University of California, Davis

DOE/ER/54269--T1

**Progress Report('94-'95)
Diagnostic of the Spatial and Velocity
Distribution of Alpha particles in Tokamak
Fusion Reactor using Beat-wave generated
Lower Hybrid Wave
(DOE# DEFG03-94ER-54269)**

**D. Q. Hwang, R. D. Horton, R. Evans
Department of Applied Science
University of California, Davis/Livermore**

RECEIVED

FER 23 1998

OSTI

**J. H. Rogers and E. Valeo
PPPL collaborators
March, 5, 1995**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

**Portions of this document may be illegible
electronic image products. Images are
produced from the best available original
document.**

I. Introduction:

The alpha particle population from fusion reactions in a DT tokamak reactor can have dramatic effects on the pressure profiles, energetic particle confinement, and the overall stability of the plasma; thus leading to important design consideration of a fusion reactor based on the tokamak concept. The alpha velocity distribution should be approximately isotropic and mono-energetic at 3.5 MeV. The mono-energetic nature of the alpha population represents a source of large source of free energy to be tapped by instabilities which can cause both energetic particle losses and plasma confinement. For example, one of the recently studied mode is the Toroidal Alfvén Eigenmode (TAE). Theoretical analysis has shown that the TAE instability can lead to significant fast ion losses, thus reducing plasma heating efficiency by any beam-based technique. In order to fully understand the effects of the alpha population, a non-invasive diagnostic technique suitable for use in a reacting plasma environment needs to be developed to map out both the spatial and velocity distribution of the alphas.

II. Experimental Progress(Aug. '94 to March '95):

The proposed experimental goals for the eventual demonstration of LH wave interaction with a fast ion population is given in the reduced 3 year plan in table I. At present time we are approaching the 8th month in our first year of this project. Up to now, our main effort has been concentrated in the operation of the two beat wave sources in burst mode. The second priority in the experimental project is the probe diagnostics and computer aided data acquisition system. The progress made so far is given below, and we are ready to perform the beat-wave generated lower hybrid wave experiment. Some theoretical calculation had been reported at APS meetings. More refined theoretical models are being constructed in collaboration with Drs. J. Rogers and E. Valeo at PPPL.

The experimental progress up to now can be summarized as the follows:

Preparation for the initial series of longitudinal beat-wave experiments in the Davis Divertor Torus (DDT) is complete, and data is beginning to be taken. The major system which has been constructed is a pair of high-power burst-mode microwave sources which enable a series of RF pulses to be supplied to the DDT plasma within a time short compared to the particle confinement or inductive decay time. The two sources have been operated simultaneously to deliver high power (>100 kwatt each) into the DDT vacuum vessel through tangential waveguide antennas. During this high-power operation, a newly-constructed three-dimensional scanning probe system has been used to measure the spatial distribution of pump wave fields within DDT, and to measure the spatial distribution of beat-wave driving field, i.e., the low-frequency component of the product of pump wave signals. The beat-wave driving field has been created in the ion plasma frequency range of $(1\text{MHz} < f_{pi} < 100\text{MHz})$, which encompasses the range of frequencies necessary to launch both the longitudinal plasma wave and transverse lower-hybrid wave.

Control of the scanning probe and acquisition of probe signals was accomplished with an integrated LabView 'virtual instrument'. LabView post-processing software has been written to display the results of time-dependent data (acquired at a finely distributed grid of positions over multiple repeatable plasma discharges) as a succession of two-dimensional time slices, or movie frames. The same system will be used without modification to acquire and display the distribution of beat-wave amplitudes within the plasma, a result which will be compared to numerical simulation of the beat-wave in bounded cylindrical plasma.

Currently, the filament plasma source which is used to produce the target plasma for DDT beat-wave experiments is being remounted to allow easy retraction during compact-torus injection experiments. The retractable filament source should be available for use in a matter of a few days, at which point measurements of longitudinal beat-wave spatial distribution will begin. After approximately three months of longitudinal operation, the waveguide antennas will be repositioned for transverse injection of the lower-hybrid wave, the polarization required for diagnosis of fast-ion transverse velocity distributions (e.g., alpha particles). The higher plasma densities required for lower-hybrid operation have already been created with the current plasma source.

Some results of DDT beat-wave operation to date are shown below. In Figure 1, the amplitudes of one pump-wave signal with magnetron operating in the XL

band (8.8 GHz) are shown during launch into the DDT vessel. In Figure 2, the nonlinear pump-wave product signal detected by a probe inside DDT is shown, at a frequency in the lower hybrid regime (50MHz) note that it appears only during the period of overlap between the pump waves.

Table I: Experimental tasks for LH detection of Alpha particle distribution

Tasks	Original Date	New Date
Beat wave excitation of LH wave	year 1	year 1
wave dispersion	year 1	year 1
probe diagnostics of wave	year 1	year 1
μ wave scattering	year 1	deleted
non-linear wave loss	year1	deleted
3-D effects	year1	deleted
theory comparison	year1-3	year1-3
other wave effects	year 1	deleted
effect of radial modes & beam profile	year1	year1
beat-wave to LH theory	year 2	year 2
beat wave antenna modifications	year2	deleted
wave steering effects	year 2	deleted
particle probes	year2	year 2

SS effects 3 options	year2	deleted
Installation of fast ion source	year3	year 3
Installation of particle energy analyzer	year3	year 3
source improvements	year3	deleted
measurement of LH wave damping	year 3	year 3
measurement of ion distribution	year3	year3
new modulator circuitry	year3	deleted
SS modifications	year3	deleted

950307.0928 it =054
Probe RF signal (~9 GHz) versus major radius

Figure 1: Radial scan of 8.8 GHz pump wave, using burst-mode magnetron and scanning probe.

Tek Stopped: 522 Acquisitions

Figure 2: Scanning probe measurement of the beat frequency during high power injection near 8.8 GHz

Figure 3: DDT experimental setup.