A Microwave Plasma Discharge in Rare Gases as a VUV Source for Planetary Atmospheric Photochemistry

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A Micro-Wave Plasma Discharge in Rare Gases as a VUV Source for Planetary Atmospheric Photochemistry

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The aim of this work is to show that **micro-wave discharges in rare gases**, can be an efficient **windowless VUV photon source** for **planetary atmospheric photochemistry experiments**. In this context, we perform a **microwave discharge (surfatron) in a neon gas flow**. We characterize the **VUV photon flux emitted in different conditions**, when working in the **mbar pressure range**, and **compare it to synchrotron VUV fluxes** also used for similar applications.

Experimental Setup

Neon plasma discharge: 40-cm length quartz tube, 8mm I.D. surrounded by a microwave **surfatron** resonance cavity designed for 2.45GHz.
Gas flow: from 1 to 10 sccm**,**
Pressure: measured upstream with a capacitor gauge, from 0.4 to 1.7 mbar.
Monochromator: Mac Pherson NOVA 225 VUV 1-m focal-length
The microwave plasma **discharge is placed without window** in front of its entrance slit and the gas is pumped by the monochromator pumping unit,
The neon resonance lines at 73.59 and 74.37 nm [1] are studied

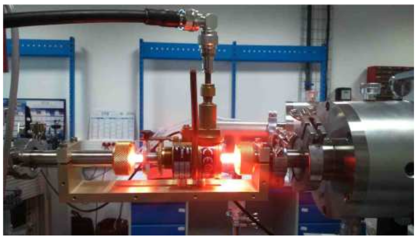

Fig. 1: the surfatron discharge in front of the VUV monochromator

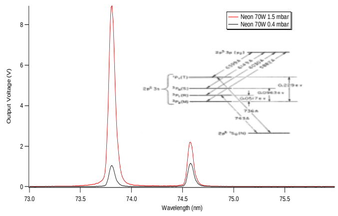

Fig. 2 The recorded Ne resonance lines

Results

The photon flux is calculated taking into account
- the **slits surfaces**: 75µm width x 4 mm height;
- as Ne is injected in the monochromator, the **absorption** is calculated along the 2m optical path using the Beer Lambert law and the Ne absorption cross section σ=9×10^{-17} cm^2 at 75 nm [2] ;
- the **grating efficiency** 6% at 75 nm ;
- the Optodiode AXUV 100 **detector efficiency** 0.22 A W^{-1} at 75 nm ;
- and the **amplifier gain** 1V for 1 nA .

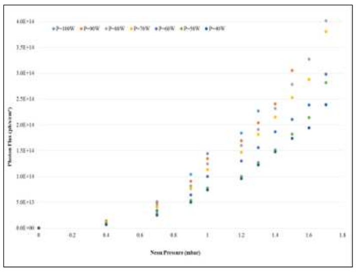

Fig. 3 Photon flux emitted at 73,6 nm in different conditions of power versus the pressure. At high powers (P_W>70W) and high pressures (P >1.5 mbar) amplifier saturates,

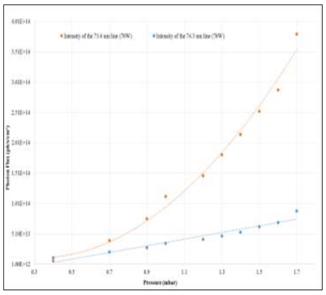

Fig. 4 Compared photon flux of the two neon lines at 73.6 and 74.3 nm for an microwave power of 70W and their quadratic and linear fits (respectively).

73.6 nm line intensity can be described by a collisional radiative model

$$I(73.6nm) \propto \frac{n_e[Ne]k(T_e)}{\nu_L}$$

The limitation of the 74.3 nm line intensity is attributed to a quenching effect

$$I(74.3\ nm) \propto \frac{n_e[Ne]k(T_e)}{\nu_L + k_Q[Ne]}$$

The VUV photon flux emitted at 73.6 nm **can be tuned from 2×10^{13} ph.s^{-1}.cm^{-2} to 4×10^{14} ph.s^{-1}.cm^{-2}** by changing the pressure conditions,
These photons flux can be compared with the **VUV DESIRS beamline of the synchrotron SOLEIL:** at 17 eV (~75 nm) and for a resolving power of 1000, the VUV photon flux can be tuned from **7×10^{12}ph.s^{-1}.cm^{-2}** (for a 4mm×8mm spot)
to **10^{16}ph.s^{-1}.cm^{-2}** (for a 200 µm×100µm spot) [4].

References

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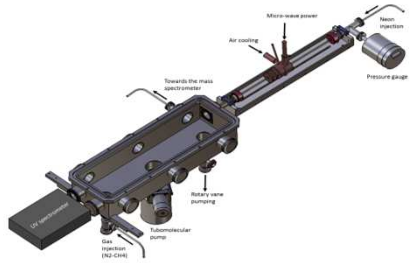
Application: Atmospheric Photochemistry



Fig, 5 The **APSIS reactor** designed for planetary atmospheric studies [3] (APSIS :Atmospheric Photochemistry SImulated by Synchrotron).

First results for photochemistry

The simulation of Titan's atmosphere with a N_2 - CH_4 mixture (95% - 5%)

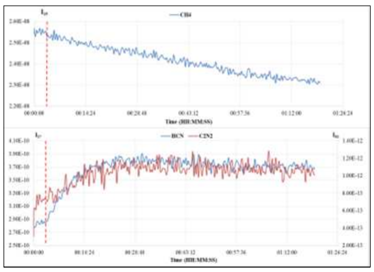


Fig. 6 Time-monitored mass spectrum
- **top**: consumption of the reactive CH_4
- **bottom**: production of HCN (27) and C_2N_2 (52)
The red dotted lines mark the beginning of the irradiation of the reactor with the Ne discharge VUV source

Conclusion

The surfatron based low-pressure micro-wave discharge is an efficient tool as a VUV windowless source for planetary atmospheric photochemistry. The photon flux can be tuned by changing the working conditions (pressure and microwave power) of the discharge.

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