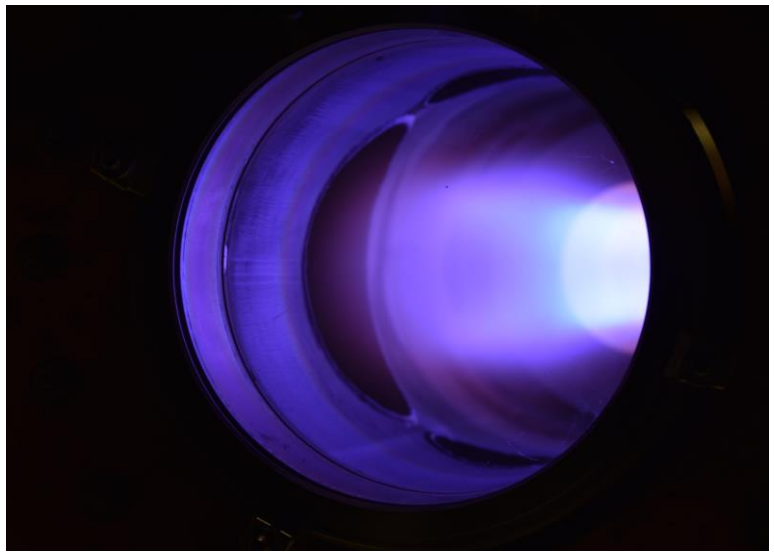
Von Karman Plasma:
Présentation et Diagnostics



Equipe:

N. Plihon (DR CNRS)

V. Dolique (IR CNRS)

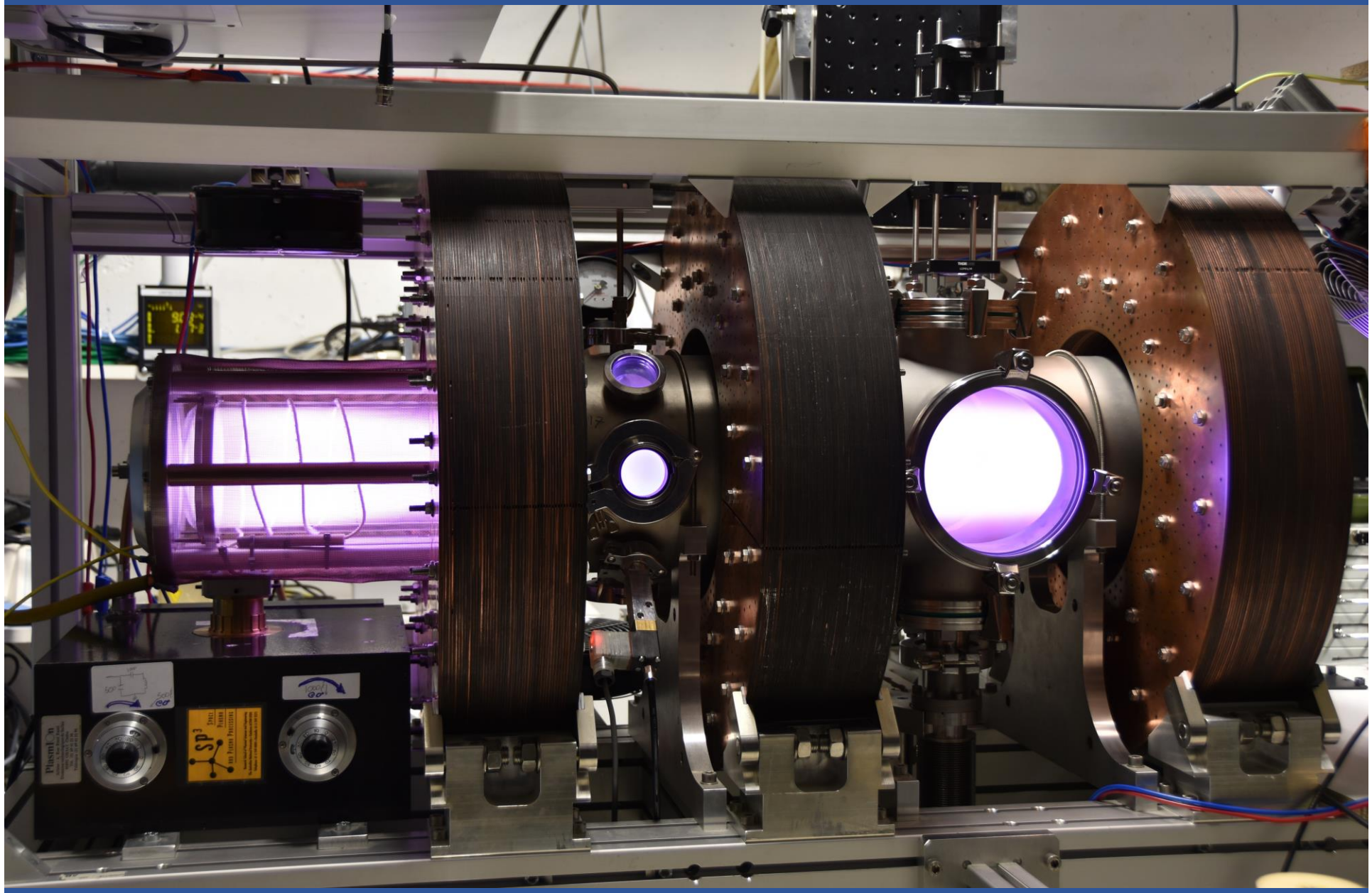
F. Pagaud (Doctorant)

Laboratoire de Physique
ENS de Lyon

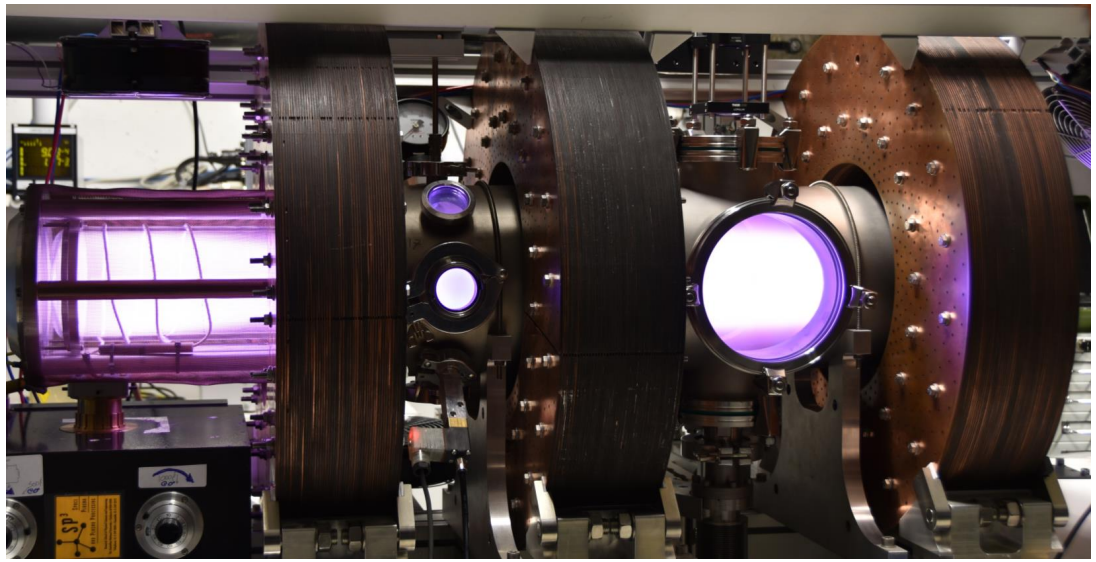
2 dernières thèses : S. Vincent et V. Désangles

GDR EMILI – Octobre 2022 - ICARE

EXPERIMENTAL SET-UP



EXPERIMENTAL SET-UP



Control parameter :

$$p_0 \sim 1 \text{ mTorr } (10^{-6} \text{ atm})$$

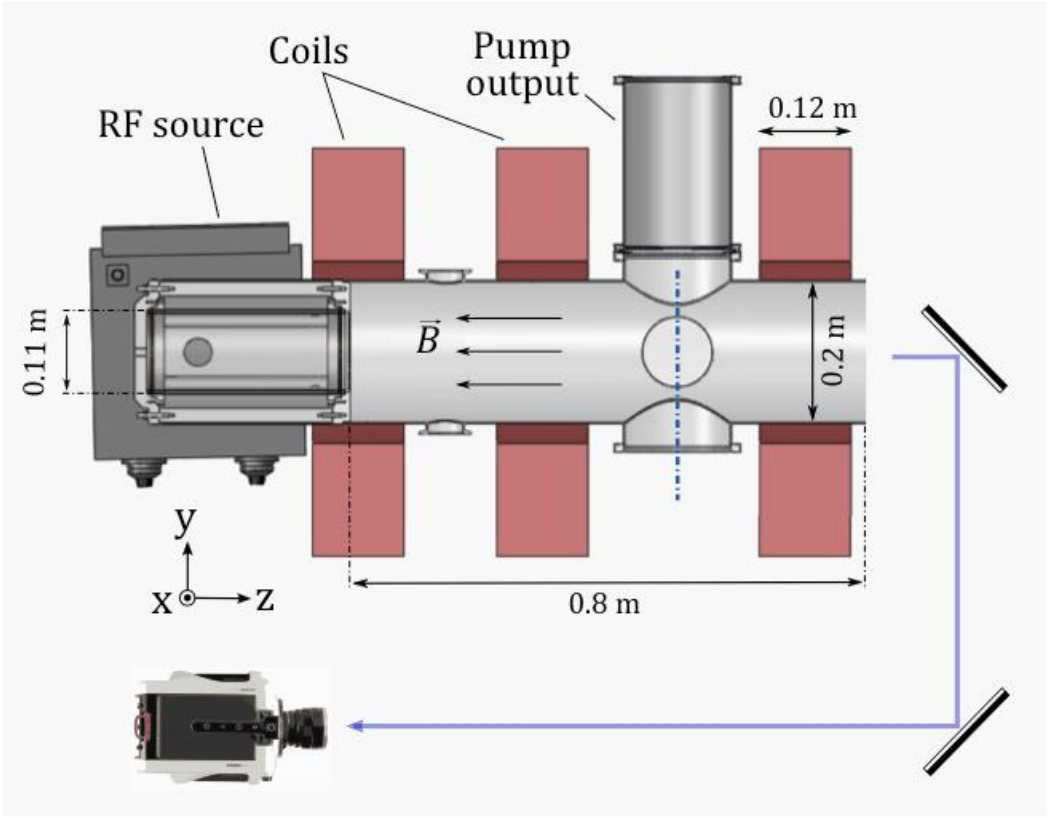
$$P_W \sim 1 \text{ kW}^{*}$$

$$B \in [100 : 1500] \text{ G}$$

$$\longrightarrow \begin{cases} n \sim 10^{18} \text{ m}^{-3} \\ T_e \sim 4 \text{ eV } (5.10^4 \text{ K}) \\ T_i \sim 0.2 \text{ eV } (10^3 \text{ K}) \end{cases}$$

Plihon *et al., Journal of Plasma Physics, 81, 345810102 (2015)*

MEASUREMENT TOOLS



- Probe measurements :
  - Density
  - Electronic Temperature
  - Plasma potential
  - Ionic velocity
  - Turbulent transport

    (phase shift density / potential)

- Camera imaging
  - Proxy for the density fluctuations

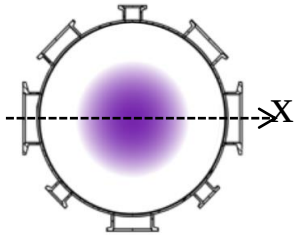
- LIF on Ar^+ ions

MEASUREMENT TOOLS : PROBES

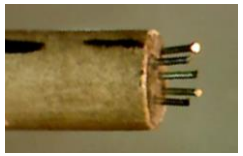
- **LANGMUIR PROBE**

I = f(V) response to a bias sweep

$$\rightarrow \quad n \;/\; T_e \;/\; V_f \;/\; V_p$$

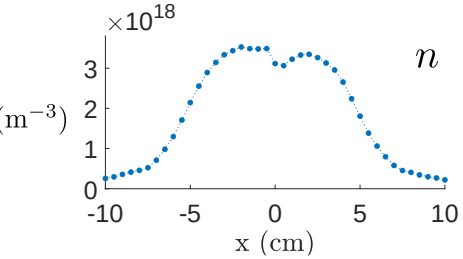


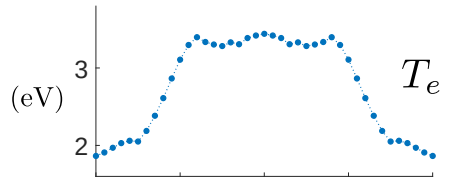
- **TRANSPORT PROBE**



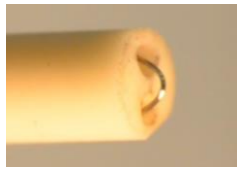
Triple probe + second V_f measure

$$\rightarrow \begin{cases} n(t) \;/\; T_e(t) \;/\; V_f(t) \\ \Delta\phi(n, V_f) \\ \Gamma^* = \langle \tilde{n}.\tilde{v}_r \rangle \end{cases}$$



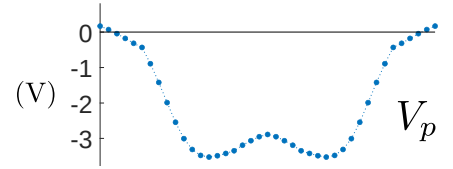


- **EMISSIVE PROBE**



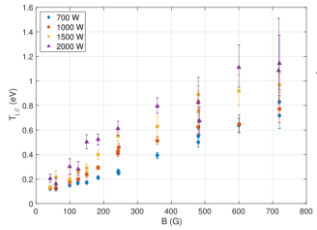
Electrode's potential when heated up

$$\rightarrow \quad V_p(t)$$



- **LIF PROBE**

$$\rightarrow \quad T_i \text{ (eV)}$$

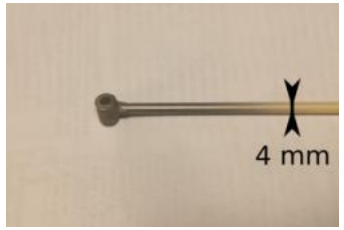


T_i (eV)

- *Chen, IEEE-ICOPS Meeting (2003)*
- *Tsui et al., Rev. Sci. Instr., 63, 4608 (1992)*
- *Sheehan and Hershkowitz, Plasma Sources Sci. Technol., 20, 063001 (2011)*

MEASUREMENT TOOLS : PROBES

- MACH PROBE



$\rightarrow \quad v_i$

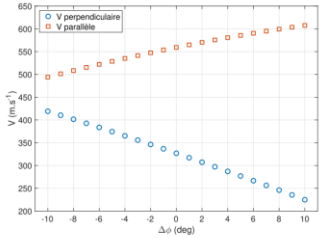
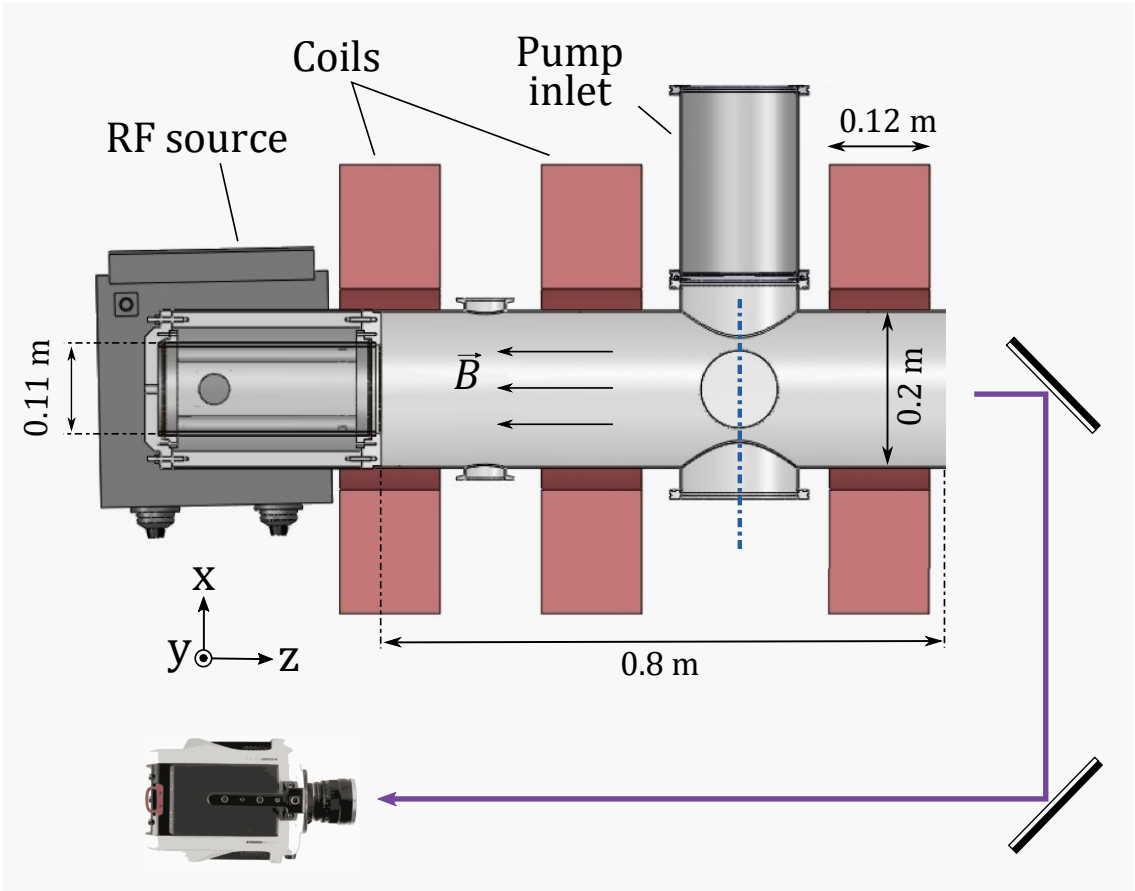
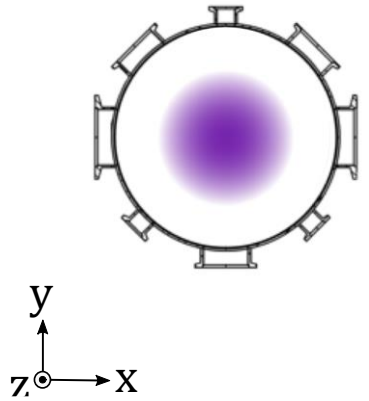


FIGURE 1.18 – Vitesses perpendiculaires et parallèles mesurées grâce aux fit de la courbe de $V_{meas}(\phi + \Delta\phi)$ en fonction de $\Delta\phi$.

- Chen, IEEE-ICOPS Meeting (2003)
- Tsui et al., Rev. Sci. Instr., 63, 4608 (1992)
- Sheehan and Hershkowitz, Plasma Sources Sci. Technol., 20, 063001 (2011)

CAMERA IMAGING





Acquisition frequency : 200 000 Hz
Résolution : 256x256 px

LIF

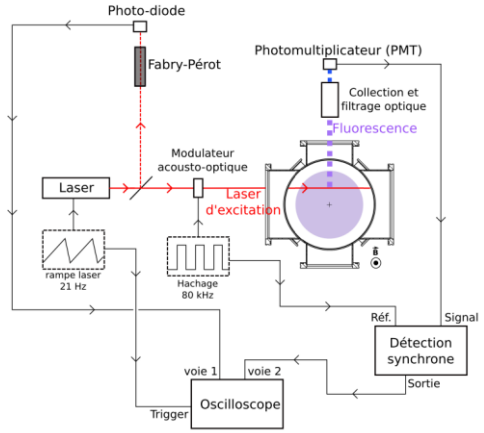
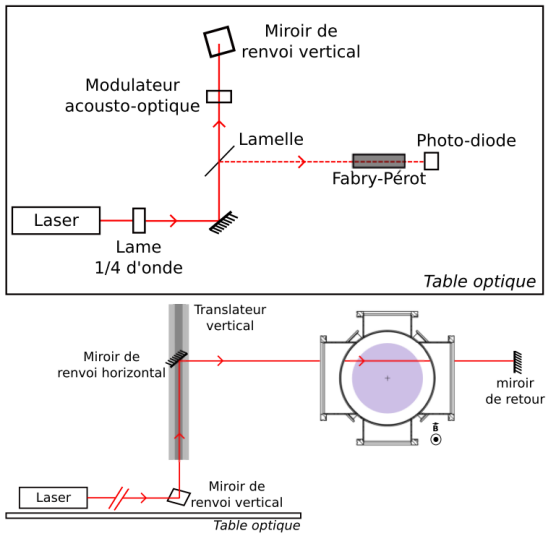
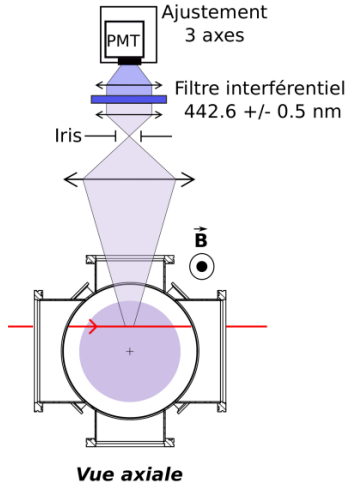


FIGURE 1.20 – Schéma complet du dispositif de LIF.

Schéma global de la mesure par LIF



Injection du laser



Detection de la fluorescence

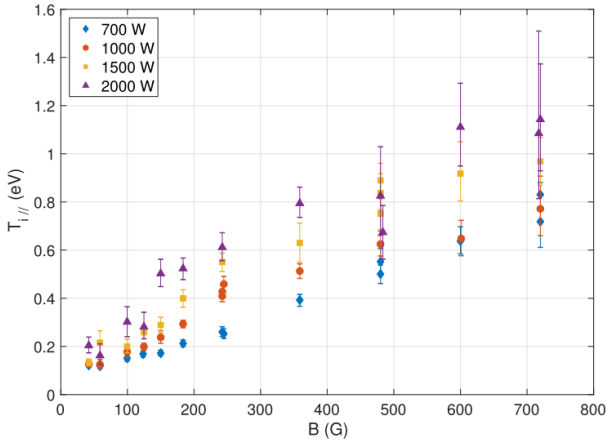


FIGURE 2.8 – Évolution de T_i parallèle en fonction du champ magnétique, mesurée au centre du plasma, pour différentes valeurs de puissance et une pression de 1 mTorr.

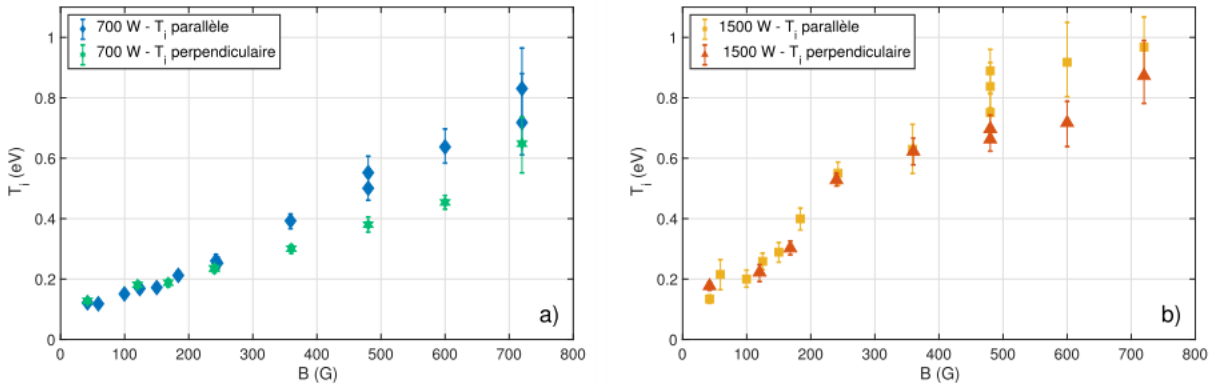
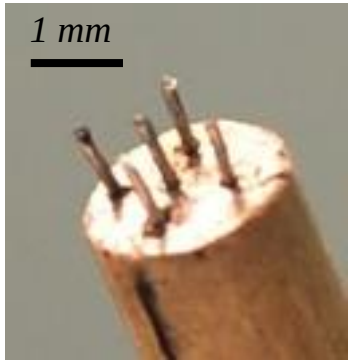


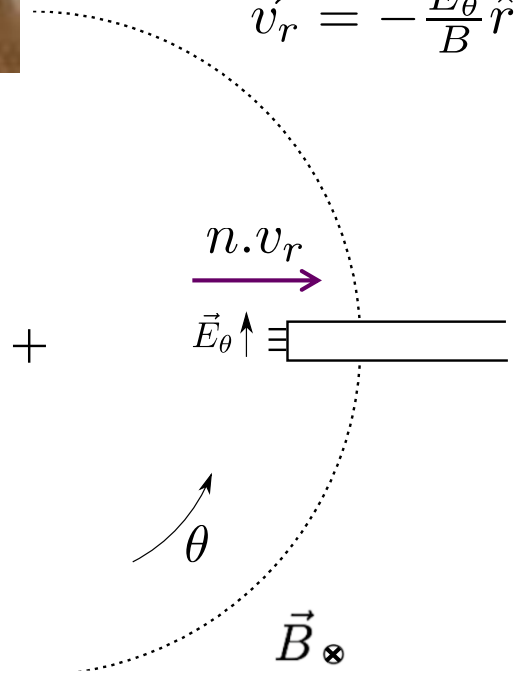
FIGURE 2.9 – Evolution des températures ioniques parallèles et perpendiculaires en fonction de champ magnétique, mesurées au centre du plasma, pour deux puissances RF différentes : a) 700 W et b) 1500 W, pour une pression de base de 1 mTorr.

5-TIPS PROBE : transport

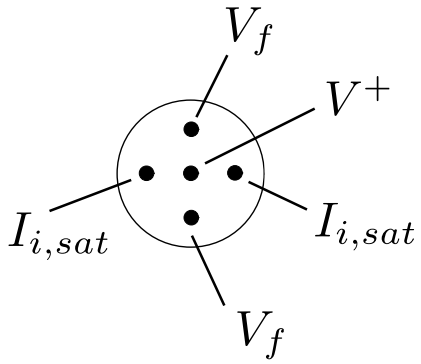


With $\vec{v} = \vec{v}_{E\times B}$:

$$\vec{v}_r = -\frac{E_\theta}{B}\hat{r}$$



Working principle



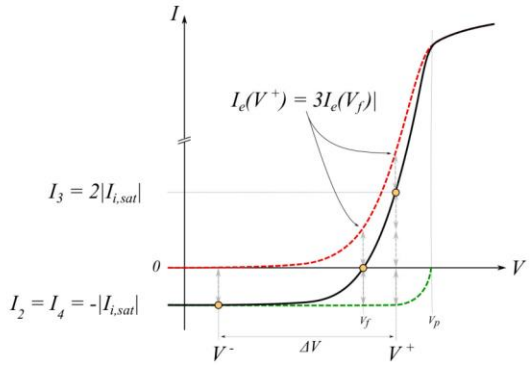
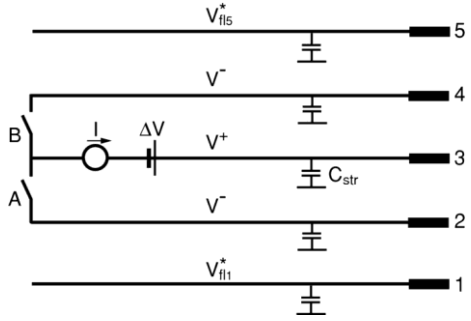


Figure 2.10: Theoretical IV curve (black) used to deduce the temperature from a 5-tips measurement, with the electronic (red) and ionic (green) parts of the total current. The points effectively measured by the 5-tips are highlighted as yellow dots.



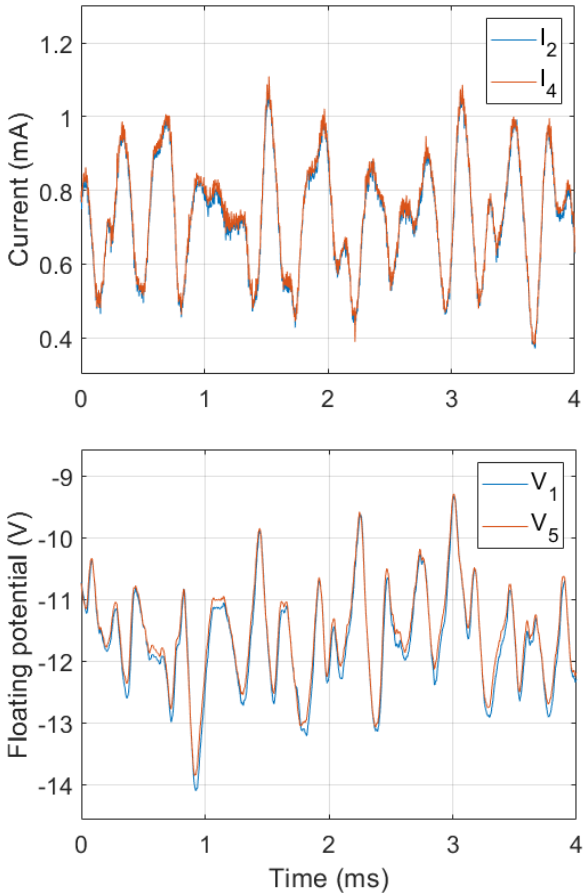
→ Simultaneous measure of :

- n
- V_f
- T_e
- $\tau_{turb} = < \tilde{n}.\tilde{v}_r >$

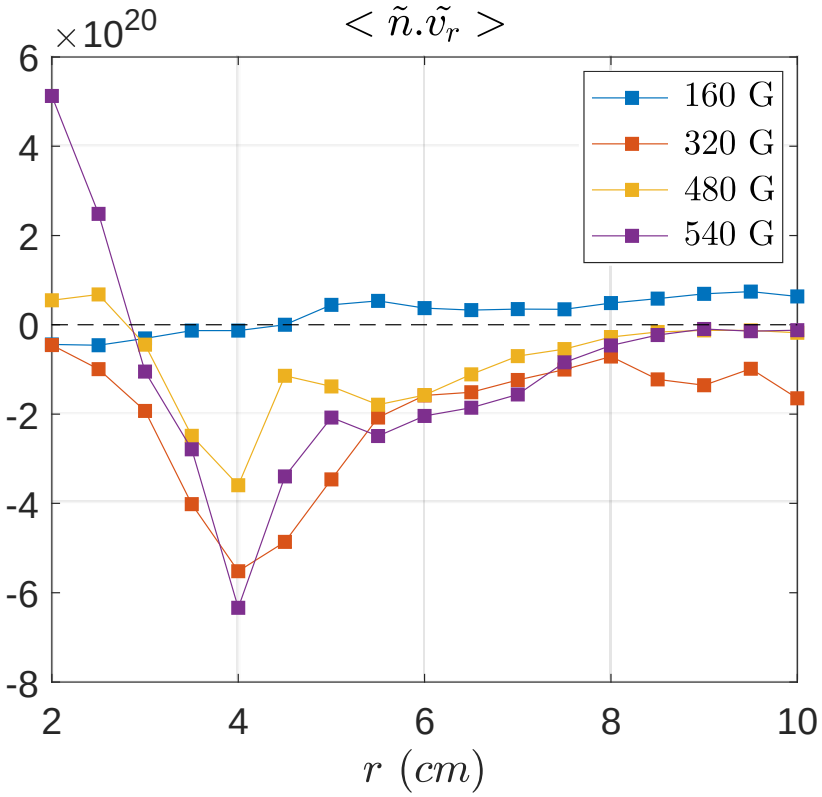
- *Tsui et al., Rev. Sci. Instr., vol. 63, 4608 (1992)*
- *Theiler et al., Rev. Sci. Instr, vol. 82,* 013504 *(2011)*

5-TIPS PROBE : transport

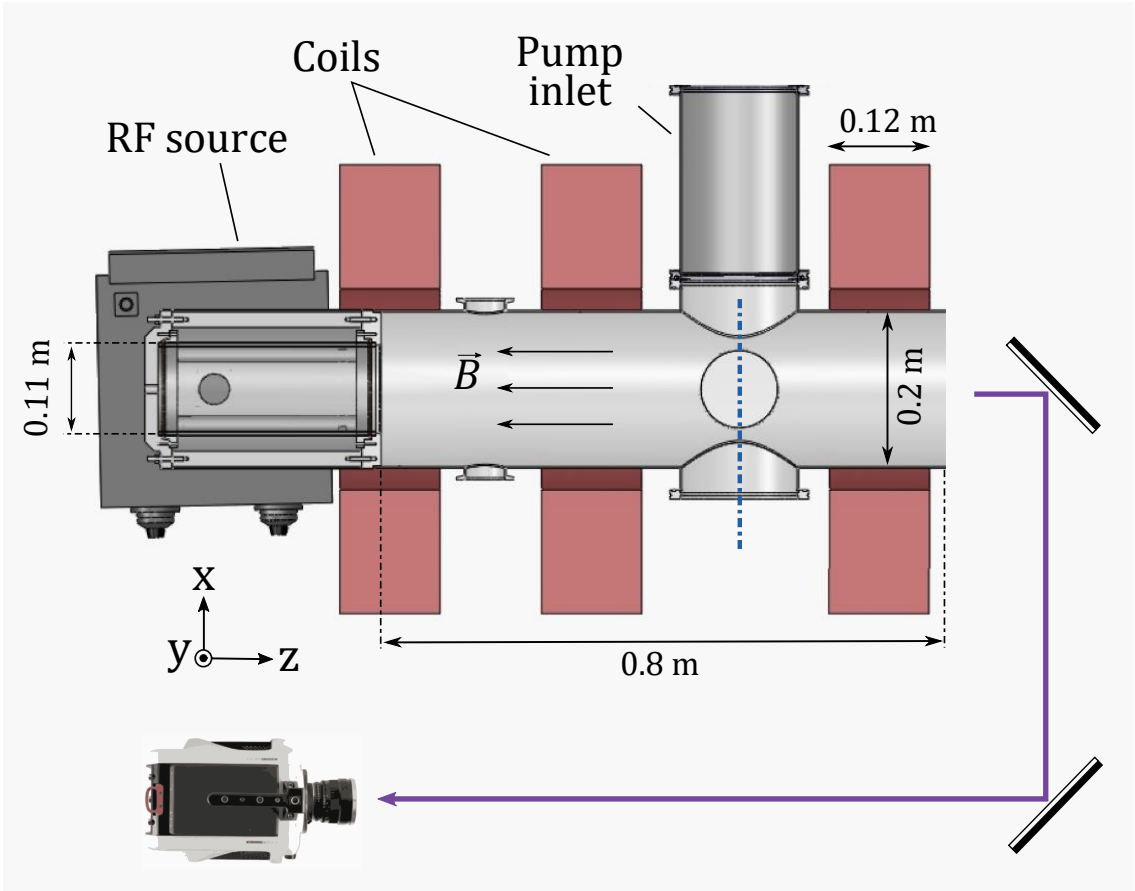
Time evolutions

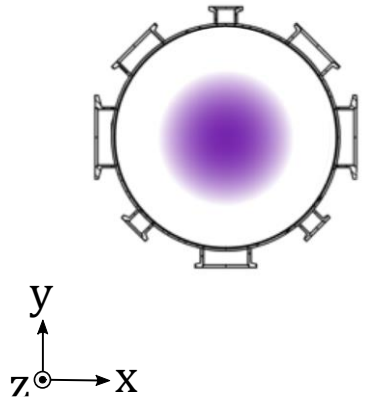


Radial profiles



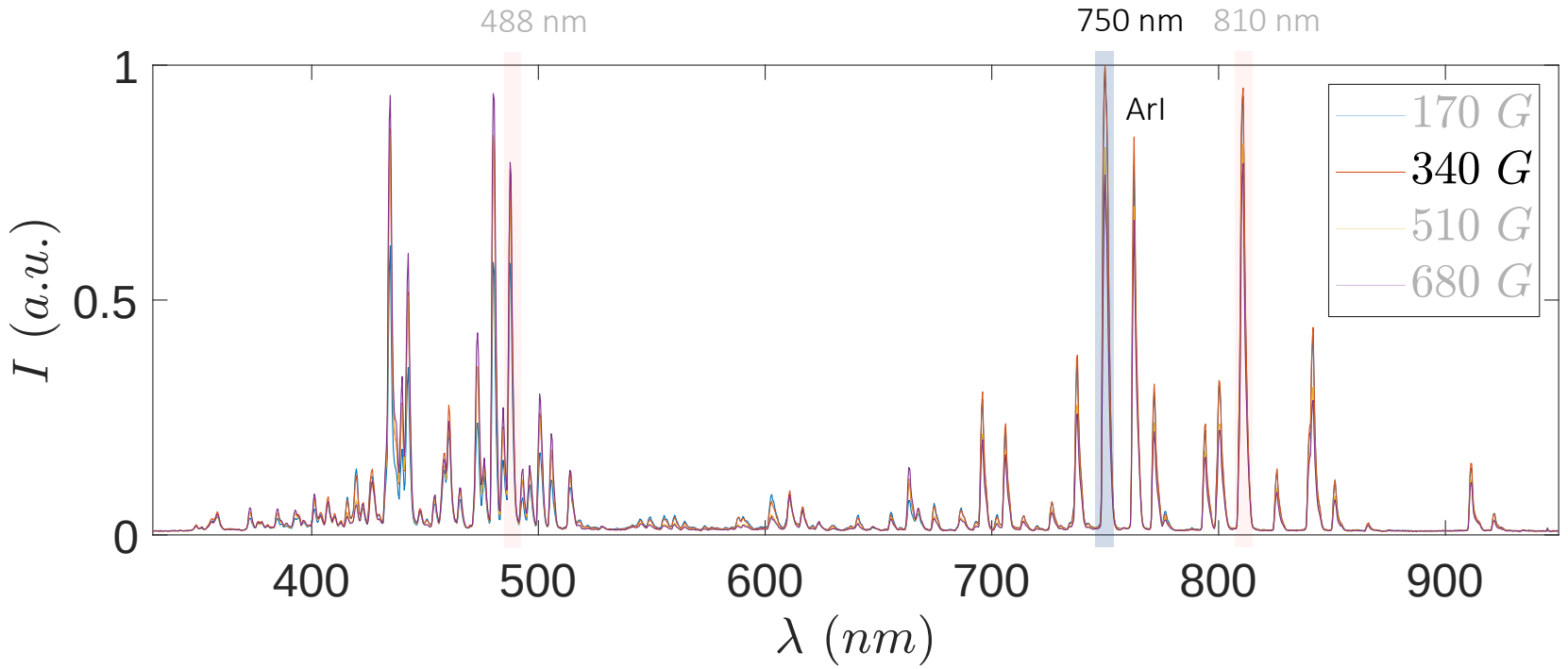
CAMERA IMAGING





Acquisition frequency : 200 000 Hz
Resolution : 256x256 px

CAMERA IMAGING – Precisions



⟶ Presentation restricted to : $\lambda = 750$ nm / $B = 340$ G

CAMERA IMAGING – What does the light represent ?

Usual assumption :

$$\tilde{I}_{cam} \propto \tilde{n}$$

Observation of « density fluctuations »

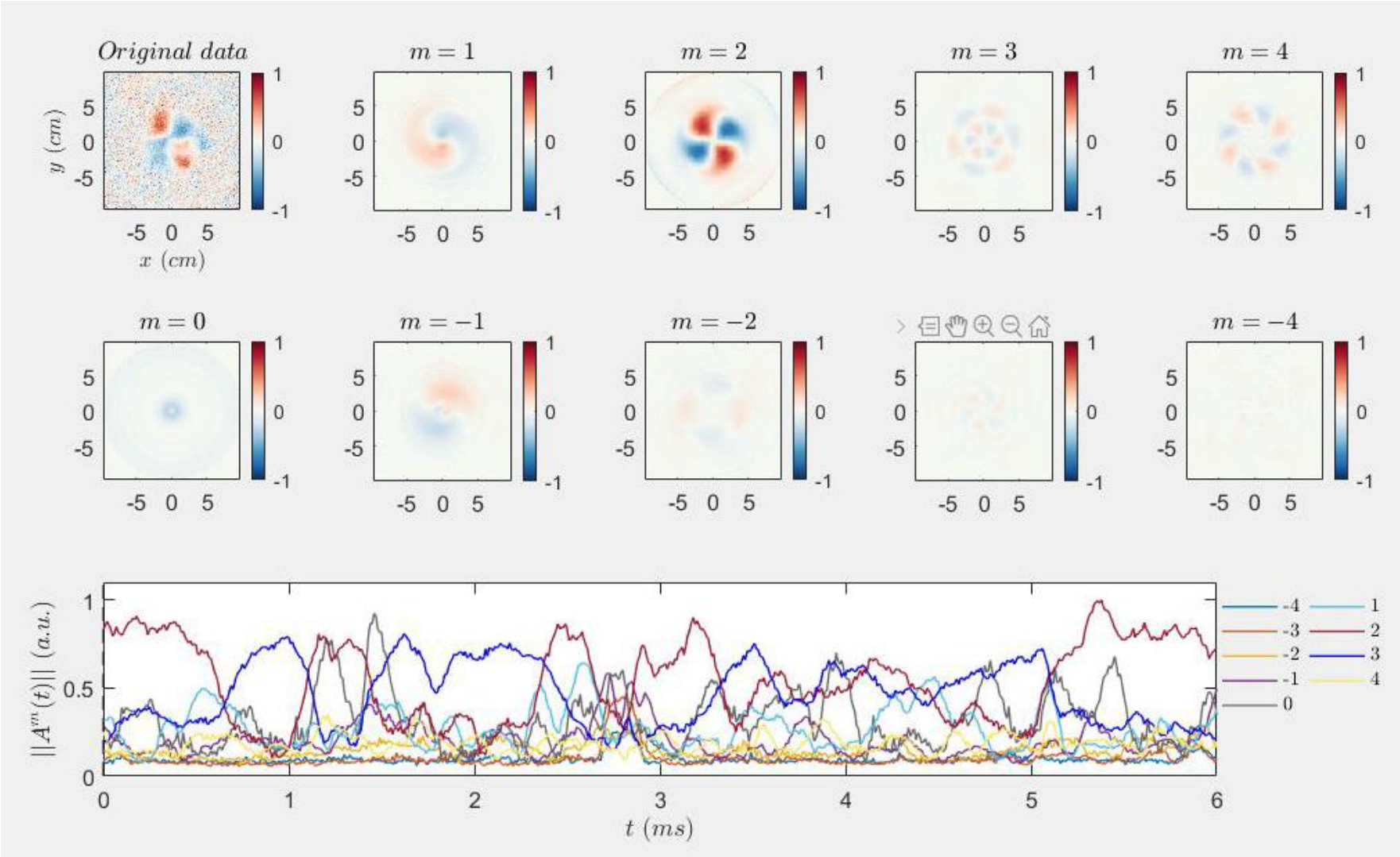
5 TIPS: mesure de $\tilde{n}_e$,$\tilde{T}_e$

- Oldenbürger *et al., Rev. Sci. Instr., 81, 063505 (2010)*
- Antar *et al., Phys. Plasmas, 14, 022301 (2007)*
- Cui *et al., Phys. Plasmas, 22, 050704 (2015)*

Simon Vincent, Vincent Dolique, *and* Nicolas Plihon
, "High-speed imaging of magnetized plasmas: When electron temperature matters", Physics of Plasmas 29, 032104 (2022)

CAMERA IMAGING – 2D Fourier Transform

Time evolution of m-modes amplitudes (B = 510 G)



IDENTIFICATION OF THE WAVES: imaging camera and 5 tips probe

Drift waves

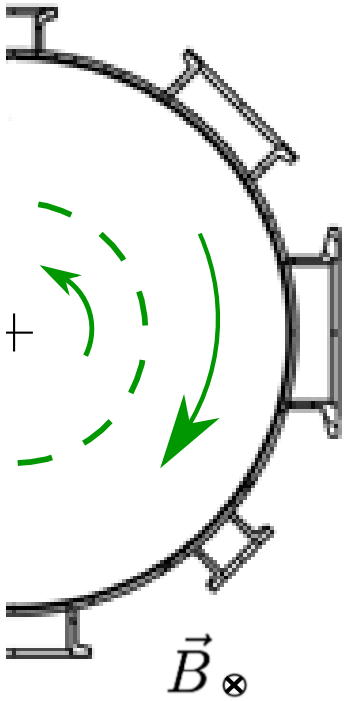
Density gradient
⊥ B

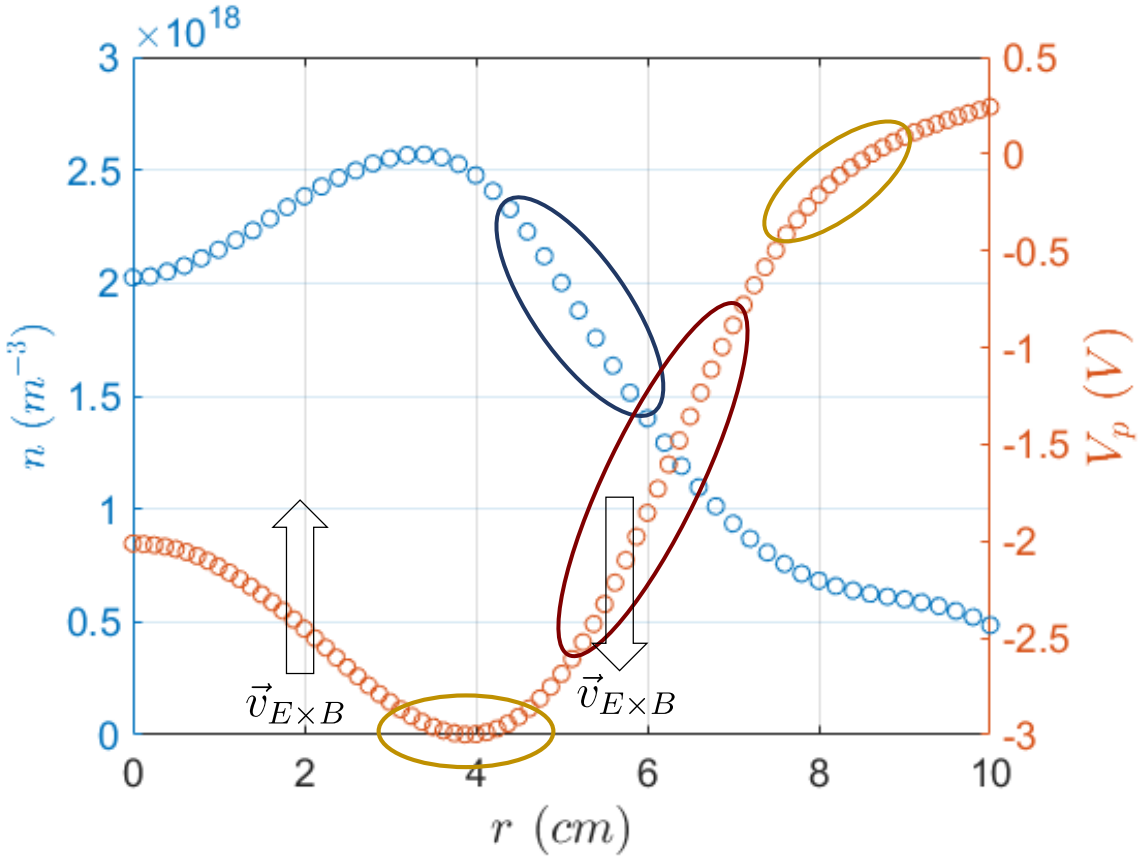
Rayleigh-Taylor

Density gradient
Centrifugal force

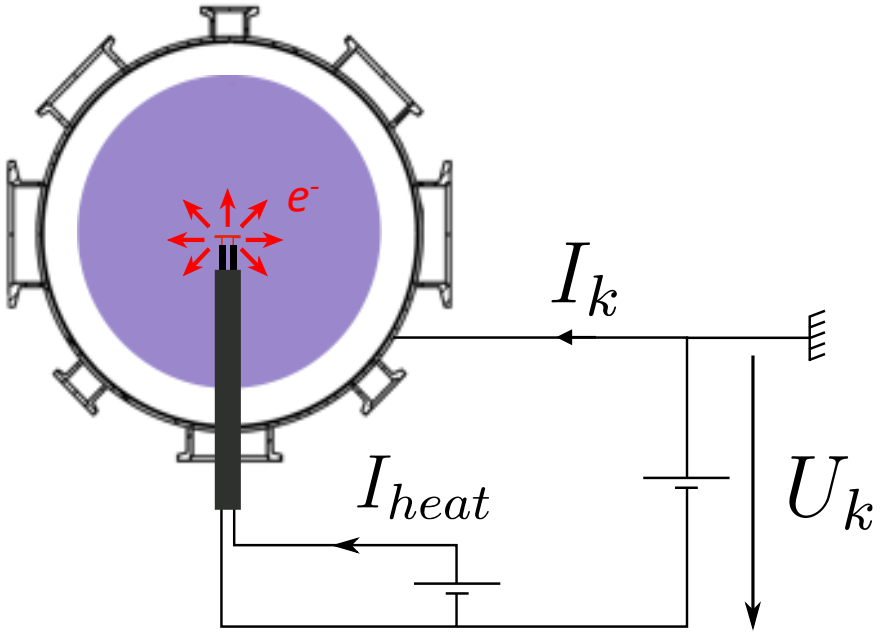
Kelvin-Helmholtz

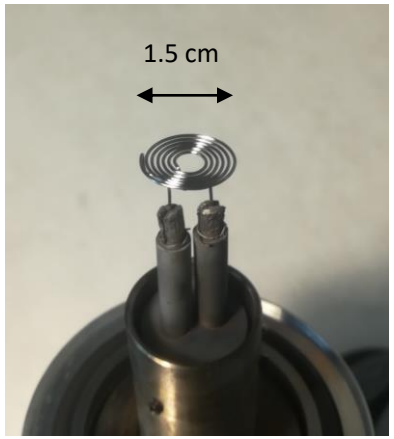
Shear





INFLUENCE OF AN EMISSIVE CATHODE

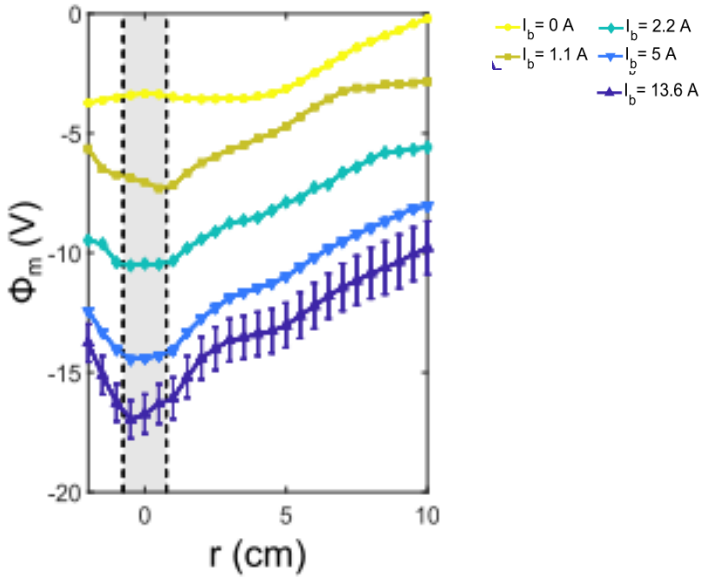




$$U_k \sim 10 - 60 \text{ V}$$
$$I_k = 0 - 10 \text{ A}$$

Désangles *et al.*, *Journal of Plasma Physics, 87, 905870308 (2021)*

INFLUENCE OF AN EMISSIVE CATHODE



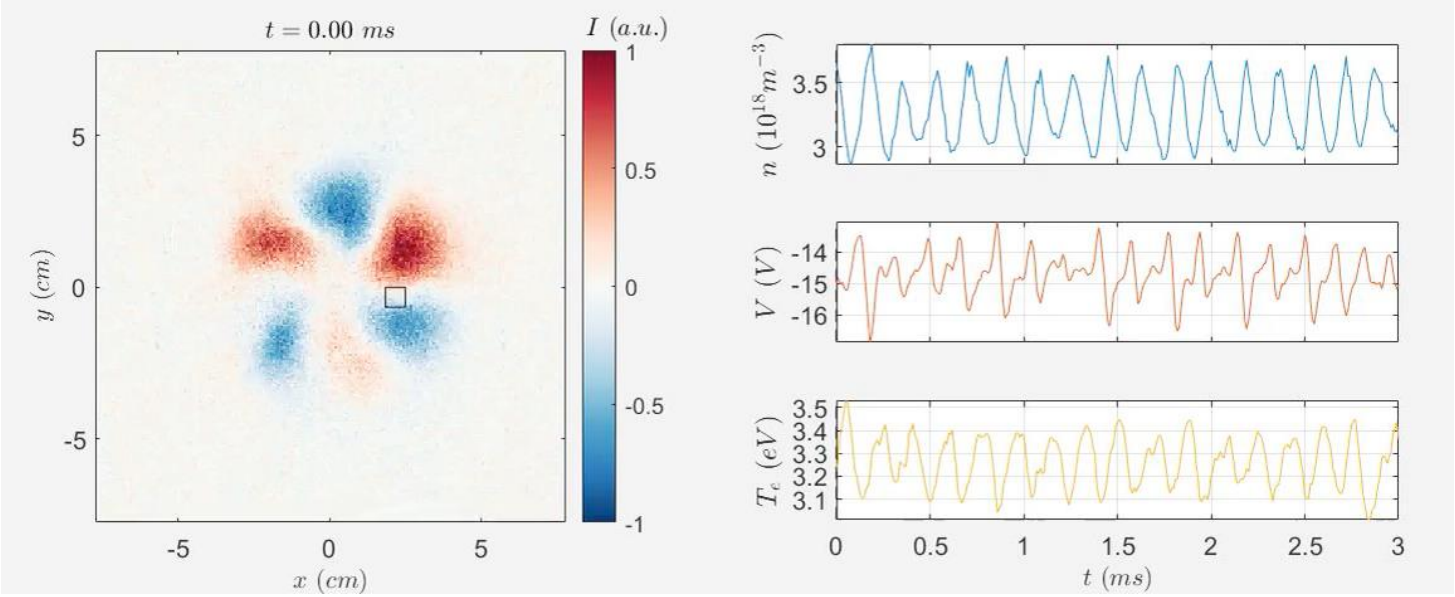
On-going collaboration with B. Trotabas & R. Gueroult
Laplace lab., Toulouse

Projet ANR déposé avec LAPLACE, PIIM, et M2P2.

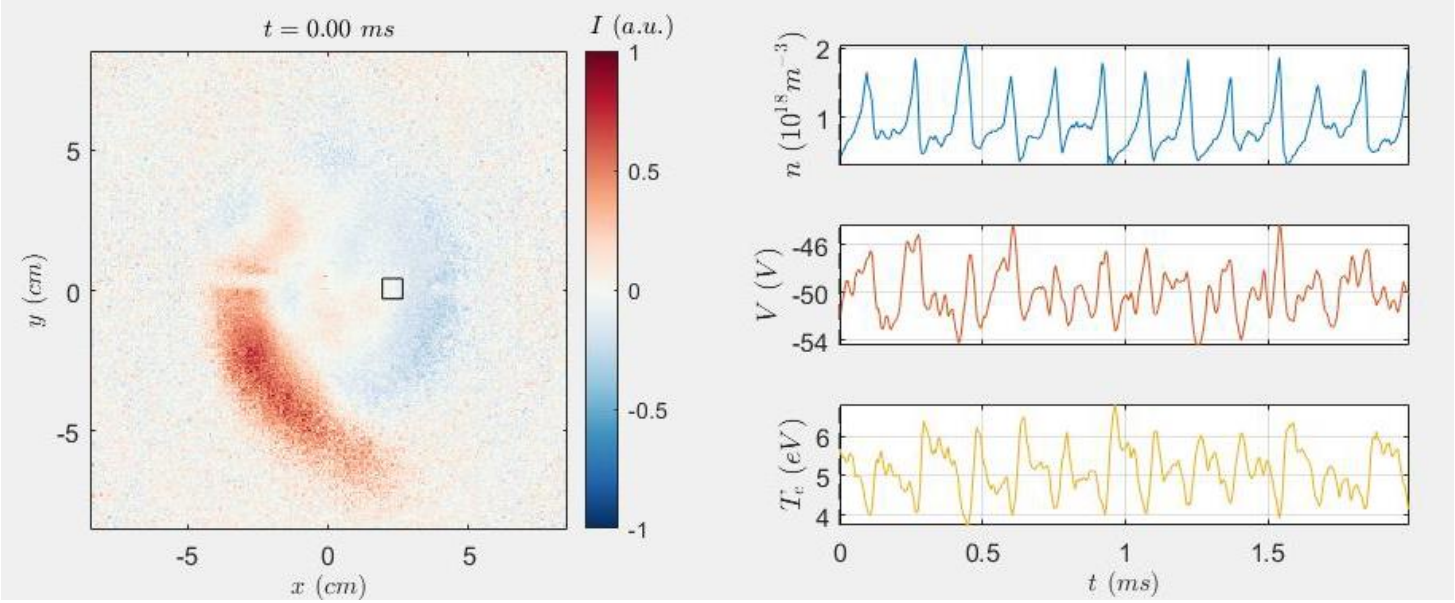
- Gueroult *et al., Phys. Plasmas, 26, 122106 (2019)*
- Liziakin *et al., Plasma Source Sci. Instr. , 29, 0150808 (2020)*

INFLUENCE OF AN EMISSIVE CATHODE

No Cathode



I_k = 10 A



PROJET 2023: DOUBLE SOURCE EN FACE A FACE