Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**			
Title: Nonlinear Evolution of "Angelfish"			
OP-XP-?	Revision: **1.0 (2/17/2010)**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*	
PROPOSAL APPROVALS			
Responsible Author: W. Heidbrink			Date
ATI – ET Group Leader:			Date
RLM - Run Coordinator:			Date
Responsible Division: Experimental Research Operations			
Chit Review Board (designated by Run Coordinator)			
MINOR MODIFICATIONS (Approved by Experimental Research Operations)			

NSTX EXPERIMENTAL PROPOSAL

TITLE: Nonlinear Evolution of Angelfish No. **OP-XP-?**
AUTHORS: W. Heidbrink, E. Fredrickson et al. DATE: **2/17/2010**

1. Overview of planned experiment

"Angelfish"—MHz modes with rapidly sweeping frequency--are produced. The mode structure and fast-ion profile are measured. The addition of HHFW heating increases the effective collision rate of the resonant fast ions, which will suppress the frequency sweeping (if the Berk-Breizman theory of phase-space holes and clumps is applicable).

2. Theoretical/ empirical justification

Although much is known about the linear stability of fast-ion driven instabilities, nonlinear saturation is less understood. Some instabilities (such as the classic PDX fishbone) have frequencies that change by a factor of two on a millisecond timescale, while the frequencies of other instabilities are virtually constant on this timescale. A fundamental understanding of these differences can guide predictions of the saturated amplitude of alpha-driven instabilities in ITER and other burning plasmas.

A simplified model developed by Berk and Breizman explains some of the nonlinear phenomenology of fast-particle driven instabilities. In their model [1], frequency chirping is associated with the formation of holes and clumps in the phase space that describes the fast-particle distribution function. When collisions are weak, these phase-space structures persist and frequency chirping is possible. When the effective collision rate is large, the structures are rapidly destroyed and no frequency chirping occurs.

Maslovsky and Mauel [2] used energetic electrons in a dipole to test the Berk-Breizman model. When additional RF energy was absorbed by the resonant electrons, chirping was suppressed.
Modeling indicated that the increase in the effective collision rate could account for the suppression.

An experiment to replicate the Maslovsky-Mauel hot-electron experiment with beam ions in NSTX was performed in 2004 [3]. In the 2004 experiment, beam-driven chirping was observed in three frequency bands. Fishbones in the lowest frequency band were unaffected by the HHFW. In the TAE band, HHFW altered the modes but did not suppress chirping. In the MHz band, angelfish chirping apparently was affected by the HHFW in some shots but not in others.

The previous publication [3] attempts a quantitative comparison with theory but the results are inconclusive. The paper concludes that, in future experiments, "detailed measurements of the fast-ion distribution function should ascertain which fast ions interact with the instabilities and the stochastic acceleration of those particular fast ions by the RF." The development of the multi-channel FIDA and reflectometer diagnostics in the intervening years can address the main deficiency of the previous experiment.

Operationally, four conditions are required.

1. **Low Toroidal Field.** Because the largest observed effect in the previous experiment was on the MHz instabilities, this XP focuses on these modes. Generally speaking, angelfish are more common at low toroidal field, so the experiment will operate at 4 kG or less. Although the focus is on angelfish, HHFW will also be applied to any other chirping instabilities that occur during the experiment.

2. **L-mode.** It is essential to measure the mode structure to ascertain which fast ions drive the instability. The reflectometer diagnostic requires a peaked density profile to measure the eigenfunction, so the experiment will be conducted in L-mode.
3. **Small outer gap & low edge density.** Efficient coupling of HHFW power is essential so the plasma shape will have a small outer gap and some lithium will be employed to minimize the edge density.
4. **Beam modulation.** On some repeat shots, the beams will be modulated to check the FIDA background subtraction and to determine if the NPA & SSNPA signals are from active or passive charge exchange.

[1] H.L. Berk *et al.,* Phys. Plasmas **6** (1999) 3102.
[2] D. Maslovsky *et al.,* Phys. Plasmas **10** (2003) 1549.
[3] W.W. Heidbrink *et al.,* Plasma Phys. Cont. Fusion **48** (2006) 1347.

3. Experimental run plan

1. Establish L-mode condition with Angelfish. The preliminary target discharge is #128783 (700 kA, 3.5 kG); however, if strong angelfish are observed prior to the experiment during the 2010 campaign, we will switch to that condition.

1a. If no Angelfish, try different beam sources. If still no Angelfish, lower toroidal field.

2. Adjust density for optimal reflectometer data (as necessary).

3. Apply 30 ms HHFW pulses during Angelfish.

3a. If effect on neutron rate is small, change HHFW phasing.

4. If HHFW has an effect on the Angelfish, run several repeat shots with and without RF to confirm reproducibility.

5. Beam notches in best cases to check FIDA/NPA data.

6. If HHFW has an effect, lower HHFW power to find the threshold for suppressed frequency chirping.

4. Required machine, NBI, RF, CHI and diagnostic capabilities

Machine: Lithium available.

Beam: All three sources; modulation.

ICRF: HHFW—at least 2 MW. Phasing chosen to optimize fast-ion heating.

Diagnostics: Magnetics and reflectometer; fast-ion (FIDA, neutrons, NPA, SSNPA, sFLIP); plasma (Thomson scattering, CHERS) for theoretical fast-ion distribution function.

5. Planned analysis

Analysis of the studied instabilities to determine which fast ions drive the modes. TRANSP and FIDA simulation analysis to infer the effective collision rate ν_{eff} associated with the RF for the fast ions that drive the modes. Comparison with the Berk-Breizman theory, as in Ref. [3].

6. Planned publication of results

A journal article similar to Ref. [3].

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Previous shot(s) which can be repeated: 128783

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): 42-48 Flattop start/stop (s): 0/0.75

I_P (MA): 0.8 Flattop start/stop (s): 0.25/0.5

Configuration: Double null with small inner and outer gaps

Equilibrium Control: rtEFIT

Outer gap (m): 0.04 Inner gap (m): 0.02 Z position (m): 0

Elongation κ: ~1.9 Upper/lower triangularity δ: ~0.4

Gas Species: D Injector(s): Fuel from outside to avoid H-mode

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C:** 90 Duration (s): Modulate

ICRF Power (MW): >2 Phase between straps (°): 90 Duration (s): 30 ms

CHI: **Off** Bank capacitance (mF):

LITERs: On Total deposition rate (mg/min):

EFC coils: Off Configuration: **Odd / Even / Other** *(attach detailed sheet*

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Bolometer – tangential array		**X**
Bolometer – divertor		**X**
CHERS – toroidal		**X**
CHERS – poloidal		**X**
Divertor fast camera		**X**
Dust detector		
EBW radiometers		
Edge deposition monitors		
Edge neutral density diag.		**X**
Edge pressure gauges		
Edge rotation diagnostic		**X**
Fast ion D_alpha - FIDA	**X**	
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP	**x**	
Filterscopes		
FIReTIP	**x**	
Gas puff imaging		
Hα camera - 1D		
High-k scattering		**X**
Infrared cameras		**X**
Interferometer - 1 mm		
Langmuir probes – divertor		
Langmuir probes – BEaP		
Langmuir probes – RF ant.		**X**
Magnetics – Diamagnetism		
Magnetics – Flux loops	√	
Magnetics – Locked modes		
Magnetics – Pickup coils	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		
Magnetics – RWM sensors		
Mirnov coils – high f.	**X**	
Mirnov coils – poloidal array	**X**	
Mirnov coils – toroidal array	**X**	
Mirnov coils – 3-axis proto.	**X**	

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE		**X**
NPA – E‖B scanning	**X**	
NPA – solid state	**X**	
Neutron measurements	**X**	
Plasma TV		
Reciprocating probe		
Reflectometer – 65GHz	**x**	
Reflectometer – correlation		
Reflectometer – FM/CW		**X**
Reflectometer – fixed f	**x**	
Reflectometer – SOL		
RF edge probes		**x**
Spectrometer – SPRED		**x**
Spectrometer – VIPS		
SWIFT – 2D flow		
Thomson scattering	**X**	
Ultrasoft X-ray arrays		**X**
Ultrasoft X-rays – bicolor		
Ultrasoft X-rays – TG spectr.		
Visible bremsstrahlung det.		**X**
X-ray crystal spectrom. - H		
X-ray crystal spectrom. - V		
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		