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ABSTRACT

Operation parameters of near infrared Al II laser transitions were investigated in a large diameter hollow cathode Ne-Al discharge where Al vapour was produced by cathode sputtering. The results of measurements support a charge transfer collision excitation mechanism.

АННОТАЦИЯ

Исследованы параметры Al II лазерных переходов в ближней инфракрасной области в разряде Ne-Al с применением полого катода, где пары Al были созданы катодным распылением. Результаты измерений подтверждают, что возбуждение осуществляется посредством обмена зарядов при столкновениях.

KIVONAT

A közeli infravörösben sugárzó Al II lézer átmenetek müködési paramétereit nagy átmérőjü üreges katodu Ne-Al kisülésben vizsgáltuk, ahol az Al gőz katódporlasztás révén keletkezett. A mérési eredmények megerősitik, hogy a gerjesztési mechanizmus töltéskicserélő ütközés.

In recent hollow cathode laser research important development has occurred due to the application of cathode sputtering for production of metal vapour active materials. CW laser oscillation on transitions of Al II utilizing cathode sputtering for production of Al vapour was observed first in slotted hollow cathode Ne discharges [1, 2]. Later on oscillation was obtained also in an internal anode high voltage hollow cathode tube [3]. Since only few data are known of the cathode sputtering operated Ne-Al ion laser, it seemed to be of interest to perform further experiments in this field. In the present paper we report results of our investigations performed on a large diameter hollow cathode Ne-Al ion laser. The measured dependence of laser operation parameters on discharge conditions supports the charge transfer excitation mechanism suggested in Refs. [1] and [2].

The scheme of the hollow cathode laser tube used in our experiment is shown in *Fig. 1*.

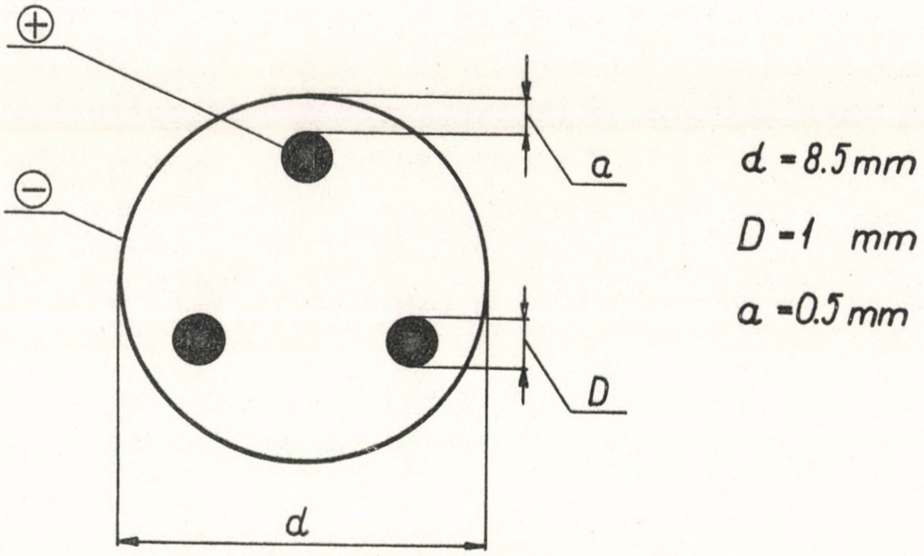

Figure 1

Section of the hollow cathode discharge tube

The inner diameter of the pure Al hollow cathode was 8.5 mm, the internal anode consisted of three wolfram rods placed inside the cathode as can be seen in the figure. To increase discharge stability the laser was built of segments [4], the length of each cathode being 10 cm. The active length of the tube was 40 cm at the beginning of the experiment, due to the failure of one segment during the measurements the investigations were continued with 30 cm length, however. The discharge was excited by half wave rectified alternating current where the repetition rate was reduced to 12.5 Hz. No arcing occurred within the discharge current and pressure range investigated. Stable laser operation at the 704.2 nm Al II transition was obtained also using 50 Hz excitation frequency. Mirrors totally reflecting in the wavelength range 640-790 nm were used in the experiment. No special procedure as described in [1] was used to remove the oxide layer from the surface of the Al cathode. It is noted, however, that the Al hollow cathode tube was operated for a long time /∿20 hours/ as a He-Kr laser before the present investigations on the Ne-Al laser were started.

It was found that addition of a small amount of Ar to Ne decreases the threshold current for laser oscillation. Threshold currents of the 704.2 nm and 692 nm Al ion transitions measured as a function of Ar partial pressure are shown in *Fig. 2*. The data were obtained with 40 cm active length, optimum Ar partial pressure is 0.04 torr. This decrease of threshold current occuring at Ar pressures below 0.1 torr was not observed by Schuebel [2]. By exciting the discharge with single 22 A peak current 6 msec duration pulses laser oscillation was observed at the 747.1 nm Al II transition. Using this single pulse excitation laser operation occurred at all three Al II wavelengths in a 1.1 torr 1/1 Ne-Ar mixture. No lasing was observed, however, in pure Ar or by using He-Ar.

The 704.2 nm transition was investigated in detail using 30 cm active tube length. *Fig. 3* shows dependence of threshold current on Ne pressure measured at optimum Ar partial pressure. The lowest threshold current occurs at a Ne pressure of 1 torr. Laser intensity as a function of Ne pressure is shown in *Fig. 4*, the optimum pressure is about the same as where threshold current is minimum. The pressure times diameter product p·d = 8.5 torr-mm

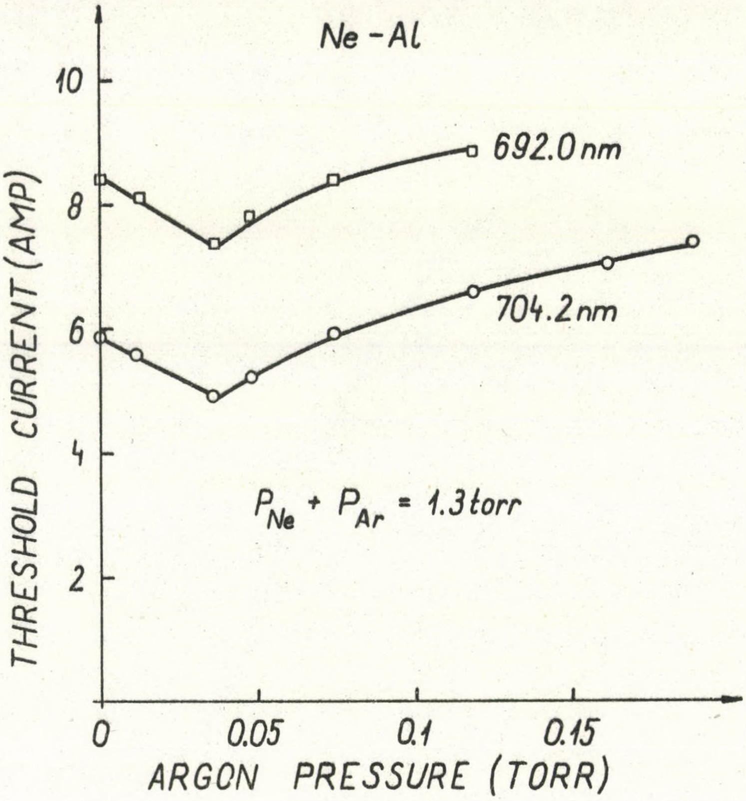

Figure 2

Dependence of threshold current on Ar pressure

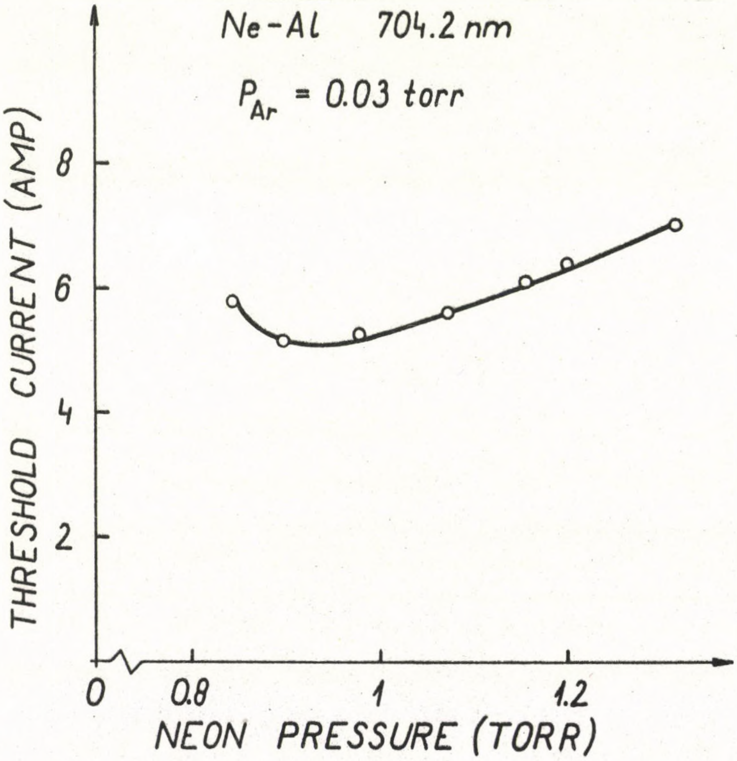

Figure 3

Dependence of threshold current on Ne pressure

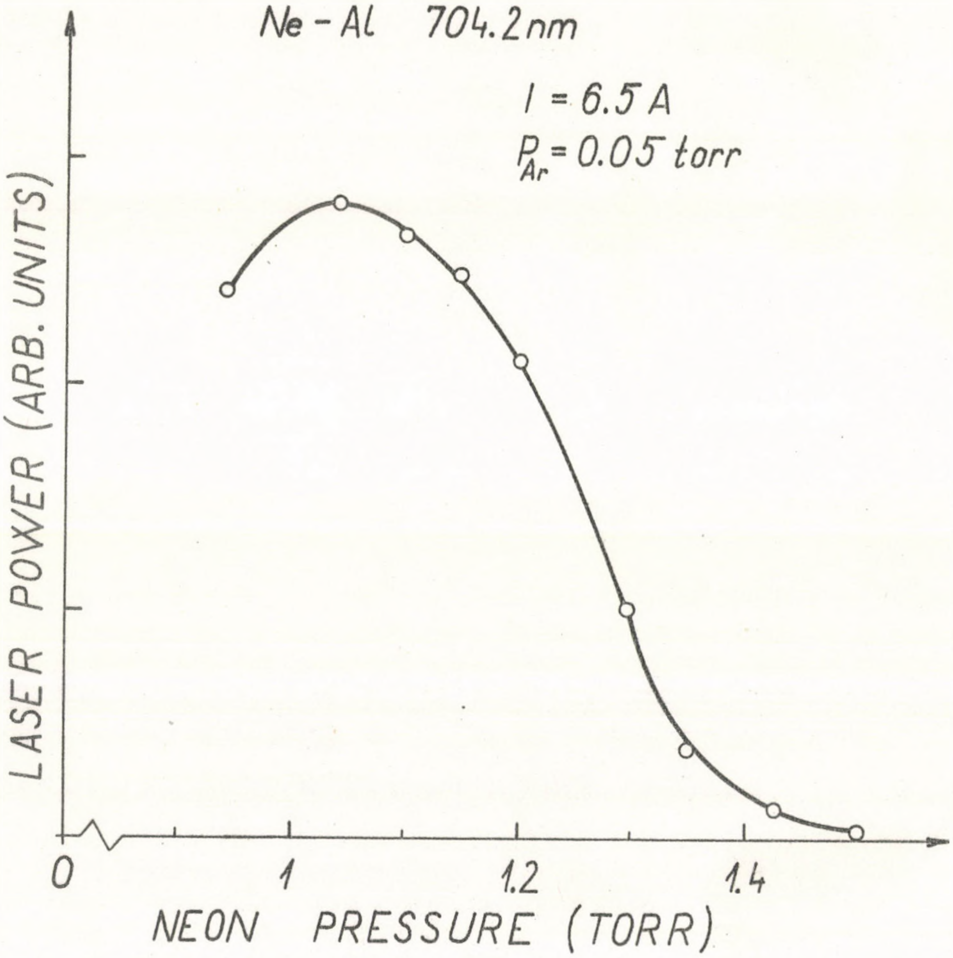

Figure 4

Dependence of laser power on Ne pressure

agrees well with the value 8 torr-mm measured in [1]. The somewhat lower optimum p·d = 6 torr-mm obtained in [2] was measured in the presence of H_2, this may be the reason for the difference. The dependence of laser intensity on instantaneous discharge current measured at different Ne pressures is shown in *Fig. 5*. The curves obtained are slightly non-linear. Tube voltage, spontaneous intensity of the 396.1 nm Al I line and Ne ion density are plotted in *Fig. 6* as a function of Ne pressure. Tube voltage and 396.1 nm intensity were measured at 5 A discharge current, the curve corresponding to Ne ion density was measured in [5] in an Al hollow cathode tube of 16 mm diameter. To be able to compare this result to ours p·d is used for pressure scale in *Fig. 6*.

In Refs. [1] and [2] the excitation mechanism suggested for the Ne-Al laser is charge transfer collisions between Ne^+ ions and Al atoms. The upper level of the 704.2 nm line is assumed to

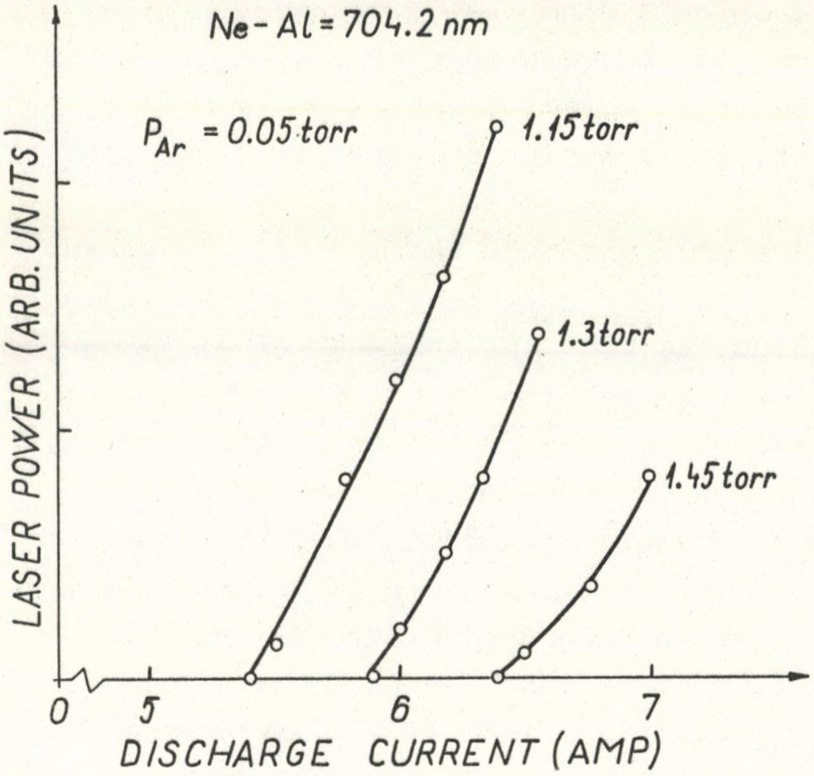

Figure 5

Dependence of laser power on discharge current

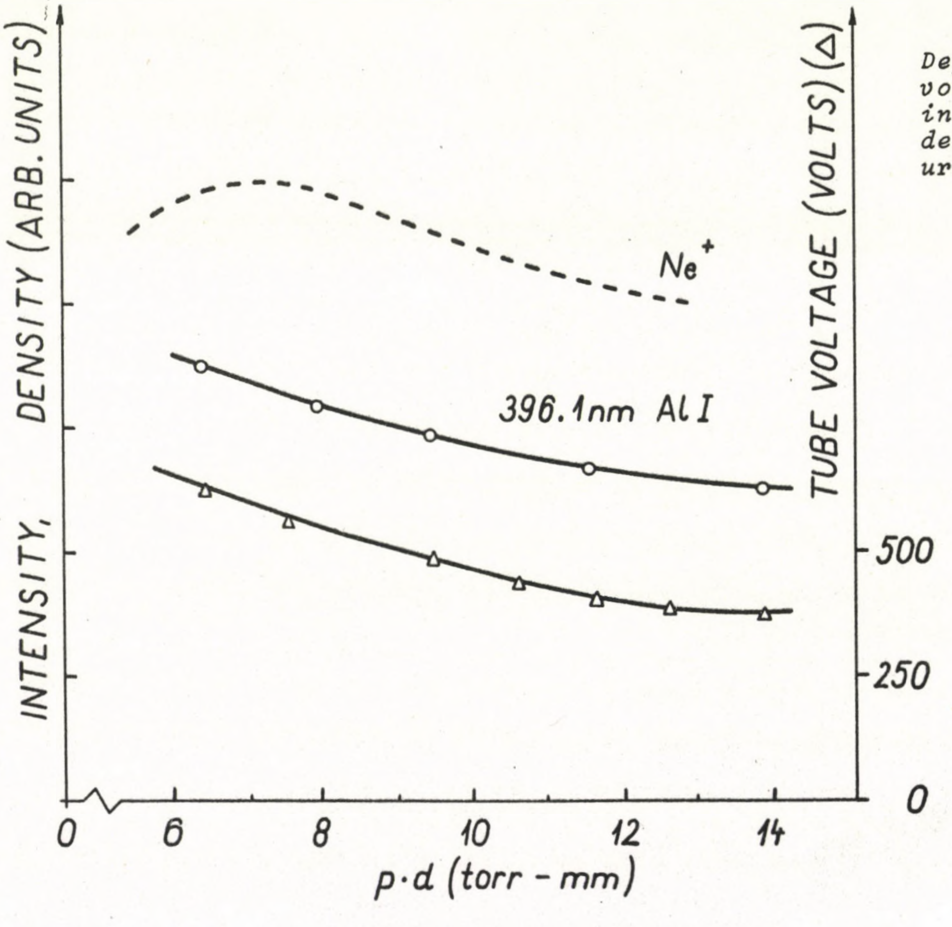

Figure 6

Dependence of tube voltage, 396.1 nm intensity and Ne^+ density on Ne pressure /in p·d units/

be populated by radiative cascade from charge transfer excited higher energy Al II states. Our results support the suggested excitation mechanism. It was found that the use of Ne is crucial for obtaining laser operation, no lasing occurred in other gas mixtures. Also the p•d = 8.5 value obtained for optimum laser operation corresponds quite well with the optimum p•d = 7 measured for Ne^+ ion density in [5]. The increase of laser power with decreasing Ne pressure is due to both the increase of Al vapour density and that of Ne^+ ion density. The change in Al vapour density is indicated qualitatively by the increase of the intensity of the 396.1 nm Al I line. The decrease of laser power at Ne pressures below the optimum is due to the decrease of Ne^+ ion density. This is believed to occur partly because of the increased sputtering of Al which by charge transfer collisions results an increased rate of destruction of Ne ions. In this low pressure region due to the rather high voltage /600 V/ the increasing role of other ion species /Ne^{2+}, Al^+/ in maintaining the discharge [5] can also lead to a reduction of the Ne^+ density.

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