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TOPICS IN TOKAMAK RESEARCH

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Wave Propagation in Tokamaks [Ref. 1-3, 6,7,9,10, 14]

Lower hybrid (LH) waves have been used extensively for plasma heating, current drive, and ramp-up as well as sawteeth stabilization. The wave kinetic equation for LH wave propagation is extended to include the effects of both magnetic and density fluctuations. This integral equation is then solved by Monte Carlo procedures for a toroidal plasma. It is shown that even for magnetic/density fluctuation levels on the order of 10^{-4} , there are significant magnetic fluctuation effects on the wave power deposition into the plasma. This effect is quite pronounced if the magnetic fluctuation spectrum is peaked within the plasma. For Alcator-C Mod parameters, it seemed possible to be able to infer information on internal magnetic fluctuations from hard X-ray data from the JT-60 tokamak.

We have also shown that LH wave scattering from fluctuations plays a critical role in large aspect ratio divertor plasmas even though the edge density fluctuation levels are only at 1%. This is seen in theoretically calculated electron power-density profiles which can be directly correlated to the standard experimental chordal hard X-ray profiles. It thus seems that fluctuation effects must be included in determining rf current-density profiles.

The ponderomotive effects of higher harmonic waves in the LH waveguide grill power spectrum are considered. It is found that even though these short-wavelength modes have only a few % of the coupled power, they play an important role in the inhomogeneous scrape-off layer in a tokamak plasma. Using a barometric representation of the ponderomotive potential for the electron density, the full wave coupled theory is solved self-consistently for 4 modes using a shooting and matching method to satisfy the surface impedance boundary conditions determined from infinite grill theory. For a symmetric LH spectrum and below a threshold power, it is found that the total reflection coefficient is independent of the coupled power. Isolated plasma density depressions (cavitons) are formed in regions of constructive superposition of short and long wavelength modes. Intense mode conversion also occurs in these regions. For power levels above threshold, the reflection coefficient increases with power and eventually saturates. Numerical results are presented for the ASDEX tokamak and its 24 waveguide grill.

Pellet Ablation Research (Ref. 4, 5, 8)

We have solved the ablation dynamics of LiT pellets are solved self-consistently over a modest range of parameters using a surface dissociation model. The self-consistently determined parameters are then used to modify the standard low-Z pellet penetration codes. Since LiT pellets have certain advantages over carbon [in particular, Li conditioning of the walls and T for refueling a D-T reaction], the penetration of LiT into fusion plasmas is considered.

A nonequilibrium model is necessary to model the outer regions of the ablatant cloud even for thermonuclear plasma conditions when the cloud is very dense. Also, the effect of the ionization of the ablatant by the incident plasma electrons is found to be 10% or less for even the C^{+3} region in the thermonuclear regime. The model used for the heating of the ablatant by the plasma electron is that for a neutral carbon ablatant.

We have also formulated a theory to describe the dynamics of the high density, partially ionized region of the ablation cloud in the vicinity of a spherical light-atom refractory pellet exposed to a tokamak plasma. Owing to the finite sublimation energy of refractory pellets, the surface boundary conditions require a more detailed treatment than in the case of a frozen hydrogen. With the exception of conditions that lead to relatively cold ablation clouds (low plasma density, or small pellet radius), transonic flow solutions were found to exist for most parameters of interest. The shielding properties of the ablation cloud, degree of ionization at the $M = 1$ surface, and the surface flow Mach number were found to be in fairly good agreement with some heuristic models.

Lattice Boltzmann Research (Ref. 11, 15)

Thermal Lattice Boltzmann (TLBE) techniques are used to consider the time evolution of free-decaying 2D turbulence induced by a double velocity shear layer. In particular, we considered the effect of this turbulence at a Reynolds number of 2555 on a strong temperature gradient. Since all structures are resolved on the 1024×1024 grid, the Smagorinsky model is employed to compute directly the eddy viscosity and eddy diffusivity. These transport coefficients play an integral part in large eddy simulations at very high Reynolds numbers where a direct simulation cannot resolve all excited states. TLBE codes have the virtue of being readily extended to 3D, can readily handle non-periodic geometries, and are ideally suited for multi-parallel computer architectures.

Divertor Research (Ref. 12, 13, 16)

Recent experiments and 2D laminar plasma-fluid simulations have indicated that plasma detachment from the divertor plate is strongly tied to plasma recombination. With plasma recombination, a neutral gas blanket will form between the divertor plate and the plasma flame front. Because of plasma-neutral coupling, the plasma flow along the field lines will drive neutral gas flow with Mach number ≥ 1 and Reynolds number ≥ 1000 . A compressible set of conservation and transport equations are solved with 2D mean toroidal flow and 3D turbulence effects over various toroidal cavity geometries. The radial structure of the temperature profile is determined for both turbulent and laminar flow as the flame front propagates down the toroidal cavity. Quantitative results are obtained for the increased heat transfer to the toroidal walls due to turbulence as well as radial profiles for the transport coefficients. It is found that heat loads to the toroidal walls can be increased by factors of 5 to 20 over that for laminar flow over cavity geometries studied here. This increased heat transfer to the toroidal walls will lead to decreased levels of heat flux hitting the divertor plate.

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