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PLASPAMS : PLASmas Pour l'Analyse en Masse des Surfaces (CSOSG 2014)

B. Brahim¹, C. Sonnichsen¹, E. Louarn¹, H. Mestdagh¹, R. Herren¹, G. Perilhous¹, J. Lemaire¹, M. Heninger¹, S. Pasquiers², J. Santos Sousa², G. Bauville², P. Jeanney², N. Blin-Simiand², B. Burnonville², M. Fleury², V. Puech², J Leprovost³, D. Robin³, P. Gremillet³, E. Bauchard³

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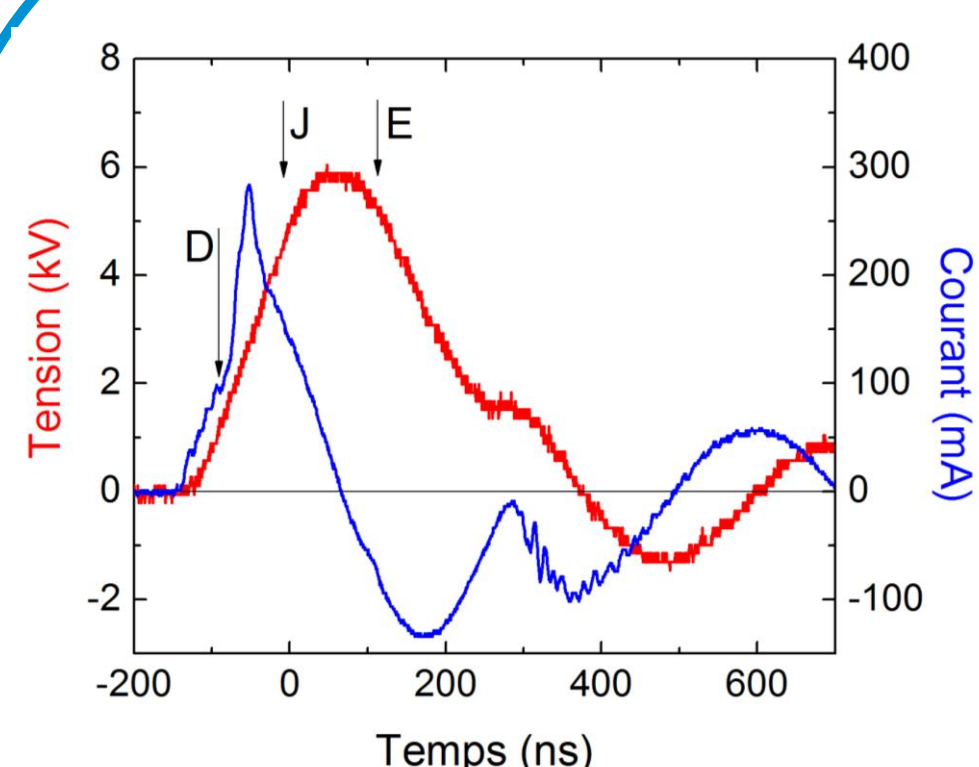
Context

The analysis of compounds at trace levels, on site and in real time have a great interest in various fields related to security. When targeting compounds in very low concentrations the possibility to desorb and analyze compounds of low volatility remains a considerable analytical challenge that could improve the protection of citizens and infrastructures.

The PLASPAMS project aims at the development of an instrument associating the desorption of molecules through the use of cold plasmas jets and mass spectrometry for a sensitive detection of trace species in real time. It will allow the detection and the identification of species at trace levels either in air or on surfaces.

The developed instrument will give the possibility to detect a broad range of molecules including explosives residues, narcotics and/or drugs. It will also detect many pollutants and/or contaminants opening the way to environmental applications.

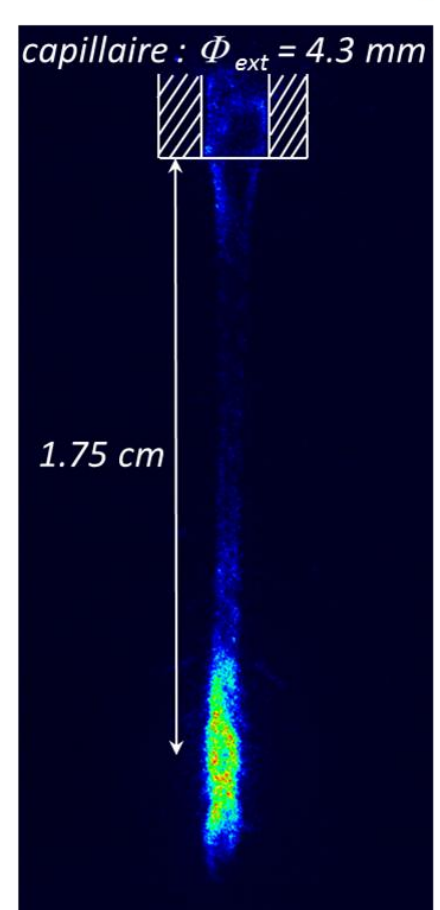
Microplasma jets



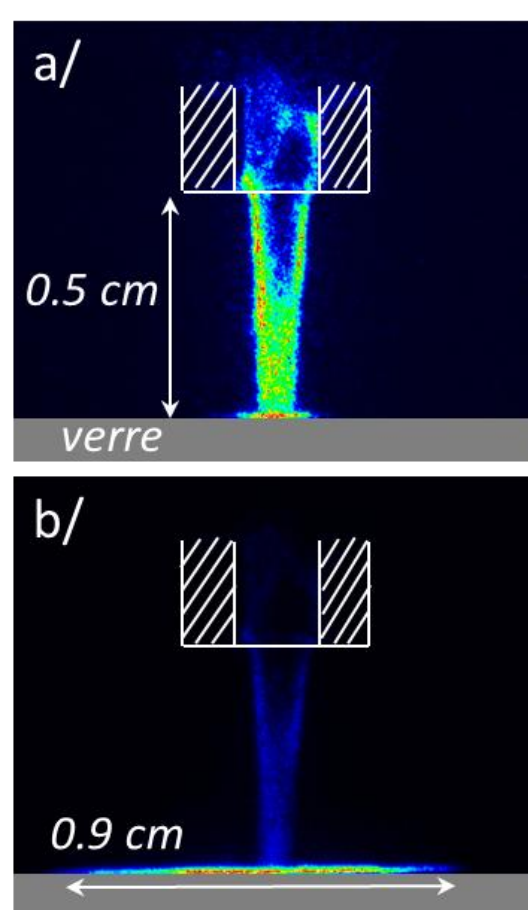
The behavior of an argon microplasma jet has been studied using fast imaging associated to time resolved measurements of electrical parameters.

Temporal evolutions of voltage and current for the argon jet. The frequency is 20 kHz :

D : beginning of the dielectric barrier discharge.
J : beginning of the plasma propagation out of the quartz capillary.
E : example of plasma fluorescence shown below

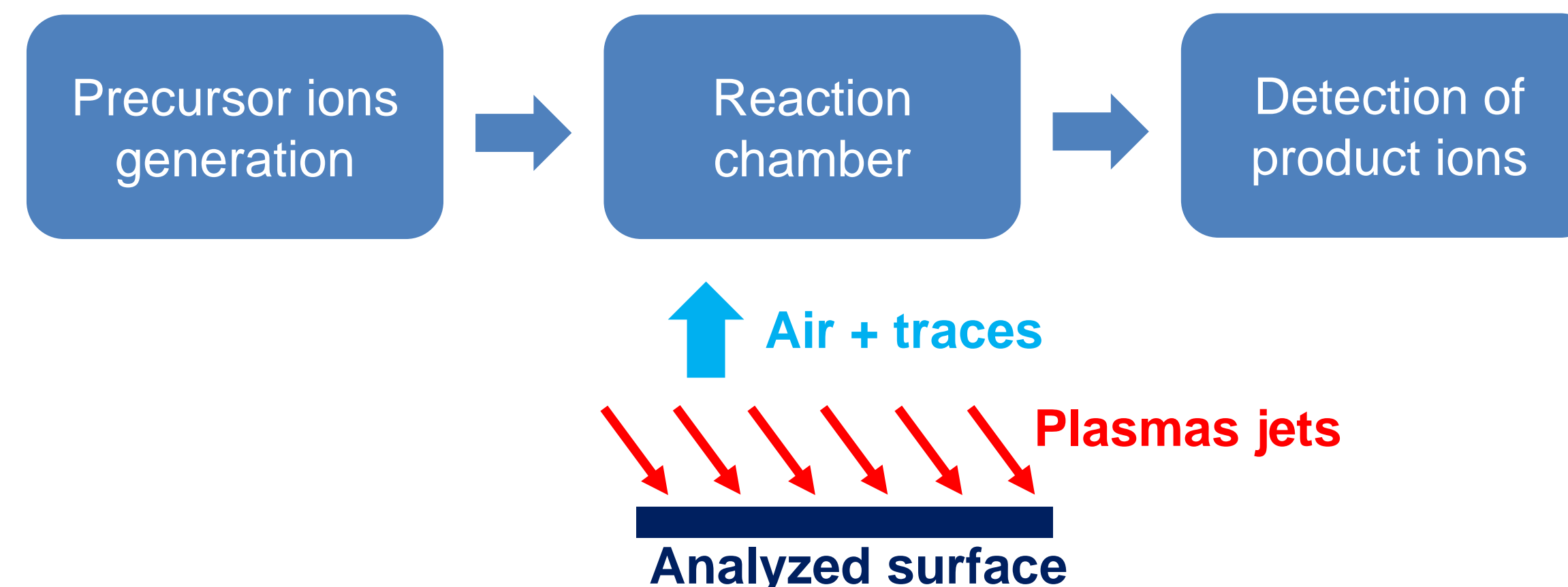


Plasma fluorescence measured with a fast intensified CCD camera using a 20ns acquisition time and accumulating over 10 successive pulses.



Plasma fluorescence measured using similar conditions (20ns acquisition time and 10 accumulations) when a glass surface is placed 0.5cm away from the capillary exit.
a) When the ionization front reaches the glass surface
b) 40ns later an emission is observed from the surface with diameter nearly twice as large as the capillary-surface distance

General description



- Simultaneous sampling of volatile and low volatility compounds (using Cold Plasmas Desorption)
 - > Generation of microplasma jets in different rare gases
 - > Desorption of low volatility compounds deposited on surfaces
- Selective chemical ionization of analytes (using Proton Transfer Reaction)
 - > Optimization of analyte's protonation yield
 - > High flux of precursors ions
 - > Efficient transmission of ions into the mass analyzer
- Mass spectrometric analysis of all produced ions
 - > Large dynamic range of detection
 - > Allow analysis in positive or negative ion mode

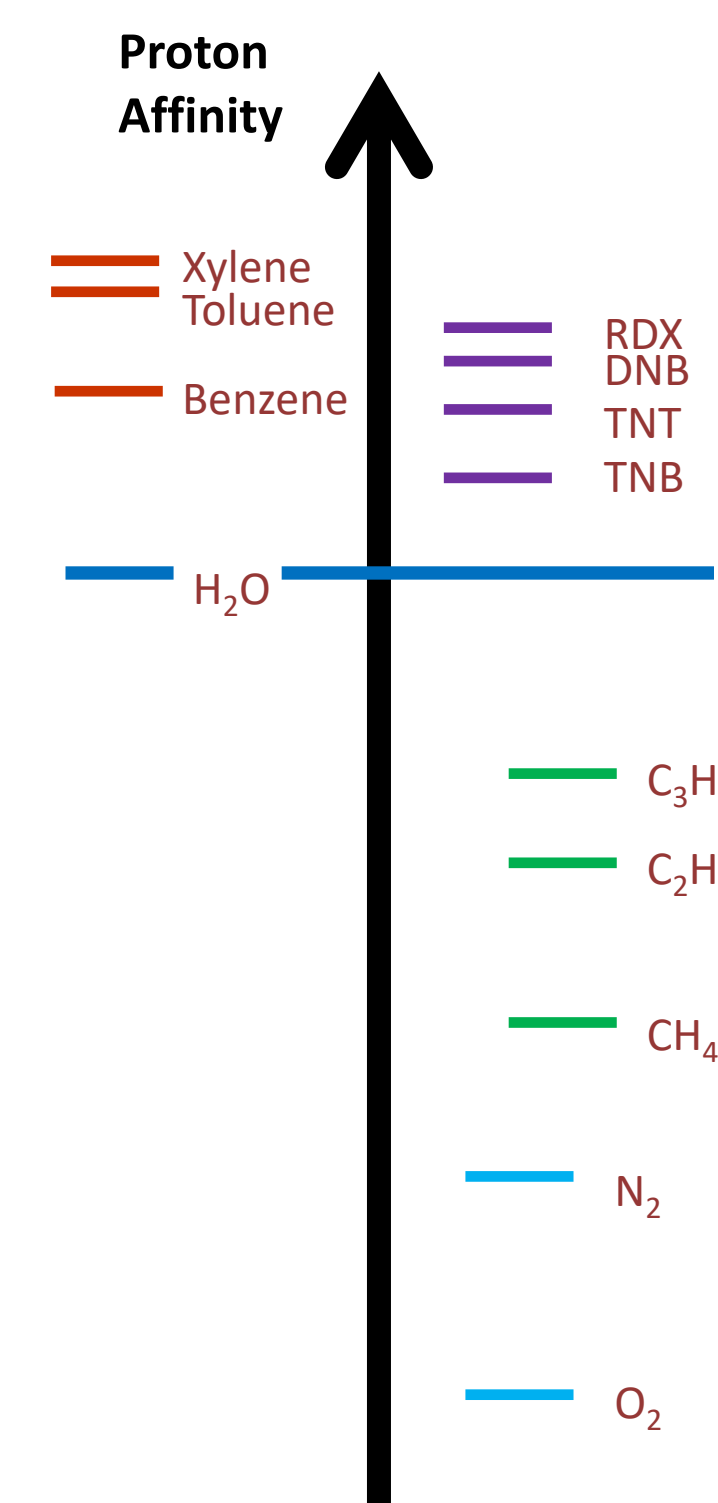
Proton Transfer Reaction

Selective ionization of trace compounds

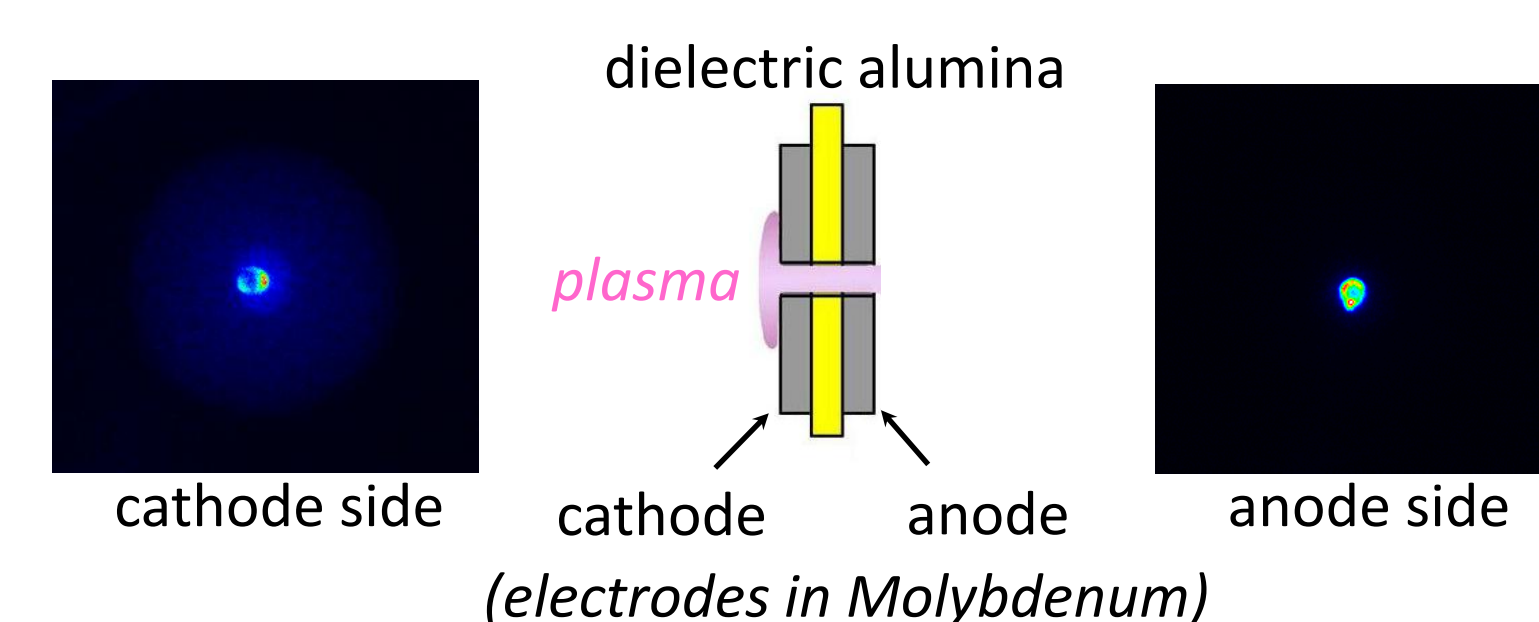
The most used ion molecule reaction for trace detection in air is the proton transfer from H_3O^+ ions (protonated water)



The reaction will be fast and efficient for molecules having a proton affinity higher than water (such as aromatic compounds, alcohols, aldehydes, nitrated explosives, narcotics,...) but will not occur with compounds having a proton affinity lower than water (which is the case for the main constituent of air N_2 , O_2 , Ar and also for alkanes, CFCs,...)



Micro Hollow Cathode Discharge for the generation of H_3O^+ ions

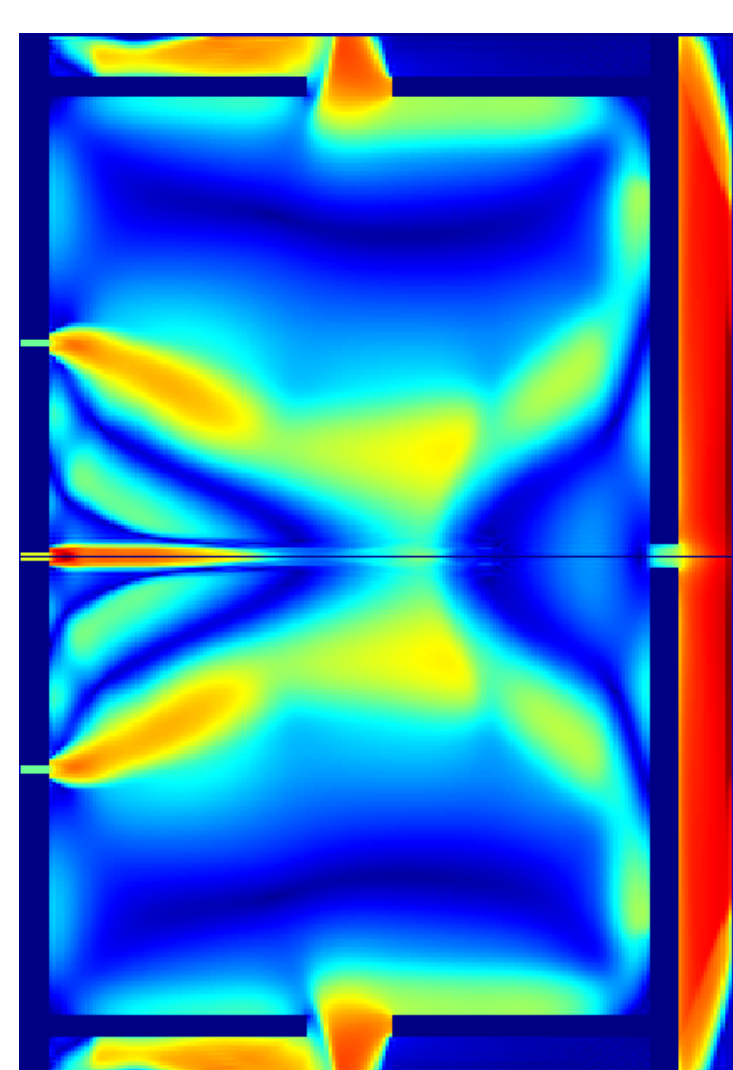
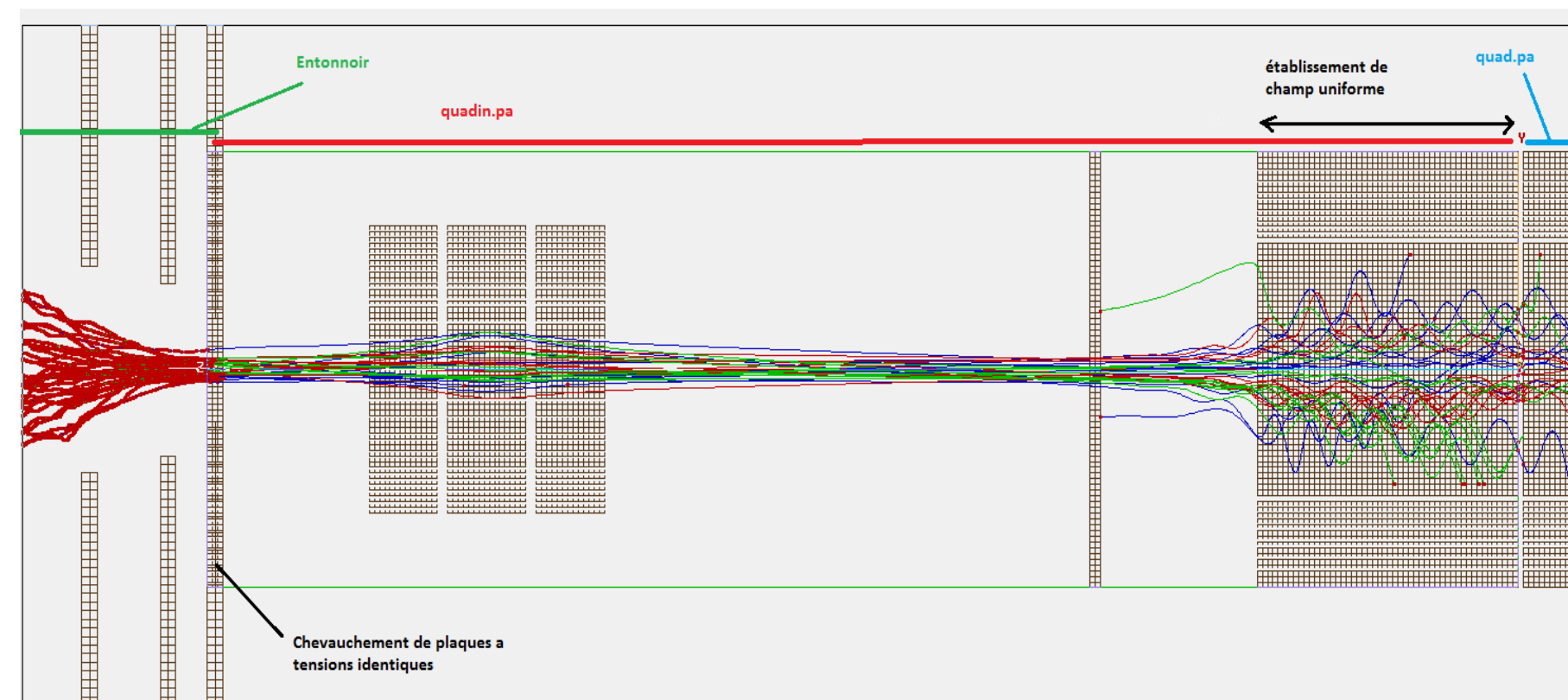


Continuous operation has been obtained when working in Ar / H₂O mixtures.

Optimisation of the analyzer configuration

Simulation of ion trajectories

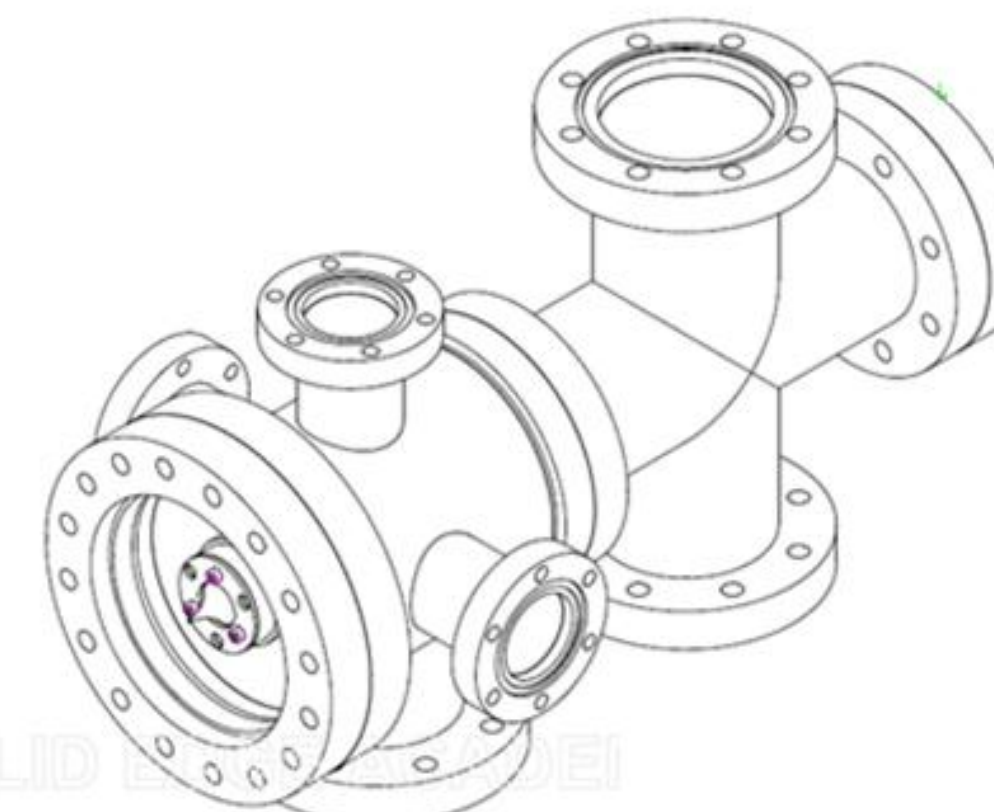
SIMION software was used to describe the potential generated in each point of space by a given configuration of electrodes. Then ion trajectories are calculated in the presence of static or varying (RF) electric fields.



Modeling the hydrodynamics

Virtual Jet software allows the simulation of gas molecules' trajectories flowing around and in the electrode system (hydrodynamic simulations). These simulations are based on the "large particle" model, derived from the "Particle in cell" model and accelerating calculations by depicting the set of molecules in a cell by a larger particle. The result of these hydrodynamic simulations can then be exported in SIMION in order to calculate ion trajectories while taking into account collisions with the neutral gas using realistic density and speed distributions.

Differential pumping of the analyzer



The reaction chamber is operated at a pressure of approximately 2 mbar.

A double chamber system has been developed in order to ensure a differential pumping between the reaction chamber and the quadrupole analyzer. Indeed, with only one chamber, the pressure on the analyzer side was too high for correct operation of the quadrupole. With the double chamber system, the pressure of the quadrupole chamber will be around 10^{-6} mbar and a polarizable skimmer will sample the central part of the jet, favoring the transmission of ions.

Conclusion

PLASPAMS is an instrumental project based on the development of a compact equipment for the analysis of compounds at trace level in air or adsorbed on surfaces such as explosives or narcotics. The analyzer incorporates an ion source where precursor ions will be produced in a micro hollow cathode discharge, a reaction chamber where analytes are selectively ionized by chemical ionization and a mass spectrometer (a quadrupole which will later be replaced by an ion trap). Microplasma jets will be used in order to desorb low volatility compounds deposited on surfaces.

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