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BUDAPEST

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ON THE DETERMINATION OF GAS PRESSURE AND MIXTURE RATIO IN SEALED OFF He-Ne LASER TUBES

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ABSTRACT

A simple spectroscopic method is described for the determination of gas content and pressure in sealed off He-Ne laser tubes, measuring the intensity ratio of the lines He 5016 Å, He 5876 Å and Ne 5852 Å.

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Egyszerü spektroszkópiai módszert ismertetünk lezárt He-Ne lézercsövek nyomásának és keverékarányának mérésére, a He 5016 Å, He 5876 Å és Ne 5852 Å szinképvonalak relativ intenzitásának mérése alapján.

РЕЗЮМЕ

Описан спектроскопический метод определения состава и давления газа без разрушения трубки гелий-неонового лазера, основанный на измерении относительных интенсивностей линий He 5016 Å, He 5876 Å и Ne 5852 Å.

For the development of long life time 6328 Å He-Ne gas laser tubes, and for investigation of failure causes, it is necessary to determine - without opening the tube - how the gas filling changes with the time. Studying gas clean up in high frequency excited He-Ne lasers Turner et al [1] found, that the intensities of some Ne lines, compared to that of the He 4026 Å line, change in a different manner with the total gas pressure and with the neon partial pressure and therefore can be used for pressure measurements.

Studying the life time of cold cathode He-Ne laser tubes, the same problem was faced by us. To solve it, Turner's spectroscopic method was also applied, but by using other lines. From the many possibilities, lines were searched, the intensity ratio of which depend from only one parameter: either from the total gas pressure or from the partial pressure of Ne.

It was found that the intensity ratio of the strong green /5016 Å/ and yellow /5876 Å/ helium lines fulfills the first requirement, since it depends strongly on the total gas pressure, but do not depend on the Ne partial pressure in the $P_{He}/p_{Ne} = 5/1 \div 10/1$ mixture ratio region.

On the other hand lines, the intensity ratio of which does not depend on the total gas pressure, could not be found. Therefore, for a given pressure determined from the I_{5016}/I_{5876} ratio, the intensity ratio of the He 5016 Å and the strong Ne 5852 Å lines was choosen, which varies very sensitively with changing the Ne partial pressure.

The simple arrangement used for the measurement of spectral line intensities is shown on Fig. 1. The spontaneous light coming from the side of the laser tube was detected. The inner diameter of the capillary tube amounted to 1,3 mm. The spectral lines were selected by a grating monochromator and measured by an EMI 9664 photomultiplier. Before the beginning of the measurement, it took about 30 minutes, untill the thermal and cataforetic effects ceased to act. The discharge current used was always 5 mA.

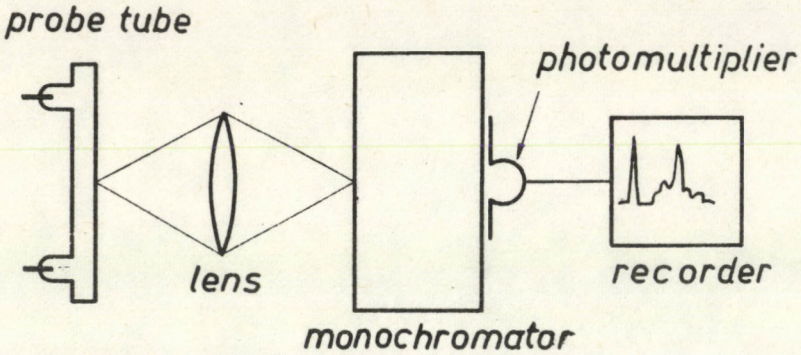

Fig. 1 Arrangement for measurement of spectral line intensities.

The measured pressure dependence of the I_{5016}/I_{5876} intensity ratio is shown on Fig. 2. It can be seen, that in the pressure region 2-4 torr, and mixture ratio $P_{He}/p_{Ne} = 5/1 \div 10/1$ it depends only on the gas pressure. Fig. 3 shows the calibration curves for the intensity ratio I_{5016}/I_{5852}. It can be seen that the dependence of the intensity ratio on the neon partial pressure is linear and the slope of the line is rather steep, that means it is very sensitive to changes in Ne partial pressure.

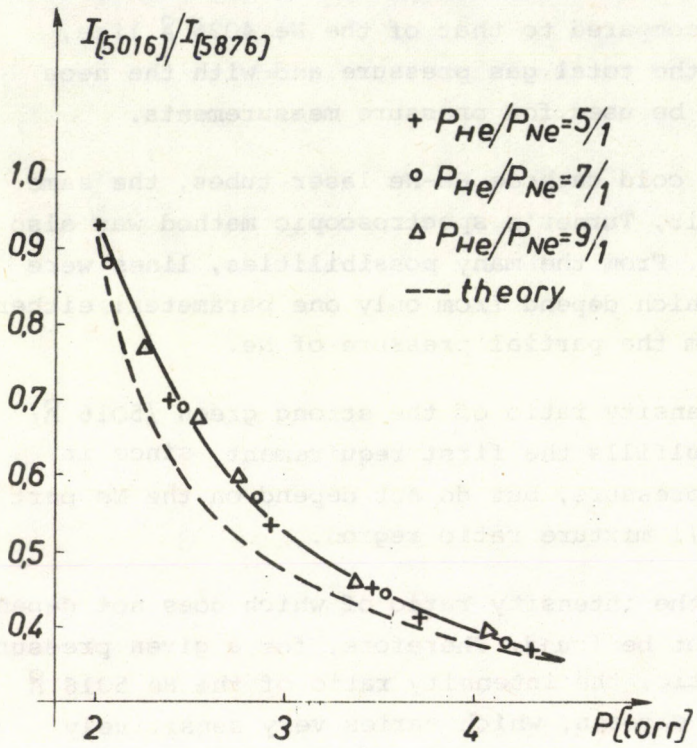

Fig. 2 Pressure dependence of the I_{5016}/I_{5876} intensity ratio

The accuracy of the measurement amounts to about 5%, but relative changes in the pressure or in the mixture ratio can be detected much more accurately. It has to be noted, however, that contaminations, such as hydrogen, change the intensity ratios and can cause systematic errors. In our case, the gas filling was practically free from hydrogen /the red H_α line could hardly be detected/.

The independence of the intensity ratio of the He 5016 Å and He 5876 Å lines from the Ne partial pressure is connected simply with the fact that the electron temperature of a He-Ne discharge is practically independent from

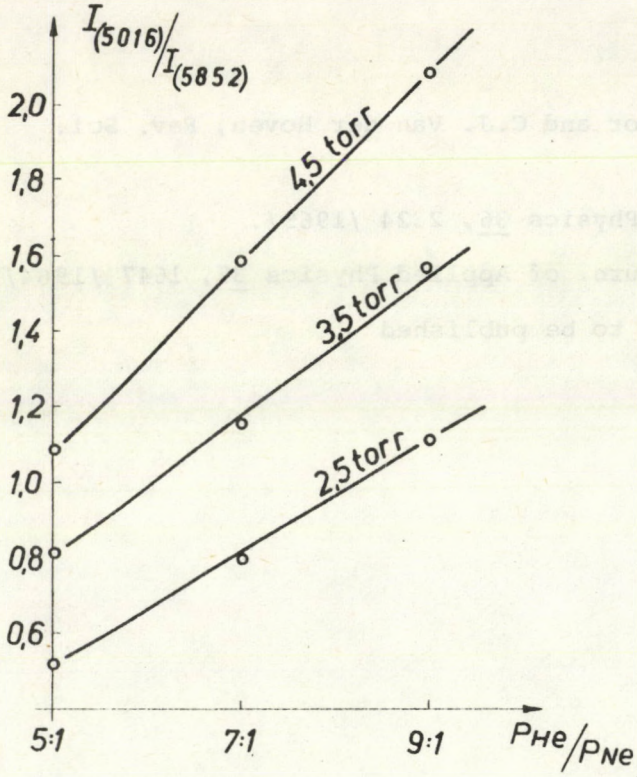

Fig. 3 Calibration curves for the I_{5016}/I_{5852} intensity ratio.

the Ne partial pressure, in the region, above mentioned. This was shown by calculations of Young [2]; electron temperature measurements in He-Ne discharges supporting these calculations were performed by Labuda and Gordon [3].

The dependence of this intensity ratio on the gas pressure can also be explained. On Fig. 4 the main physical processes which are involved in the excitation of these lines are illustrated. Both upper levels are excited from the He ground state mainly by direct electron collisions. The cross sections for these collisions are functions of the electron temperature, thus also of the gas pressure. In addition to this the He 5016 Å transition is coupled to the ground state through the strong vacuum UV resonance transition, and therefore radiation trapping occurs, which is also pressure dependent.

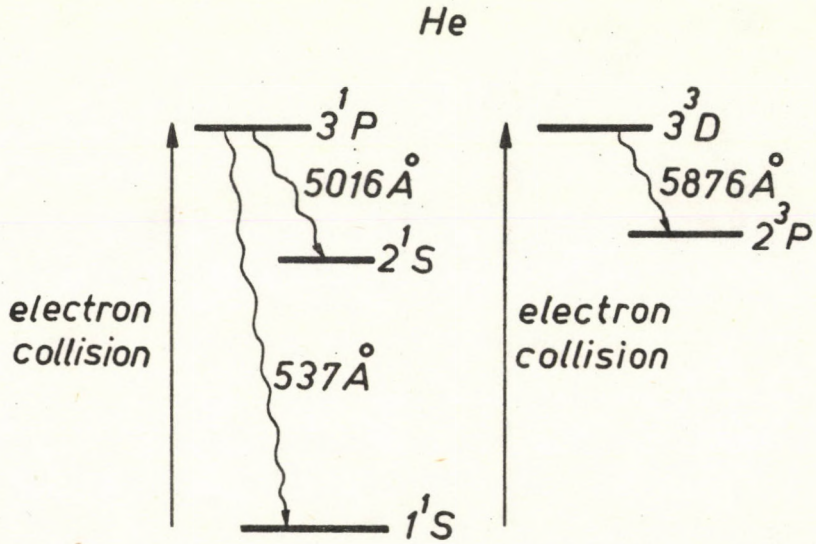

Fig. 4 Excitation processes for the He 5016 Å and 5876 Å lines.

On the basis of this excitation model, using rate equation analysis, the pressure dependence could be calculated [4]. The calculated curve, matched at the lowest pressure value /see Fig. 2/ to the experimental one, follows quite well /better than 10%/ the experimental curve. Regarding the simple assumption used, this agreement seems to be satisfactory.

Our method for determination of gas pressure and mixture ratio in sealed off laser tubes is not restricted to He-He mixtures, it can be applied in the case of other gas mixtures as well.

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