A LINEar device dedicated to understanding radio-frequency sheaths

S. Devaux, E. Faudot, J. Moritz and S. Heuraux

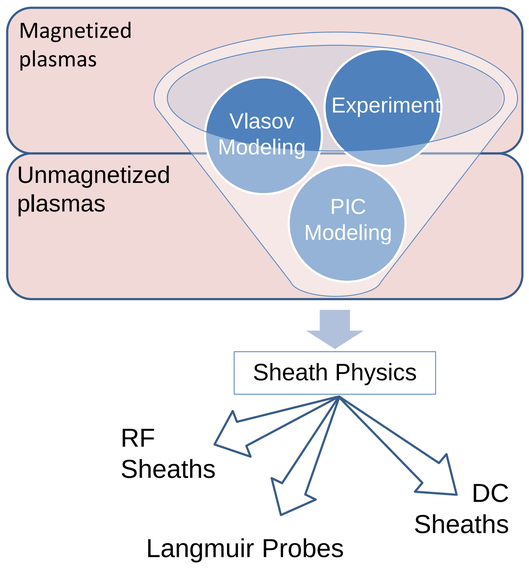
Institut Jean Lamour - UMR CNRS 7198 - Université de Lorraine - Faculté des Science, 54500 Vandoeuvre lès Nancy

Introduction : ALINE, a link between theory and experiments

The ALINE device has the goal to study Radio Frequency (RF) sheaths in magnetized plasmas. Thanks to its design, the plasma is easily accessed by diagnostics so that electric potential, temperature, densities are accurately measured.

The stability and reproducibility of the plasma in ALINE, together with the local competences in Particle in Cells and Vlasov modelling, makes the Aline Experiment a great opportunity for a direct link between theory and experiment in sheath physics.

With the new diagnostics to be soon installed on ALINE, such as Laser Induced Fluoresce (LIF) that gives access to ion distribution functions, and an infrared camera, which gives surface temperature and heat fluxes, sheaths transfer coefficients will be accessible to experiment and compared to simulation and theory for RF and DC magnetized sheaths in magnetized plasmas.



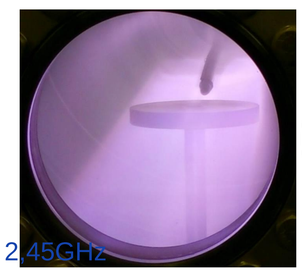
ALINE: Experimental Setup

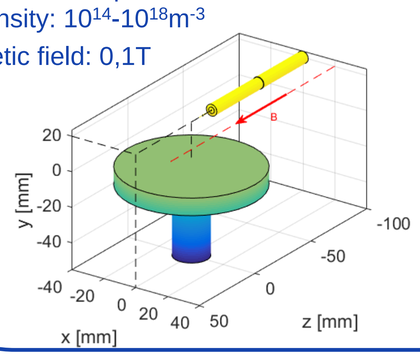
Chamber: 100cm x 30cm cylinder stainless steel
Gas: Ar/He/(H) plasma

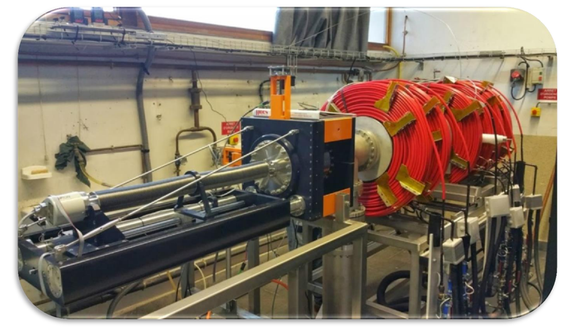
Plasma generation:
- Radio Frequency (RF): 600W @ 0,1-200MHz
- Electron Cyclotron Resonance (ECR): 3kW @ 2,45GHz

Plasma:
- Electron Temperature: 1-6 eV
- Density: 10^{14}-10^{18}m^{-3}

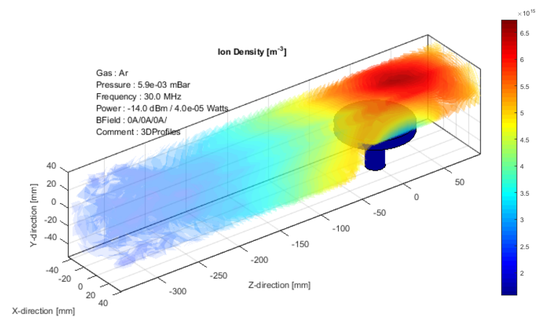
Magnetic field: 0,1T

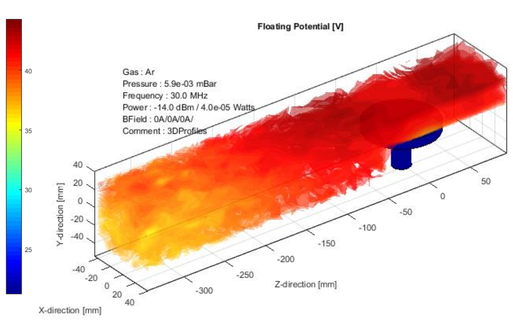






3D Maps: Plasma and Sheath without Magnetic Field

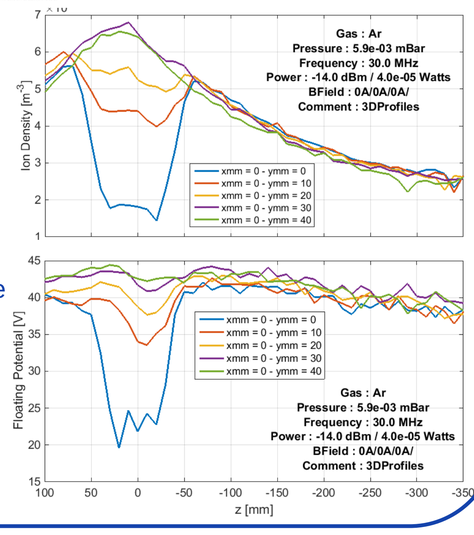




Remote arm:
- allows scans in the three space dimensions
- accuracy < 0,1mm in positioning (can be improved)
- maps of 3-4000 points (~6 hours in a stable plasma)

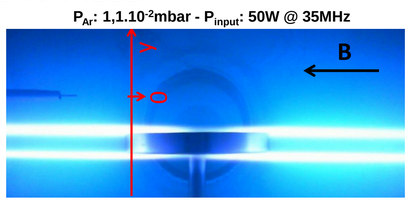
Maps:
- Floating (& plasma) potential ~ constant in the chamber
- Density peaks in a 3D structure on top of the antenna
- Density gradients measured over 30cm from the cathode

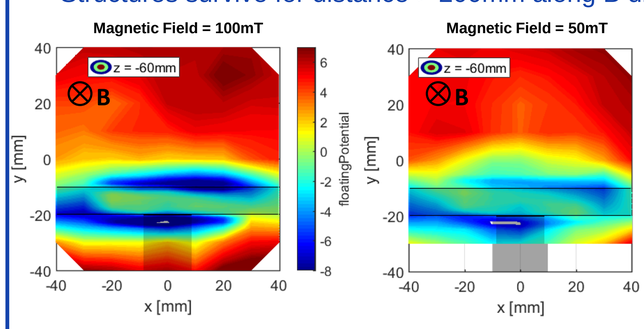
RF Presheaths and sheaths
- Centimetric sheaths are resolved with ~ 10 points
- Density drops by 2 in the presheath as expected
- 3D effects affect sheaths around the antenna

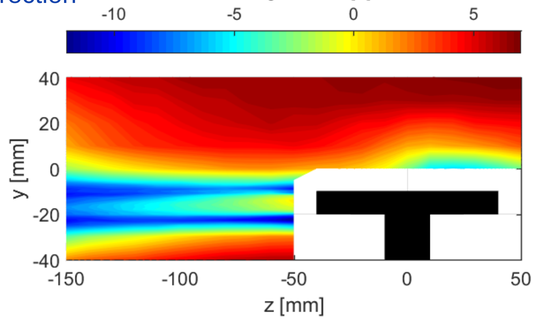


3D Maps: Plasma and Sheath with Magnetic Field

Magnetized plasmas in ALINE
- Higher densities in layers on both sides of the cathode
- Blue due to Ar^{2+} (target of Laser Induced Fluorescence)
- Reduced sheath on top of both faces of the cathode
- Potential & density drop exist in between them
- Structures survive for distance > 200mm along B direction

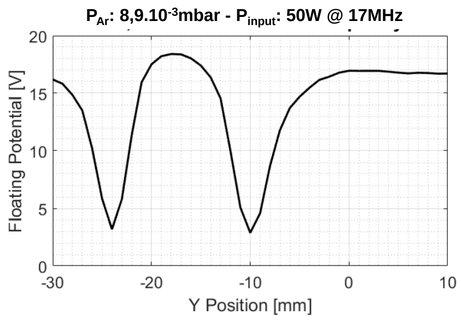


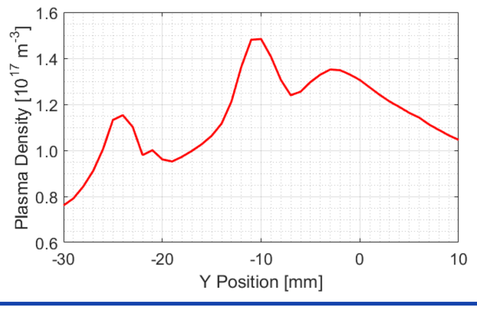


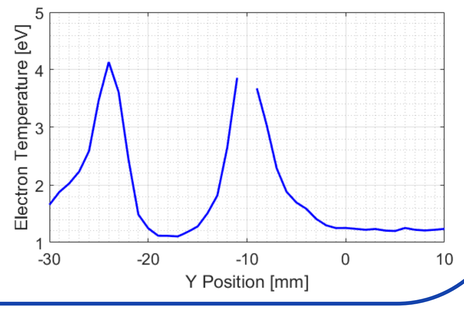


Symmetries and Asymmetries
- floating potential drop are similar on yOz plane (x=0)
- left/right and top/bottom asymmetries otherwise
- The depth of potential wells increases with B

RF sheath structure in parallel to the wall B field
- Fine structure of a few mm linked to sheaths
- Density and electron temperature match potential
- No “perpendicular sheath” observed so far…







Plasma diagnostics

Pyrometer and Infrared
(to be tested soon)

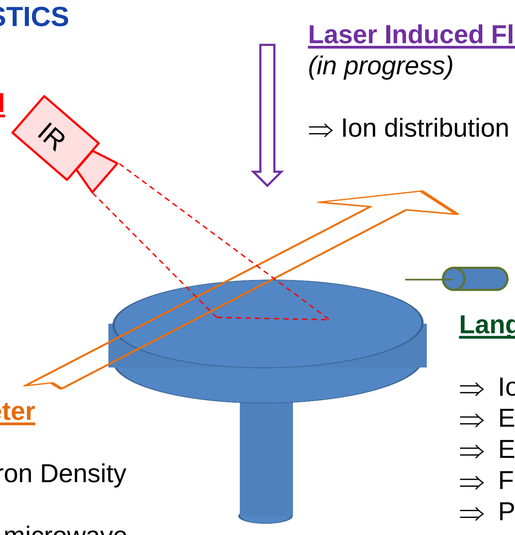
⇒ Surface temperature
⇒ Heat flux (modeling)

- ❑ FLIR SC655
- ❑ 640x480 detector
- ❑ up to 200Hz

Microwave Interferometer

⇒ Line integrated Electron Density

- ❑ MWI 2650 emitting a microwave beam at 26,5 GHz - 40mW
- ❑ Density range: 10^{15}-10^{18}m^{-3}



Laser Induced Fluorescence
(in progress)

⇒ Ion distribution function

B
Magnetic field parallel to the surface

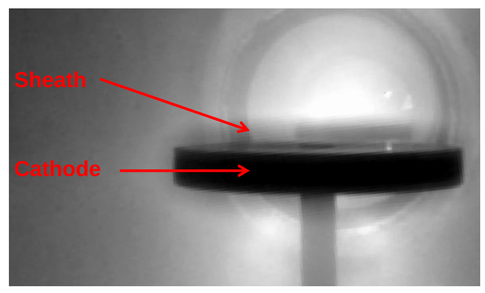
Langmuir Probe (3D)

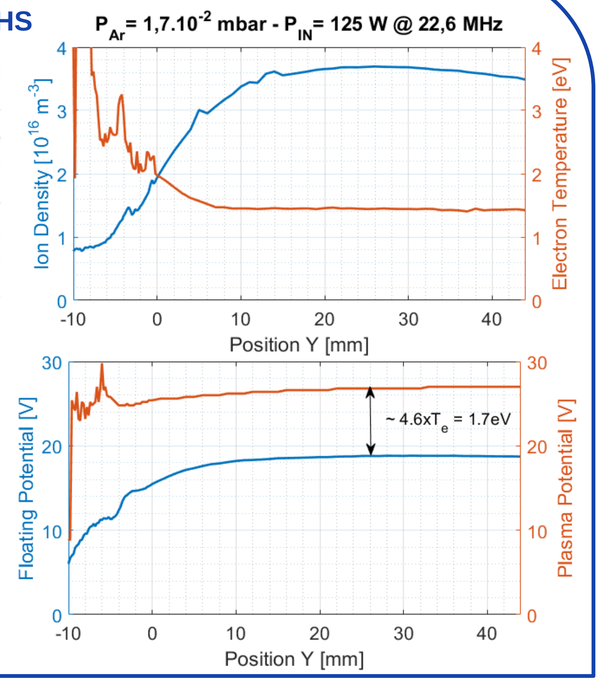
⇒ Ion Density
⇒ Electron Density
⇒ Electron Temperature
⇒ Floating Potential
⇒ Plasma Potential

- ❑ Hidden analytical
- ❑ 0,15x10mm cylinder
- ❑ RF compensated

Sheaths For Investigating Sheaths

Sheaths around the surface are investigated by a Langmuir probe, which relies on sheaths physics to deliver meaningful data! One has to proceed with care when measurements come from within the cathode sheath as all the outputs may not be valid anymore (Te). Moreover, sheaths 3D geometry has to be taken into account when it comes to such large sheaths (1cm on the picture). Simulations will be required.



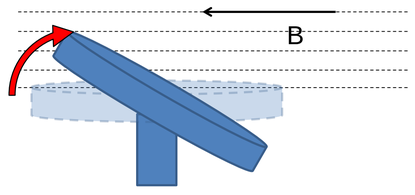


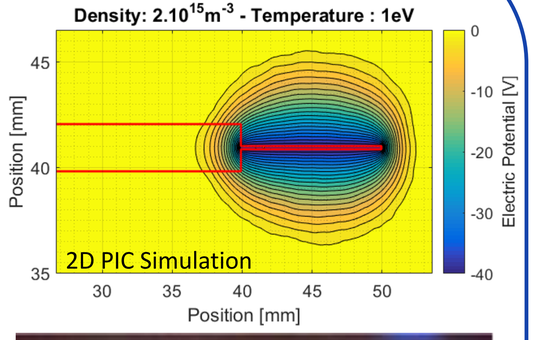
Conclusion

- ➢ Aline experiment allows accurate measurements within magnetized sheaths and presheaths
- ➢ 3D maps in and around the surface are easily achieved

What's next ?

- ❑ Simulations of probe in magnetized plasmas
- ❑ Development of a tiltable and polarizable cathode to investigate sheaths with a non-parallel magnetic B-field
- ❑ ECR to use the cathode as a passive surface
- ❑ Test of new cathode shape designs
- ❑ Change for Tungsten to reduce sputtering





New cathode Design : NCC 1701