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MHD Polarimetry Using the MSE Optics in JET ILW Plasma Regimes

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MHD polarimetry using the MSE optics in JET ILW plasma regimes

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Introduction

The Motional Stark Effect diagnostic (MSE) at JET has 25 lines of sight, probing the light emitted by neutral deuterium from JET octant 4 neutral beam injector, covering a plasma region with major radius ranging from 2.68m to 3.88 m. The MSE polarimeter consists of two photo elastic modulators (PEMs), working at 20 kHz and 23 kHz in tandem, with their fast axis oriented at 45^{o} to each other and a linear polarizer working as an analyzer. Fourier analysis of the raw data from the JET MSE diagnostic, have revealed MHD signatures on the respective spectrograms with unprecedented clarity, not seen before the new ITER-like Wall (ILW) at JET[1]. An example of those observations is depicted in figure 1, in JET hybrid plasma regimes for JET pulse #83533, where a n = 1 MHD can be observed on spectrograms from Mirnov coils (figure 1 a) and MSE channel 17 (figure 1 b) with plasma location close to 3.128 m. Also it is possible to observe on the MSE spectrogram a MHD reflection around 23 kHz. Similar phenomena has been reported from DIII-D tokamak [2]. The signature of MHD events from MSE data, has also been reported from JT-60 tokamak [3]. In both reports the analysis uses the MHD fluctuation as a perturbation to the conventional MSE signals, i.e. data coming directly from the Stark emission of the dedicated MSE neutral injector.

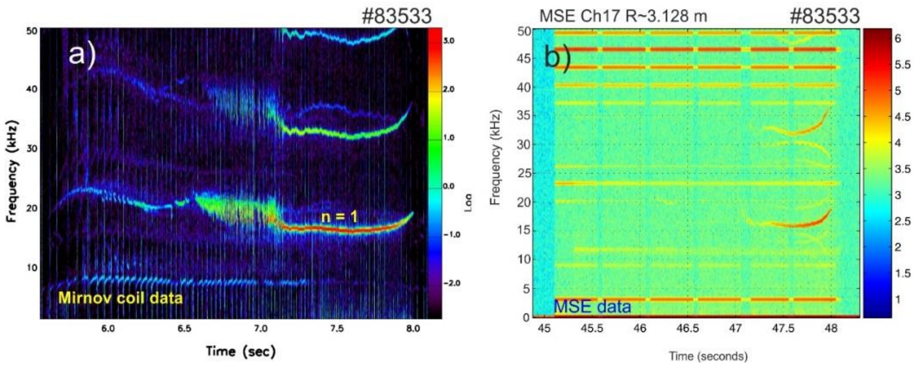

Figure 1: Spectrograms showing a n = 1 MHD from a) magnetics data and b) MSE data

In this communication, we will use a technique which measures the amplitude of the fluctuations on the raw MSE signals, for each MSE channel, following carefully the frequency of the observed MHD on Mirnov spectrograms or by choosing a defined frequency bandwidth. The proposed technique, can be used even when the dedicated MSE neutral beam injector it is not firing.

Coherence between MSE, ECE and Mirnov signals

The observation of the marking of MHD events on MSE, Mirnov and ECE signals, has suggested to further investigate coherence between those signals in a variety of configurations, such MSE single channel and all ECE channels or all MSE channels with a single magnetic probe. Coherence between two signals can be defined as:

$$C(\omega) = \frac{\langle X(\omega)Y^{*}(\omega)\rangle}{\langle X(\omega)X^{*}(\omega)\rangle^{1/2}\langle Y(\omega)Y^{*}(\omega)\rangle^{1/2}}$$

Where $X(\omega)$ and $Y(\omega)$ are the Fourier transform of the measured signals. It is worth to note, that processed MSE data has been used as well, to compute the coherence, giving similar results to those obtained from MSE raw data. Results of the analysis are plotted in figure 2 for JET pulse #83533, where coherence, between the raw signal coming from MSE channel 17 close to the plasma core and all available ECE channels, has been computed for time slices when the n = 1 MHD it is absent (figure 2 a) or present (figure 2 b).

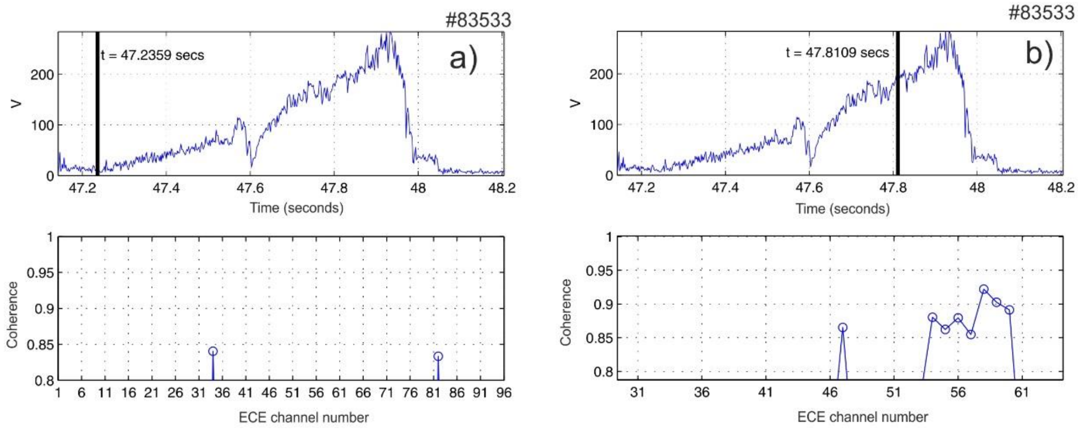

Figure 2: Measurement of the coherence between MSE channel 17 and all ECE channels a) outside of the MHD and b) inside of the MHD. Top traces shows the amplitude of the measured Mirnov signal.

To test the method, ECE channel 57 data (R_{maj} = 3.128 m), which is one exhibiting high degree of coherence and very close to MSE channel 17, has been Fourier analyzed to retrieve the respective spectrogram. The result is presented in figure 3 where the n = 1 MHD can be observed.

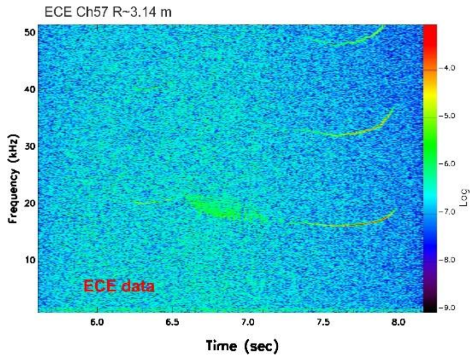

Figure 3: Spectrogram from ECE channel 57 data for JET pulse #83533

Experimental examples of the technique in JET ILW plasmas

The technique has been used in several JET ILW plasma scenarios. The first example is in hybrid plasma regimes. A very common feature of those plasmas is the occurrence of n = 1, m = 1 internal kink MHD with behaviour closely linked to impurity peaking, which is followed by T_e sawtooth flushing out the accumulated impurity. This behaviour can be observed on SXR traces (see fig. 5c for similar results).This kind of plasmas has been investigated in hybrid development experiments at JET and the related phenomenology is described in figure 4. Here the impurity flush out can be interpreted as a cold pulse propagating from the plasma centre to the edge. This cold pulse signature is clearly signed on the MSE data. Furthermore, a possible electron ITB is signed by the grad(T_e) criteria (figure 4 b) which is also signed by the MSE polarimeter (figure 4 c). It is worth to note that careful analysis of the T_e traces shows evidence of non-local effects.

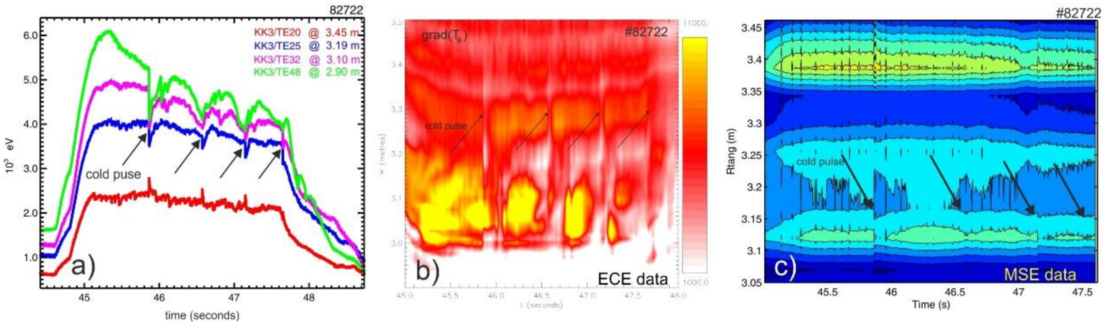

Figure 4: a) T_e traces shows sawteeth related with impurity flush out, b) the grad(T_e) criteria signs the cold pulse propagation and c) the MSE polarimeter is able to monitor the cold pulse and a possible eITB.

Another interesting example on the application of the technique, can be found in the so called baseline ELMy-H mode scenario. Here a strong m/n = 3/2 MHD is present and closely related to impurity peaking at the plasma centre as can be seen in figure 5c. Here the edge transport barrier (ETB) (figure 5 b) signed by the grad(T_e) criteria has a behaviour clearly determined by impurity. The impact of the accumulated impurity on the ETB dynamics is signed by the MSE polarimeter as well.

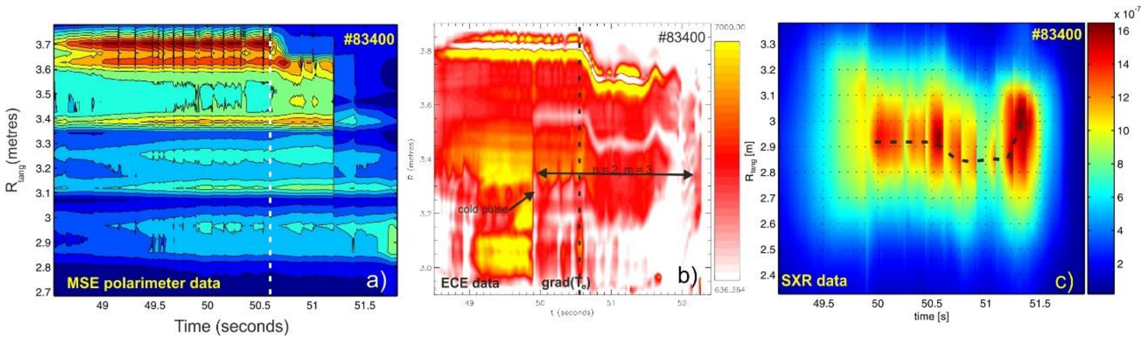

Figure 5: Impact of impurity accumulation on ETB as observed by a) MSE polarimeter b) ECE data; c) and Soft X-Ray data

Finally, the technique has been applied in JET hybrid ILW plasmas during q_{95} scan experiments for JET discharges #84667, #84669 and #84670 where the q_{95} parameter has been varied from 4.0 to 3.0 approximately. During the discharges m/n = 3/2 and 4/3 tearing activity is observed. Amplitude fluctuations on the MSE polarimeter signals has been scanned at very low frequency (typically 400 Hz to 50 Hz bandwidth). The result of the MSE data (figure 6 a), b), and c) matches exactly the measured bremsstrahlung emission (figure 6 a). This result can be interpreted by considering the perturbation on the bremsstrahlung emission by the tearing [4]. The visible broadband bremsstrahlung emission is given as:

$$\frac{dI_B}{d\lambda} = 2.27 \times 10^{-14} \frac{n_e^2 \, Z_{eff}}{\lambda T_e^{1/2}} e^{-hc/\lambda T_e}$$

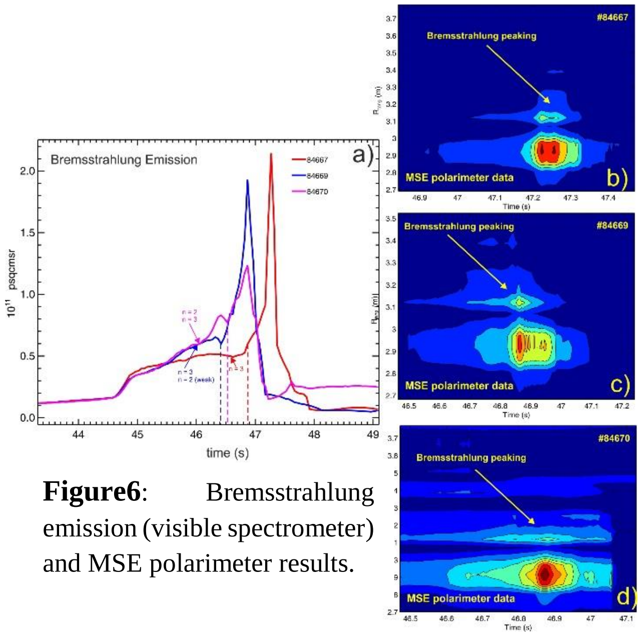

Figure6: Bremsstrahlung emission (visible spectrometer) and MSE polarimeter results.

While the fluctuation $\tilde{I}_B$ on bremsstrahlung emission induced by the tearing, can be written as $\tilde{I}_B \propto \xi \nabla I_B$, being ξ the radial displacement of the MHD. Regarding the dependence of the emitted light on n_e^2 the fluctuation $\tilde{I}_B$ is a measure of density fluctuations induced by the tearing. From these considerations, we can conclude that the MSE polarimeter is likely measuring density fluctuations. The light source for the MSE polarimeter is broadband visible bremsstrahlung. It is worth to note, that bremsstrahlung emission under these conditions, might be linearly polarized light [5].

Conclusions

The question of MHD observation through Fourier analysis of MSE polarimeter data has been addressed. Measurement of the coherence between MSE polarimeter signals ECE and Mirnov coils data, gave us confidence to go further on the use of this novel technique in JET ILW experiments. Results using this technique from q_{95} scan experiments in hybrid scenarios, have shown that the light source for the MSE polarimeter is broadband bremsstrahlung emission. Specifically when tearing activity is perturbing that emission.

Acknowledgement

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