Transition Probabilities of CuII Lines

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Relative transition probabilities of 7 CuII lines in the visible spectral region have been measured by side-on observation of a plasma jet emerging out of a capillary as well as by using an axial discharge-type of an exploding copper wire. The results are compared with those of two other experiments.

In a recent paper the authors reported on the application of a capillary discharge technique for the determination of plasmadiagnostically relevant atomic quantities [1]. This method facilitates in particular the production of plasmas containing atoms of chemical elements which exist only in the solid state under normal conditions. In addition, seeding of these plasmas with elements serving for calibration of temperature or electron density can be performed in a simple way. The inner wall of the capillary (length 60 mm, diameter 5 mm) is coated with paraffine, in which the substances of interest can be introduced. Paraffine includes hydrogen, which is very useful for the electron-density-determination via the profile of the H_β-line. For the ignition of this pulse-heated type of discharge a thin copper wire (diameter 20 μm) is axially placed inside the capillary. As the electrodes are not directly attached to the ends of the capillary, the plasma jets emerging out of both ends of the capillary show good radial symmetry even at distances of a few centimeters from the end of the capillary, which is caused by the predetermined discharge channel due to the wire ignition. In that way these plasma jets can be investigated in regions where the symmetry for Abel inversion is still sufficient, but optical thickness becomes negligible. For the measurements of transition probabilities the short circuit ringing period of the discharge was 180 μs. The charging voltage of a 20 μF-capacitor bank was 16 kV. For further details concerning the method the reader is referred to [1] and [2]. The determination of the CuII transition probabilities was carried out in two consecutive steps.

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The first one was the determination of CuI transition probabilities by adding BaO_2 and Cu_2O to the paraffine-coating of the capillary wall. Using the transition probabilities for the BaII lines 452.5 nm and 585.4 nm (upper levels 5.24 eV and 2.72 eV) given in [3] the temperature could be evaluated by the relative intensity method. The electron density was found by comparing the obtained H_β half widths with the values given by Griem [4]. So a set of relative transition probabilities and Stark widths of CuI lines could be established (see [1], [2]). As now CuI transitions probabilities were available for a temperature determination by a Boltzmann-plot (using the CuI lines 427.513, 437,820, 458.695, 465.113, 510.554, 529.252, 578.213 nm; differences of the excitation energies of about 4 eV are given), the capillary discharge could be produced without inserting Ba-containing compounds into the inner capillary wall, thus reducing the risk of overlapping line profiles. Temperatures from 18 000 to 24 000 K and electron densities between $5 \cdot 10^{17}$ and $8 \cdot 10^{17}$ wer obtained.

The determination of the CuII transition probabilities performed in this way turned out to give values with relatively large uncertainties; mainly because of partly overlapping line profiles which still took place in this case. So, finally another lightsource was taken for this purpose: The axial discharge type of an electrically exploded Cu wire. Using this method CuII values with smaller uncertainties could be measured. These values were lying within the error limits of those obtained by the capillary discharge.

An axial discharge in an exploding wire experiment can be produced by proper choice of the experimental conditions such as discharge circuit parameters, wire dimensions and pressure of the surrounding gas. This kind of explosion starts with the development of a non luminous vapor column caused by the evaporation of the wire. After the cylindrical vapour cloud is expanded to a diameter of about one or two centimeters an ignition of a discharge along an exactly axial zone of diminished pressure takes place. The plasma column expands radially faster than the vapor cloud. At the time the whole vapor cloud is converted into the plasma state one has a pure metal plasma. The plasma column has an ideal cylindrical symmetry with radial distributions of the plasma parameters well-suited for side-on investigations with help of Abel inversion. The variation of the discharge conditions per-

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Table 1. Relative transition probabilities of CuII lines. The values of Lux [6] and Hefferlin et al. [7] and of this work are normalized to $A_{ki} = 1$ for line 455.592 nm.

Wavelength (in nm)	Relative transition probability		
	This work	Ref. [6]	Ref. [7]
404.352	2.0 ± 18%	2.0	0.36
422.790	0.48 ± 18%	0.45	–
450.600	1.3 ± 25%	–	0.56
455.592	1	1	1
475.842	2.4 ± 20%	2.3	1.2
483.224	0.42 ± 25%	–	0.28
488.969	0.26 ± 25%	–	0.27

mits to change the plasma parameters within certain limits.

The applicability of this light source for determinations of plasmadiagnostically relevant atomic quantities was first shown in [5]. Using such a plasma, Lux [6] has already determined transition probabilities of four CuII lines. His discharge circuit had a capacitor bank of 21 µF, which could be charged up to 30 kV. The short circuit ringing period could be varied between 30 and 300 µs by using different induction coils. Lux [6] obtained temperatures between 23.000 and 30.000 K and electron densities from $8 \cdot 10^{17}$ to $2 \cdot 10^{18}\,\text{cm}^{-3}$. He determined his temperatures by using literature values for CuI transition probabilities.

For the production of our axial discharge wire explosions we used the same discharge circuit as for our capillary discharges, but reduced the short ringing period to 25 µs. The diameter and the lengths of the copper wires were $d = 0.05$ mm and $l = 13$ cm. The static pressure of the surrounding air was 0.25 bar.

As can be seen in Table 1, our CuII values show very good agreement with those of Lux. A comparison with the "approximative values" of Hefferlin et al. [7] indicates large discrepancies. This may mainly be caused by the large uncertainity in the temperature determination of these authors, which is reported being about 50%.

[1] T. Neger and H. Jäger, Z. Naturforsch. **41 a,** 1094 (1986).
[2] T. Neger and H. Jäger, Z. Naturforsch. **42 a,** 429 (1987).
[3] B. M. Miles and W. L. Wiese, At. Data **1,** 1 (1969).
[4] H. R. Griem, Spectral Line Broadening by Plasmas, Academic Press, New York 1974.
[5] H. Jäger and W. Lochte-Holtgreven, Exploding Wires **4,** p. 41 (ed. W. G. Chace and H. K. Moore) Plenum Press, New York 1968.
[6] B. Lux, Dissertation, Universität Kiel 1973.
[7] R. Hefferlin, H. Kuhlmann, J. Penz, and D. Wheeler, Bull. Amer. Phys. Soc. **16,** 106 (1971).