rect Energy Converter for D-^{3}He Fusion

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Analytical studies on a traveling wave direct energy converter (TWDEC) [1,2] for D-^{3}He fueled fusion are carried out. The TWDEC consists of a modulator and a decelerator both of which consist of an array of metallic grid meshes and a transmission circuit.

The applied traveling wave potential to the modulator modulates the velocity of fusion proton beams. This modulation makes a form of bunched protons at a down stream of the modulator:

$$n_p(x,t) = n_{p0}\left[1 + \frac{4\pi e V_{m0}}{m v_t^2}\sin(k_m x - \omega_m t)\right], \quad (1)$$

here, V_{m0}, k_m and ω_m are the potential, wave-number and frequency of the applied wave, respectively, and v_t corresponds a Doppler spread at the birth of fusion protons. The second term indicates the spatial bunching at the down stream of the modulator field.

At the decelerator, the wave number k_d of the potential wave V^e due to bunched protons is changed spatially by the coupling to the excited traveling wave on the transmission circuit (Fig.1). From this circuit the potential V_n is governed by a forced oscillation due to the potential of bunched protons:

$$\left(2+\frac{C_s}{C}\right)\left(\ddot{V}_n + \frac{R}{L}\dot{V}_n\right) + \frac{V_n}{LC} - \left[\ddot{V}_{n+1} + \ddot{V}_{n-1} + \frac{R}{L}\left(\dot{V}_{n+1} + \dot{V}_{n-1}\right)\right] = \frac{C_s}{C}\left(\ddot{V}_n^e + \frac{R}{L}\dot{V}_n^e\right). \quad (2)$$

In this transmission circuit, the form of the potential wave can be transmitted is given by :

$$V_n(t) = f_p(t)\cos(\theta_n - \omega_d t), \quad (3)$$

here θ_n is the phase of n-th grid and the function f_p changes much slower than the traveling wave. Under this situation we have a non-trivial solution, provided that the resonance condition:

$$\Omega^2 - \omega_d{}^2 - \frac{\nu^2}{4} = 0, \quad (4)$$

is satisfied. Here Ω is the characteristic frequency of the transmission circuit:

$$LC[\,2(1-\gamma)+C_s/C\,]$$

and $\nu \equiv R/L$. The potential V_n of n-th grid is obtained:

$$V_n(t) = \left[V_n(0)\frac{\exp(-\nu t/2)}{\cos\Psi_n(0)} - \frac{\varepsilon}{\nu\omega_d}\left(1+\frac{\nu^2}{16\omega_d{}^2}\right)^{-1/2}\left(1-\exp(-\nu t/2)\right)\right] \times \cos\Psi_n(t), \quad (6)$$

here,

$$\varepsilon \equiv \omega_d{}^2\frac{C_s}{C}\tilde{V}\sqrt{1+\frac{\nu^2}{\omega_d{}^2}}\,\frac{1}{2(1-\gamma)+C_s/C},$$

$$\Psi_n(t) \equiv \int^{x_n} k_d\,d\xi - \omega_d t - \phi + \tan^{-1}\frac{4\omega_d}{\nu},$$

$$\phi \equiv -\cos^{-1}\frac{1}{\sqrt{1+R^2/L^2}}, \quad \gamma \equiv \cos(\theta_{n+1}-\theta_n).$$

As a result the power obtained from the decelerator is given by using the steepness of resonance Q ($\equiv \omega_d L/R$) :

$$P_{out} = \frac{8\varepsilon^2}{\omega_d^5 L}\,\frac{Q^5}{(16Q^2+1)(Q^2+1)}. \quad (7)$$

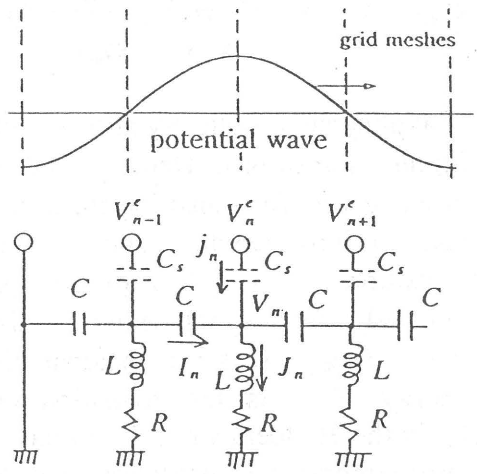

Fig.1 The transmission circuit in the decelerator, consists of a inductance L, a capacitor C, and a register R. The stray capacitance between proton beams and grid meshes is denoted by C_s.

Reference

1) Momota, H., LA-11808-C, Los Alamos Natl. Lab., New Mexico, (1989) 8.
2) Shu, L.Y., Miley, G.H., Tomita, Y., and Momota, H., Trans. Fusion Technol., 27 (1995) 551.