Spectroscopic observations and analysis of the Fulcher Bands of hydrogen an its isotopologues in divertor region of the ITER-like wall JET tokamak

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Molecular processes in divertor plasma are now more and more widely studied via calculations and modeling in a variety of fusion machines. They suggest, that the molecules in divertor region are an important component, due to molecular gas puffing and strong recycling. There are no easy diagnostics which can verify the results of those calculations. Most of the attempts are either spectroscopic study of atomic lines intensities, to determine which part of it comes from formation of excited atoms by molecular dissociation[1], or direct spectroscopic observation of excited hydrogenic molecules[2]. Those molecules have relatively strong spectral features only in two wavelength regions: VUV, where the singlet Werner and Lyman (B, C →X) bands are located (very difficult region to observe with high enough resolution to distinguish molecular bands from other broadband features) and yellow/red part of visible wavelength range, where triplet Fulcher bands are located (strongest transition is d→a, but it's not the only one visible in that region).

All those transitions are with relatively energetic upper level – from 11.4 eV for B, to nearly 14 eV for d. Fulcher bands due to their wavelength region can be recorded with high resolution, so they are the most commonly observed spectral feature. Last campaigns in JET concentrated on isotope effects – there were (light) hydrogen, deuterium and tritium campaigns, with many pulses of mixed isotope plasmas, including deuterium-tritium mixture. This situation made possible observations of hydrogen molecules with varying isotopic composition.

In this contribution we present Fulcher band spectra for different isotopic versions of the hydrogen molecule, with estimations of the rotational temperature and vibrational population distributions in upper d state of the transition, for the different divertor conditions (attached and detached). As reported previously [2] for deuterium, both rotational and vibrational population distributions for molecules observed in metallic wall tokamak differ strongly from those observed in the carbon-wall machines (e.g. TEXTOR or JET-C [3]), which is a phenomenon still under investigation.

We present also an experiment, in which we attempted to calibrate the effective D/XB factor for Fulcher bands in the JET divertor, by puffing the known number of molecules from the point gas source located in the middle of the horizontal tile directly into the view of a calibrated visible spectrometer.

[1] K. Verhaegh et al, Nuclear Materials and Energy **26** (2021) 100922.
[2] G. Sergienko et al, Journal of Nuclear Materials **438** (2013) S1100–S1103.
[3] A. Pospieszczyk et al, Journal of Nuclear Materials **337–339** (2005) 500–504.

* See the author list of "Overview of JET results for optimising ITER operation" by J. Mailloux et al. to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)"