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I. GOALS AND APPROACH

Anomalous ion thermal conductivity remains an open physics issue for the present generation of high temperature Tokamaks. It is now believed to be due to the Ion Temperature Gradient (ITG or η_i) instability. The production and identification of this instability is being studied in the simpler and experimentally convenient configuration of the steady state Columbia Linear Machine (CLM).

The slab branch of this instability has been produced (by two different heating methods), identified and reported for the first time (1,2). The transition of the slab branch to the toroidal branch (more relevant for Tokamaks) has now been studied by turning on the mirror current and gradually increasingly it in CLM. This has enabled us to identify the toroidal/trapped ion branch of the ITG mode for the first time. A preliminary measurement of the ion thermal conductivity due to the mode indicates a highly anomalous value.

Important transport scaling studies based on measurements of ion temperature profile relexation are now planned. We will experimentally determine the scaling relationship between transverse thermal conductivity, fluctuation amplitude, transverse wave number and linear growth rate. Thermal transport due to the toroidal/ trapped ion ITG mode will also be studied. Lastly, efforts at local transport measurements using micro-bolometers will begin.

II. PROGRESS TO DATE

1. Slab Branch of ITG Mode

The slab branch of the ITG mode has been produced and identified in CLM (via a novel heating scheme of acceleration and

thermalization) for the first time and reported (1). The slab branch has also been produced via a transit time heating scheme. The resulting mode is very similar to the mode described above (2).

2. Toroidal Branch of ITG Mode

The transition of the slab branch to the toroidal branch has been studied by gradually increasing the mirror current in CLM and thereby increasing the curvature drive and trapped particles. Mode amplitude first increases and then decreases with increasing mirror ratio. The azimuthal mode number (m=2), parallel wavelength ($\lambda_\parallel$ - 2 to 3 machine length) and real frequency (~ 10 - 15 KHz) remain the same. The results may be consistent with the transition to a trapped ion ITG mode.

3. Anomalous Ion Thermal Transport

A preliminary experiment on the anomalous ion thermal transport due to the ITG mode has been performed. It is observed that as the heated ions (with increased $T_{i\parallel}$) travel down the machine along with the propagating ITG mode, the $T_{i\parallel}$ radial profile relaxes due to enanced transverse thermal conduction. By matching the temperature profiles (up stream and downstream) with the predictions of a $1\frac{1}{2}$d thermal conduction model, we estimate $K_{i\perp} \sim 6 \times 10^3$ cm^2/sec. This is three orders of magnitude higher than classical and and one order of magnitude lower than Bohm. This estimate is surprisingly close to the Tokamak results.

4. Theory and Computational Support

1. Our theory of anisotropic $\eta_i(\eta_{i\parallel}, \eta_{i\perp})$ has been able to predict the threshold, $k_\parallel$ and $m \geq 2$) of our experimental observations of the slab mode.

2. We have developed theories of toroidal and trapped ion ITG modes with anisotropic $\eta_{i\parallel}$, $\eta_{i\perp}$. Our experimental observations of the toroidal/trapped ion ITG mode are roughly consistent with our theoretical predictions.

3. Collaboration with LLNL (Bruce Cohen, Linda LoDestro) using a Gyrokinetic Particle Simulation has confirmed our $\eta_{i\parallel} - \eta_{i\perp}$ threshold.

4. Collaboration with PPPL (Scott Parker, W.W. Lee) using a 3rd Gyrokinetic Particle Simulation with CLM parameters has confirmed the dominance of m=2 mode in the non-linearly saturated state as seen in our experiments.

Talks and Publications

1. "Production and Indentification of the Ion-Temperature Gradient Instability," A.K. Sen, J. Chen and M. Mauel, Phys. Rev. Letts. 66, p. 429, (1991).

2. Experimental Study of an Ion Temperature Gradient Driven Instability in a Linear Machine," R.G., Greaves, J. Chen, and A.K. Sen, accepted for publication in Plasma Physics.

3. "Production and Observation of The Ion Temperature Gradient Instability," Physics of Fluids, 4, p. 512, (1992).

4. "Toridal Branch of ITG Mode with Anisotropic η_i," H. Song and A.K. Sen, Annual Meeting of DPP, APS, Nov. 4-8, (1991).

5. "Experimental Study of The Effects of Curvature Drive, Trapped Particles and Rotational Shear On the ITG Mode," J. Chen, R.G. Greaves and A.K. Sen, ibid, (1991).

6. "Identification and Parametric Study of η_i Mode in the Columbia Linear Machine," J. Chen, A.K. Sen, M. Mauel, and R.G. Graves, Annual Meeting of DPP, APS, Oct. (1990).

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