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Off-Axis Current Generation by Helicons and LH Waves in Core of Modern Tokamaks and Reactors FNSF-AT, ITER, DEMO and by Alfven Waves in Pedestal Plasmas. Scenarios, Modeling and Antennae

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The Innovative concept and 3D full wave code modeling Off-axis current drive by RF waves in large scale tokamaks, reactors FNSF-AT, ITER and DEMO for steady state operation with high efficiency is proposed. The scheme uses the helicons radiation (fast magnetosonic waves at high (20-40) IC frequency harmonics) at frequencies of 500-1000 MHz, propagating in the outer regions of the plasmas with a rotational transform [1]. Modeling with full wave three-dimensional codes PSTELION and STELEC2 showed flexible control of the current profile in DIII-D, T-15 and KSTAR and reactor plasmas of ITER, FNSF-AT and DEMO, using multiple frequencies, the positions of the antennae and toroidal waves slow down. Commercially available klystrons of MW/tube range, CW working, are promising for commercial stationary fusion reactors. The compact antennae of waveguide type in Traveling Wave regime are proposed, and the example of possible RF system for today's tokamaks and proposed for russian FNSF-AT project is given. For spherical tokamaks the Helicons excitation scheme does not provide efficient Off-axis CD profile tayloring flexibility due to strong coupling of helicons with O-mode, also through the boundary conditions in low aspect machines, and intrinsic large amount of trapped electrons, as will be shown by STELION modeling for the NSTX tokamak. Alfven Resonance Heating/CD method for ELMs and EHO control pedestal plasma is proposed. New possibility is to control the plasma current in pedestal being an essential element in peeling/ballooning modes stability. We propose to use the Alfven resonance scheme based on well known shear Alfven wave relation for frequencies well below of ion cyclotron ones: $\omega = K//VA$. The slow waves and KAW are absorbed mainly by the electrons in pedestal area. Respectively, with properly toroidally phased antenna the SLOW/KAW waves highly efficiently (similar to LH) drive non inductive current to be exploited for ELMs and EHOs control in tokamaks. The antenna with ICRF-like poloidal loops or RMP coils arrays excites the near fields which penetrate into plasma. Thus exploration of Alfven Resonance scenario to low frequencies from megaherz to tenth kHz evidences the importance of KAW excitation in tokamak pedestal area, with possible influence on MHD unstable modes like ELMs and EHO.

[1] Vdovin V. Plas Phys. Rep Vol.39 (2013), N2 95

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