MEASUREMENTS OF LOCAL AND GLOBAL RADIATED POWER IN ALCATOR C-MOD PLASMAS

R.L. Boivin, J. A. Goetz, J. Irby, E.S. Marmar, C.S. Pitcher, J.E. Rice, J.L. Terry and S.J. Wukitch

Plasma Science and Fusion Center, MIT, USA

Introduction

Recent developments in silicon based photodiodes have made possible the measurement of radiated power across a wide range in photon energies (visible to X-ray). These detectors have recently been installed on the Alcator C-Mod tokamak for measuring total radiated power, through which we can study localized and rapid phenomena such as transport barrier formation (internal or H-mode). Part of the system [1] is composed of a 20 channel array looking at the outer edge of the plasma, with 2mm chordal resolution, and a 16 channel array looking at the outer half of the plasma, with 2cm resolution. Both arrays are located at the midplane of the tokamak. In addition, a single channel detector views the whole plasma and serves as a global monitor. These complement the standard foil bolometer system [2], which consists of 16 channels looking tangentially at the midplane outer half of the plasma.

The photodiode detectors have numerous features that make them very attractive. Because of their relatively large sensitivity, very small dimensions are possible, leading to very good spatial resolution combined with an intrinsic (silicon) high temporal resolution. They are also not sensitive to low energy (<500 eV) neutrals. This feature allows a quantification of neutral radiated power when the measured brightness is compared to the one obtained from standard bolometers.

Experimental Results

Performance of the new system was verified by comparing bolometric techniques following a trace impurity injection (in this case niobium) into an ohmic discharge. Shown in Fig. 1 is the time evolution of the total radiated power. The solid line shows the radiated power as measured by the photodiode array, and the dashed line is the measurement from the standard bolometers. We observe good agreement between the techniques. Note that the bolometric system has a built-in 20 msec smoothing time-scale,

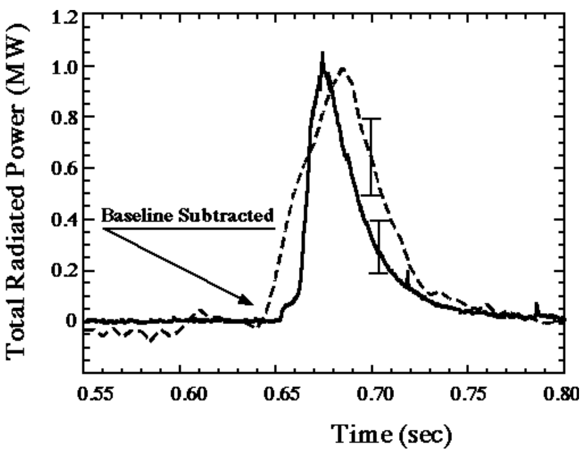

Figure 1: Measured total radiated power time history following a trace niobium injection. The dashed line results from analysiacrobats of the foil bolometers, while the solid line comes from the photodiode measurements.

and that the baseline has been subtracted for reasons explained below. In this case, the impurity confinement time is 25 msec, a typical number obtained in ohmic L-mode [3].

The high spatial resolution has been exploited in studying the local radiated power emissivity near the edge of the plasma. Shown in Fig. 2 is the total emissivity, derived from Abel inversion of the brightness profile, as a function of major radius for a discharge with L and H-mode phases. We see that the emissivity drops outside the separatrix, and increases dramatically inside during an elm-free H-mode. We also observe that the pivot point, at which the emissivity stays constant, is at or near the location of the separatrix, within the uncertainty of both points.

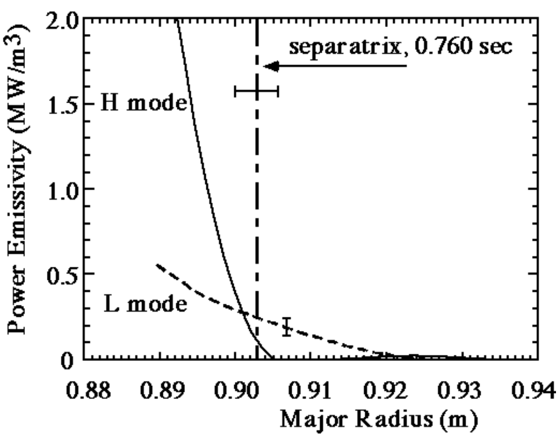

Figure 3: Measured emissivity profiles (edge) during L and H-mode.

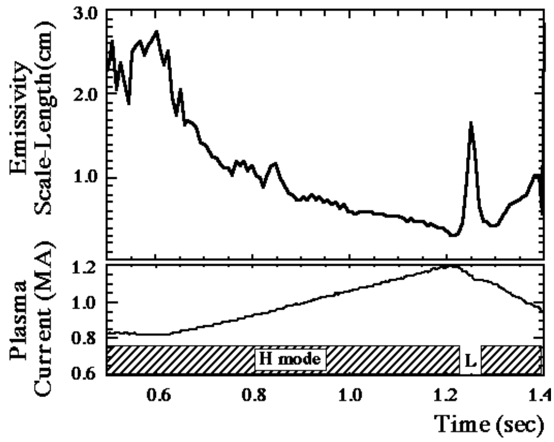

Figure 2: The edge emissivity scale-length E/(dE/dR) decreases with increasing plasma current.

Further experiments were performed where the plasma current was ramped up during an H-mode phase. We found that the emissivity scale-length, defined as L_E=E/(dE/dR), dropped from a few centimeters down to a few millimeters, as shown in Fig. 3, as the plasma current was increased. In a similar experiment, done with a current ramp down, the symmetric effect on the scale-length was seen. In contrast, a ramp in toroidal field, at fixed plasma current, during a similar H mode showed no change in L_E.

As mentioned above, one interesting feature of the photodiodes is their insensitivity to neutrals. The neutrals found in the main chamber, especially in high-density discharges, normally obtained on Alcator C-Mod, have the potential of carrying a significant amount of power away from the edge of the plasma through the charge-exchange process. The high plasma density also means that low energy neutrals (< 500 eV) can escape only from the first few centimeters near the plasma edge, due to their short mean free path for ionization. Note that Alcator C-Mod does not utilize neutral beam heating, and consequently, no source of fast neutrals exists in the experiment. It is thus possible to quantify the amount of power carried by neutrals, simply by looking at the differences in brightness (chord integrated measurements) between the standard foil bolometers and the photodiodes. The difference can then be Abel-inverted, which then gives the neutral power emissivity profile. A small part of the observed difference could be due to a difference in sensitivity at lower photon energy (e.g. near UV), but for the most part the measured emissivity (e.g. Lyα) at those wavelengths is significantly smaller than the contributions from charge-exchange neutrals. The result of the inversion gives the net emissivity, which includes any ionization along the chord. However, in the presence of absorption, the Abel inversion is technically invalid, since one has to take into account the non-axisymmetry of the problem. The issue can be resolved by including the attenuation of the signal, mainly through ionization, along the path, which requires some knowledge of electron temperature and density (electron impact ionization dominates by far over ion impact ionization at those energies of interest).

Shown in Fig. 4 is an example of the neutral emissivity profile inferred from the two measurements. In the case shown, no correction has been made for attenuation. As expected, most of the power originates from the edge of the plasma. It is noteworthy that the neutral power emissivity is comparable to photon power emissivity, at least in the extreme edge region. Shown also is the calculated neutral emissivity based on a simple 1-D neutral Monte-Carlo simulation. These calculations take in account the plasma density and temperature profile, and a measurement of the neutral pressure outside the plasma. The agreement is very good, increasing our confidence for in this interpretation. Note that in this model, a negative emissivity is possible since neutrals can be "absorbed" through ionization. To further verify this effect we produced nearly pure helium discharges (less than 10% percent deuterium), in which the charge-exchange process should be almost absent (i.e. down, at least, by a factor of 10) at the energies of interest. We find good agreement between the 2 techniques, giving us additional confidence that the difference seen in deuterium discharges is not due to any significant difference in spectral sensitivity.

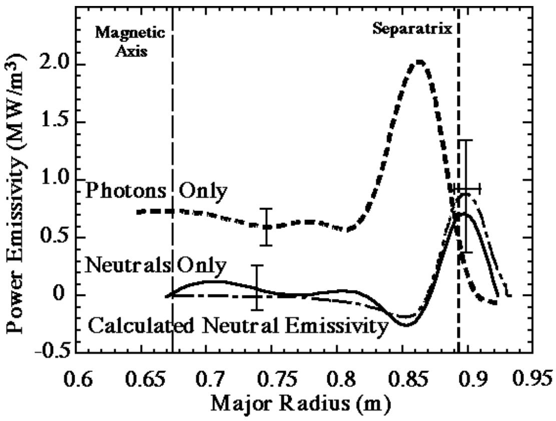

Figure 4: Measured emissivity profiles for photons only (dash) and neutrals only (solid). Also shown is the calculated emissivity for neutrals (dot-dash).

Acknowledgement

We thank the entire Alcator C-Mod staff for their help in these experiments. Supported by US DOE Contract No. DE-AC02-78ET51013.

References

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