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In situ Measurements of Fuel Retention by Laser Induced Desorption Spectroscopy (LIDS) in TEXTOR

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Introduction

Fuel retention by co-deposition is a critical issue for ITER and future fusion devices. This requires both fuel retention **control and mitigation** techniques. As a prerequisite a **space resolved diagnostic to monitor fuel retention** is required to locate high retention areas and assess the quality of fuel mitigation and cleaning techniques.

For ITER, laser based methods in combination with spectroscopy are proposed as possible **in situ** methods to characterise fuel retention and material deposition. One of them, Laser Induced Desorption Spectroscopy (**LIDS**), is presented here like it is used in the TEXTOR tokamak **during plasma operation.** Detection limits and reproducibility under different plasma conditions, laser energies and desorption positions are shown experimentally.

Summary

For a-C:H layers in micrometer range the overall reproducibility of the LIDS measurement is **±13 %**.
The LIDS measurement is **robust** against changes of plasma conditions despite 3 x higher H_α background with 8 x higher fluctuation amplitude:

- **only factor 1.1** higher average LIDS value in NBI heated discharges compared to ohmic discharges
- **no increase of signal scatter** for NBI heated plasmas

Increase of **distance between plasma and measurement position** broadens H_α light pattern significantly but the integrated signal is preserved as long as it stays in the detection volume.

Non-destructive laser heating or destructive heating with layer removal give the same H concentration.

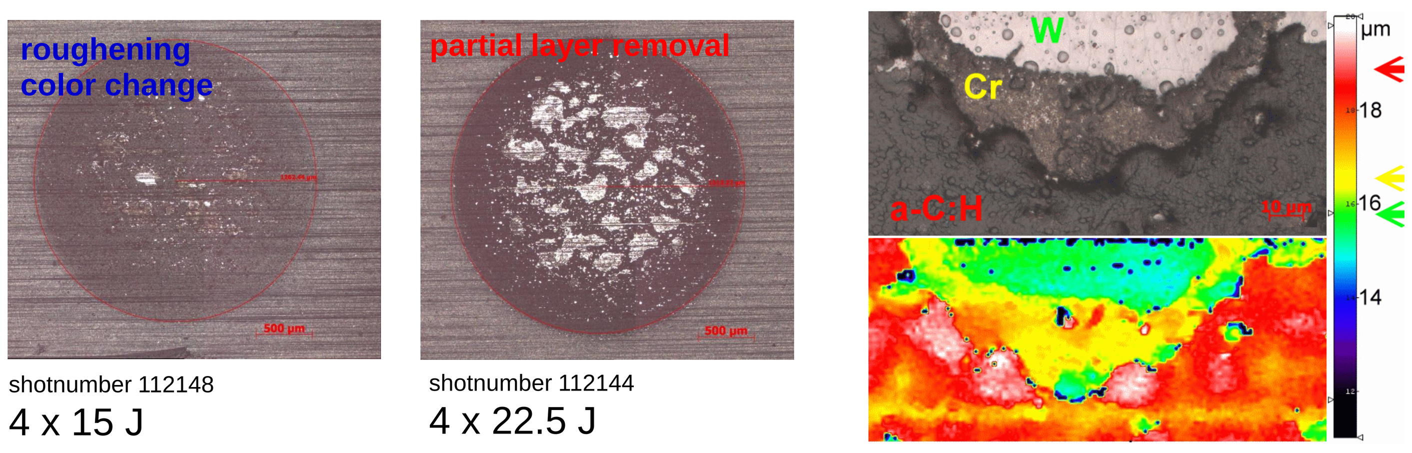
LIDS detection limit in TEXTOR deduced from H_α background fluctuations:
$4 \cdot 10^{20}$ H/m² (in ohmic plasmas) and **$3 \cdot 10^{21}$ H/m²** (in NBI heated plasmas)

Sample

homogenous a-C:H layer (2.5 µm)
Cr based interlayer (0.6 µm)

BALINIT® coating provided by œrlikon balzers

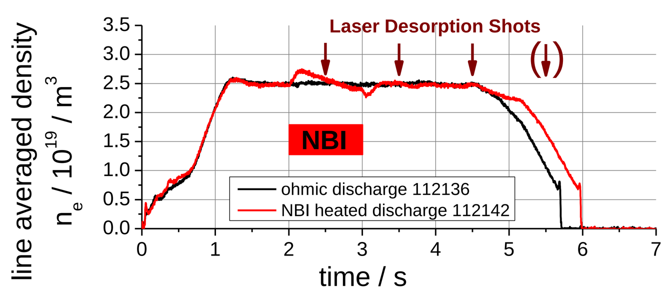
substrate: W



shotnumber 112148 — 4 x 15 J

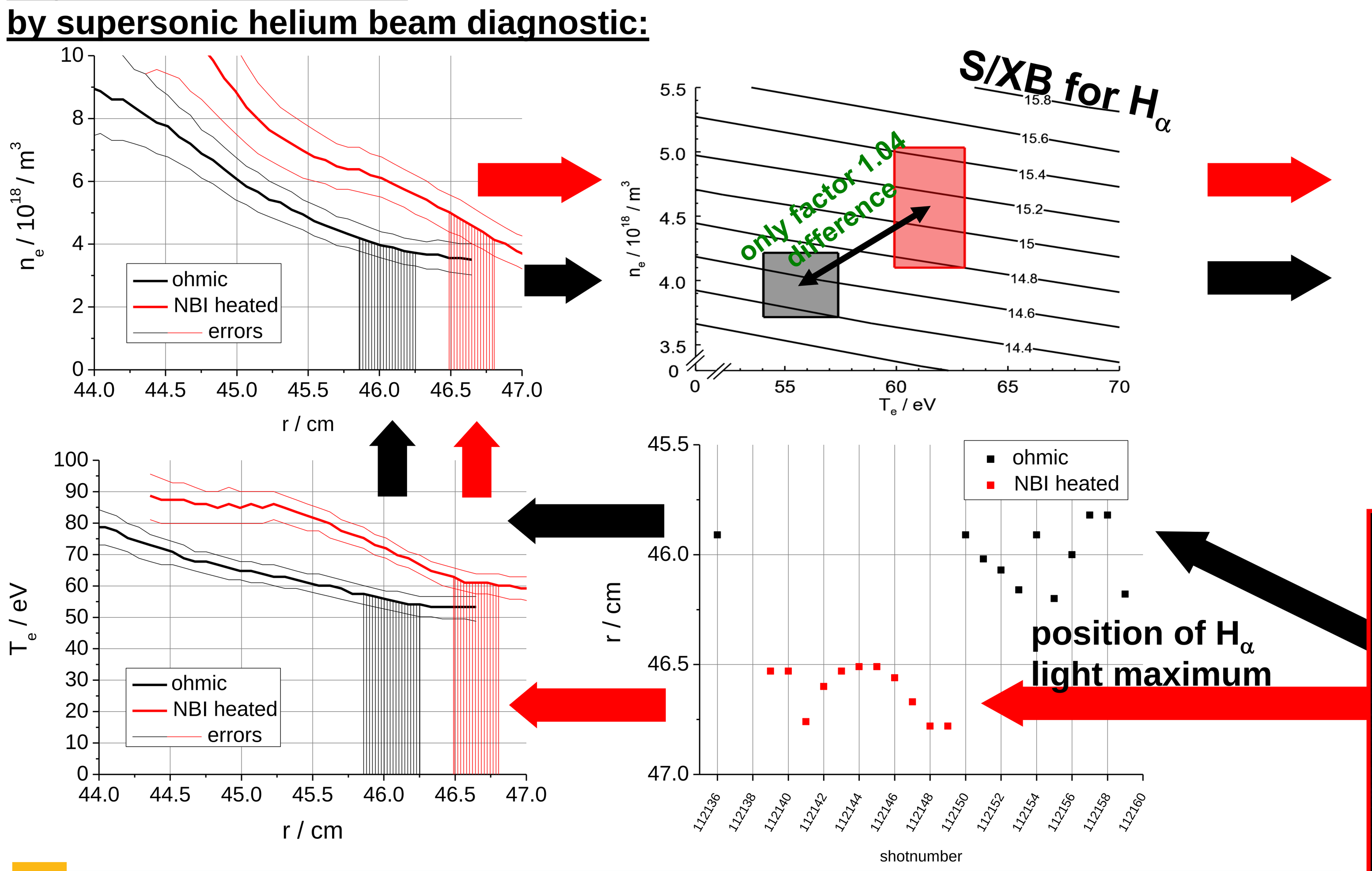
shotnumber 112144 — 4 x 22.5 J

Plasma Conditions



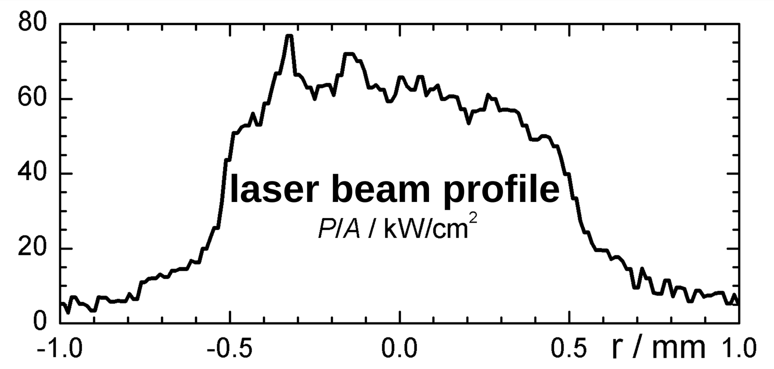
global plasma parameters:
central line average densitiy: $2.5 \cdot 10^{19}$ / m³
toroidal magnetic field: 2.25 T
plasma current: 350 kA
deuterium plasma, NBI injects hydrogen

edge plasma parameters by supersonic helium beam diagnostic:

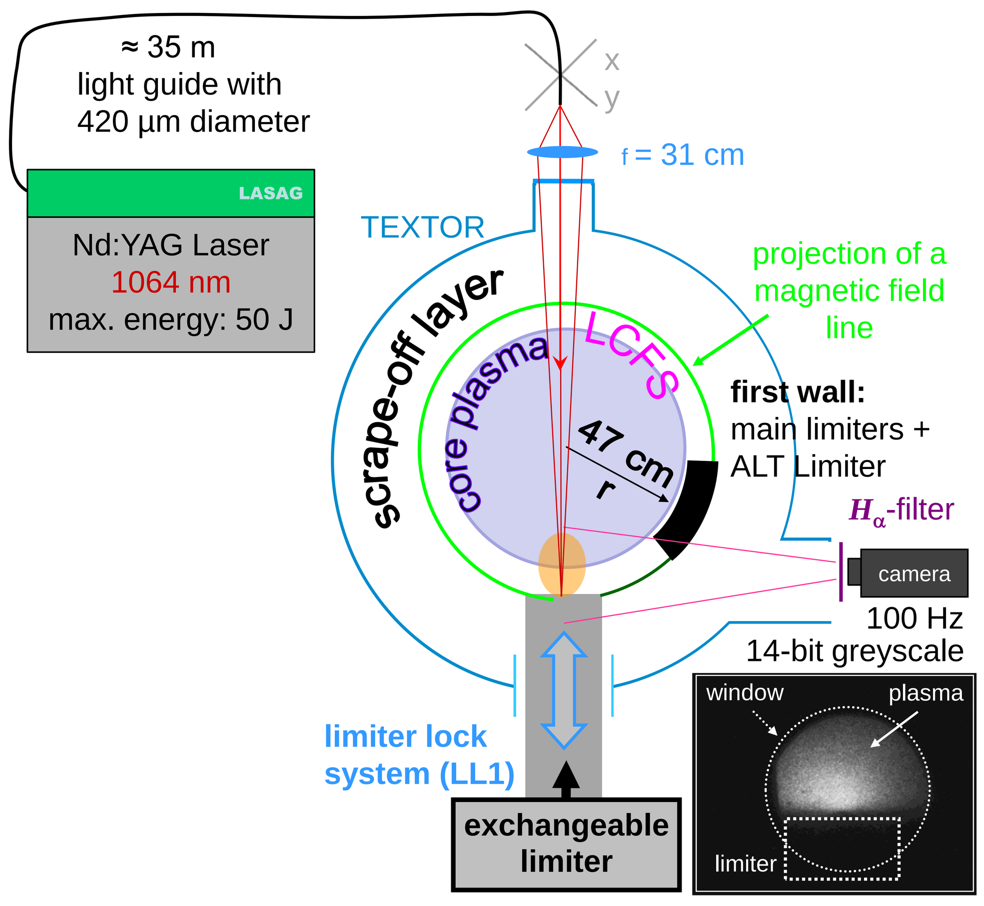


In situ Hydrogen Retention Measurement

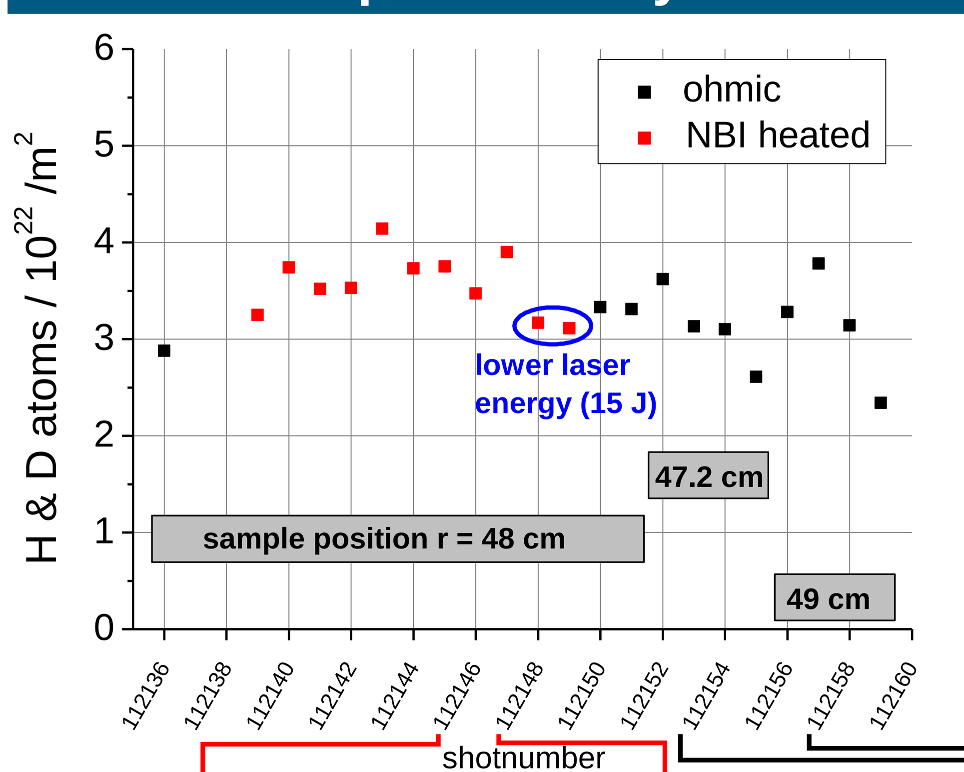
laser and sample parameters	for heating	destruction
initial laser energy	15 J	22.5 J
laser pulse duration	3 ms	
⇒ laser power	5 kW	7.5 kW
losses at fibre and lenses	24 %	
losses at vacuum window	8 %	
losses by reflection on sample	14 %	
total losses	40 %	
heating energy	9 J	13.5 J
⇒ heating power	3 kW	4.5 kW
laser spot area	5.3 mm²	5.3 mm²
⇒ intensity	566 MW/m²	850 MW/m²
calculated surface temperature	2000° C	3000° C



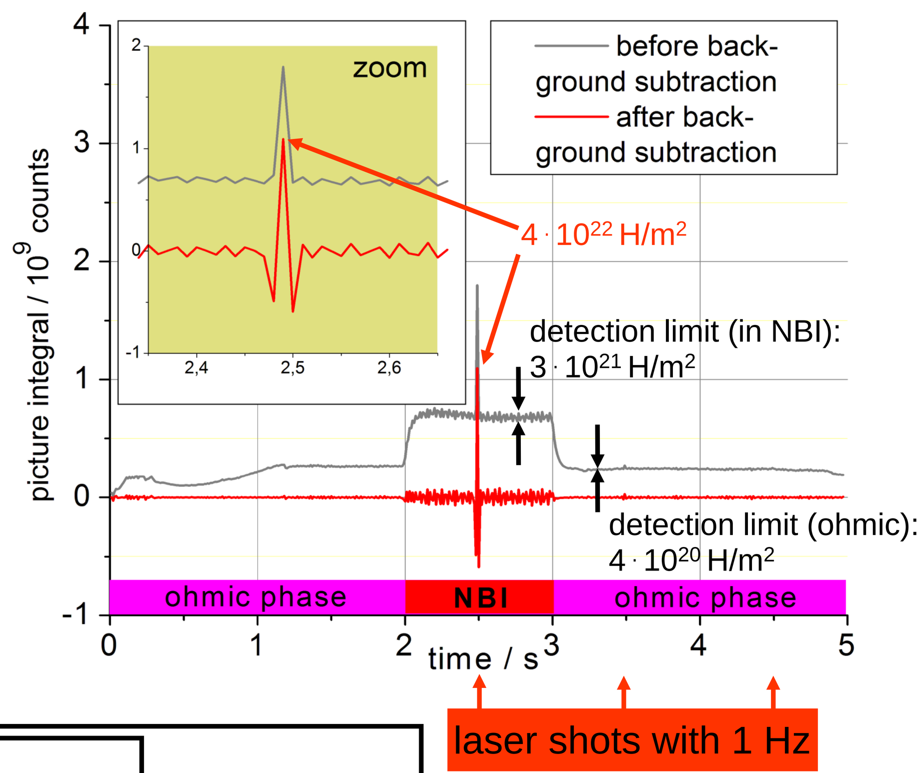
Reference: F. Irrek, Forschungszentrum Jülich GmbH – Zentralbibliothek, Nr. 4279 (2008)

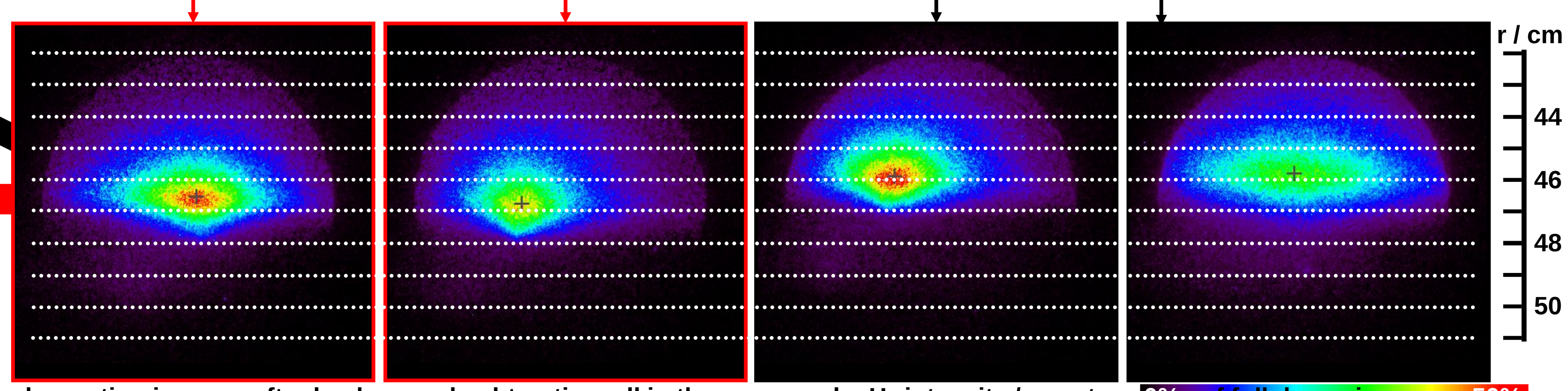


Reproducibility



H_α Background & Detection Limits





desorption images, after background subtraction, all in the same scale: H_α intensity / counts 0% of full dynamic range 50%

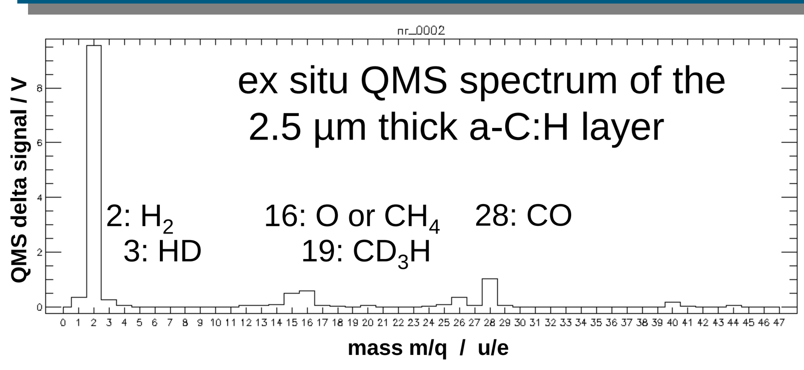
Data Evaluation Steps

laser induced light emission is recorded by a 100 Hz camera with picture intensifier

1) subtraction of plasma background of the two neighbouring images pixel by pixel (result: see "desorption images" on the right)
2) integration of the light of that difference image
3) light intensity **I** via calibration factor obtained by calibration of the camera detection system with a certified Ulbricht sphere at the same position as the desorption light
4) application of visibility factor **V** for uncaptured light (depending on radial and toroidal spot position and plasma density) *typically 1 ... 4, here: V=1, will not be needed in future setup with coaxial detection system because the light collection path will follow the laser beam*
5) conversion to number of H&D-atoms by **S/XB-** conversion factor (depending on T_e, n_e at position of main light emission)*; typically 10 ... 20; here: see S/XB plot above n_e and T_e measured by an edge diagnostic (He- or Li-beam, Langmuir probe etc.)*
6) increase by atomic yield factor **Y**, that accounts for pre-ionization before molecule dissociation; *typically 2.0 ... 2.5, here Y=2.2*
7) normalize by desorbed area, which equals laser spot area for layers with good heat contact to the substrate

→ **result: H&D atoms per m²**

Comparison with ex situ LID-QMS



laser induced desorption in vacuum chamber with quadrupole mass spectrometer
laser intensity as in TEXTOR: 850 MW/m² ⇒ T = 3000° C
but on 7.1 mm² (energy for heating: 18.2 J, 6 kW)

evaluation of only H_2 and HD: $5.7 \cdot 10^{22}$ H/m²
with CH_4 and CD_3H: $6.5 \cdot 10^{22}$ H/m² (14 % hydrocarbons)

Outlook: Future Diagnostic Procedure

Thicker a-C:H layers lose their good thermal contact to the substrate. Then the laser induced heat spreads strongly inside the layer causing an increase of the desorption area which is unknown in in situ measurements. Therefore a selection of always the same spots on the first wall has to be desorbed regularly **before the layer is too thick**. Then the layer should be removed by a destructive laser pulse.

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