon ion OGS as a function of the laser intensity and the lamp current, we realized how suggestive it can be to perform the optogalvanic spectroscopy of rare-gas ions, putting the availability of a coherent radiation source, stable and intense, tuned precisely over the transitions of interest, together with the simplicity of the experimental set-up and other advantages of the optogalvanic technic, like the high signal-to-noise ratio, the relief from optical detection devices and the resolution limited almost only by the laser linewidth.

The observation and study of the OGS in rare-gases ions could be conveniently extended to other ion laser transitions, including those from the kripton ion (Kr II) and those achieving the ultraviolet range of the spectrum (obtained by either Ar III or Kr III transitions) provided one just manufactures suitable lamps and takes into account the undesirable interferences arising from the photoelectric effect in the hollow cathode.

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