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Feasibility of fusion fuel isotope detection below 1% using Penning gauge optical spectroscopy

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The species-selective (or Optical) Penning gauge approach to the measurement H2/D2/T2 fuel isotopic composition [1] and He/D2 concentration [2] in the neutralized particle exhaust of fusion devices is almost universally used nowadays across all fusion facilities. Although recent studies have shown that, through spectroscopic detection optimization, He/D2 detection is feasible down to at least 0.1% [3], an ongoing overview of existing data (JET) points to an apparent isotopic concentration detection limit of ~1% [4]. A laboratory study suggested that surface interactions with the isotopic species may be playing a role in this apparent limit [5].
In this paper, results from laboratory study, specifically designed to explore the impact of surface interactions, inside the Penning gauge, on this detectability limit will be presented. The study included baking of the gauge and a series of isotopic exchanges.
Penning bake-out at ~150°C is found to dramatically reduce the H2 background in D2 only fueling cases. However, some self-cleaning by the Penning plasma discharges, after operating at high neutral pressure, can also be achieved.
A preliminary wall model for the gauge is used to interpret the findings of the laboratory study. The model presently includes hydrogen isotope retention in the surface, isotopic exchange and desorption from the surface.
Conclusions also include recommended procedures for optimization of isotopic composition analysis. The immediate application will be for the recently upgraded, divertor gas analysis system on JET [3]. However, this will extend to other current devices, as well as to the ITER Diagnostic (DRGA) [4] .

[1] D.L Hillis et al., Rev. Sci. Instr. 70, 359 (1999)
[2] T. Denner, K. H. Finken and G. Mank, Rev. Sci. Instr. 67, 3515 (1996)
[3] C.C. Klepper et al., Rev. Sci. Instrum. 87 (2016) .
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[5] C.C. Klepper et al., J. Instrum, Proceedings ECPD-2017

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