Plasma Heating with Upgraded ECRH System on the HSX stellarator

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Overview

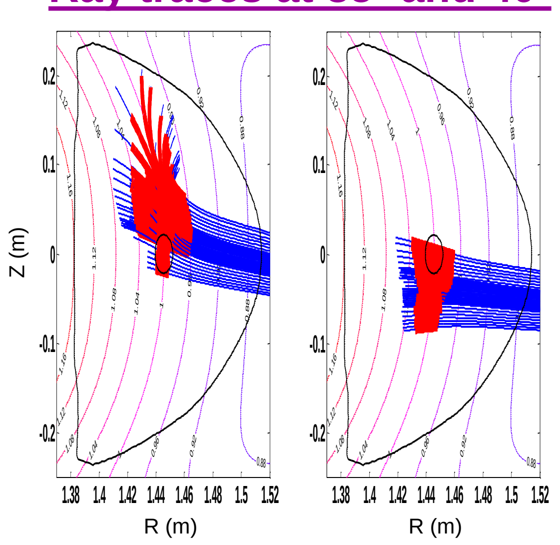
- ECRH experiments on the HSX stellarator are carried out with two gyrotrons now
- Plasma heating as a function of power density is studied using the steerable mirror of the second launcher. Absorption is estimated with the ray tracing code
- Electron thermal diffusivity is measured in the plasmas with modulated heating power and impulse gas puffing

Modeling of Energy Deposition

ECRH Power Density strongly depends on the launching angle of the second beam

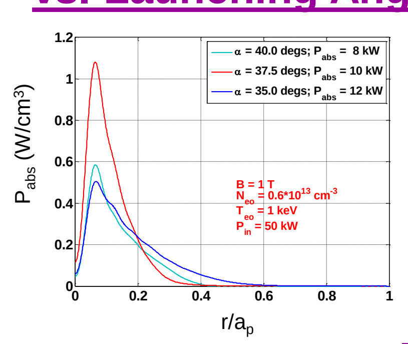
HSX Vertical Cut

Ray traces at 35° and 40°

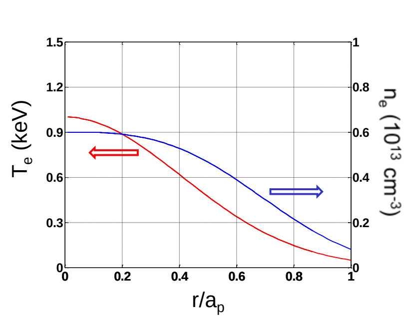


- Launching angle can be vary between 35 and 50 degs that corresponds to the variation of energy deposition in the range of (0 – 0.5)*r/a_p
- Second beam can deviate from the plasma core due to the grad(n_e) while the first beam always propagates towards the plasma axis
- To get a maximum power density in the plasma core the second beam should be launched at an optimum angle
- Broadening of energy deposition and reduced power density in plasma core are due to strong refraction of the second beam

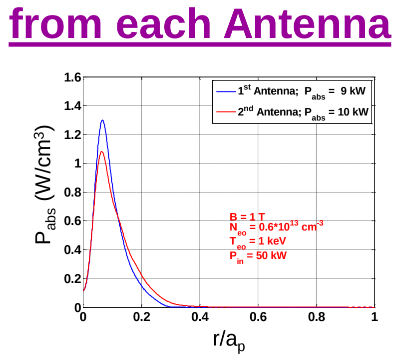
Absorbed Power Profile vs. Launching Angle



Model Plasma Density and Electron Temperature Profiles



Deposition Profiles from each Antenna

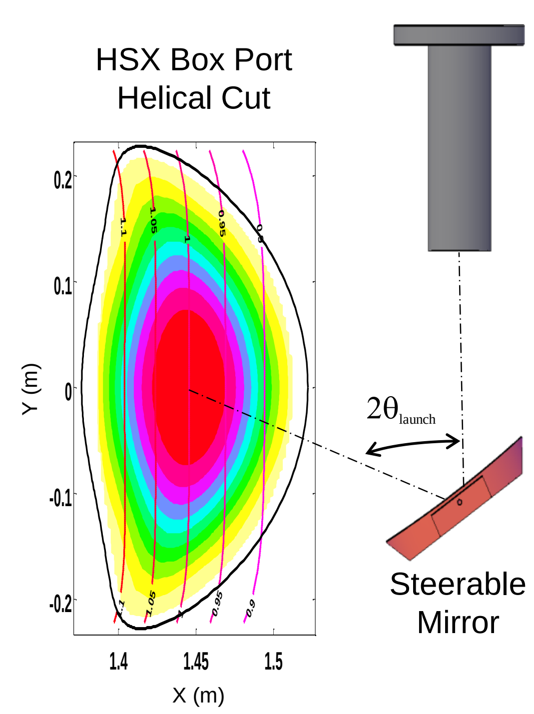


- For optimum launching angle the absorbed power profile from the second antenna is close to that of the first antenna

Optimizing ECRH with Second Launcher

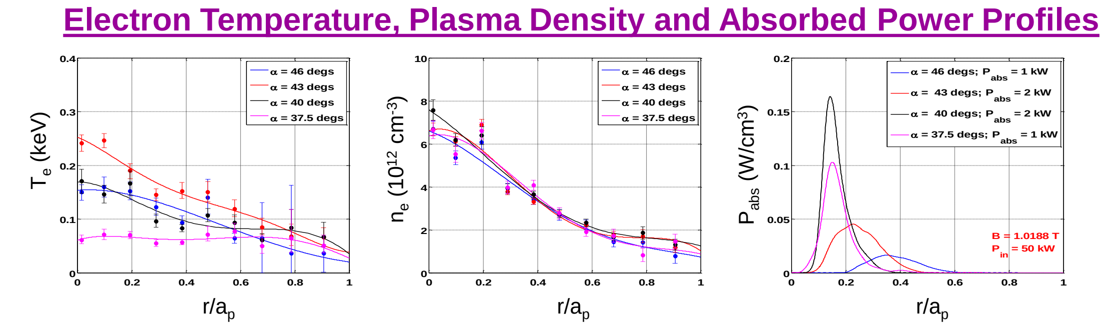
Scans of Magnetic Field and Launching Angle Have Been Made to Maximize T_e in the Plasma Core

Second ECRH Launcher



- Results presented below have been obtained in the experiments with 50 kW from each 28 GHz gyrotron at the fundamental resonance (1 T / O-wave)
- Steerable mirror of the second launcher is used to scan the wave beam across the plasma in a poloidal plane in order to study plasma heating as a function of microwave power density as well as to broaden T_e profile
- Second wave beam is launched below the mid-plane of the box port; deviation of the beam axis from the plasma core is compensated in the experiments by adjusting the mirror angle

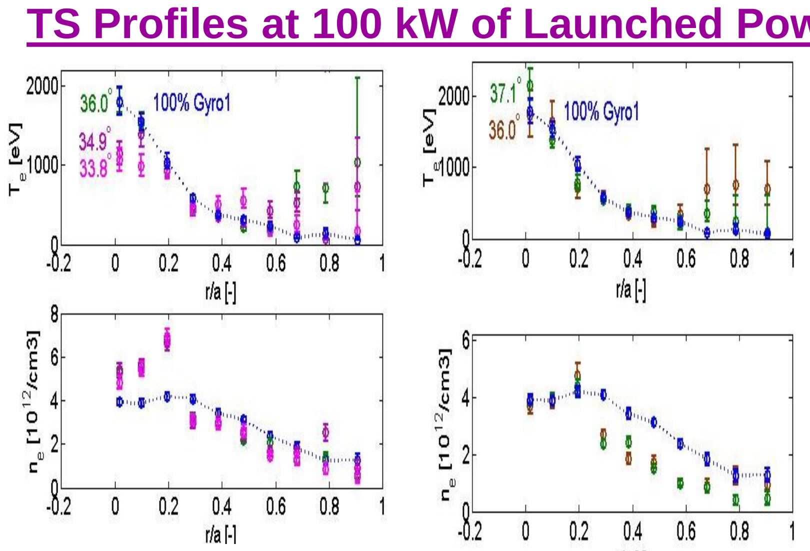
Electron Temperature, Plasma Density and Absorbed Power Profiles



- At the same line averaged plasma density the more peaked N_e profile has been obtained with the second launcher as compared to that from the first one; the fueling is possible explanation for such difference: the gas puff is located far away from the second launcher (about one field period) while it is next to the first antenna
- Due to the strong wave refraction the energy deposition is low in the plasma core that results in the low values of central T_e

Plasma Profiles with Two 50 kW Sources are Slightly Different from Profiles with Single 100 kW First Gyrotron

TS Profiles at 100 kW of Launched Power

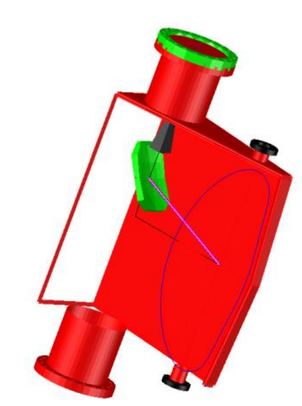


- With the dual system we get almost the same central T_e (~ 2 keV) at the higher N_e as compared to that from the first gyrotron and above 2 keV at the same N_e in the core; again the neutral gas fueling can make a difference

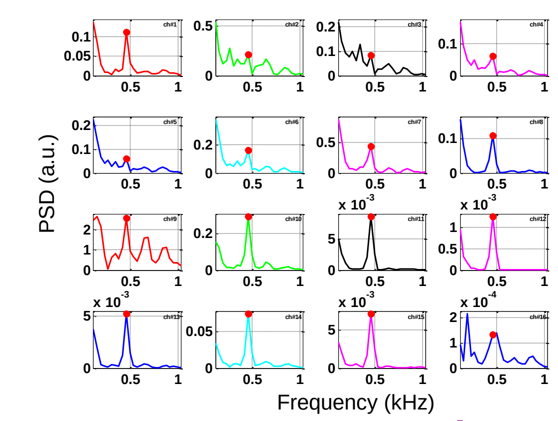
Electron Thermal Diffusivity from Modulation Experiments

Heat Pulse Propagation From ECRH Region Is Measured By 16 Channel ECE Radiometer

ECE Antenna

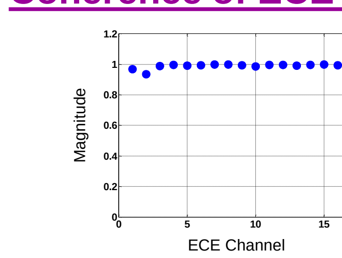


FFT of ECE signals

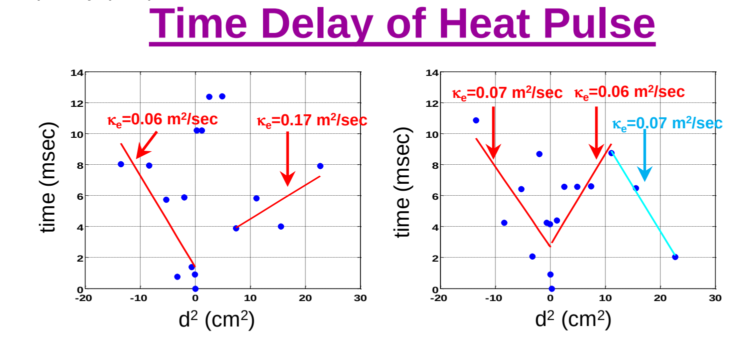


- Modulation of second gyrotron power is made in 40 msec window by a square waveform
- Spectral amplitude and phase of each signal are retrieved by FFT

Coherence of ECE signals



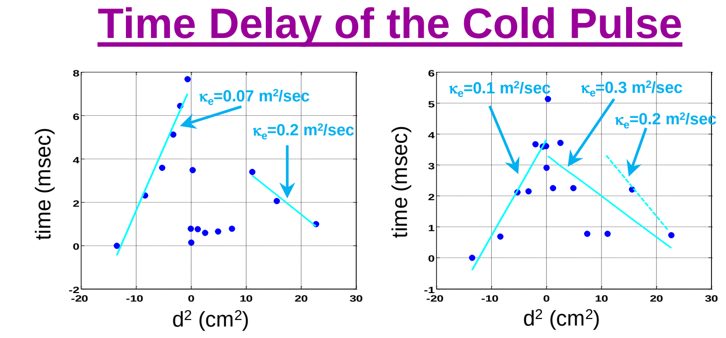
Time Delay of Heat Pulse



- Most coherent results have been obtained at modulation frequency of 500 Hz and modulation depth of 10% of total input power
- Electron thermal diffusivity estimated from these experiments is ~ 0.2 m²/sec ($k_e = 3/8 \cdot d^2/t_d$)
- Measured thermal diffusivity is in reasonable agreement with that obtained from power balance by W.Guttenfelder (PRL 2008)

Cold Gas Propagation from Impulse Puff Is Detected In Plasma Core

Time Delay of the Cold Pulse

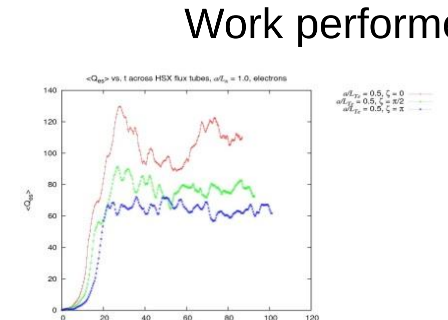


- Impulse (700 Hz) puff makes a cold gas that propagates into HSX plasma core; κ_e from this perturbation is found to be close to that from the heat pulse propagation

Ongoing Gyro-Kinetic Modeling

Electrostatic heat flux is Estimated for HSX Plasma with GENE Code with Kinetic Electrons

Work performed by B.Faber and H.Mynick



- κ_{hp}/κ_{pb} >> 1 in tokamaks and ~ 1 in stellarators; Why?
- Next step is examine the dependence of fluxes on gradients to simulate ECRH modulation

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