Emission of photoelectrons and their impact on the plasma sheath in hydrogen plasmas

Max-Planck-Institut für Plasmaphysik

D. Wünderlich, U. Fantz and the NNBI team
Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

XXXII ICPIG, Iasi, Romania 26–31 July 2015
P1.31

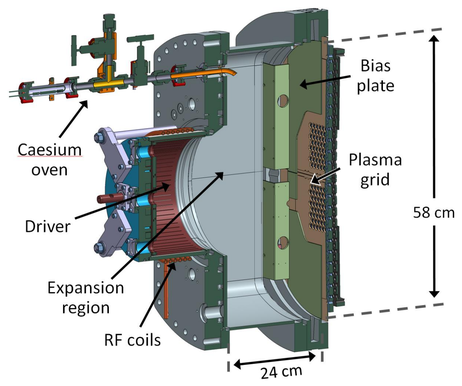
Introduction

H^- sources for ITER NBI

Surface production of H^-…

… is based on a low work function Φ

- Reduction of Φ by thin (several ML) cesium layers on source surfaces
- Most relevant H^- production process: Conversion of H on the plasma grid (PG) surface
- Hot and dense plasma in the driver
  ⇒ intense UV radiation impinging the PG



- Amount of photoelectrons (PE) produced by photoelectric effect at PG?
- Influence of PE on the plasma sheath and source performance?

→ Results presented in [1]:
No effect of PE
But calculated...
- ...for H_2 continuum $a^3 \rightarrow b^3$ only, neglecting $B^1 \rightarrow X^1$, $C^1 \rightarrow X^1$ as well as L_α radiation of H
- ...using (by mistake) a too high quantum efficiency

← Apply models simulating the emission of all relevant atomic and molecular transitions

Simulation of hydrogen emission

Hydrogen atom...

Collisional radiative models available and intensively benchmarked ✓

Hydrogen molecule...

Ro-vibrational simulation needed for precise determination of photon energy distribution

⇒ Up to now no ro-vibrationally resolved CR model for H_2 available

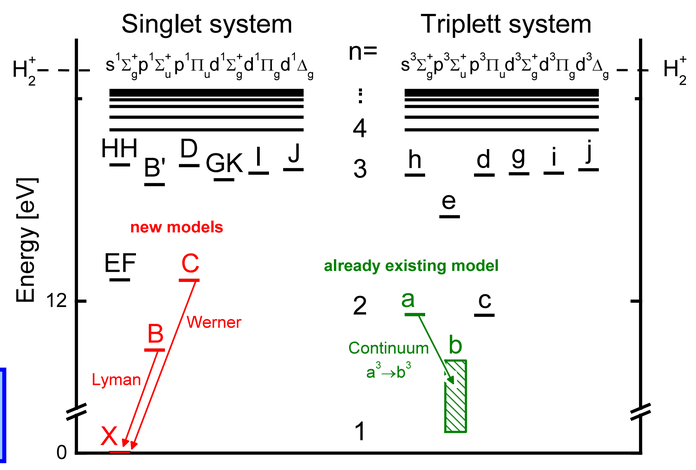
⇒ Construct Corona models for two transitions as first step

Ro-vibrational Corona models for H_2

Excited states of H_2:

- Electronic, vibrational and rotational excitation ⇒ huge number of levels
- Necessary input data:
  - Level energies
  - Einstein coefficients
  - Excitation cross sections
- Available ro-vibrationally resolved data base is scarce

Extension of the existing data, mainly based on the Level code[2]

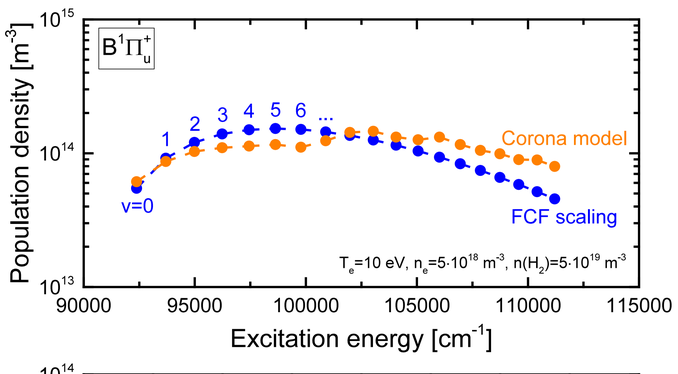


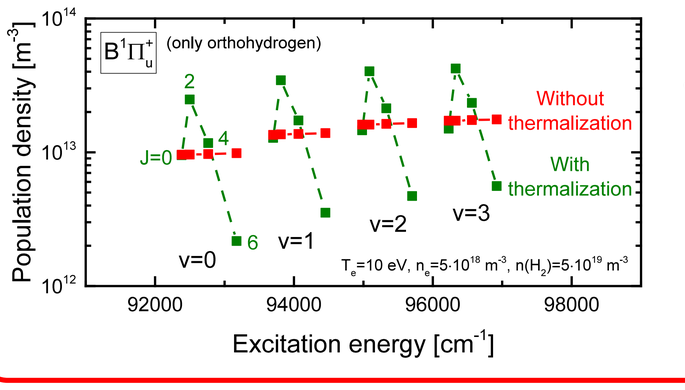
Input of the performed calculations

- Potential energy curves, adiabatic correction terms and dipole transition moments from [3]
- Hönl-London factors from [4]

→ **Output:** Level energies and Einstein coefficients

Additionally used: Vibrationally resolved cross sections from [5] and [6]





Vibrational and rotational population of electronically excited states

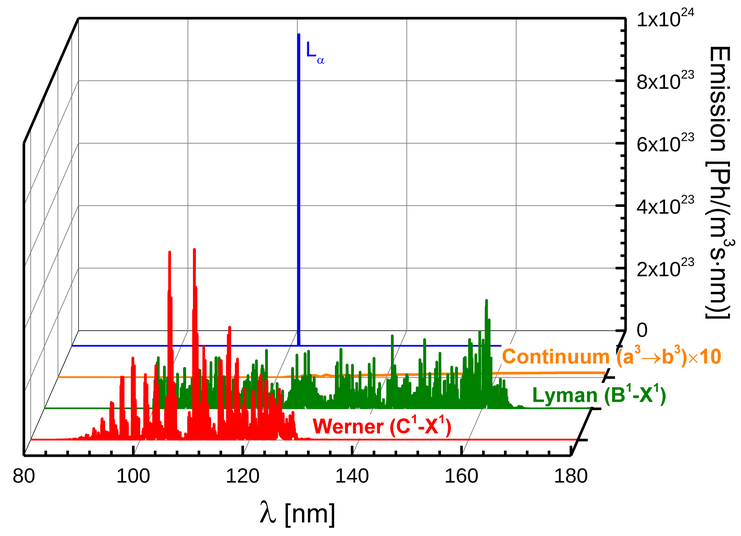
- Population of vibrational levels determined mainly by $T_{vib}(X^1)$
  ⇒ Application of vibrationally resolved cross sections essential
  ⇒ Significant difference between Corona model and FCF scaling
- No ro-vib resolved cross sections available. But: much smaller energy distances of rotational levels
  ⇒ Levels thermalize with the background gas
  ⇒ Introduce additional thermalizing collision reaction

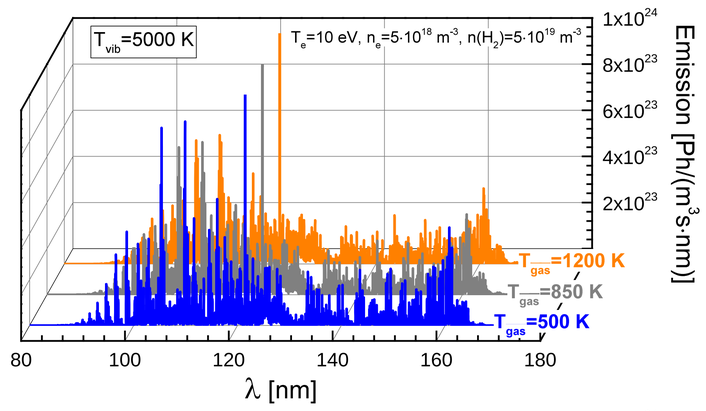
Results

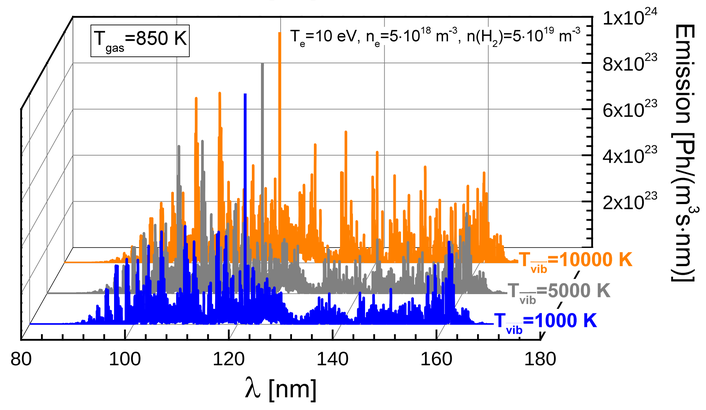
First results of the Corona models

Emission spectrum for the VUV range

- Typical shape of spectra agrees well with experimental results ✓ (→ Poster 1.32)
- Significant overlap, especially in the range λ=100÷130 nm
  ⇒ high relevance for the interpretation of measured spectra
- Spectra shown for driver plasma (T_e=10 eV, $n_e=5\cdot10^{18}$ m^{-3}, T_{vib}=5000 K, T_{gas}=850 K)







Variation of T_{gas} and T_{vib}

Clearly visible influence on the structure of the spectrum

- Comparison with experiment can be used for benchmarking the Corona models

Comparison model ↔ experiment: Poster 1.32 (U. Fantz)

- Benchmarked model can be directly applied for plasma diagnostics

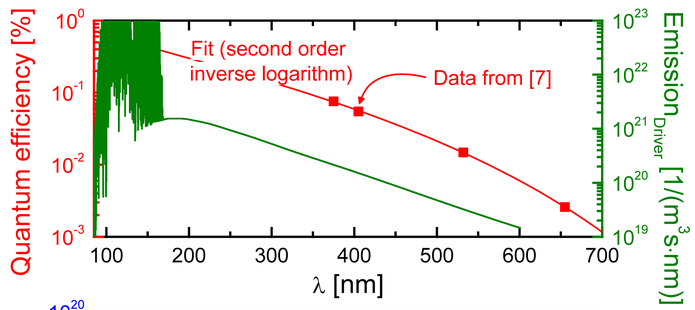
Photoelectrons in the H^- source

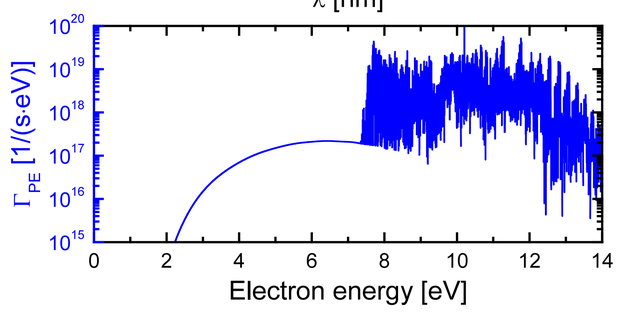
Driver: origin of UV photons

L_α (atom)	$8.04\cdot10^{23}$ 1/(m³s)	21 %
$C^1 \rightarrow X^1$	$1.18\cdot10^{24}$ 1/(m³s)	30 %
$B^1 \rightarrow X^1$	$1.69\cdot10^{24}$ 1/(m³s)	43 %
$a^3 \rightarrow b^3$	$2.32\cdot10^{23}$ 1/(m³s)	6 %

Production of PE

- PE flux: $1.61\cdot10^{20}$ 1/(m²s)
- Flux of H^- from the PG: $5.51\cdot10^{21}$ 1/(m²s)
- Additionally m_e=1/1836·m(H^-)
  ⇒ Space charge generated by PE much smaller compared to H^- (checked by applying the 1d PIC code Bacon[8])





Emission of PE on the PG surface does not influence the plasma sheath ✓

Conclusions

Estimation of the influence of PE on the plasma in H^- sources

- Significant amount of photons originate from $B^1 \rightarrow X^1$, $C^1 \rightarrow X^1$ and the atomic Lyman lines
- Only ro-vibrationally resolved models for H_2 can precisely calculate the energy distribution of the relevant UV photons
- New Corona models represent first steps towards a ro-vibrationally resolved CR model

Corona models for $B^1 \rightarrow X^1$ and $C^1 \rightarrow X^1$

Good general agreement with the experiment, further benchmarking in preparation

⇒ PE produced at the PG do not influence the plasma sheath and the source performance

References
[1]: D. Wünderlich et al, Proc. 30th ICPIG (Belfast, 28 August–2 September 2011)
[2]: http://leroy.uwaterloo.ca/programs/
[3]: http://fizyka.umk.pl/ftp/pub/publications/ifiz/luwo/
[4]: A. Hansson et al, J. Mol. Spectrosc. **233** (2005), 169
[5]: R. Janev et al, Report Jül-4105, Forschungszentrum Jülich, 2003
[6]: R. Celiberto, private communication (2004)
[7]: K. L. Jensen et al, J. Appl. Phys **102** (2007) 074902
[8]: D. Wünderlich et al, Plasma Sources Sci. Technol. **18** (2009) 045031

Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany, Tel.: +49 89 3299-1916; E-mail: dirk.wuenderlich@ipp.mpg.de