Calculation of the Influence of Suprathermal Electron Radiation on ECE Spectra,with oblique Direction of Observation

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The plasma is considered with respect to the electrons as consisting of a thermal main part and a small optically thin suprathermal part. The thermal part is described on the basis of temperature and density profiles as measured via Thomson scattering. Concerning energy and density distribution of suprathermal electrons, the following assumptions seemed most practicable [1] :

(1) exponential shape of energy distribution function, being zero below a certain energy ,
(2) ratio $q = v_{\|}/v_{\perp} = const$,
(3) arbitrary density profile.

The emission of the thermal main part is calculated by means of the optical depth and Kirchhoff's law,that of the suprathermal part by means of the single particle radiation formula. The latter emission is partly absorbed in the thermal background on its way to the observer.

For the optical depth of the thermal plasma expressions given by several authors [2] – [6] are used . The calculation is done onedimensional with sheath model.

The total radiation of a suprathermal electron per solid angle unit in direction Θ with respect to the B-field is [7] :

$$\xi = \frac{e^2\omega^2}{8\pi^2\epsilon_0 c}\sum_{l=1}^{\infty}\left((\frac{cos\Theta-\beta_{\|}}{sin\Theta})^2 J_l^2(x) + \beta_{\perp}^2 J_l'^2(x)\right)[W] \quad , \quad x = \frac{l\beta_{\perp} sin\Theta}{1-\beta_{\|} cos\Theta}$$

o-mode x-mode

The distribution funktion is:

$$f(E) = \frac{1}{EO}\cdot e^{-\frac{E-ECO}{EO}} \quad \text{for} \quad E \geq ECO$$

The emission of an electron gas of density n (radiation power per volum unit, frequency unit and solid angle unit in direction Θ) is calculated from the line radiation, as energy per frequency interval :

$$j(\omega) = \xi\cdot\left|\frac{dn}{d\omega}\right| \quad , \quad \left|\frac{dn}{d\omega}\right| = \frac{dn}{dE}\cdot\left|\frac{dE}{d\omega}\right| = n\cdot f(E)\cdot\left|\frac{dE}{d\omega}\right|$$

$$\omega = \frac{l\omega_b}{\gamma - a\sqrt{\gamma^2-1}} \quad , \quad a = \frac{cos\Theta}{\sqrt{1+\frac{1}{q^2}}}$$

$$\left|\frac{d\omega}{dE}\right| = \frac{l\omega_b}{m_0c^2}\frac{\pm 1}{\gamma^2(1-\beta_{\|}cos\Theta)^2}\left(1-\frac{a\gamma}{\sqrt{\gamma^2-1}}\right) \quad \text{for} \quad \begin{cases}\gamma < F_{UMK} \\ \gamma > F_{UMK}\end{cases}$$

$$F_{UMK} = \sqrt{\frac{1+q^2}{1+q^2 sin^2\Theta}}$$

Fig.1 shows the o.mode lines ξ for $\Theta < \pi/2$ for growing energy E starting at $ECO = 0$: at first the positiv Dopplershift dominates (the gyrating electrons approach the observer) the relativistic decrease of frequency, it is $\omega/\omega_b > 1$. For

$$E > E_{UMK} = m_0c^2\cdot(F_{UMK}-1)$$

the resulting increase of frequency decreases again. The line density there gets infinity, caused by the assumption $q = const$. For

$$E > m_0c^2\cdot\frac{2a^2}{1-a^2}$$

$\omega/\omega_b < 1$ holds.The curves show $j(\omega)$ for both modes. From $q \approx 2$ on F_{UMK} is already near its asymptotic value $1/sin\Theta$; so even when electrons with a distribution in pitchangle are present a pronounced maximum of emission near $1/sin\Theta$ can be expected. Because the frequency there is greater than $l\omega_b$ at the point of emission , no reabsorption by the thermal background plasma takes place on its way outside to the observer across the decaying B-field of a toroidal machine, and as its frequency has a nearly constant distance to $l\omega_b(r)$ for $q > 2$ (for $q = const$ exactly constant), one can get an image of the suprathermal density distribution superposed to the thermal temperature profile obtained from the measured spectrum, at least in the case when its energy distribution is independent of radius (s.fig.2).

In reality the energy distribution of the suprathermals is hardly independent of the radius; but a measurement with $\Theta \neq \pi/2$ should at least give a clear indication on the presence of such electrons with $v_{\parallel} \neq 0$.

Literature:

[1] C.M.Celata,D.A.Boyd, Nuclear Fusion 17 (1977) S.735

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[7] G.Bekefi, Radiation Prcesses in Plasmas J.Wiley,N.Y.1966

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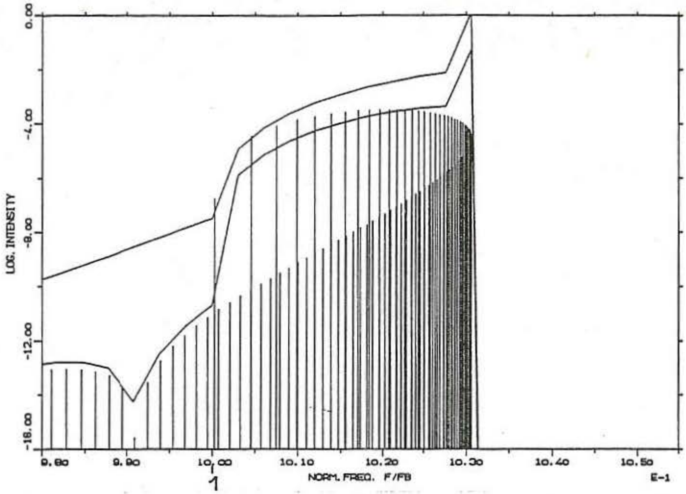

Fig.1: O.mode lines ξ for $\Theta = 70^0$ and frequency spectrum around a cyclotron harmonic FB for both modes; B-field = constant.

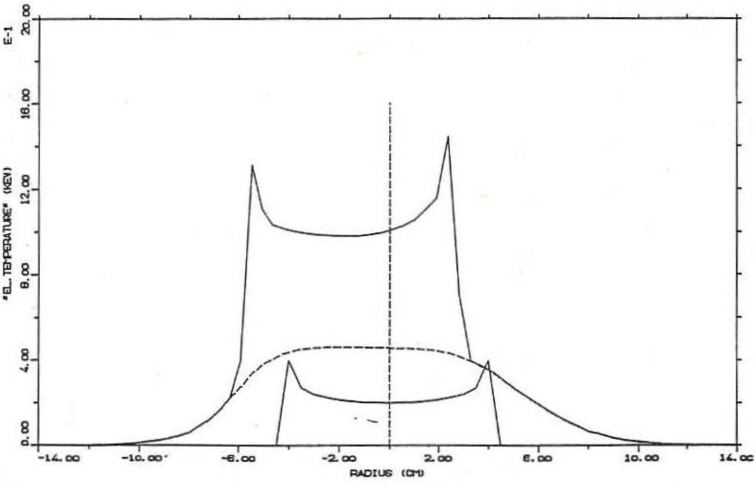

Fig.2: Computed profile (by $r \sim 1/F$ from the frequency spectrum). Lower curve : shape of the (arbitrarily chosen) suprathermal density distribution , upper one: the addition of the undamped suprathermal emission upon the thermal one (dashed).