• Geodesic acoustic mode (GAM) is a specific mode of low-frequency radial electric field and density oscillations. GAM do not participate in radial transport directly, although create strong inhomogeneity of radial electric field (shear) and transverse rotation velocity, and thus affect anomalous transport through control of turbulence level. GAM-induced shear of $E_r$ is not constant in time, therefore possibility of LH-transition initiation in this case is to be studied.

• The following situation was observed in TUMAN-3M tokamak: GAM oscillations were detected before LH-transition by means of HIBP and Doppler reflectometry; no oscillations were detected after transition [1,2].

Can GAM be a trigger, initiating LH-transition?

• Simulation of density profile evolution with $E_r$-shear-dependent diffusion coefficient shows possibility of LH-transition, initiated by a space- and time-localized GAM burst, if GAM parameters are within certain limits. Those limits are related with each other and also depend on plasma parameters, primarily ion temperature; experimental GAM amplitude was found to be in range of transition initiation possibility.

GAM observation on TUMAN-3M

• GAM were detected by means of HIBP [1] and Doppler reflectometry [2]

Electric field representation

• Total radial electric field $E_r = E_{NEO} + E_{GAM}$

Diffusion suppression

• Analytical dependence $K_{tr}(\omega) = 1/(1 + (\omega/\gamma)^2) + K_{neo}$ [4]
  - $K_{neo}=0.05$ describes fully suppressed anomalous transport
  - for the present modeling TEM mode with $\gamma = 0.7 \times 10^8 \text{s}^{-1}$ was used

• Oscillating field shear has weaker effect on turbulence suppression [5]
  - effective shear value for oscillating electric field component should be used: $\sigma_E = \sigma F(2\pi f_G, T) ; F \rightarrow 0$ if $2 \pi f_G T > > \gamma$

Modeling results

• For specific combinations of GAM and plasma parameters, GAM-initiated transport barrier becomes self-sustaining and exists after GAM switching-off

• If GAM burst duration (a) and amplitude (b) overcome certain threshold values, plasma goes into H-mode; GAM parameters (amplitude, frequency, wavelength) and $T_i$ define $t_{trans}$ - minimal time of GAM existence required for transition initiation

There are LH-transition initiation threshold values for different GAM parameters e.g.:

- threshold field decrease rapidly with ion temperature
- GAM frequency decrease facilitates initiation of LH-transition

Comparison with suppression

• Parameters of typical TUMAN-3M discharge with GAM activity:
  - $B_r < 1 \text{T}, B_t < 180 \text{kA}, q_a = 2.5-3.3, n_i = 0.8-0.9 \times 10^{10} \text{m}^{-3}$

• GAM were detected before LH-transition; single burst duration ~ 0.1 ms

• HIBP measured potential oscillations $\Delta \Phi = 10-15 \text{V}$ in central plasma ($\text{HIBP} \approx 6 \text{cm}$) [1]

• GAM frequency $f_{GAM} = 33 \text{kHz}$ and localization area $\Delta \rho_{GAM} = 1.2 \text{cm}$ were obtained from Doppler reflectometry measurements [2]

• Combination of $E_{GAM}$ and $\lambda_{GAM}$ define central $\Delta \Phi = \int E_{GAM}(r, t) \text{dr} = 10 \text{V}$ potential oscillations amplitude $\Delta \Phi$

• GAM wavelength value was not obtained from experiments; two characteristic “limiting” cases were chosen:
  - $\lambda_{GAM} = 1 \text{cm}, E_{GAM} = 4.5 \text{KV/m} (\lambda_{GAM} < 2 \Delta \rho_{GAM}); \lambda_{GAM} = 2 \text{cm}, E_{GAM} = 2.5 \text{KV/m} (\lambda_{GAM} \approx 2 \Delta \rho_{GAM})$

• Conditions on radial wavelength are chosen corresponding to the fact that GAM with short wavelength (compared to localization area, i.e. $\lambda_{GAM} < < 2 \Delta \rho_{GAM}$) could not be detected by means of central HIBP measurements

• Experimental GAM amplitude for different $\lambda_{GAM}$ is higher than threshold in a certain range of $T_i$ values

• GAM frequency decrease before and during the transition may be one of causes of LH-transition initiation

References