1. INTRODUCTION

Solids, liquids and gases have been studied for centuries and the boundaries between these states of matter are clearly defined and well understood. Low density plasmas have also been extensively studied in the laboratory and although the boundary between an "ideal classical plasma" and a gas is less clearly defined, the properties of plasmas are such that they are very different from either solids, liquids or gases. Plasmas have often been considered as a fourth state of matter.

Plasmas also exist at very high densities and here the boundaries between a high density plasma on one hand and solids, liquids and ideal plasmas on the other become even more confused. The major cause of this confusion arises because there is no precise definition of plasma. In an ideal classical plasma, the plasma can be defined in terms of the Debye length and requiring that the finite dimensions of the plasma exceed this Debye length. In very dense plasmas, however, this definition tends to have little meaning since the Debye length becomes less than the inter-particle spacing. In other words, there is less than one particle in a sphere of radius of Debye length. An alternative definition which is sometimes used for dense plasmas requires that there be significant ionisation. This also is fraught with difficulty since both solid and liquid metals have significant ionisation and are usually not considered to be plasmas. We shall see, however, that the theories that have been developed to explain the properties of liquid metals are particularly useful for dense plasmas.

Figure 1 shows the boundaries between gases, liquids and solids and plasmas plotted in temperature - density parameter space. The actual
boundaries, of course, vary from material to material and the boundaries between gases, solids and liquids on one hand, and plasmas on the other, is not well defined. Three other lines are drawn on this graph, one which represents very high temperature effects associated with relativistic motion of the particles of the plasma. The dashed line labelled $E_F = k_B T$ represents the boundary where the Fermi energy of the electrons is equal to the thermal energy. The continuous line labelled $\Gamma = 1$ represents the boundary between an ideal classical plasma and a strongly correlated plasma. It is this region of quantum degenerate and strongly-coupled plasmas and the boundary between them and the ideal classical plasma which has received very little attention both experimentally and, to a lesser extent, theoretically.

The development of high power short pulse lasers has made it possible to create warm, dense plasmas in the laboratory and to study this material for the first time. As is often the case in plasma physics the development of diagnostics can prove difficult. This is particularly true in relatively cool dense plasmas where the plasma is likely to be optically thick to any self emission. When such circumstances prevail the self emission represents the state of the plasma only very near to the surface and this is often not representative of what is happening in the bulk of the material.

In this type of plasma, X-ray absorption techniques become very important since they can give information about what is happening in the bulk

![Graph showing density-temperature parameter space](image-url)

**Figure 1.** *Density - temperature parameter space showing the boundaries between solids, liquids, ideal plasmas, quantum degenerate plasmas and strongly correlated plasmas.*