II THEORY

2.1 X-ray emission from a plasma

A hot dense plasma emits radiations through three types of electronic transitions, namely the free-free(Bremsstrahlung), free-bound (recombination) and bound-bound (line) transitions. The first two types of transitions contribute to the continuum of the radiation spectrum whereas the third gives rise to characteristic lines of the plasma constituents including impurities.

The x-ray emission power per unit frequency interval per unit volume of a single ion specie plasma is given by

$$E_{ff}(\nu) = An_e n_i Z_i^{\,2}\left(\frac{\chi_H}{kT_e}\right)^{1/2} \bar{g}_{ff}\exp(h\nu/kT_e) \qquad .....(1)$$

for free-free transitions; and

$$E_{fb}(\nu) = \sum_n An_e n_{i+1} Z_i^4 \left(\frac{\chi_H}{kT_e}\right)^{3/2} \left(\frac{\chi_{i,n}}{\chi_H}\right)^2 \bar{g}_{fb}\, \xi_n \exp\left(-\frac{h\nu-\chi_{i,n}}{kT_e}\right) \qquad .....(2)$$

for free-bound transition, where

A = 1.7×10^{-40} erg-cm^3

n_e, n_i are the electron and ion densities in cm^{-3} of the plasma respectively;

Z_i = the charge-state of the ion specie;

T_e = the electron temperature of the plasma;

χ_H = 13.6eV = the ionization potential for hydrogen;

$\chi_{i,n}$ = the ionization potential of the n^{th} state of the ion with charge $Z_i e$;

n = the total number of electron in the n^{th} state;

ξ_n = the number of vacancies in the n^{th} state; and $\bar{g}_{ff}$ and $\bar{g}_{fb}$ are the free-free and free-bound Gaunt factors respectively.

For a plasma with multiple ion species,the total radiation power per unit wavelength emitted from unit volume of the plasma source can be obtained by summing the contributions from all ion species if their relative population densities are known.

It can be seen[6] that the x-ray emission decreases exponentially toward the shorter wavelength and with higher electron temperature, and, thus, the spectral intensity over a limited range is a sensitive function of the electron temperature. For a deuterium plasma at a nominal $T_e \sim 1$ keV, x-ray emission is predominantly Bremsstrahlung radiation with peak at $\lambda \sim 6.2\,\mathring{A}$. The x-ray intensity is relatively low due to low Z value of the plasma. Enhancement of x-ray intensity is by using high Z gases such as argon, krypton, and neon. The focussed plasmas produced in these gases are found to emit predominantly the hydrogen-like and helium-like line radiations. For example, the emission spectrum of an argon plasma focus is expected to consist of strong line radiation at $\lambda \sim 4\,\mathring{A}$ superimposed onto a relatively low background of free-free and free-bound continuum.