LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

Collaborative work on surface vicinity production of negative ions in hydrogen plasma

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Outline

1. Scientific frame

- Hydrogen electronegative plasma in the ITER project
- Research program and collaborative works

2. Theoretical and experimental tools

- Gains and losses mechanisms of negative ions H-
- Experimental set-up and diagnostics (LPSC / LPP)
- Modelling of surface mechanisms and of hydrogen plasma (LPSC / LCAR / LIMHP)

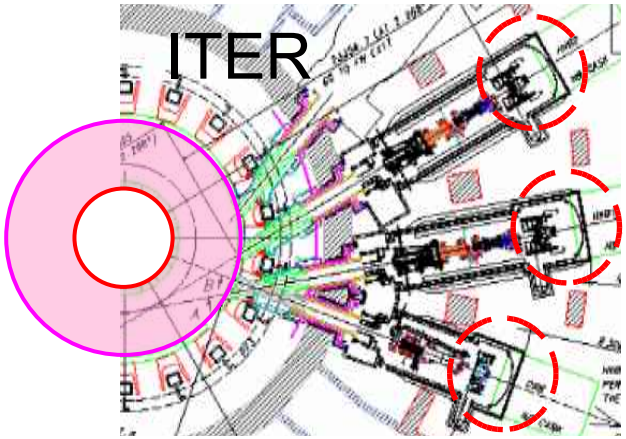
3. Experimental results

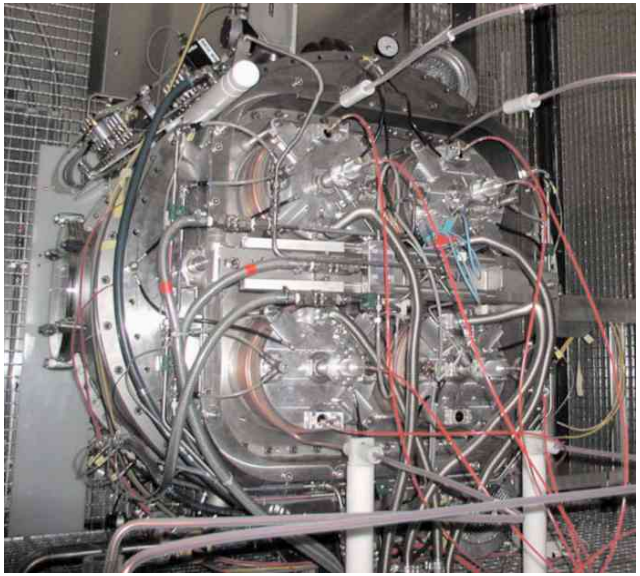
- Optical emission spectroscopy
- Laser photodetachment

4. Conclusions

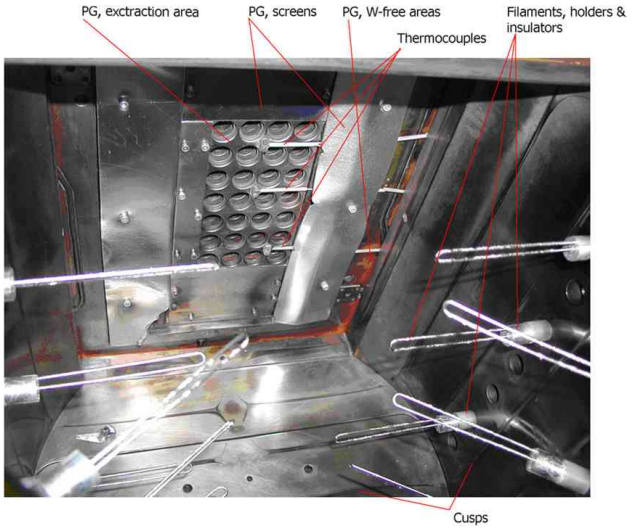
Hydrogen negative plasma

- **ITER program**
  - ICP ion source (1 MHz / 140 kW / 0.7 Pa) IPP Garching
    - Cs seeding
  - KAMABOKO-III ion source (45 kW / 0.3 Pa) JAERI Japan
    - W Filaments
    - Cs seeding





U. Fantz *et al.*, *Rev. Sci. Instrum.*. **79**, 02A511 2008



A. Krylov *et al.*, Nucl. Fusion **46** (2006) S324–S331

- **Research programs**
  - CEA/IRFM – Fédération Fusion 2008 et 2009 grants
  - PEPS ST2I (2008-2009)
  - ANR Blanc ITER-NIS (2009-2011)

Gains and losses mechanisms

Volume production

Associative detachment

$H^- + H \longrightarrow H + H + e$

Electronic detachment

$H^- + e \longrightarrow e + H(1s) + e$

Mutual neutralization

$H^- + H^+ \longrightarrow H^*(n=2;n=3) + H(1s)$

Losses

Vibrational excitation

$H_2(v''=0) + e\ (>10\ eV) \longrightarrow e + H_2^*$

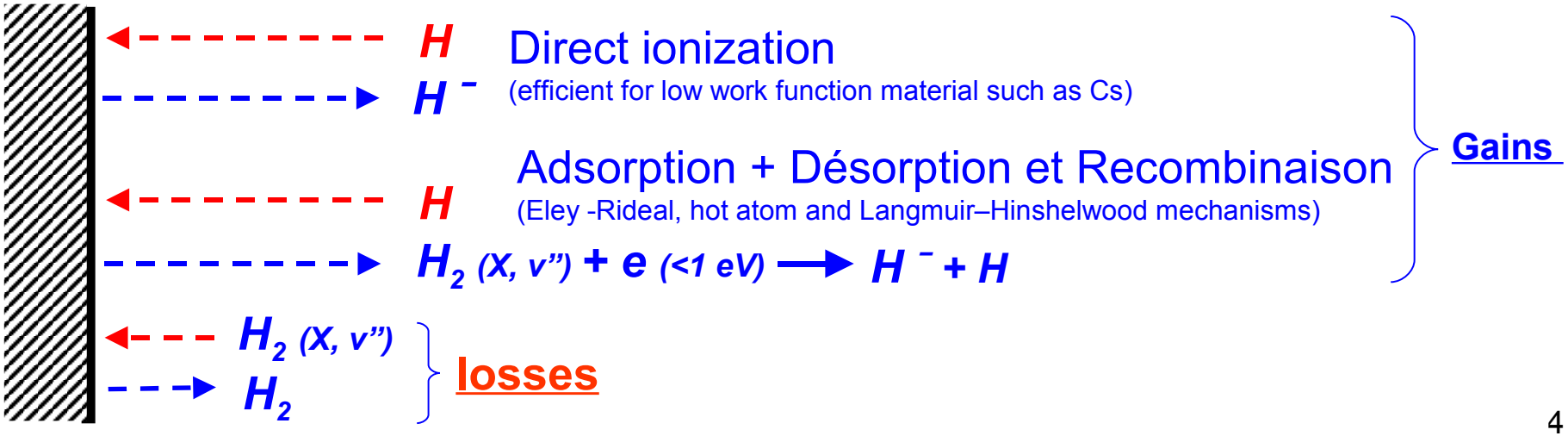
$H_2^* \longrightarrow H_2(X, v'') + h\upsilon$

Dissociative attachment **(DA)**

$H_2(X, v'') + e\ (<1\ eV) \longrightarrow H^- + H$

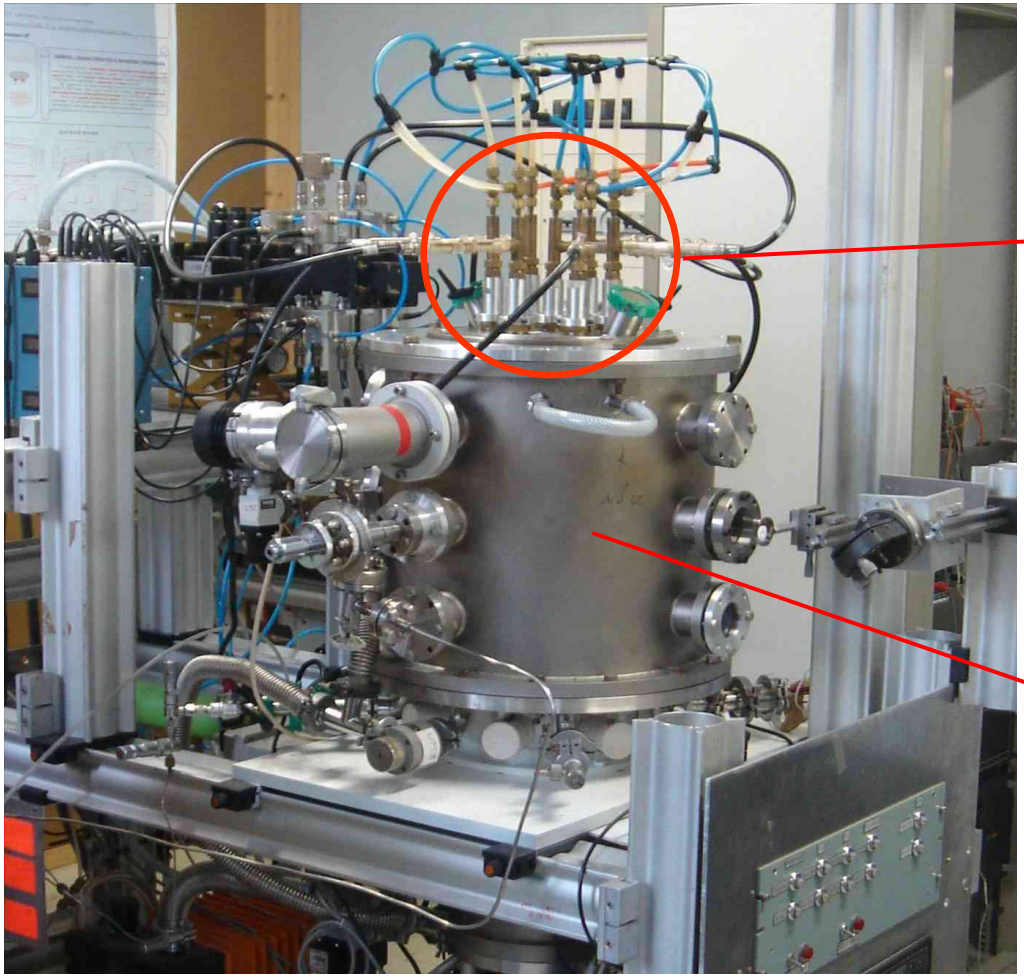
Gains

Surface vicinity production mechanisms



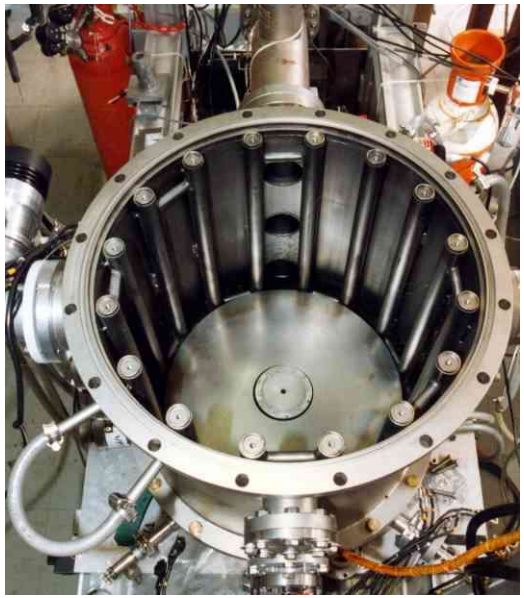
Experimental set-up “Camembert III”

Microwave dipolar sources (@ 2.45 GHz) / 0.4 Pa



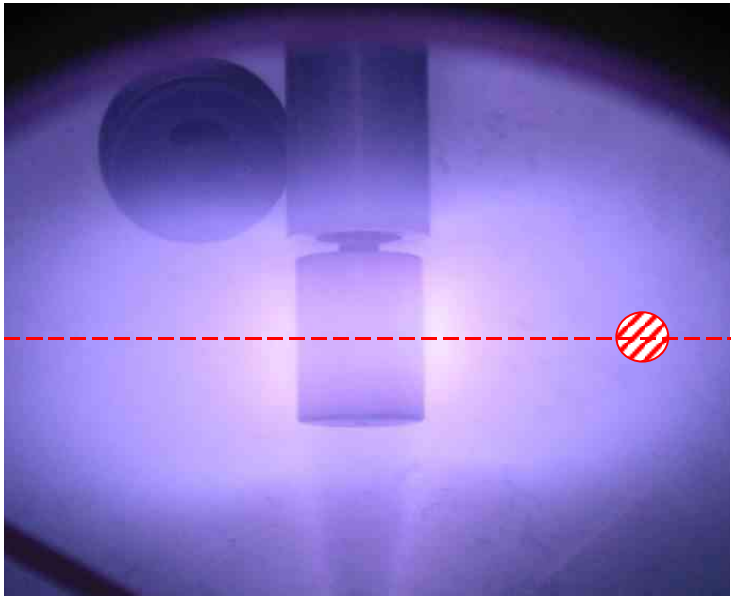
140 W (× 7)

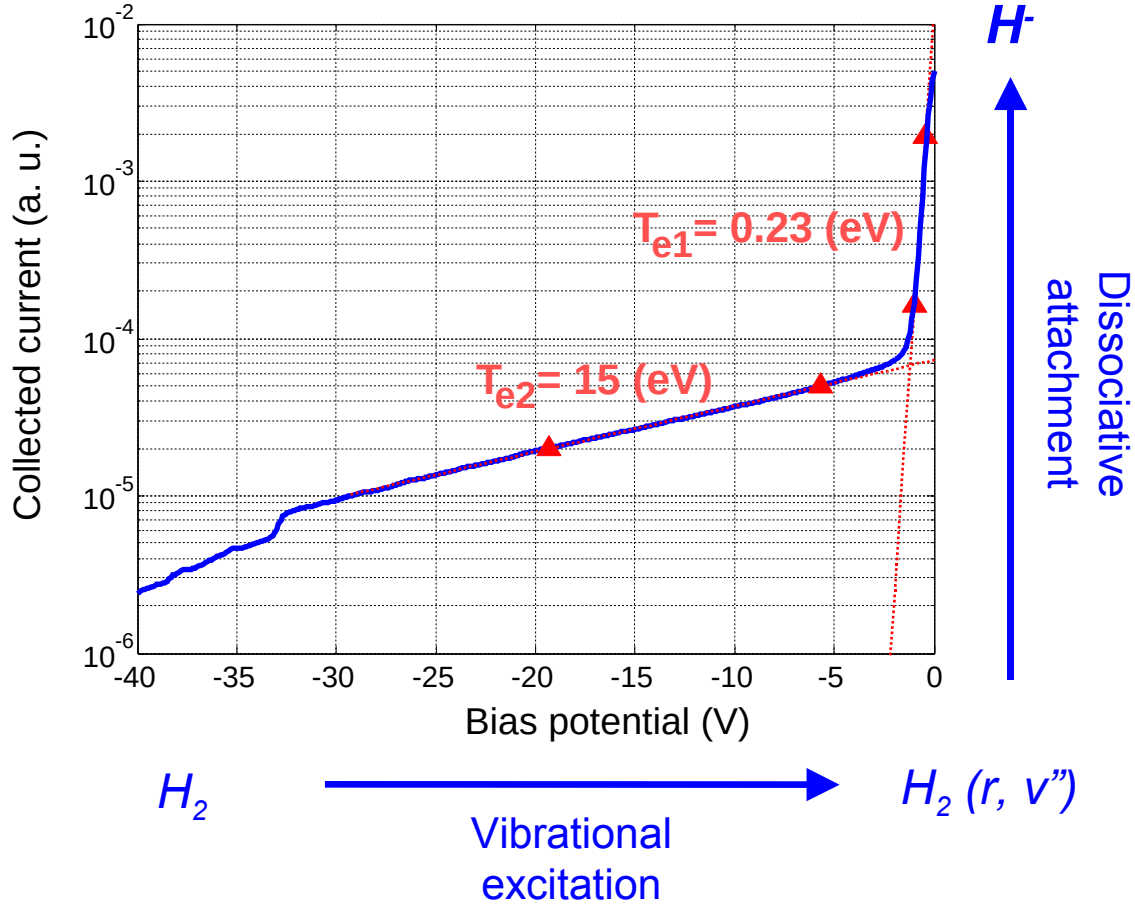
Magnetic shield



Experimental set-up – multi-dipolar plasma

Dipolar source in argon



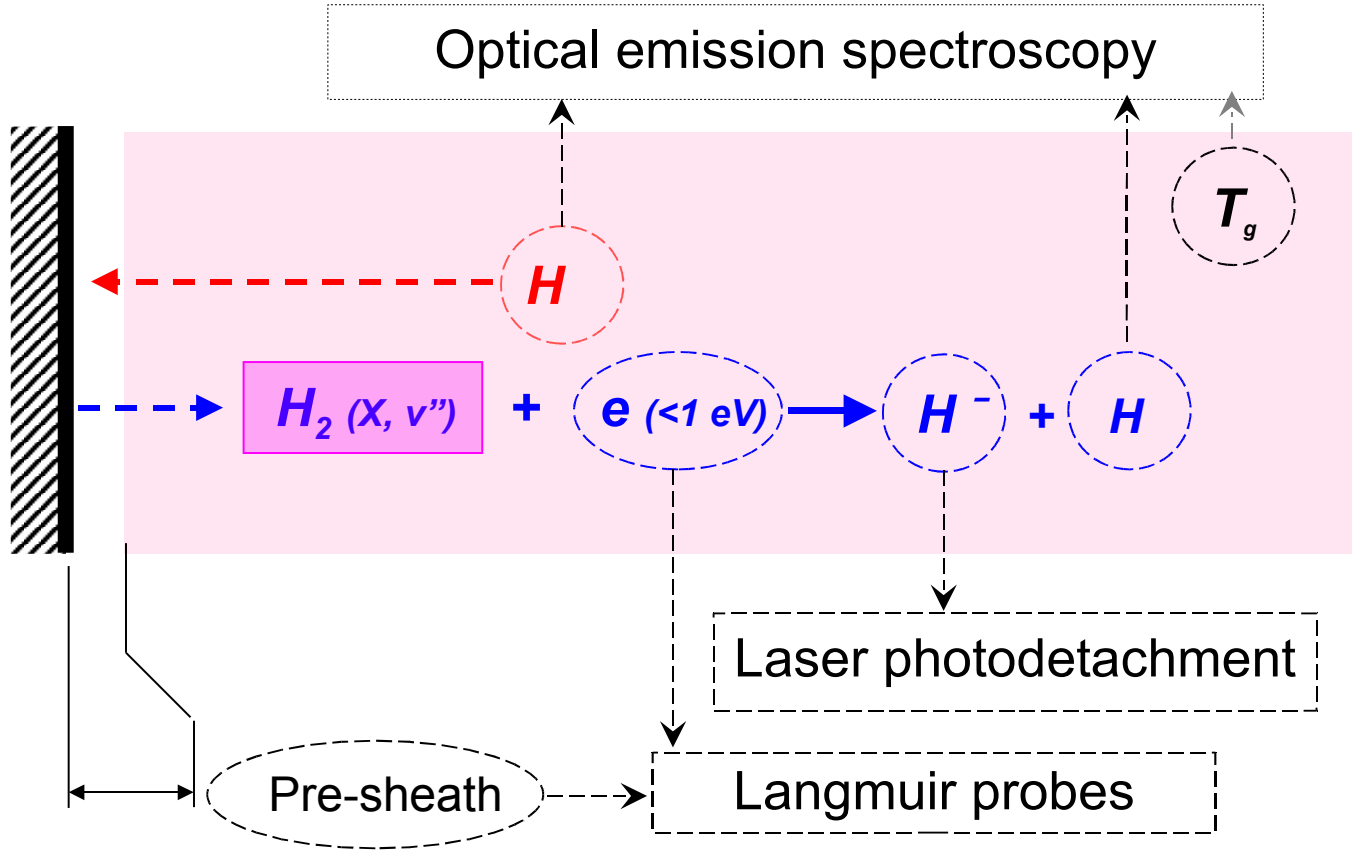


Overview of the diagnostics

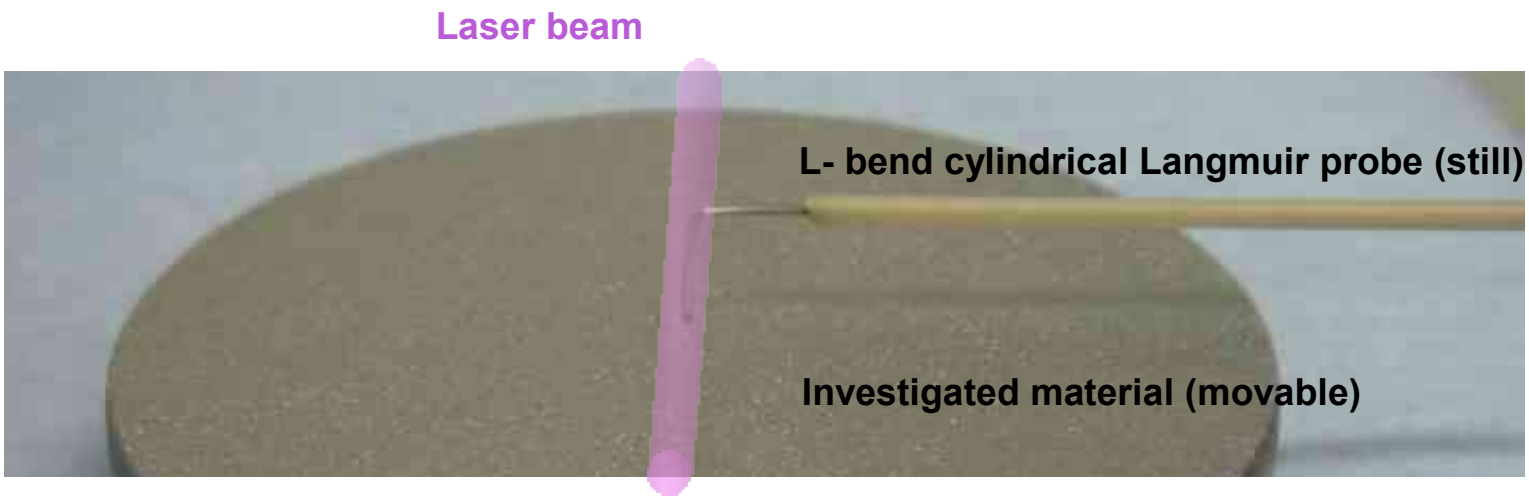
Adsorption + surface-mediated recombination and desorption
(Eley -Rideal, hot atom and Langmuir–Hinshelwood mechanisms)

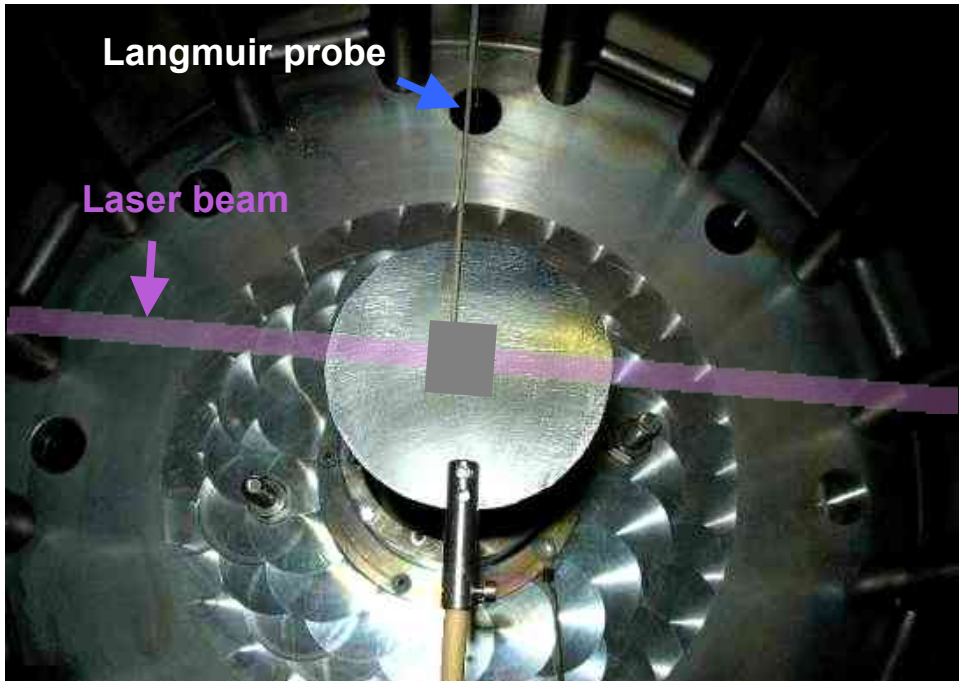
Substrate holder

- Displacements (30 mm)
- DC (+/- 50 V)



Laser photodetachment diagnostic of H^- (LPSC/LPP)





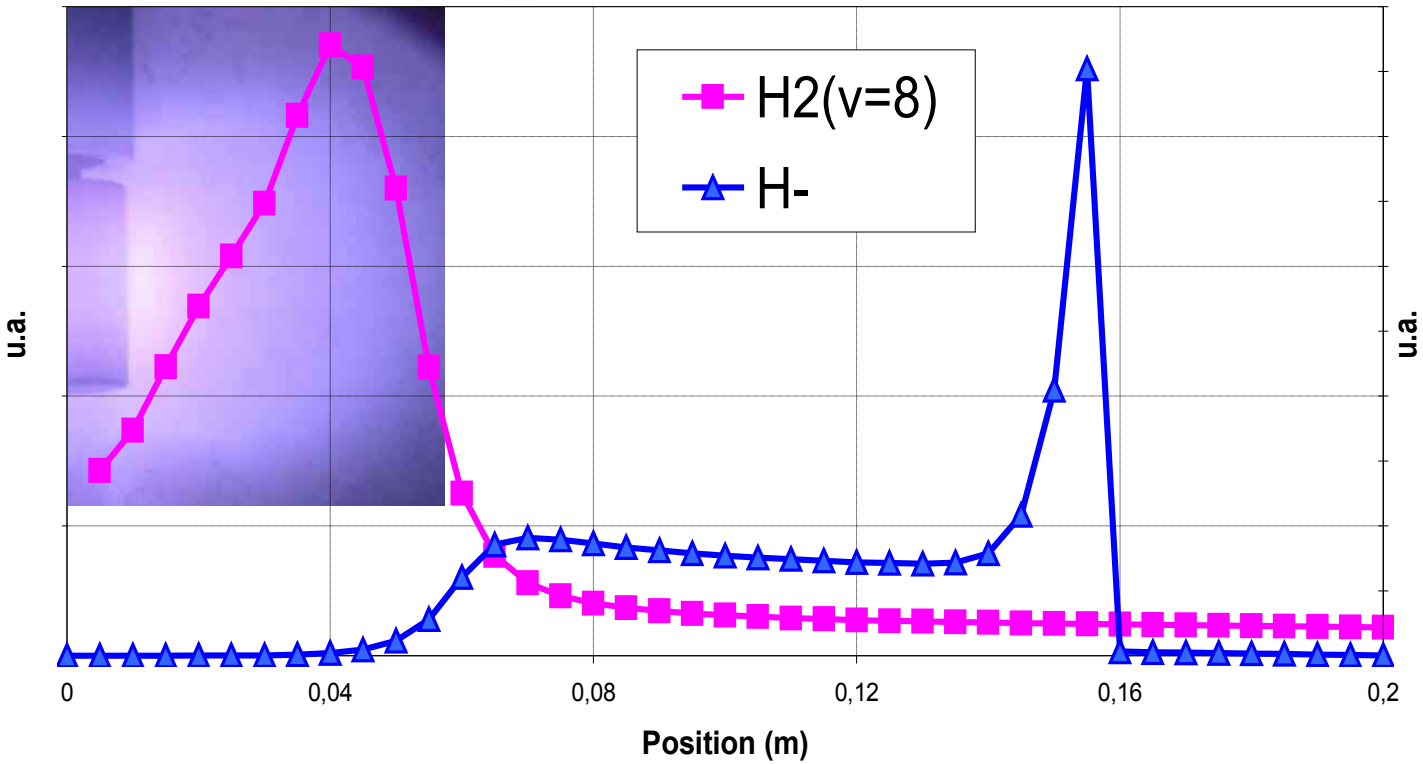
- 30 mm displacement width to investigate the surface vicinity
- Samples:
  - disk, Ø 7 cm (stainless steel, Ta)
  - square, 1×1 cm (HOPG graphite)
- Laser beam:
  - 0.093 J/cm² (@ 1064 nm),
  - Ø 9 mm
- L-bend Langmuir probe:
  - Ø 0.5 mm, l ≈ 17 mm
- Emissive probe

Modelling (LCAR / LIMHP / LPSC)

- Hydrogen Plasma (LIMHP / LPSC)
  - 1D RF Code (Fluid / Monte Carlo) gathering the main chemical reactions of the hydrogen plasma

⇒ Radial distribution of the plasma species (H / H_2 / H^+ / H_2^+ / H_3^+ / H^-)

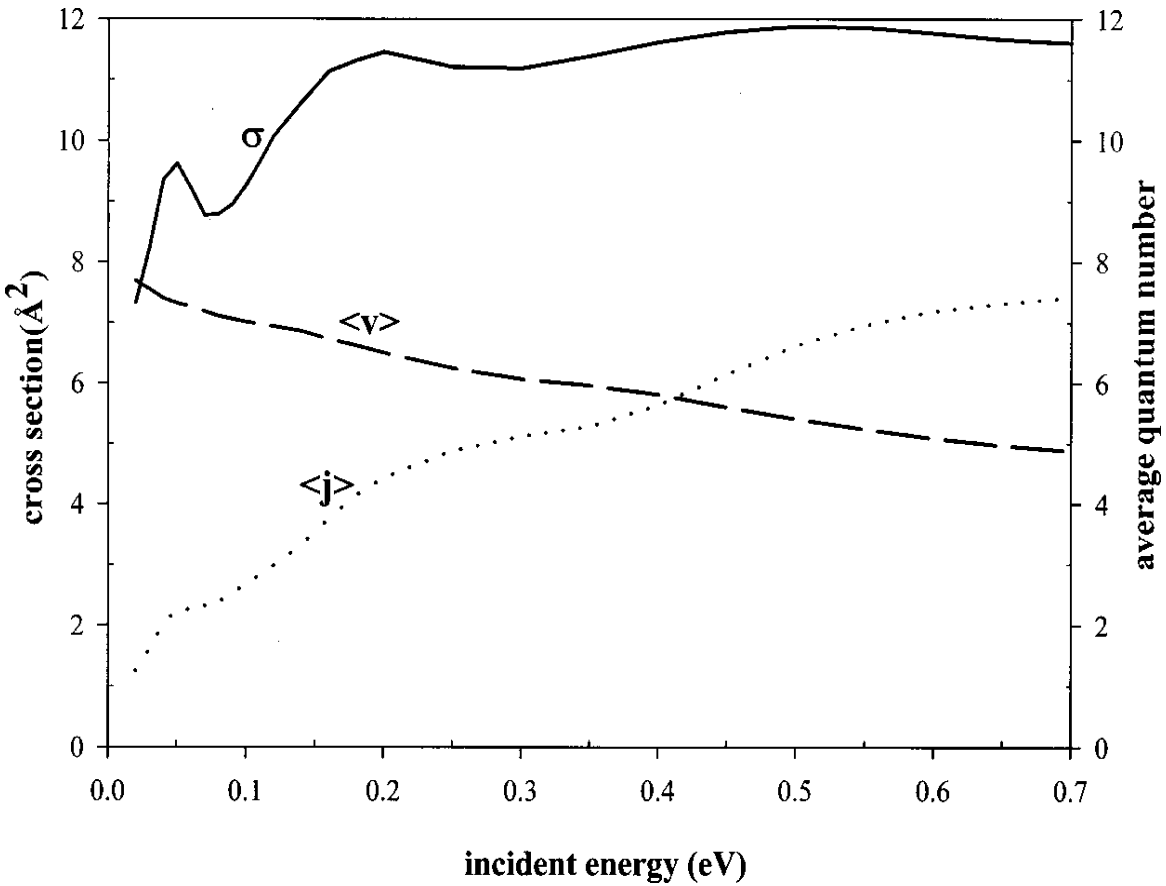
⇒ Enhancement of the negative ions production



Modelling (LCAR / LIMHP / LPSC)

- Surface mechanisms (LCAR)
  - Quantum modelling of Eley-Rideal reaction cross sections and vibrational distributions

⇒ Selection of relevant materials to produce $H_2(v")$



Sha, Jackson, Lemoine, J. Chem. Phys. 116 (2002) 7158

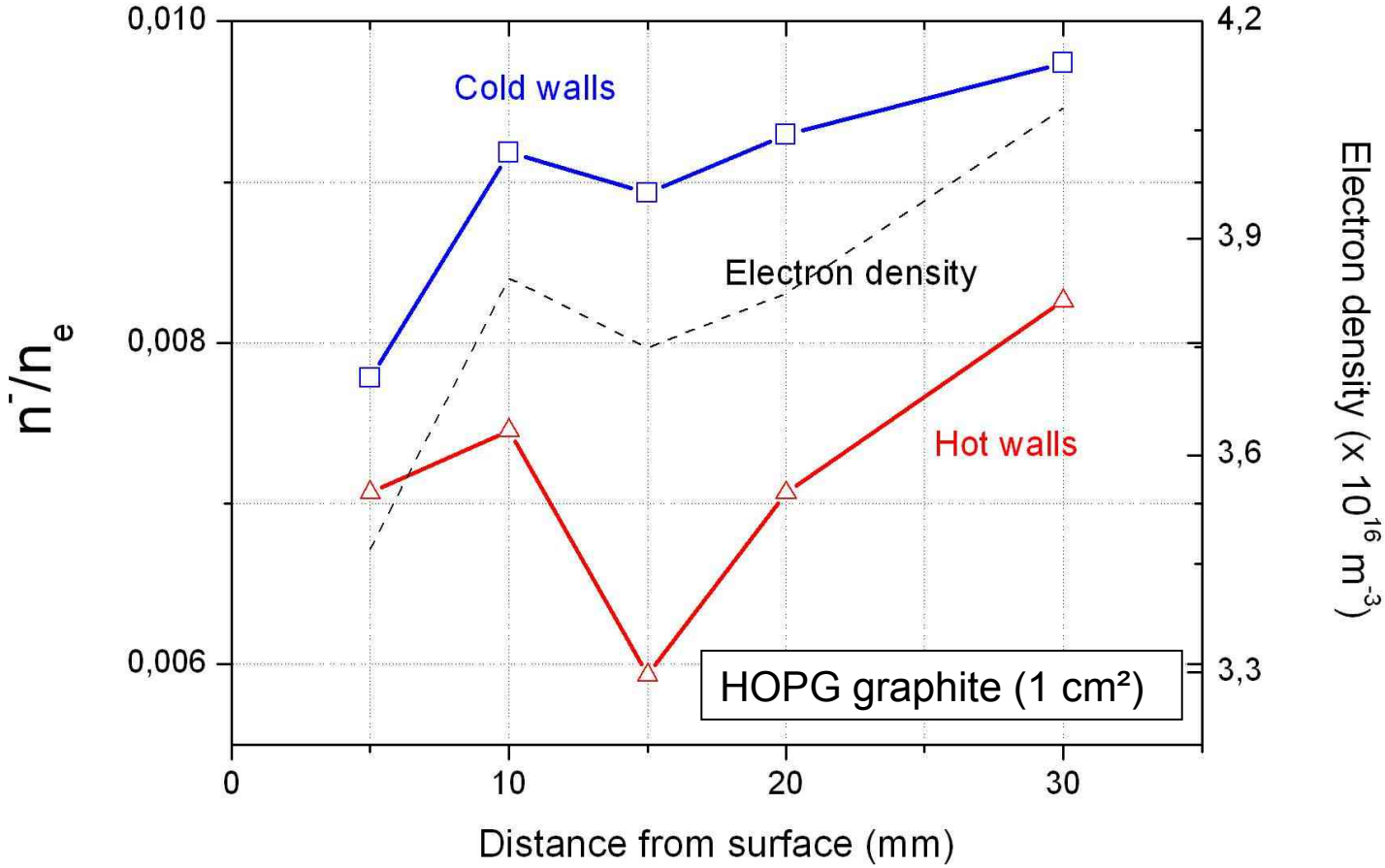
Laser photodetachment

Dissociation rate effect:

$$H + H_{surface} \xrightarrow{ER\ /\ LH\ /\ HA} H_2\ (X, v'')$$

$$H_2\ (X, v'') + e\ (<1\ eV) \xrightarrow{AD} H^- + H$$

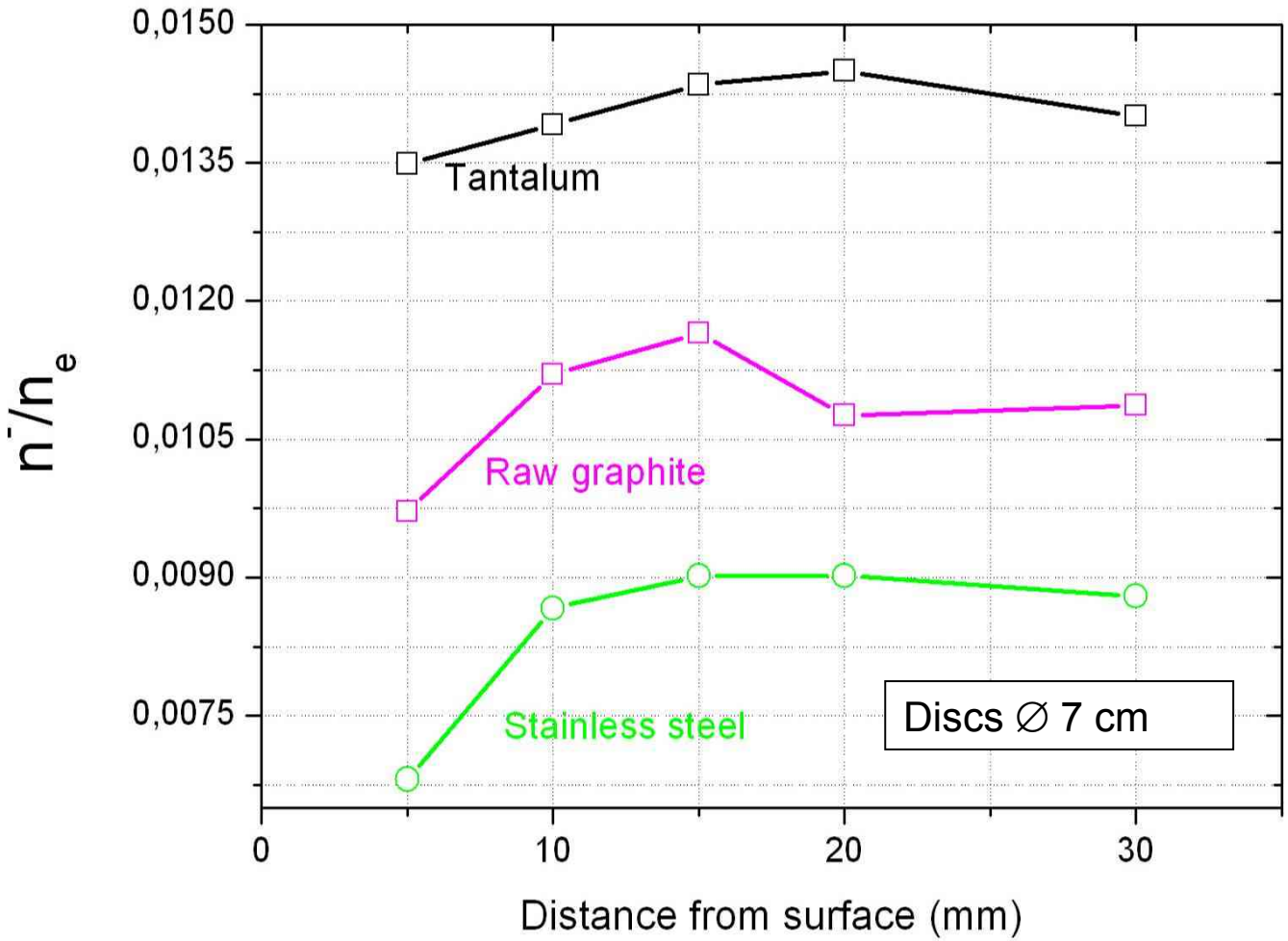
- Hot walls : hot gas / low dissociation
- Cold walls : cold gas / high dissociation



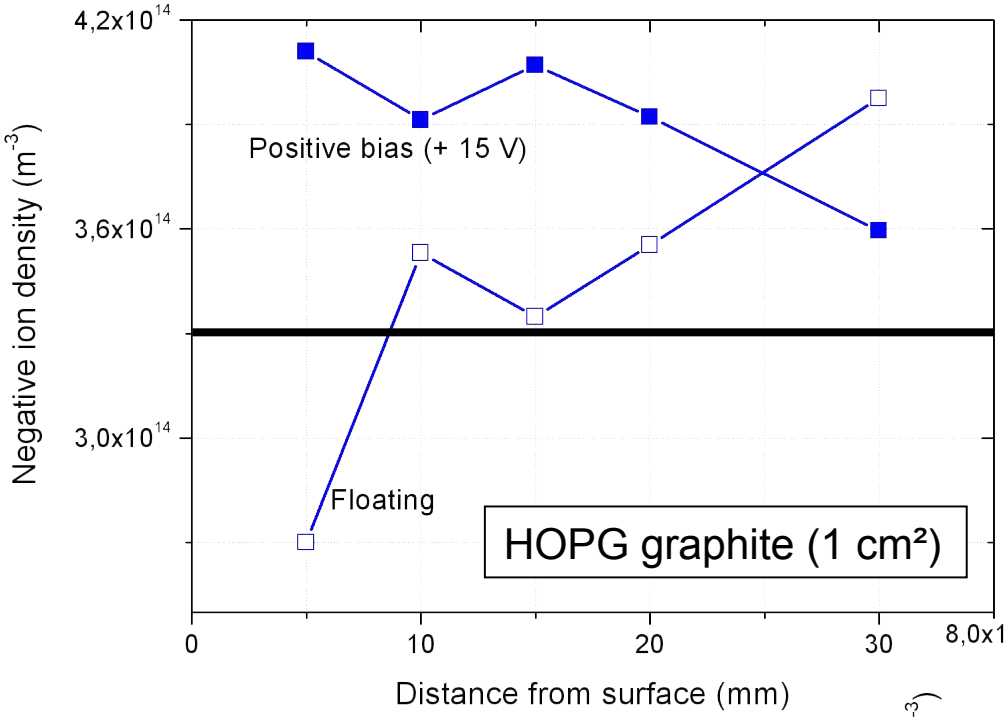
Laser photodetachment

Material effect :

- Tantalum
- Graphite
- Stainless steel



Laser photodetachment



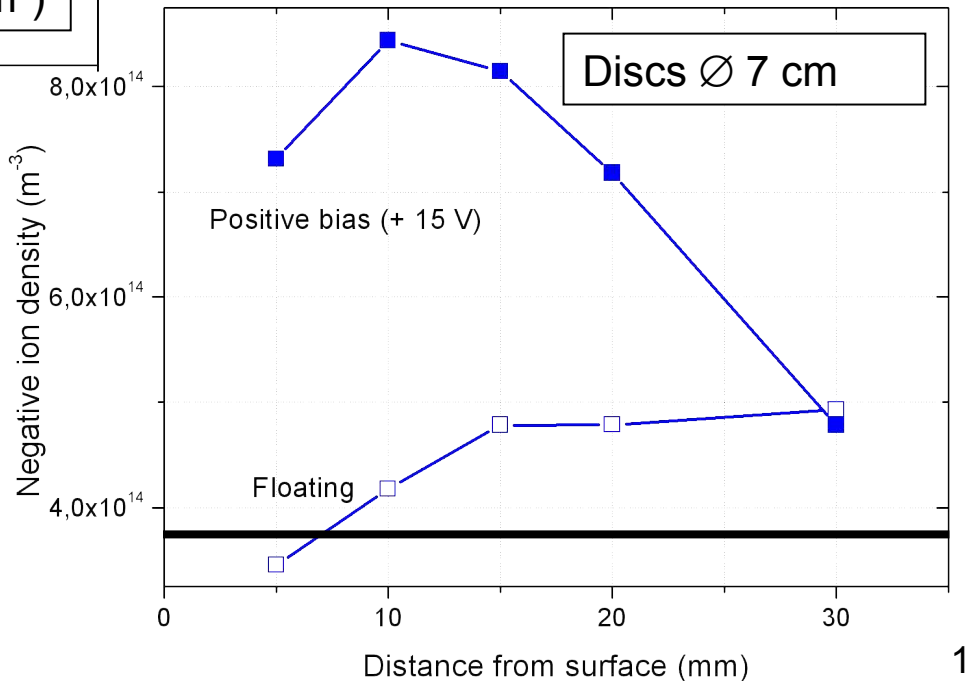
Bias effect:

- Floating
- Biased (+ 15 V)

Volume production (wt sample)
~ 3.3 10^{14} m^{-3}

Material effect :

- HOPG graphite (1 cm²)
- Tantalum (disc ∅ 7 cm)



Future works (2009 – 2010)

- Two impulse laser photodetachment
  - Negative ions temperature measurements
- Cold (77 K) or hot (750 °C) sample surfaces and / or biased
  - Control of surface mechanisms
- LIF VUV (TU/e Eindhoven)
  - H_2 (v" >4)
  - LIMHP 1D code checking
- Optical emission spectroscopy in the vicinity of a dipolar plasma source
  - Creation zones of H(r), H_2(v"<4)(r)
  - Recombination coefficients
  - LIMHP 1D code checking

Overview of the collaborative work

- LPP (M. Bacal)
  - Laser photodetachment
  - Hydrogen plasma
  - Extraction
- LCAR (D. Lemoine)
  - Relevant material for surface ***vicinity*** production
  - Hydrogen plasma
- CEA – Cadarache – IRFM (A. Simonin)
  - A first step in the “fusion world” (ITER-NIS / Fédération Fusion)
- LIMHP (K. Hassouni)
  - 1D RF Code (Fluid / Monte Carlo)

Many thanks to the GdR ARCHES !!

- TU/e Eindhoven (R. Engeln)
  - VUV-LIF (H_2(v”))
- FOM Institute for Plasma Physics Rijnhuizen (Aart kleyn)
  - SiC material

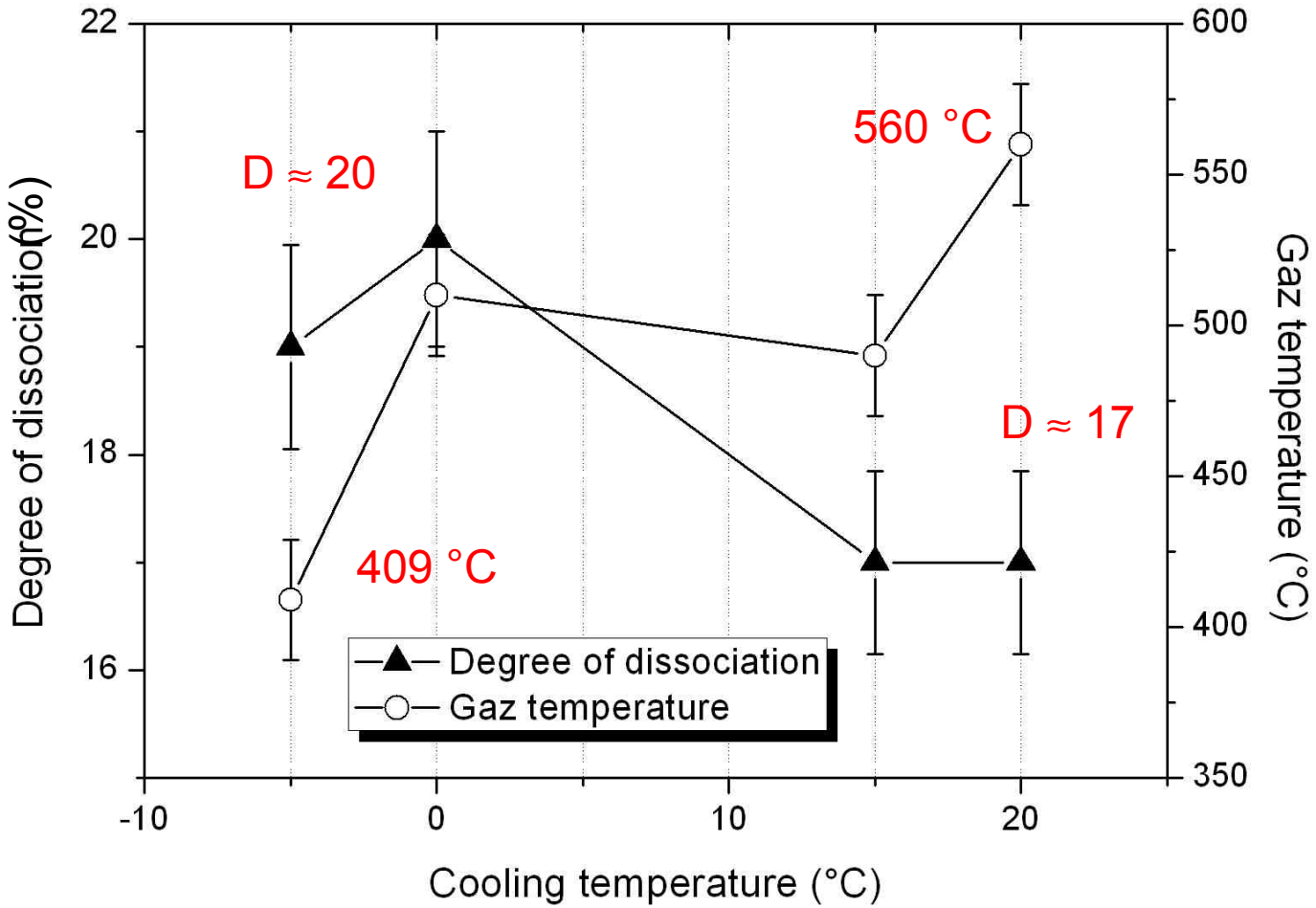
Spectroscopie optique

Influence du taux de dissociation :

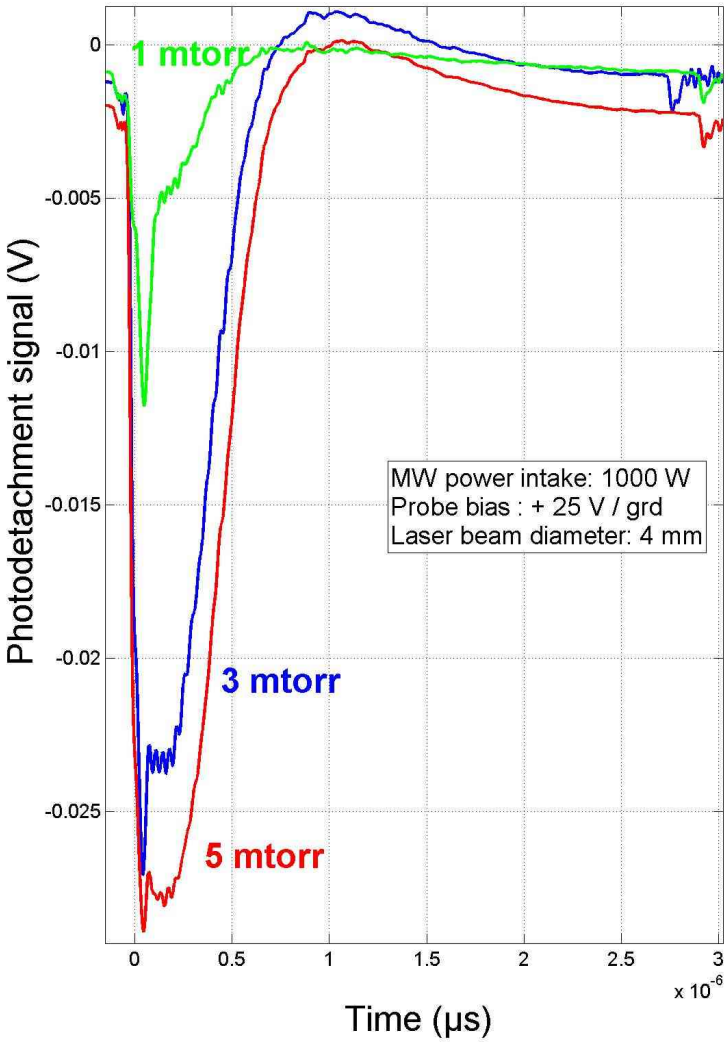
- Paroi chaude : gaz chaud / faible taux de dissociation
- Paroi froide : gaz froid / fort taux de dissociation

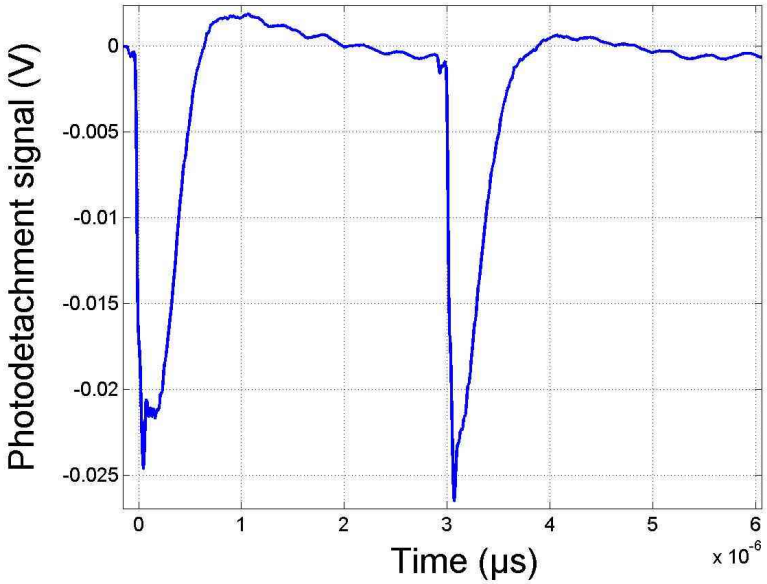
$[H] / [H_2] \approx 50\ \%$

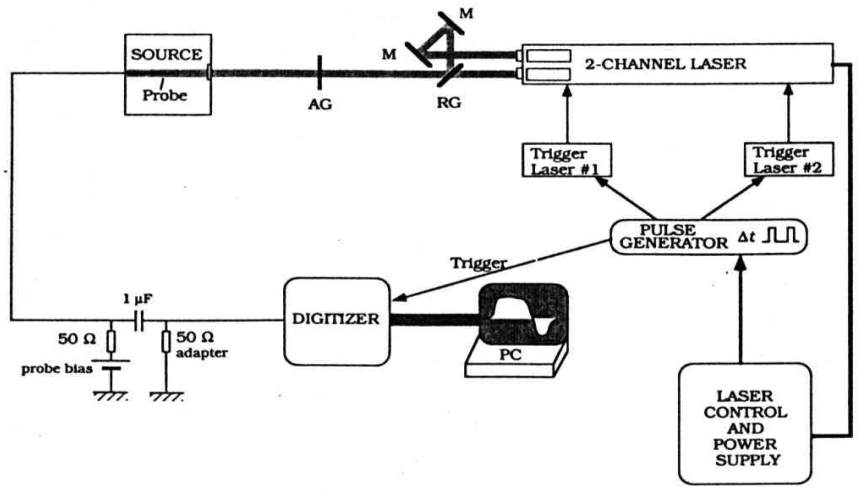
$[H] / [H_2] \approx 40\ \%$



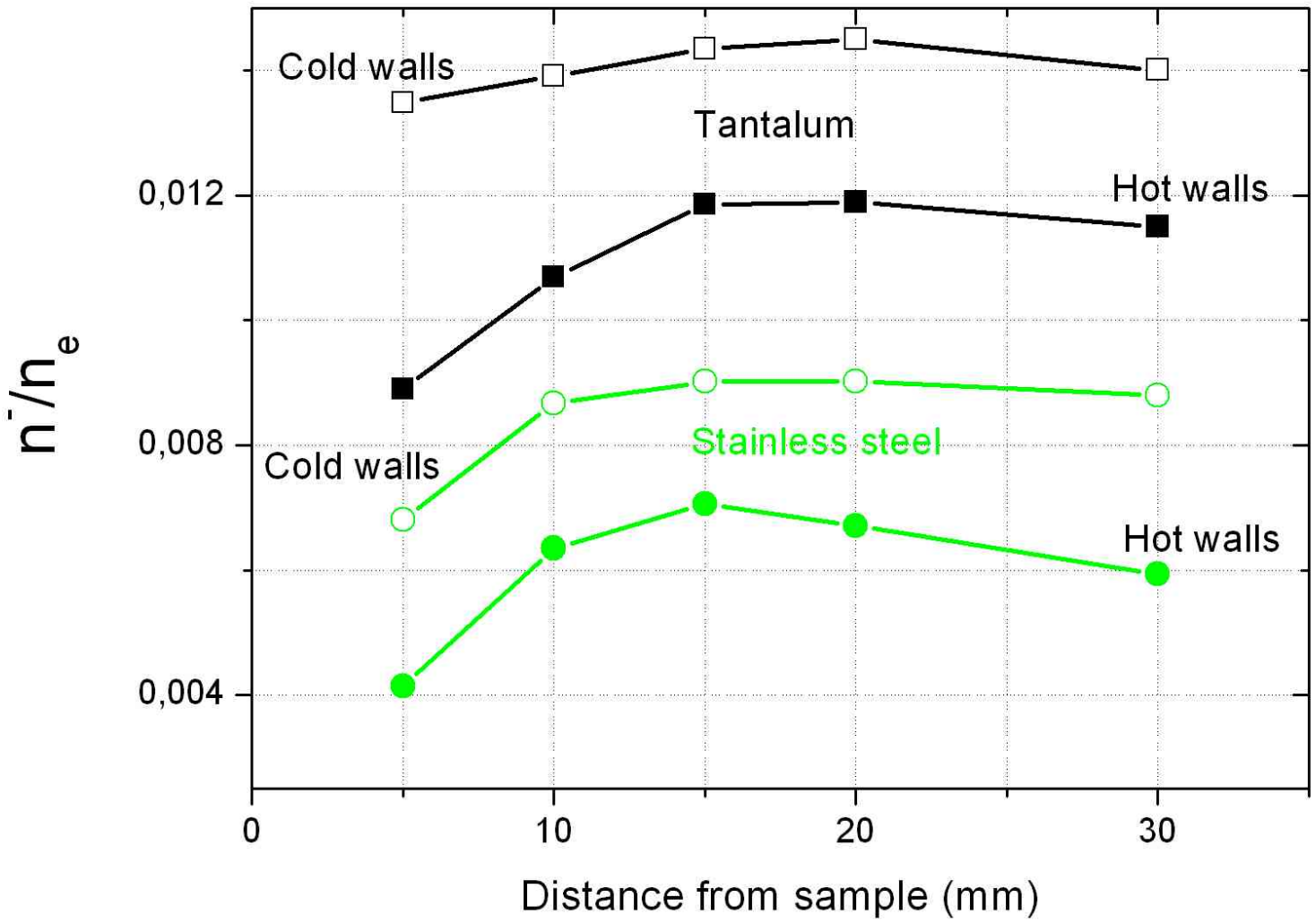
Photodétachement laser







Photodétachement laser



Photodétachement laser