

INTRODUCTION TO PLASMA DIAGNOSTICS

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ABSTRACT

Plasma diagnostics are based on a multitude of different physical processes with wavelengths in the range from sub-nm to tens of cm. Many different techniques are being employed for measuring the spatial profile and evolution of various plasma parameters. Although most of them are already well established, plasma diagnostics is still a very challenging and vivid discipline. On the one hand this is caused by the always-continuing effort to attain a better spatial and temporal resolution, to reach higher accuracies and to measure with more spatial channels. On the other hand diagnostic techniques based on more subtle physical processes (than used in the routine diagnostics) are continuously being developed. This paper will give a brief introduction into the field of plasma diagnostics.

1. INTRODUCTION

During the last decade the field of magnetic confinement fusion has evolved from a discipline with many small-scaled devices to one in which the main research is done on a limited number of large machines. Equivalent scientific breakeven was achieved in JET and JT-60U,^{1,2} whereas more than 16 MW of fusion power was generated in JET.³ Although present knowledge is sufficient for building the next step machine ITER,⁴ it is a given fact that many phenomena, which take place in the plasma, are still not well understood. For instance a basic understanding of the anomalous losses of energy and particles from the plasma is still lacking. Even though it is generally accepted that the anomalous losses are caused by fluctuations in the confining electric and magnetic fields, no theory has been developed giving a satisfactory explanation of the experimental observations.

This lack of understanding has not hindered plasma physicists from finding advanced operational regimes in which the overall confinement is improved. Examples are the reversed or optimized shear discharges⁵ and the radiation improved modes⁶ that have been established on many devices. For proper operation of the tokamak in these regimes, the active control of many plasma parameters is needed. This implies that new robust and failsafe diagnos-

tic techniques have to be developed, for instance to control the temperature, density and current density profiles. So roughly speaking, progress in plasma diagnostics is dictated by the desire to understand the detailed physical processes underlying transport, as well as by the wish to actively control many important plasma parameters. An additional driver for diagnostic innovation comes from the requirement to have improved machine protection systems.

To obtain a better insight in the processes taking place in the plasma it is a prerequisite that as much as possible plasma parameters are diagnosed simultaneously, preferably with temporal and spatial resolutions smaller than the typical time and length scales of the instabilities. Because many of the instabilities seem to depend on the gradients of one or more plasma parameters, there is a need for multi-channel diagnostics.

Plasma diagnostics can be categorized in various ways. In this paper a sub-division according to the underlying techniques is used. In gross lines the various plasma diagnostics can be categorized in seven subgroups (magnetics, probes, spectroscopy (visible, UV, X-ray), mm- and sub-mm diagnostics, laser-aided diagnostics, particle diagnostics and fusion product diagnostics). The various groups will be discussed in some detail in this paper. The emphasis will be put on those diagnostics that are not presented elsewhere in these proceedings.

II. GENERAL CONSTRAINTS

The constraints that are imposed upon the diagnostics are quite severe. Temperatures in magnetic confinement devices may range from several eV in the scrape-off layer to tens of keV in the plasma core. Also the density range covers many decades from 10^{17} – 10^{21} m⁻³. Therefore, the diagnostic systems should preferably have a large dynamic range; even more so because access to the plasma is usually strongly limited by a small number of available ports.

For the measurement of the basic discharge behavior it is sufficient to apply diagnostics with rather coarse spatial and temporal resolution. However, if one is interested in transport processes and the underlying instabilities, the

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