

b) 1165, 1236 Å

Die Energie der Kryptonlinien genügt zwar, um bei der Photodissoziation primär $\text{NO}(\text{A}^2 \Sigma^+)$ und $\text{NO}(\text{B}^2 \pi)$ zu bilden, es ist aber anzunehmen, daß mindestens ein Teil der Fluoreszenz ebenfalls durch Sekundärreaktionen zustande kommt. Denn durch Photodissoziation läßt sich das Auftreten von zwei Bandensystemen bei verschiedenen N_2O -Drucken so-

wie die Intensitätsabhängigkeit von der Strömungsgeschwindigkeit und vom NO-Zusatz kaum erklären. Eine weitergehende Deutung des Fluoreszenzmechanismus bei den Xenon- und Kryptolinien ist ohne größere Willkür nicht möglich.

Wir danken Herrn Prof. Dr. W. GROTH für die Förderung der Arbeit und der Kernforschungsanlage Jülich des Landes Nordrhein-Westfalen e.V. für finanzielle Unterstützung.

Measurements on a Stable and Unstable Mode Observed in a Lithium Reflex Arc

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(Z. Naturforschg. **20 a**, 445—451 [1965]; eingegangen am 1. Dezember 1964)

A powerful P. I. G. reflex arc in lithium vapour has been studied using spectrographic, mass spectrometric and probe measuring techniques. The Li-vapour has been produced in a special Li-oven; the vapour entered through a small tube directly into the hollow anode cylinder. The residual gas pressure was 10^{-7} mm Hg with the arc in operation, the density in the plasma column was about 10^{13} cm^{-3} .

The discharge showed two different modes of operation. We observed that at a fixed flow of Li-vapour the discharge can be operated in a stable state (Mode I) only below a certain limit of the applied electrical power. An increase of electrical power (or a decrease of the flow of Li-vapour) causes a strong instability (Mode II).

1. *Mode I* showed the discharge column to be very well stabilized by the confining magnetic field. Electrostatic probe measurements showed no voltage fluctuations. The electron temperature ranged from 1.8 to 8 eV, depending on the electrical power applied.

2. *Mode II* showed the plasma column to become diffuse. Large voltage fluctuations of several volts in the megacycle region could be detected on the electrostatic probe. A powerful flux of ions leaving the plasma column perpendicular to the magnetic lines of force and hitting the walls with energies up to 327 eV has been measured. These energetic ions are responsible for the strong light emission of the walls of the vacuum tube, this light intensity being much higher than the intensity of the plasma column.

The experimental results are similar to those observed by NEIDIGH, WEAVER, NEZLIN and SOLNTSEV under different experimental conditions.

A highly ionized Li-arc plasma produced in the inner part of a molecular ion injection machine — like the D.C.X.-, M.M.I.I.- or OGRA-machine — in which deuterium molecular ions are injected should offer the possibility to dissociate the D_2^+ -ions, maintaining the back ground pressure at the same time at rather low values and thus avoiding charge exchange losses. Led by this idea a lithium arc experiment has been set up in the Oak Ridge National

Laboratory¹. This simple D. C. arc runs in an axial magnetic field between a cathode and an anode, the latter being fed by lithium vapour. Measurements on this arc have been published in two reports^{2, 3}.

For the same purpose, another discharge type, namely a hollow anode reflex arc experiment has been set up in this laboratory^{4, 5}. Measurements made on this discharge when running in pure lithium vapour will be reported here.

¹ Semiann. Progr. Rep. ORNL-3011, Oak Ridge 1960, pages 46 to 50.

² Semiann. Progr. Rep. ORNL-3104, Oak Ridge 1961, pages 49 to 58.

³ Semiann. Progr. Rep. ORNL-3239, Oak Ridge 1961, pages 48 to 61.

⁴ M. FUMELLI and F. C. GILBERT, Report EUR-CEA-FC-86; Fontenay-aux-Roses, February 1961.

⁵ M. FUMELLI, Report EUR-CEA-FC-155, Fontenay-aux-Roses, April 1962 or Report EUR 1627. f Euratom-Bruxelles.



Experimental

The experimental arrangement of the reflex arc is the same as described in the preceding publications⁴⁻⁷. Figure 1 is a schematic drawing of the apparatus, and the position of the spectrographs, the mass spectrometer and the probe used in our experiment is shown.

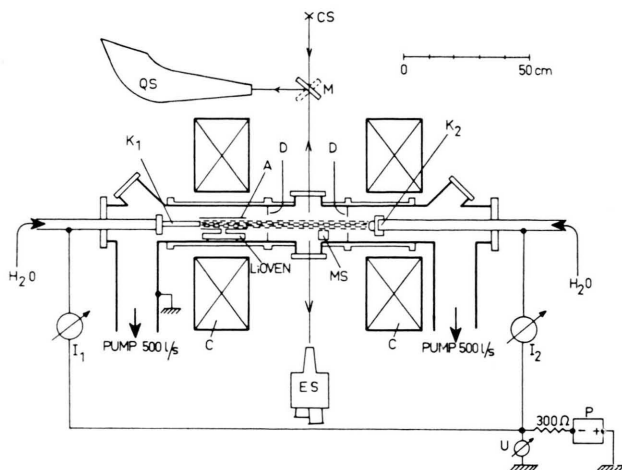


Fig. 1. Experimental arrangement (schematic drawing), A = hollow anode with inner diameter of $2R_0 = 3$ cm; K_1 = cathode 1; K_2 = cathode 2 (reflector); D = diphragm; MS = mass spectrometer; or electrostatic probe; QS = Hilger medium quartz spectrograph; ES = Reosc echelle spectrograph; M = mirror; CS = Calibration source; P = Power supply; C = Magnetic coils. The distance between K_1 and K_2 is $L = 65$ cm, the length of the hollow anode A is $l = 10$ cm.

The arrangement of the electrodes is basically the same as used in a conventional P. I. G. discharge. The main-arc discharge runs between the cylindrical hollow anode A, where the lithium vapour is introduced, and the cathode K_1 . The cathode K_2 acts as reflector for electrons. The anode is grounded together with the whole vacuum system. The same negative potential is applied to both cathodes. The confining magnetic field is in axial direction; it is produced by two coils, C. The field strength between the two coils is half as high as in the center of the coils, (mirror ratio = 2). When the discharge is running, a plasma column of about constant brightness extends along the axis from cathode K_1 to cathode K_2 . The diameter of this column is approximately equal to the inner diameter $2R_0$ of the hollow anode, A, i. e. $2R_0 = 3$ cm. Before initiating the discharge purified lithium metal is heated in the Li-oven, and the lithium vapour thus produced at temperatures of about 705°C enters through a small tube into the hollow anode cylinder, the flow being $2.5 \cdot 10^{-4}$ g/sec. With the discharge running, the residual gas

pressure is about $1 \cdot 10^{-7}$ mm Hg, and the Li-vapor pressure in the anode cylinder is about $5 \cdot 10^{-3}$ mm Hg.

Typical parameters of the discharge are: Applied voltage $U = 400$ to 800 volt; current $I_1 = 1.5$ to 6 Amp; current $I_2 = 0.2$ to 1.5 Amp; magnetic field strength $B_z = 2000$ to 4000 G in the center of the coils.

For the spectrographic measurements a conventional Hilger medium quartz spectrograph and a Reosc echelle spectrograph were employed, the latter having a reciprocal dispersion of 4 \AA/mm and an aperture ratio⁸ of $f/5$.

The position of the mass spectrometer MS is shown in Fig. 2. The axial magnetic field B_z served for deviating the ions.

For more detailed informations the reader may be referred to the mentioned publications, especially to⁵.

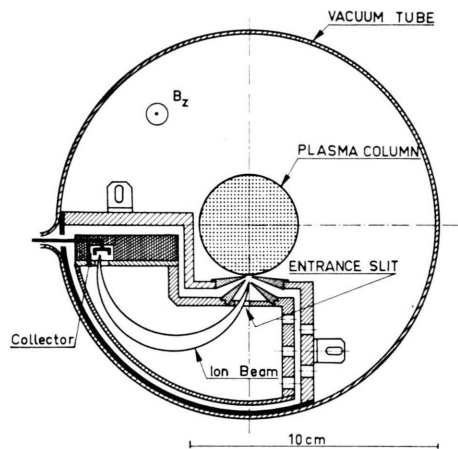


Fig. 2. Experimental arrangement of the mass spectrometer used in this experiment.

Experimental Results

Two very different kinds of discharges have been observed. They may be called Mode I-arc and Mode II-arc. The Mode I-arc shows a well confined plasma column without electrostatic perturbations; in the Mode II, the plasma column becomes diffuse and shows strong electrostatic perturbations.

a) The Mode-I-Arc

This discharge showed a green colour, the discharge column was very well stabilized by the confining magnetic field. The visible "green" diameter

⁶ H. W. DRAWIN and M. FUMELLI, Report EUR-CEA-FC-264, August 1964; to be published in Proc. Phys. Soc., London.

⁷ H. W. DRAWIN, M. FUMELLI and G. WESTE, Report EUR-CEA-FC, August 1964; Z. Naturforschg. **20 a**, 184 [1965].

⁸ A. BAYLE, J. ESPIARD, C. BRETON, M. CAPET, and L. HERMAN, Rev. Optique **11**, 585 [1962].

of the plasma column was about 3 to 4 cm, the brightness depending on the Li-vapour pressure and the electrical current through the discharge. The arc could be operated for hours without contaminating the quartz windows with Li-metal. The electrical parameters are: $U = 700$ to 400 volt, $I_1 = 1$ to 3 Amp., $I_2 = 1$ to 1.5 Amp.

1. Spectroscopic Measurements

A typical emission spectrum is shown in Fig. 3 *. The most intense line was in all cases the green triplet of Li^+ , $\lambda = 5483$ to 5486 \AA , having the Li^+ -metastable state 2^3S as lower state. The Li^0 -lines are all of lower intensity. Neither the hydrogen, nor the Li^0 -lines showed a slant line effect. The Li^+ -lines seem to be inclined for radial distances $r > 2$ cm, but it is not possible to determine the DOPPLER shift sufficiently accurate. Impurity lines, which are observed, are: H^0 and Na^0 ($\lambda = 5889/96 \text{ \AA}$). (Na originates probably from small Na-traces in the Li-metal, and H originates eventually from the walls, the electrodes etc. . . , since the arc has also been run in hydrogen gas).

Using the intensity ratio of the Li^0 -lines and assuming the BOLTZMANN distribution between the higher excited states to be valid, one derives an electron temperature of 3000°K . This temperature is much too low for the strong emission of the Li^+ -lines. Using for the temperature determination — with the same assumption as above — the Li^+ -lines $\lambda = 5483/85 \text{ \AA}$ and $\lambda = 4672 \text{ \AA}$ one obtains a temperature of nearly $40\,000^\circ\text{K}$.

The reason for this discrepancy is probably due to the fact that the neutral particles are not in equilibrium with the corresponding excitation, ionization, and recombination processes, since their mean free paths are so large that they can traverse the plasma column without being in an instantaneous steady-state equilibrium with the electrons. It has been shown ⁷ that in this case the BOLTZMANN distribution among the highly excited levels is disturbed, and the SAHA equation — in general at least applicable for the higher excited states — will not further be valid. Taking into account the influx of neutral particles into the plasma column one will obtain temperatures 10 to 50 times higher, and these values

are, within a factor two or three, in agreement with those derived from mass spectrometric and probe measurements, as has been shown for helium and hydrogen ⁷.

2. Mass Spectrometric Measurements

A small mass spectrometer as shown in Fig. 2 has been employed to derive an electron temperature from the ratio of the ion currents, $I(\text{Li}^{2+})/I(\text{Li}^+)$, with the Li-ions being extracted from the plasma column at a radial distance of $r \cong 2$ cm. This kind of temperature determination is based on the coronal ionization formula ⁹⁻¹²:

$$N_{r+1}/N_r = S_r(T_e)/Q_r(T_e), \quad (1)$$

in general valid for low density steady-state plasmas. N_r and N_{r+1} are the number densities of r - and $(r+1)$ -fold ionized atoms of the same chemical species, $S_r(T_e)$ and $Q_r(T_e)$ are the ionization and recombination coefficients respectively. T_e is the electron temperature. Equation (1) is independent of n_e . Using the ratio of the measured ion currents, $\frac{1}{2} I(\text{Li}^{2+})/I(\text{Li}^+)$, this ratio equals N_{r+1}/N_r , and one is therefore able to derive T_e without any assumption on n_e .

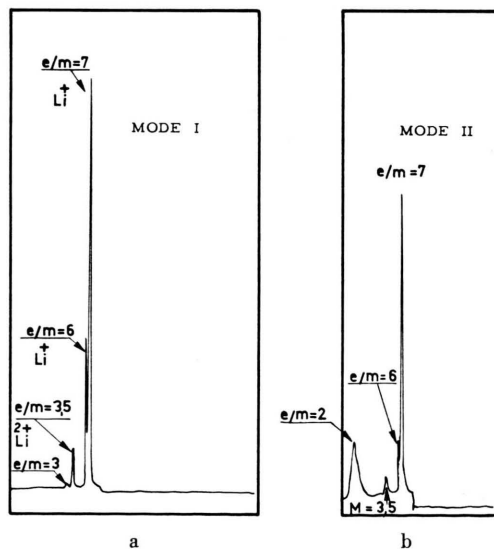


Fig. 5. a) Mass spectrogram of the mode I-arc. b) Mass spectrogram of the mode II-arc, the sensitivity is 30 times larger than for a.

* Fig. 3, 4, 6, see p. 448 a.

⁹ G. ELWERT, Z. Naturforschg. **7 a**, 432 [1952].

¹⁰ G. KNORR, Z. Naturforschg. **13 a**, 941 [1958].

¹¹ A. UNSÖLD, Physik der Sternatmosphären, 2. Auflage, Verlag Springer, Berlin-Göttingen-Heidelberg 1955, p. 653.

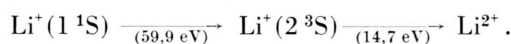
¹² R. v. D. R. WOOLEY and D. W. N. SIBBS, The Outer Layers of a Star, The Clarendon Press, Oxford 1953, p. 232.

Although the ions will probably not be in a complete equilibrium concerning the ionization and recombination processes $\text{Li}^+ \rightleftharpoons \text{Li}^{2+}$, one will nevertheless obtain a value of the right order of magnitude for T_e which will not be too far from the reality.

A typical mass spectrogram of the Mode I-arc is shown in Fig. 5 a. If we assume that all ionisation processes $\text{Li}^+ \rightleftharpoons \text{Li}^{2+}$ occur directly from the Li^+ -ground state, 1^1S_0 , we obtain from the mass spectrometric measurements an electron temperature of

$$T_e \cong 85\,000 \text{ to } 95\,000 \text{ }^\circ\text{K}.$$

There is a high probability that the Li^+ -metastable state, 2^3S , plays an important role as intermediate stage for an ionization process of the following kind:



If we use this two-step process the temperature derived from the mass spectrometric values reduces to

$$T_e \cong 50\,000 \text{ }^\circ\text{K},$$

which is not too far from the $40\,000 \text{ }^\circ\text{K}$ obtained from the Li^+ -lines.

3. Electrostatic Probe Measurements

A simple LANGMUIR probe has been used, the electron temperature has been deduced in the usual way from the slope of the $\text{Log } I - \Delta U$ curve. The temperatures obtained varied from 1.8 eV to about 8 eV, depending on the electrical power applied.

The electron density derived from electrostatic probe measurements was

$$n_e = 2 \text{ to } 5 \cdot 10^{12} \text{ cm}^{-3}.$$

No electrostatic voltage fluctuations could be measured with a probe introduced into the plasma column (Fig. 6 a), confirming that the plasma column was well stabilized.

b) The Mode-II-Arc

This type of discharge is obtained by an increase of the electrical power, more precisely: when the power exceeds about 2.5 kW at a standard Li-flow of $2.5 \cdot 10^{-4} \text{ g/sec}$.

Typical electrical parameters of the mode II-arc are: $U = 500 \text{ to } 800 \text{ volt}$, $I_1 \cong 5 \text{ to } 3 \text{ Amp}$; $I_2 \cong 0.5$

to 0.2 Amp. The transition time from mode I-arc to mode II-arc is of the order of several seconds.

The column of the discharge is gray and the intensity of light is very low. The edge of the plasma column is not well defined, the radial distribution of the light emitted from the column is rather diffuse.

We observed a high transport of matter to the walls: After about one hour of arc operation, the windows are contaminated with Li-metal. This is not the case when the arc runs in the mode I. Collector measurements showed (see above) that high energetic Li-ions are ejected from the plasma column across the magnetic field lines.

The walls of the vacuum tube show a very bright light emission of red colour, probably due to an excitation of the metal — condensed on the walls — by energetic ions.

Similar observations have been made by NEIDIGH and WEAVER¹³ in a hydrogen discharge under different experimental conditions. Following these authors, we called our instable mode the "mode II". NEZLIN and SOLNTSEV¹⁴ found also a similar mode when studying a strong plasma-electron beam interaction in hydrogen and lithium arc experiments. On the basis of the model of a strong plasma-electron beam interaction we explain the observed transition from the mode I-arc to the mode II-arc as follows: The increase of the electrical power applied causes an increase of the temperature of the cathode and subsequently an increase of the thermal emission of electrons. The instability develops when the electronic emission exceeds a certain critical value¹⁵.

1. Spectroscopic Measurements

The principal difference between the spectra of the mode I- and the mode II-arc is shown in Fig. 4 a and 4 b. We mentioned that the Li^+ -line $\lambda = 5483/85 \text{ \AA}$ is the most intense for the mode I-arc. When the arc is running in mode II, the Li^+ -lines practically disappear, the Li^0 -lines become longer, and strong emission of the Na^0 -resonance line occurs. The Li^0 - and the Na^0 -lines show practically no radial intensity distribution, whereas a radial intensity distribution of the very weak Li^+ -lines is well established. The Li^+ -lines on one hand and the Li^0 - and Na^0 -lines on the other obviously are emitted from different geo-

¹³ R. V. NEIDIGH and C. H. WEAVER, Proc. 2nd. U. N. Intern. Conf. on the Peaceful Uses of Atomic Energy, Geneva 1958, Vol. 31, p. 315—318.

¹⁴ M. V. NEZLIN and A. M. SOLNTSEV, Soviet Phys.-JETP **18**, 576 [1964].

¹⁵ M. V. NEZLIN, Soviet Phys.-JETP **14**, 723 [1962].

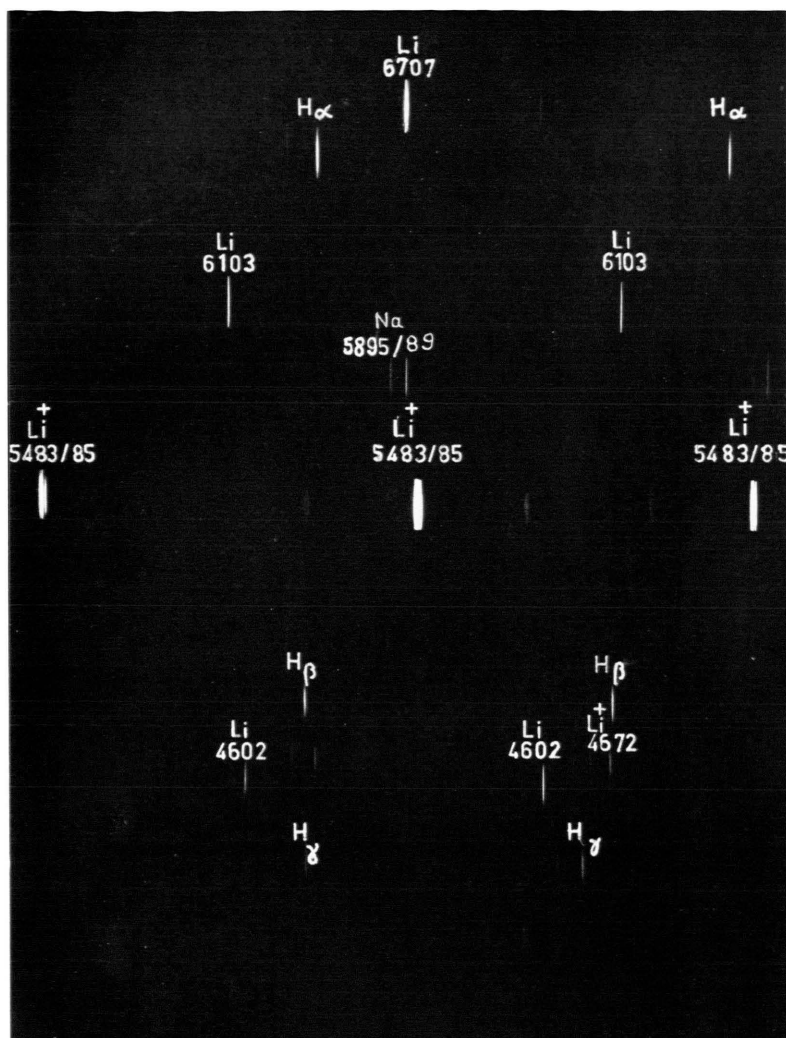
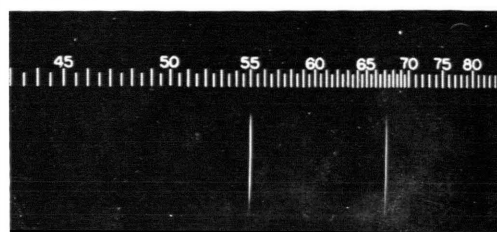
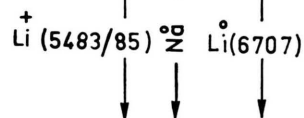


Fig. 3. Spectrum of the mode I-arc, taken with the Rosc echelle spectrograph.

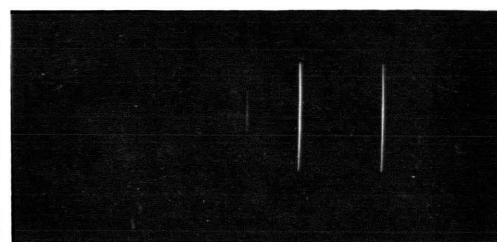
MODE I



a)



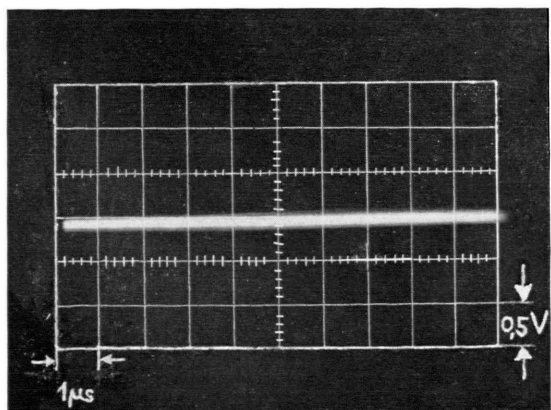
MODE II



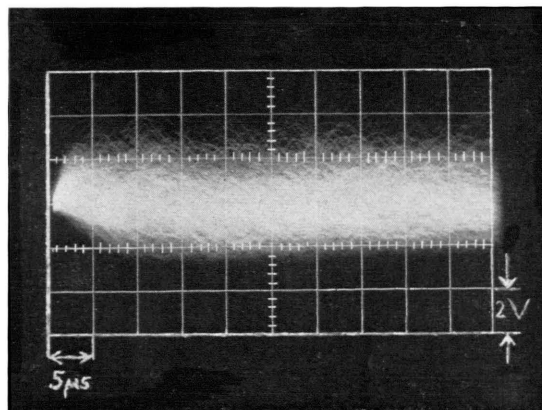
b)

Na 5889/95

Fig. 4. a) Spectrum of mode I-arc showing the strong emission of the Li-line $\lambda = 5483/85 \text{ \AA}$. b) Spectrum of the mode II-arc showing the strong emission of the Na-line $\lambda = 5889/95 \text{ \AA}$. Exposure time as for a.



a)



b)

Fig. 6. a) Probe signal from mode I-arc. b) Probe signal from mode II-arc.

metrical zones. From the optical spectra it was impossible to calculate reasonable electron temperatures and electron densities:

The application of different excitation formulae led to the conclusion that free electrons could not be responsible for the observed light emission of the Li^0 - and Na^0 -lines, and that the observed lines are probably due to fast heavy particles which hit the walls and react with the Li- and Na-metal condensed there, and it is the excitation of this Li- and Na-metal which is observed ¹⁶.

The Li^+ -lines emitted from the gray plasma column showed a DOPPLER inclination caused by a rotating plasma column. From the Li^+ -lines $\lambda = 5483/86 \text{ \AA}$ we obtained rotation velocities \bar{v}_{rot} and angular frequencies $\bar{\omega} = 2\pi\bar{\nu}$ as shown in Fig. 7 for $B_z = 1380 \text{ G}$. It is a remarkable feature that the angular frequency of the plasma column is constant over the whole radius.

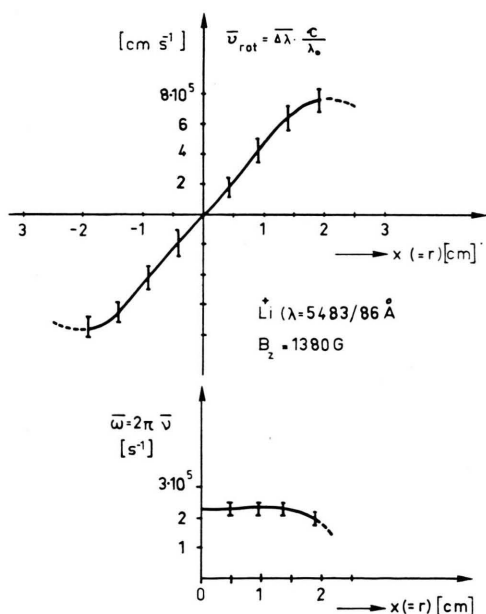


Fig. 7. Rational drift velocity \bar{v}_{rot} and angular frequency $\bar{\omega}$ for the mode II-arc, derived from the Li^+ -triplet $\lambda = 5483/85 \text{ \AA}$.

2. Electrostatic Collector Measurements

To get further evidence for the assumption that fast (heavy) particles hit the walls we made collector

measurements using an experimental arrangement as shown in Fig. 8. If positive ions of high energy are present, one should be able to measure a collector current I_{coll} even for positive grid voltages U_{grid} . Neutral particles of high kinetic energy — on the other hand — should produce secondary electrons on the collector, thus giving rise to an (electron) current in the opposite direction, and further, this current should be independent of the grid voltage U_{grid} .

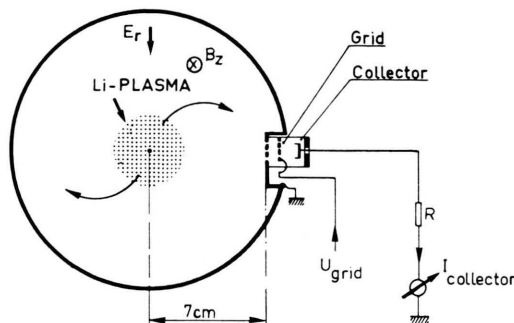


Fig. 8. Experimental arrangement for the collector measurements.

The results of the measurements are shown in Fig. 9. The minimum detectable collector current was about $5 \cdot 10^{-9} \text{ Amp}$. The mode I-arc gave practically no increase of the collector current with the discharge in operation. The mode II-arc showed a rather high background current of $5 \cdot 10^{-8} \text{ Amp}$., probably originating from secondary electrons produced on the collector by fast neutral particles ¹⁷. Moreover, positive charged particles of kinetic energies up to 160 eV could be detected.

Due to the curvature of the lines of flight the real kinetic energy of the ions should be higher than 160 eV, since a necessary condition that (single-fold) Li^+ -ions can reach the collector is that the radius of curvature of the ions must be at least the half of the distance between the plasma column and the collector. For an applied magnetic field strength of $B_z = 1380 \text{ G}$ the energy of the Li^+ -ions therefore has to be higher than 167 eV. Ions with lower energies should not reach the collector. Adding the value of 167 eV to the measured maximum value of 160 eV, one can conclude that Li^+ -ions with kinetic

¹⁶ The lithium metal used contained about 1% Na impurities. Since the vapour pressure of Na is higher than that of Li, the Na-metal evaporates faster than the Li-metal (fractional distillation). Therefore, the metal condensed on the walls is enriched with Na-metal.

¹⁷ The emission of photo-electrons can practically be excluded since the mode I-arc with its much higher light intensity gave no collector current.

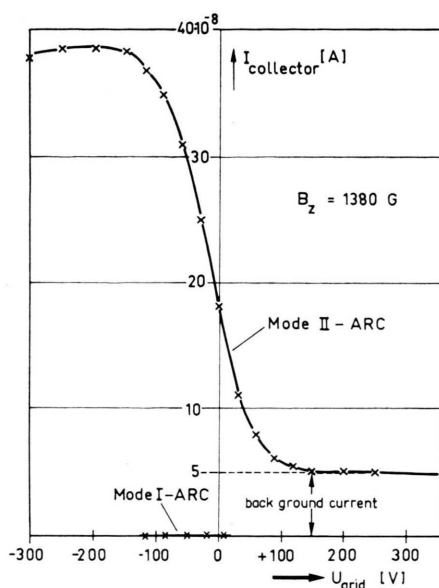


Fig. 9. Collector current I_{coll} as function of the grid voltage U_{grid} for the mode I- and the mode II-arc. The axial magnetic field strength is $B_z = 1380$ G.

energies up to 327 eV are present. These particles leave the plasma region in the center of the machine since the magnetic field strength is too low for a confinement of these fast ions.

The high energetic ions hitting the walls may be responsible for the strong emission of the Li^0 - and Na^0 -lines.

An exact reason why fast ions will leave the plasma column and hit the walls can not be given. The most probable reason will be that strong electrostatic oscillations are excited under the described experimental conditions^{13-15, 18, 19}. Especially this point deserves a more detailed experimental investigation.

3. Electrostatic Probe Measurements

These strong electrostatic oscillations, or better "perturbations", have been confirmed by measurements with an electrostatic probe immersed into the plasma column. The probe signals, for a typical case, are shown in Fig. 6b. The fluctuations are very irregular attaining several volts in the megacycle region, thus provoking fast variations of the electric field strengths in the plasma column. Applying a photomultiplier with a response time of 10^{-7} sec, we have looked for an eventual correlation

between spectral line intensities and probe signals, but no such correlation was found. The spectral lines showed practically no intensity fluctuations.

4. Mass Spectrometric Measurements

A typical mass spectrogram of the mode II-arc is shown in Fig. 5b. It is a surprising effect that the relative ion currents of Li^{2+} and Li^+ are about the same as for the mode I-arc, but an additional broad peak at the mass $m/e = 2$ (and also at $m/e = 1$) occurs, indicating the presence of hydrogen. Since no hydrogen has been introduced the H^+ - and H_2^+ -ions are obviously created by the strong ionic bombardment of fast Li-ions on the slit-pairs of the mass spectrometer and the walls of the vacuum tube, thus liberating absorbed hydrogen.

A calculation of the temperature from the ratio of the ion currents yields practically the same result as in the case of the mode I-arc.

Conclusion

We observed a stable and an instable mode of an arc running in Li-vapour. The plasma column of the mode I-arc is well stabilized and confined by the axial magnetic field. The plasma column of the mode II-arc is "unstable" in that sense that the plasma column seems not further being confined by the axial magnetic field, and strong electrostatic potential fluctuations are observed. A strong flux of ions (and eventually of neutral particles) leaves the plasma column perpendicularly to the magnetic lines of force. The energy of light emitted from the plasma in the central part of the machine is negligibly small with respect to the energy emitted from the walls due to excitation processes by fast ions which hit the surface.

The central plasma column of the mode II-arc showed spectroscopically measured rotational drift velocities of at most $8 \cdot 10^5$ cm/sec for Li^+ . This equals an energy of only 2.3 eV, whereas collector measurements indicated ions with energies of several hundred electron-volts. These energetic ions are obviously completely decoupled from the weakly rotating plasma column in the central part of the machine. As for the mechanism responsible for the production of the energetic ions which can leave the plasma column, further investigations are necessary.

¹⁸ E. R. HARRISON, *Nature*, Lond. **184**, 245 [1959].

¹⁹ G. GUEST and A. SIMON, *Phys. Fluids* **5**, 503 [1962].

The observed high energetic flux of ions eventually offers the possibility of creating a plasma with a high ion-temperature, if one would be able to confine all fast particles within a diameter which is smaller than the diameter of the vacuum tube. Due to the low strength of the confining magnetic field this is not the case in our actual experimental device.

In a note recently published by ALEXEFF and NEIDIGH²⁰ it is shown that the mode II-arc offers the possibility to create a completely ionized steady-state plasma.

²⁰ I. ALEXEFF and R. V. NEIDIGH, Phys. Rev. Letters **13**, 179 [1964].

Rekombination und Diffusion in Abhängigkeit von der Elektronentemperatur eines zerfallenden Neonplasmas

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(Z. Naturforschg. **20 a**, 451—457 [1965]; eingegangen am 17. Dezember 1964)

The object of this paper is an experimental investigation of the electron temperature dependence of the ambipolar diffusion coefficient as well as the electron-ion recombination coefficients in the afterglow of plasmas produced in neon. By means of a microwave-cavity technique the electron density was measured as a function of time during the afterglow period of a d. c. discharge while at the same time the electron energy was increased by the power level of a microwave signal. It is found that the ambipolar diffusion coefficient D_a increases with increasing electron temperature T_e following the well-known relation:

$$D_a \propto (1 + T_e/T_g),$$

while the recombination coefficient α decreases with increasing electron temperature. The dependence of α on electron temperature is found to be: $\alpha \propto T_e^{-0.4}$ from 900 °K to 2400 °K, while a weaker dependence in the range of $\alpha \propto T_e^{-0.25}$ was measured in the lower temperature region from 300 °K to 600 °K. At 300 °K the recombination coefficient in neon is found to be $\alpha = 2.0 \cdot 10^{-7} \text{ cm}^3 \text{ sec}^{-1}$. All measurements were done at electron densities of $\sim 10^9/\text{cc}$ and gas pressures of 1 mm Hg (diffusion) and 20 mm Hg (recombination).

Die Rekombination und die ambipolare Diffusion von Ladungsträgern wurden in letzter Zeit vorwiegend experimentell unter Anwendung verschiedener Meßmethoden untersucht¹⁻³. Die Bestimmung der Rekombinations- und Diffusionskoeffizienten erfolgte dabei in zerfallenden Niederdruckplasmen, sogenannten „Afterglowplasmen“, bei denen die Elektronen, die Ionen und die Neutralteilchen gleiche thermische Energie (0,04 eV) besitzen. Erhöht man in einem solchen isothermen Plasma die Elektronentemperatur, so ist eine Änderung der entsprechenden Träger-Verlustmechanismen zu erwarten.

Als erste haben BIONDI und BROWN⁴ die Abhängigkeit des Rekombinationskoeffizienten α von der Elektronentemperatur T_e in einem isothermen Plasma gemessen. Sie fanden für ein Wasserstoffplasma im Temperaturbereich von 303 bis 413 °K das empirische

Gesetz: $\alpha \sim T_e^{-0.8}$, während sie in einem Neonplasma zwischen 77 und 410 °K keine Temperaturabhängigkeit des Rekombinationskoeffizienten feststellen konnten. GOLDSTEIN, ANDERSON und CLARK⁵ beobachteten bei Erhöhung der Elektronentemperatur eines Heliumplasmas ein Abnehmen der Lichtemission und bezeichneten die Erscheinung als „Afterglow quenching“. Unter der Annahme, daß die Lichtintensität als Folge der bei der Rekombination entstehenden angeregten Atomzustände aus dem Plasma abgestrahlt wird, läßt sich aus diesen optischen Messungen der Rekombinationskoeffizient als Funktion der Elektronentemperatur bestimmen. CHEN, LEIBY und GOLDSTEIN⁶ fanden so für ein Heliumplasma zwischen 300 und 1200 °K die Abhängigkeit $\alpha \sim T_e^{-3/2}$, während FARHAT⁷ auf die gleiche Weise in einem Neonplasma $\alpha \sim T_e^{-0.9}$ gemessen hat.

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² M. A. BIONDI, Phys. Rev. **129**, 1181 [1963].

³ R. HACKAM u. J. J. LENNON, Proc. Phys. Soc., London **84**, 133 [1964].

⁴ M. A. BIONDI u. S. C. BROWN, Phys. Rev. **76**, 1697 [1949].

⁵ L. GOLDSTEIN, J. M. ANDERSON u. G. L. CLARK, Phys. Rev. **90**, 486 [1953].

⁶ C. L. CHEN, C. C. LEIBY u. L. GOLDSTEIN, Phys. Rev. **121**, 1391 [1961].

⁷ N. E. FARHAT, Proc. IEEE, **51**, 1063 [1963].