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Physics and applications of ICRH on W7-X

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An important aim of W7-X is to demonstrate fast ion confinement at volume averaged beta values up to 5%, corresponding to plasma densities above 10^{20} m^{-3}. Energetic H or D ions in W7-X with energies 50< E < 100 keV mimic alphas in a reactor. To this end, an ICRH system is prepared for W7-X ,with RF power up to ~1.5 MW at frequencies between 25-38 MHz in pulses up to 10 s. For optimal coupling the antenna surface is carefully matched to the standard magnetic configuration of W7-X. A complex 3D antenna shape has thus to be made with state of the art CNC machines. The antenna can also be radially moved over 35cm and a gas puffing system is implemented to improve local coupling whenever needed.

With minority heating, and despite better absorption of RF waves at high densities, the tail energy of RF-heated minority ions scales as $1/n_e^2$. The production efficiency of fast particles can be much improved using a new so-called three-ion heating ICRH scenario. Two majority gases (e.g. H and D) are used in a well chosen proportion to locate the maximum of the left-hand polarized electric field (E+) of the magnetosonic wave at the resonance position of a third minority species (3He). The new scheme allows for a low concentration of 3He, (< 1%) thus a large amount of RF power is absorbed per particle.We find that perpendicular energies between 50 and 100 keV or higher can be produced, even for $n_e > 2\times10^{20}$ m^{-3}. The three-ion scheme will be used at f ~ 25 MHz. At f ~ 38 MHz also minority heating or second harmonic absorption can be used. If n_H/n_e > 2–3%, H ions dominantly absorb RF power resulting in efficient plasma heating. If n_H/n_e < 2% fast second harmonic heating of D ions becomes the dominant power absorption channel, offering thus a second option to create fast D ions in high density W7-X plasmas.

With the permanent magnetic field of W7-X, ICRH can also be used for Ion Cyclotron Wall Conditioning (ICWC). The coupling of RF power to create a plasma is not limited to cyclotron resonance layers. Via collisional absorption homogeneous discharges can be created extending into the SOL which ensures an optimal plasma wetted wall area. The conditioning procedure consists of series of short ICRF pulses (2-5 s) with a duty cycle of 5 to 20%. The wall released hydrogen and impurities are efficiently evacuated in the interval between subsequent ICRF pulses.

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