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TWO METHODS FOR PRESSURE MEASURING IN USED SEALED-OFF GAS LASER TUBES

M. Ristici, Iosefina Ristici, Madalina Nicolae, Iris Badicu
National Institute for Lasers, Plasma and Radiation Physics
P.O. Box MG. 6, R-76900 Bucharest-Magurele, Romania

The non-destructive evaluation of gas pressure in sealed-off gas laser tubes was performed using measurements based on emission spectroscopy and measuring of drop-out current. Using a 2 mm bore diameter He-Ne laser tube attached to a gas filling station to vary the pressure in the range (1÷20) x 10^2 Pa, we have obtained a set of calibration curves for various values of the discharge current. In the method of drop-out current the current measurements show that current decreases when the pressure increases. For pressure measurements in a sealed-off laser tube, both methods were used and compared.

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1. Introduction

The loss of gas in laser tubes limits the lifetime of any sealed-off gas lasers. For still working lasers, it is important to determine how many hours may it be used yet. This is possible by measuring the gas pressure.

It is desirable to have means of determining the composition and pressure of the filling gas in a laser discharge tube without opening the tube, so that one may ascertain whether or not a given discharge tube would be capable of sustaining laser oscillation. A non-destructive evaluation of gas pressure using measurements of emission spectroscopy was made. Csillag et al. [1] and Ahearn and Horstmann [2] have developed a method to determine the total pressure in a helium-neon laser tube.

Our work is an extension of the method developed in [1,2] with the purpose of diagnosing some He-Cd and He-Se laser tubes using helium as a buffer gas.

2. Experimental set-up

Fig.1 shows the experimental set–up used for the pressure measuring method. We have used a vacuum station able to develop 10^{-6} Torr. The sidelight is focalized on the entrance aperture of a 0.1 nm resolution grating monochromator. The electrical signal generated by the EMI 9558 QB photomultiplier is processed by a photon counting system (type PAR 1105).

To measure the total pressure by spectral analysis, we have used two spectral lines of the helium atom: λ_1 = 501.6 nm and λ_2 = 587.6 nm.

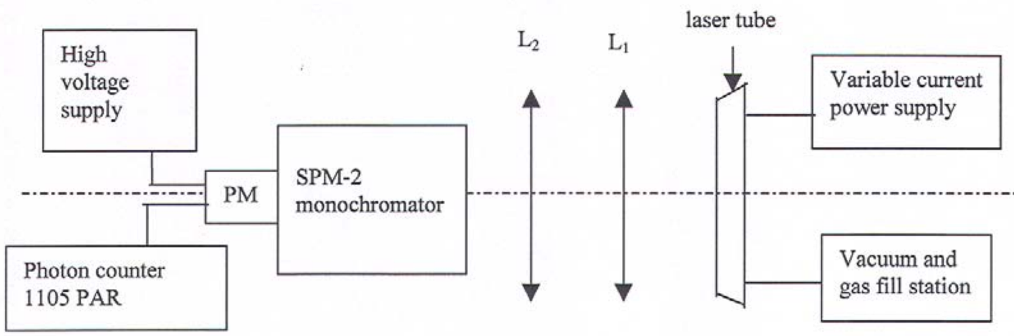

Fig.1Experimental set-up. L_1, L_2 - optical lenses, PM - photomultiplier

Fig. 2 shows the energy level diagram for the relevant emission lines. Both He lines have their upper levels of about the same energy and are excited by direct electron impact. Their electron excitation rates would be of comparable magnitude and would also have a similar dependence on the helium gas pressure. In fact, the ratio of the electron excitation rates for the 501.6 nm and the 587.6 nm lines seems to be relatively independent of helium pressure. Further, the upper state (3^3D) for the 587.6 nm line has a single radiative decay channel that is independent of the gas pressure. The upper state (3^1P) associated with the 501.6 nm transition has an alternative radiative decay scheme to the ground state by a strong resonance transition in the vacuum ultraviolet with the resulting radiation being trapped.

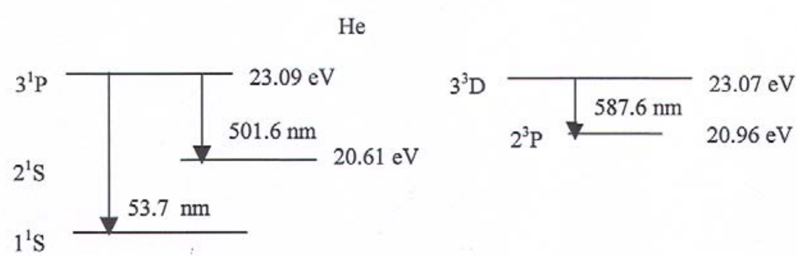

Fig.2 Energy level diagram for the helium lines involved.

3. Results and discussions

Fig. 3 shows the experimental behaviour of helium line intensities vs. gas pressure. There is an evident difference between the two curves. An explanation may be the different radiative decay channels for the two upper levels [2].

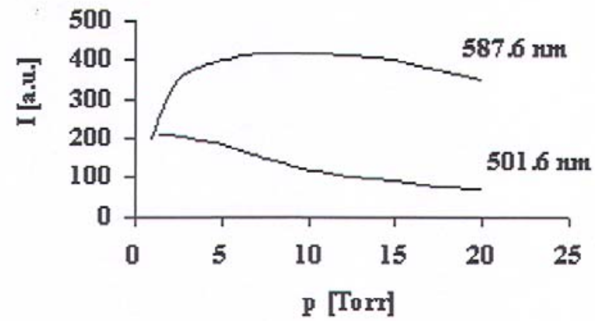

Fig.3 Helium line intensities vs. gas pressure.

Fig. 4 shows the dependence of line intensities vs. discharge current for 7.4 Torr gas pressure value. There is a significant difference between the two curves. Since the intensity of the line situated at 501.6 nm increases linearly, the intensity of the line situated at 587.6 nm has a saturated value for a current of 8 mA.

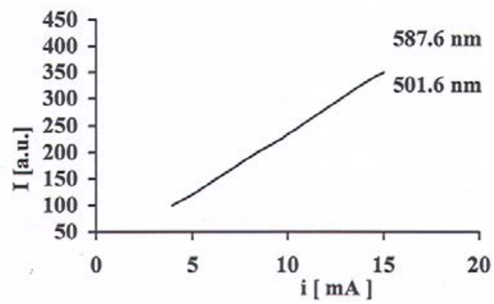

Fig. 4 Intensity dependence on current for the two helium lines.

The calibration curves are illustrated in Fig. 5. These represent the dependence of the ratio of helium line intensities r (p) = I_1/I_2 on helium pressure, for different current values (j).
Using these calibration curves, the pressure of He-Ne and He-Se (home made) sealed-off laser tubes was checked [4]. The results are in good agreement with the known values for just gas filled tubes and with those expected, after a long working time, for other laser tubes.

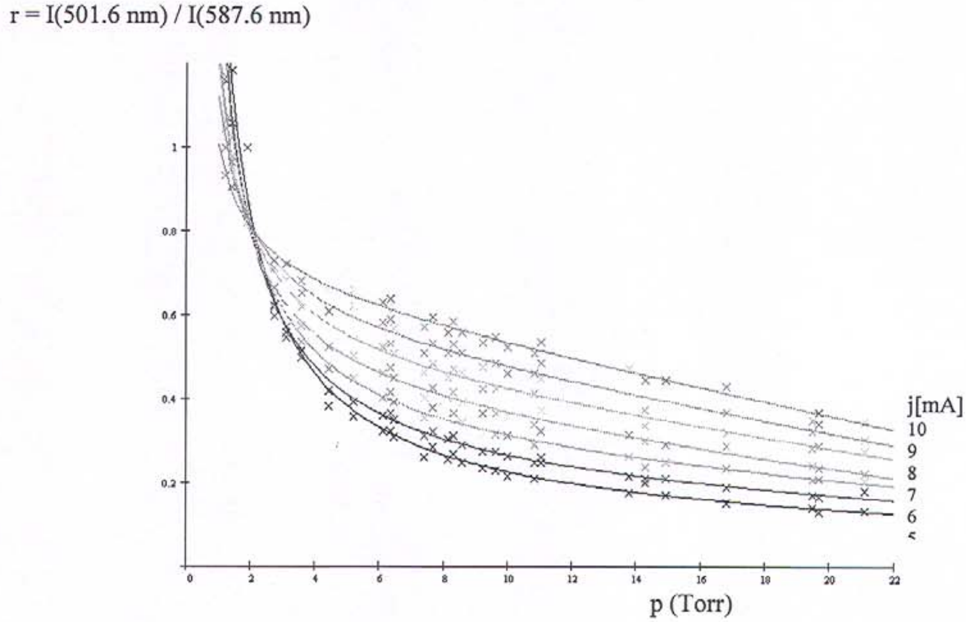

Fig. 5 Calibration curves for the different discharge current values.

In a previous paper [5] we have reported some experiments using a self-heating all Pyrex He-Se laser tube that has a 20 Torr helium filling pressure. From the calibration curves (Fig. 5) we determined that, after about 5000 hours of operation, the helium pressure is 14.7 Torr. That result is in a good agreement with the estimations based on the clean-up phenomenon. Also, the laser output power has decreased below 50% from initial value.

The measurement method involves numerical processing of experimental data i.e. fitting the experimental data with a convenient function of helium pressure, by using the least-squares method. In this case, it seems that the most convenient function is $r(p) = a \cdot p + b + c/p$ where a, b and c depend on the discharge current.

From these curves, we obtain a pressure value for each discharge current. The computed pressure value is the mean value of this set. It is easy to observe that the curve shape changes to a straight line when the gas pressure is higher than 5 Torr and the discharge current is around the 10 mA. Also, the slope of this line decreases as the discharge current, increases. Thus, if we use high discharge currents for an estimated high pressure, we can improve the measurement accuracy. For pressure values smaller than 5 Torr, we can get a good resolution by using small discharge current values.

Fig. 6, 7 and 8 show the dependence of the "a, b, c" - coefficients on the discharge current.

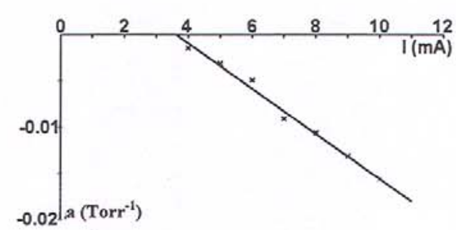

Fig. 6 Dependence of the a – parameter on the discharge current.

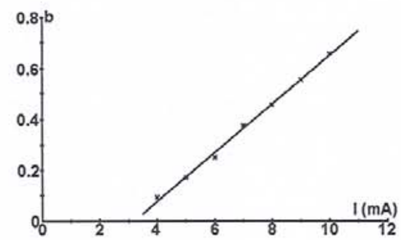

Fig. 7 Dependence of the b-parameter on the discharge current.

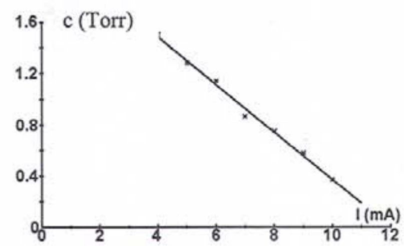

Fig. 8 Dependence of the c-parameter on the discharge current.

We can see that the a, b, c - coefficients vary in a different manner. Thus, a and c decrease when the current value is increasing, while b- increases in the same conditions. There is a value of the current at which the coefficient c is zero. In this case the calibration curve is linear r(p)=ap+b. For higher values of the discharge current the sign of the calibration curve slope changes.

4. The drop-out current method

A method for pressure diagnosis is the method of drop-out current. The drop-out current is defined as the minimum current possible to be sustained in the discharge. It depends on: the power supply, the quality of electrical connections, the ballast resistor, the tube diameter, the presence of the magnet near the capillary, the discharge current, etc.

The drop-out current results show that it decreases with increasing of the total pressure (Fig. 9).

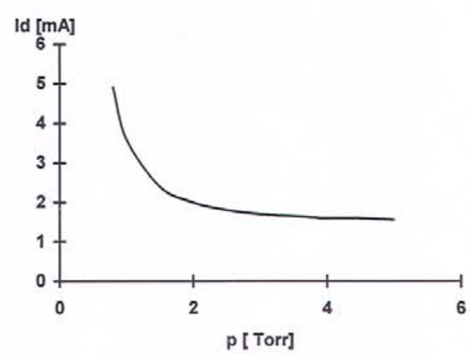

Fig . 9 Dependence of the drop-out current on total pressure of the gas discharge.

5. Conclusions

The evolution of the gas content in a gas laser tube can be surveyed if, with a simple spectroscopic set-up, we determine the intensity ratio of two helium lines. Using a previously obtained calibration curve, we can measure the helium pressure. An alternative for pressure measurements is the method of drop-out current. The results obtained for a He-Ne laser tube using the drop-out current are quite similar with the pressure values deduced from spectral analysis.

A dependence of the calibration curves on the value of the discharge current was found.

Using the least-squares method for fitting the experimental data, a mathematical relation was proposed.

The calibration curve slope changes to a straight line when the gas pressure is higher than 5 Torr and the discharge current is around the 10 mA.

Using the calibration curves, the pressure of He-Ne and He-Se (home made) sealed-off laser tubes was checked out. The results are in good agreement with the known values for just gas filled tubes and with those expected, after a long working time, for other laser tubes.

This method is useful to diagnose the He-Ne, He-Se and He-Cd laser tubes, having the same inner diameter.

References

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