THE STUDY OF ALFVÉN EIGENMODES ON THE SPHERICAL TOKAMAK GLOBUS-M2 USING DOPPLER BACKSCATTERING

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1. INTRODUCTION

Electromagnetic waves propagating along the magnetic field B with wavenumber $k_\parallel$ with a frequency $\omega = k_\parallel V_A$ (where $V_A = B/\sqrt{(4\pi\rho)}$ is the Alfvén velocity with ρ being the mass density of the plasma) are known as Alfvén waves [1]. Various types of Alfvén eigenmodes (AEs) can be driven unstable by energetic particles when the resonance condition is satisfied and are commonly observed in laboratory plasmas. In a toroidal plasma, these modes lead to the ejection the high-energy particles from the plasma which in turn can cause significant loss of beam power (with degradation of plasma performance) and damage to the plasma facing components. Thus, understanding the physics and mechanisms of the AEs is important from both a fundamental scientific perspective and for the practical realization of fusion energy.

2. AREA OF DEVELOPMENT OF ALFVEN EIGENMODES ON GLOBUS-M2

AEs have been a topic of research on the spherical tokamak Globus-M (minor radius a = 0.24 m, major radius R = 0.36 m, R/a = 1.5) and now its modernised version Globus-M2 which was designed to reach toroidal magnetic fields up to 1 T and plasma current 0.5 MA. In experiments with neutral beam injection (NBI) several types of AEs have been observed (see example in Fig.1a): Alfvén cascades (AC) are detected during current ramp up, then chirping toroidal Alfvén eigenmodes (TAE) and Doppler shifted TAE (DS TAE) can be seen at a later stage of auxiliary heating. Studies of these modes have been carried out using arrays of magnetic probes which allowed to determine their mode structure and amplitude [2,3]. TAE-induced losses of fast particles have been investigated using a neutron spectrometer and ACORD-24M neutral particle analyser (NPA) [4,5].

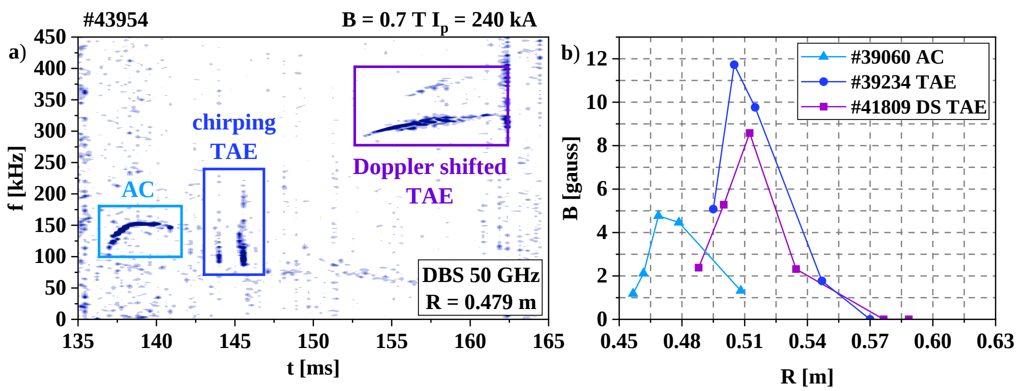

Fig. 1. a) spectrogram of phase derivative of the 50 GHz Doppler backscattering channel, b) radial profiles of AE magnetic field amplitude obtained using multi-frequency Doppler backscattering.

It had been demonstrated on Globus-M that the microwave diagnostic Doppler backscattering (DBS) can be used to detect the drift velocity fluctuations in crossed radial electric field of the Alfvén wave and tokamak magnetic field, allowing to determine their magnetic field amplitude [6,7], however the DBS system available at that time did not allow to obtain comprehensive measurements. On Globus-M2 three DBS systems are installed with 9 probing frequencies available in the range of 18 – 65 GHz which cover an interval of normalized minor radii ρ = 0.6–1.1 for typical Globus-M2 discharges [8,9]. An example of AE observations using DBS is shown in Fig.1a in the form of the spectrogram of the phase derivative of the channel with a 50 GHz probing frequency. Using DBS and radial correlation Doppler reflectometry, the localization of the various AEs was determined with the obtained profiles presented in Fig.1b. The results demonstrate that the TAE exists at radii 0.48-0.55 m and disappears in the plasma core. Doppler shifted TAE were detected in a slightly deeper plasma region at a wider range of radii 0.45–0.55 m which coincides with the region of the maximum gradient of the rotation velocity [10]. Apart from that, ACs were seen to develop at radii 0.45–0.51 m as such AEs develop in the region of the minimum of safety factor in the central plasma regions [11]. The dependence of the AE localization on plasma parameters such as magnetic field, plasma current and electron density will be presented.

3. TURBULENCE REACTION TO ALFVEN EIGENMODES

The DBS diagnostic provides characterization of density fluctuations and flows with non-invasive local measurements of their parameters. These measurements offer valuable information regarding the turbulent processes that can affect confinement in fusion devices. The turbulence level and average poloidal rotation velocity (and the corresponding radial electric field) exhibit changes during AEs. For example, in the case of chirping TAE (Fig.2a depicts the AE amplitude), it can be seen that there is a decrease in turbulence amplitude (represented by amplitude of complex DBS signal in Fig.2b) and velocity (represented by the Doppler frequency shift Δf_D in Fig.2c) associated with each burst. Additionally, bispectral analysis was applied to the DBS signals and magnetic probe signals to investigate the non-linear interaction between the plasma turbulence and AEs that may take place.

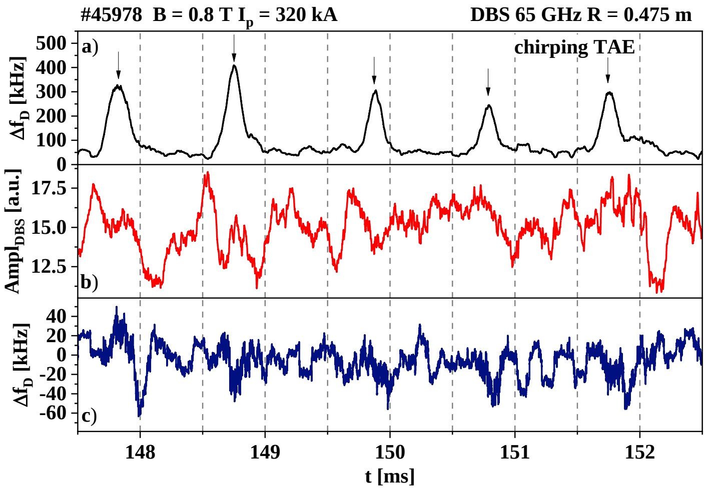

Figure 2. a) AE amplitude, b) amplitude of complex DBS signal, c) Doppler frequency shift Δf_D for the 65 GHz DBS channel.

ACKNOWLEDGEMENTS

This work was funded by the Ministry of science and higher education of the Russian Federation in the framework of the state contract in the field of science under project No. FSEG-2024-0005.

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