Electron temperature measurements from line ratios of He- and H-like argon in the Alcator C tokamak

J. E. Rice, E. S. Marmor, E. Källne, and J. Källne

Citation: [Review of Scientific Instruments](#) **57**, 2154 (1986); doi: 10.1063/1.1138714

View online: <http://dx.doi.org/10.1063/1.1138714>

View Table of Contents: <http://scitation.aip.org/content/aip/journal/rsi/57/8?ver=pdfcov>

Published by the [AIP Publishing](#)

Articles you may be interested in

[Electron density and temperature measurement by continuum radiation emitted from weakly ionized atmospheric pressure plasmas](#)

Appl. Phys. Lett. **104**, 084103 (2014); 10.1063/1.4866804

[Universal Representation of the H-like Spectral Line Shapes](#)

AIP Conf. Proc. **1125**, 29 (2009); 10.1063/1.3141696

[Absolute electron-impact ionization cross sections of free radicals from threshold to 30 eV : C H x = 2 , 3 , Si \(C H 3 \) x = 1 , 2 , 3 , and H 2 Si \(C H 3 \) radicals](#)

J. Appl. Phys. **99**, 124908 (2006); 10.1063/1.2205357

[Determination of electron temperature from spectral line intensity decay for radiation dominated plasmas](#)

Rev. Sci. Instrum. **75**, 4180 (2004); 10.1063/1.1787603

[Line shape measurements of visible light emission from the Alcator C-Mod tokamak](#)

AIP Conf. Proc. **381**, 159 (1996); 10.1063/1.51334

SHIMADZU Powerful, Multi-functional UV-Vis-NIR and FTIR Spectrophotometers
 Excellence in Science

Providing the utmost in sensitivity, accuracy and resolution for a wide array of applications in materials characterization and nanotechnology research

- Photovoltaics
- Polymers
- Thin films
- Paints/inks
- Ceramics
- FPDs
- Coatings
- Semiconductors

[Click here to learn more](#)

Electron temperature measurements from line ratios of He- and H-like argon in the Alcator C tokamak

J. E. Rice and E. S. Marmor

Plasma Fusion Center, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

E. Källne and J. Källne

JET Joint Undertaking, Oxfordshire, England

(Presented on 13 March 1986)

Line ratios of certain transitions in H- and He-like Ar are quite sensitive to electron temperature. In particular, the $1s^2-1s4p$ transition in Ar^{16+} ($\lambda = 3.200 \text{ \AA}$) lies very close to the $1s-3p$ transition in Ar^{17+} ($\lambda = 3.151 \text{ \AA}$). The intensity ratio of these two lines is a sensitive function of electron temperature, through the changing ionization balance, at least over the range $1200 \text{ eV} < T_e < 2500 \text{ eV}$. This has been exploited with a compact, high-resolution x-ray spectrometer to obtain time histories of central electron temperature in Alcator C tokamak plasmas. Time resolution of 20 ms has been achieved.

In the diagnosis of hot plasmas, it has long been recognized that the ratios of lines from successive ionization states of an element can be strong functions of the plasma electron temperature.¹ In general, for diagnostic purposes it is most convenient if the lines fall very close to one another in the spectrum, so that relative calibration of the detecting instrumentation is not required. This paper reports the application of such a technique. Specifically, the $1s^2-1s4p$ transition in He-like Ar^{16+} ($\lambda = 3.151 \text{ \AA}$) and the $1s-3p$ transition in Ar^{17+} ($\lambda = 3.200 \text{ \AA}$) have been used to obtain time histories of the central electron temperature in the Alcator C tokamak.

The measurements were taken with a high-resolution ($\lambda/\Delta\lambda = 3000$) crystal x-ray spectrometer, which has been described previously.² Argon was introduced into the discharges by gas puffing through a piezoelectric valve and subsequently recycled, reaching a steady level in the discharge after about 100 ms. Figure 1 shows two sets of spectra. For Fig. 1(a), the plasma parameters were $\bar{n}_e = 1.5 \times 10^{14} \text{ cm}^{-3}$, $B_T = 10 \text{ T}$, and $I_p = 400 \text{ kA}$, with helium as the majority species. In this case, the central electron temperature, as measured from the slope of the soft x-ray continuum, obtained with a HgI_2 pulse height system, was 2.0 keV. For Fig. 1(b), the parameters were $\bar{n}_e = 3 \times 10^{14} \text{ cm}^{-3}$, $B_T = 8 \text{ T}$, and $I_p = 300 \text{ kA}$, and hydrogen was the majority species. The central T_e for this case was about 1.6 keV. Note that the Ar^{17+} ($1s-3p$) line is much weaker, relative to the Ar^{16+} lines, for the lower temperature case. It is this strong difference which is exploited to obtain the time history of T_e .

In order to unfold the T_e from the line ratio, it is necessary to know the functional dependence of the charge state balance. In addition, the H- and He-like stages of Ar will, in general, have different radial profiles. As a first-order approximation, it has been assumed here that the charge state balance is determined by the coronal equilibrium condition,³ which is a reasonable assumption for the central regions of the Alcator C plasmas. Because of transport effects, this could be a very bad assumption for the peripheral regions of

the plasma,⁴ but the contributions to the central chord radiation from the outer portions of the plasma are negligible. Further, to account for profile effects, only the functional dependence of the Ar^{17+} and Ar^{16+} ratio has been used from the coronal equilibrium condition. The absolute ratio has been determined for a particular discharge, where T_e was

FIG. 1. Comparison of spectra near $3.15 \text{ \AA}$ for discharges with significantly different central electron temperature. Note that the H-like $n = 3$ line, at $\lambda = 3151 \text{ m\AA}$, is much brighter, relative to the He-like lines, for the higher temperature discharge. The presence of a Li-like satellite, on the short wavelength side of the H-like line, has been taken into account in the analysis.

FIG. 2. Central electron temperature inferred from the ratio of the H- and He-like lines. It has been assumed that the charge state balance is determined by coronal equilibrium. The spectra are collected with a 20-ms integration time, and the solid dots show the results of the line ratio measurements. The solid line shows the results of second-harmonic electron cyclotron emission for the time history of T_e .

measured independently by the Thomson scattering and soft x-ray continuum diagnostics. These results are therefore only at the proof-of-principal stage. A more complete analysis, taking into account the profiles and the transport, has not yet been done.

The results of this procedure are shown in Fig. 2, where the temperature has been determined as a function of time during the discharge from several successive spectra (points) and is compared to that determined from second-harmonic electron cyclotron emission (solid line). The agreement is quite good. Early in the shot (before 200 ms), there is insufficient argon in the discharge for a statistically meaningful measurement of the line ratio. The discrepancy at the end of the shot is due to plasma motion. At this time, the plasma moves out in major radius, and so the electron-cyclotron-emission diagnostic, which is tuned to the center of the vacuum vessel, views a cooler region of the discharge. The x-ray spectrometer views on a chord along the horizontal midplane, and so continues to sample the hottest portion of the discharge.

This work was supported by the U.S. DOE under Contract No. DE-AC02-78ET51013.

¹G. Bekefi, C. Deutsch, and B. Yaakobi, in *Principles of Laser Plasmas*, edited by G. Bekefi (Wiley, New York, 1976), pp. 593–596.

²E. Källne *et al.*, *Phys. Scr.* **31**, 551 (1985).

³C. Breton, C. DeMichelis, M. Finkenthal, and M. Mattioli, Association Euratom-C.E.A., Fontenay-aux-Roses, France, Report No. EUR-CEA-FC-948, 1978.

⁴J. E. Rice *et al.*, *Phys. Rev. Lett.* **56**, 50 (1986).