TAE Studies in ASDEX Upgrade

S. D. Pinches, S. Günter, M. Maraschek
and the ASDEX Upgrade Team
MPI für Plasmaphysik, EURATOM-Association, D-85748 Garching, Germany

1 Introduction

The effect of toroidicity within tokamak plasmas leads to a coupling between neighbouring poloidal harmonics and enables the formation of Toroidicity induced Alfvén Eigenmodes (TAE). These are generally weakly damped Alfvén waves with phase velocities comparable with those of energetic plasma particles.

Energetic particles arising from external heating schemes may resonately exchange energy with a series of Alfvén resonances present in the plasma. These resonances will approximately occur when

$$v_{\|} \approx \frac{v_A}{|2l-1|},$$

with the strength of the interaction decreasing for increasing l.

The neutral beam injection (NBI) system in ASDEX Upgrade produces a population of energetic particles with characteristic birth energy of 60 keV. For typical ASDEX Upgrade parameters this corresponds to a birth velocity of $v = 0.85\, v_A$ indicating that these particles will be resonant for $l > 1$. The exchange of energy between particles and waves enables either wave growth or decay to be obtained.

Recently in ASDEX Upgrade, TAE have also been found in purely ohmically heated discharges [1]. Since only thermal particles are present in this case, an excitation by fast particles as described above is impossible.

2 NBI driven TAE in ASDEX Upgrade

In ASDEX Upgrade TAE are routinely observed in NBI heated plasmas. The HAGIS code [2, 3] has been used to study the interaction between the population of energetic deuterons arising from the NBI system and a single TAE in a shaped ASDEX Upgrade plasma. HAGIS is a self-consistent nonlinear code developed for the purpose of studying the interaction of fast particles with AEs. It evolves both the waves and particles in time allowing the linear growth rates and saturation amplitudes to be calculated as well as the fast particle redistribution/losses resulting from the wave-particle interactions.

The shot investigated is #7692. The plasma parameters were chosen to simulate the injection of 60 keV deuterons into a pure D plasma with the fast particle distribution function used found by splining the experimental NBI deposition profile in radius and assuming a slowing down distribution in energy. The distribution in pitch angle is assumed to be isotropic. The radial structure of the $n = 3$ TAE calculated using CASTOR [4] for this shot is shown in Fig. 1, whilst the growthrate of this mode is presented in Fig. 2.

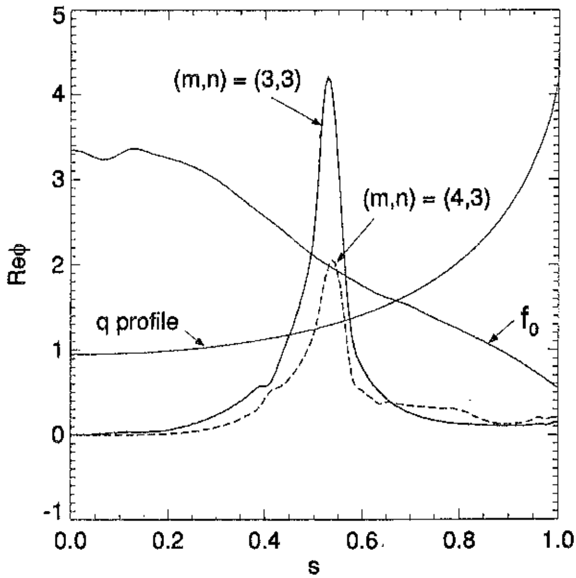

Figure 1: Plot showing TAE eigenfunctions together with the radial fast particle distribution and q-profile.

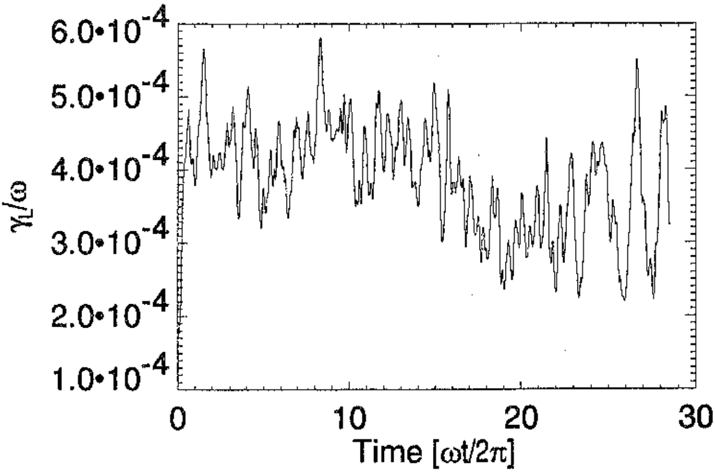

Figure 2: Growthrate of $n = 3$ TAE driven by NBI ions in ASDEX-U.

3 TAE in Ohmically Heated Plasmas

Besides the well known TAE in additionally heated plasmas, similar modes have also been observed in purely Ohmically heated plasmas.

In contrast to the bursting nature of the modes in NBI heated plasmas, in Ohmic shots the modes appear continuously throughout the discharge. Their amplitude is about one order of magnitude smaller than those in NBI heated plasmas [1]. Investigating shots with different toroidal fields B_ϕ and different ion species (mass m_i) one finds the expected frequency scaling for Alfvén modes $f \propto B_\phi/\sqrt{m_i}$. The same is true for the density dependence ($f \propto 1/\sqrt{n_e}$) which has been checked via a strong density variation within one shot.

For the theoretical investigation of these modes the resistive MHD code CASTOR [4] has been applied. In Fig. 3 the continuous spectrum for a typical ASDEX Upgrade

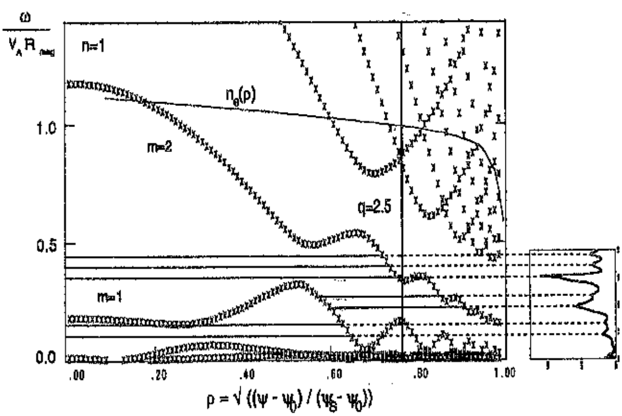

Figure 3: The Alfvén continuum frequencies for $n = 1$ of ASDEX Upgrade discharge #8630 as a function of the radius for a compressible plasma. (The slow continuum is not given here.) On the right hand side the power absorbed by the plasma as a function of the antenna frequency is drawn.

shot without additional heating is given. On the right hand side the power absorbed by the plasma as a function of the driving frequency of an external antenna is shown. The resonances in this spectrum correspond to the global Alfvén waves. In Fig. 4 the same spectrum is compared to a Fourier spectrum measured by Mirnov coils at the high field side. It is apparent that only those waves with a frequency of about 115 kHz have been observed on the Mirnov diagnostics. Considering Fig. 3 and the corresponding eigenfunctions one finds that the observed modes are located near the plasma edge (at about $q \approx 2.5$) which is in agreement with soft X-ray measurements.

A possible excitation mechanism for these modes is through drift wave turbulence at the plasma edge [5]. Such an explanation seems to be reasonable since the observed modes disappear at the L-H transition where the turbulence vanishes. Additionally the rotation

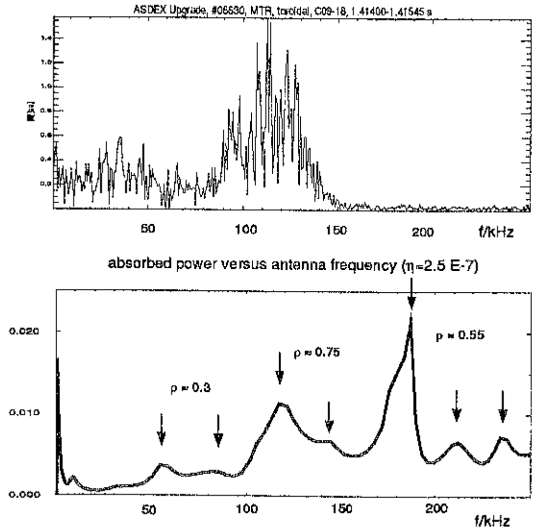

Figure 4: The Fourier spectrum measured by Mirnov coils at the high field side compared to the antenna absorption spectrum. The arrows indicate the radial location of the corresponding Alfvén wave.

of the modes in the electron diamagnetic drift direction further supports this idea since the drift waves are coupled to the plasma electrons.

Acknowledgements

The authors gratefully acknowledge the many useful conversations with Dr. A. Stäbler regarding the radial distribution of NBI ions in ASDEX-Upgrade.

References

[1] M. Maraschek, S. Günter, T. Kass, B. Scott and H. Zohm, submitted to Phys. Rev. Lett. 1997

[2] S. D. Pinches, PhD Thesis, University of Nottingham.

[3] L. C. Appel, H. L. Berk, D. Borba, B. Breizman, T. C. Hender, G. T. Huysmans, W. Kerner, M. Pekker, S. D. Pinches and S. E. Sharapov. Nuclear Fusion, **35** p.1697 (1995)

[4] W. Kerner, J. P. Goedbloed, G.T.A. Huysmans, S. Poedts, and E. Schwarz, JET report JET-P(97)04, submitted to J. Comp. Phys. (1997)

[5] B. Scott, S. Camargo, and F. Jenko, 13th Int. Conf. on Plasma Physics and Controlled Nuclear Fusion Research, IAEA-CN-64, D-3-4, DP-18, Montreal (1996)