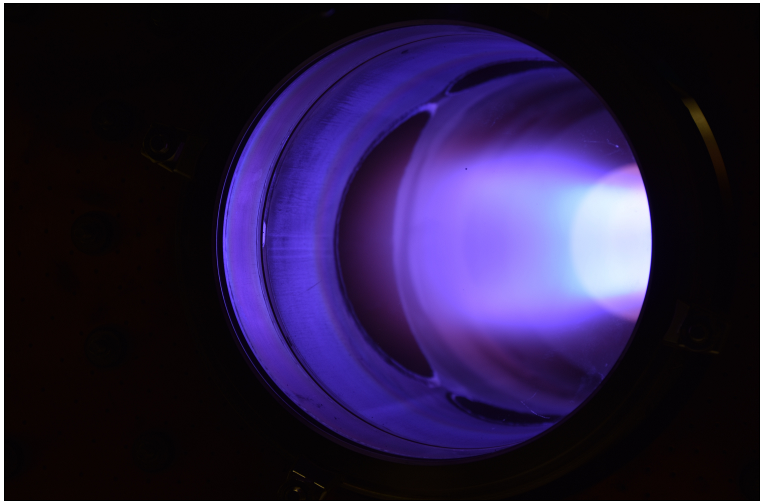
LOW FREQUENCY WAVES IN A MAGNETICALLY CONFINED PLASMA COLUMN



Simon VINCENT

November 29th 2019

Advisors : Vincent DOLIQUE, Nicolas PLIHON

Laboratoire de Physique, ENS de Lyon

PHAST PHYSIQUE ET ASTROPHYSIQUE UNIVERSITÉ DE LYON ÉCOLE DOCTORALE 52

Lab PHYS ENS de LYON

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HOW ?

EXPERIMENTAL SET-UP – Let’s **create** some plasma …

Varying B flux : induced E field

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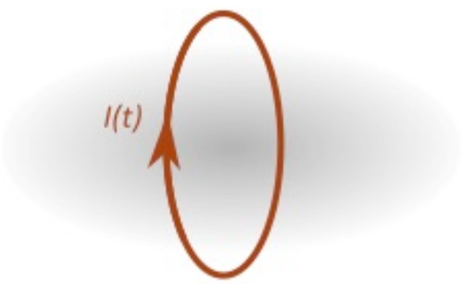

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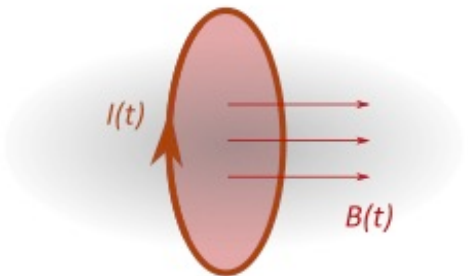

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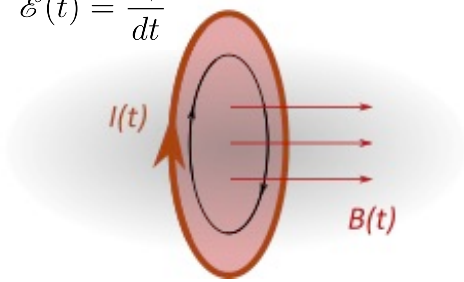
Varying B flux : induced E field

$$\mathscr{E}(t) = \frac{d\phi}{dt}$$



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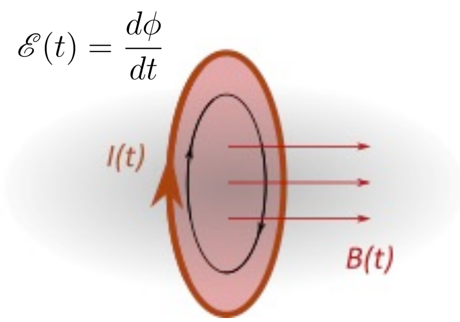

Frequency : 13,56 MHz
Power : 1 kW

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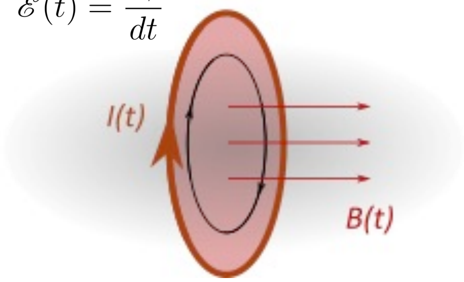

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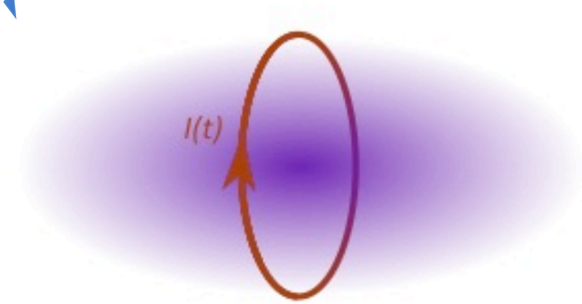

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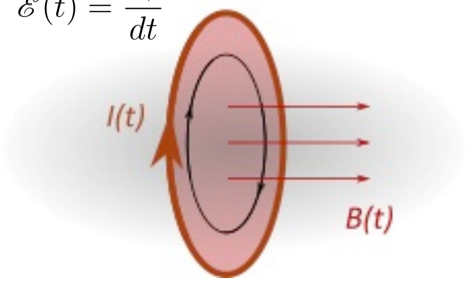

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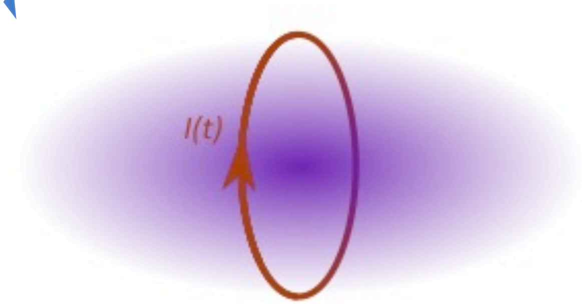
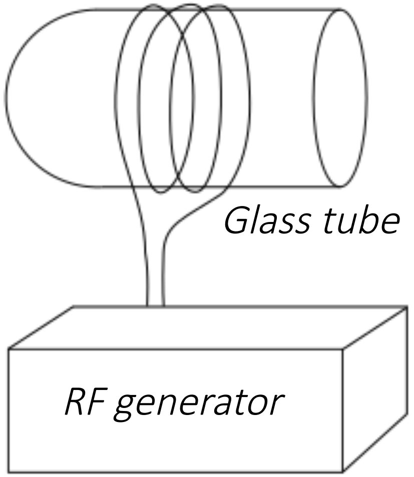
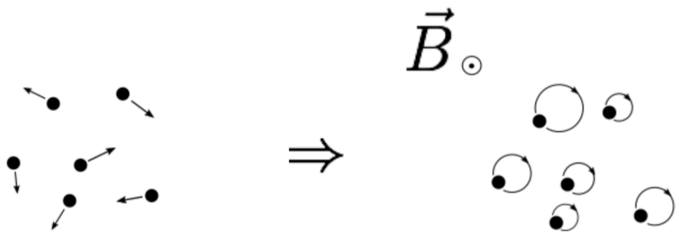




EXPERIMENTAL SET-UP – Let's **confine** some plasma …

Plasma + Magnetic field $\longrightarrow$ 2D confinement



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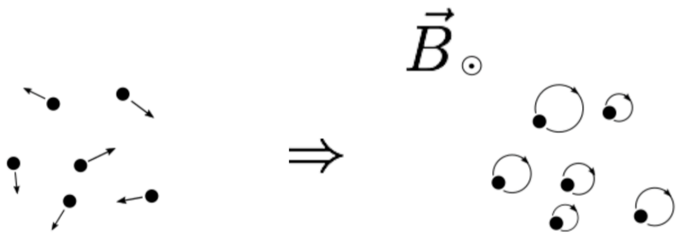

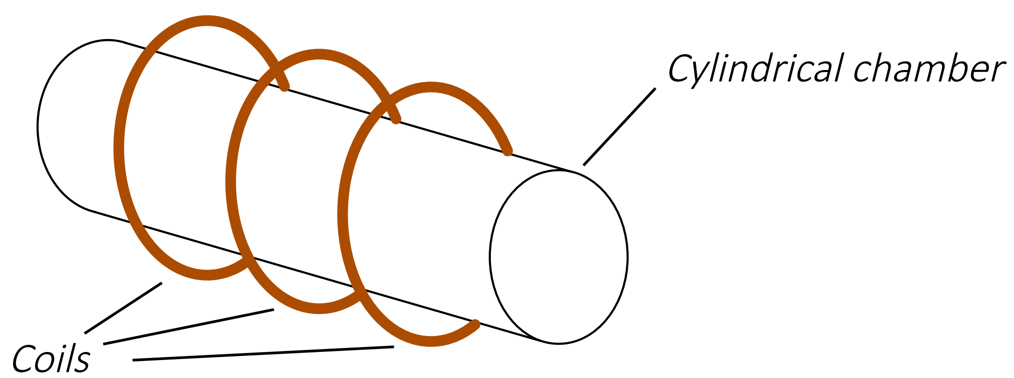

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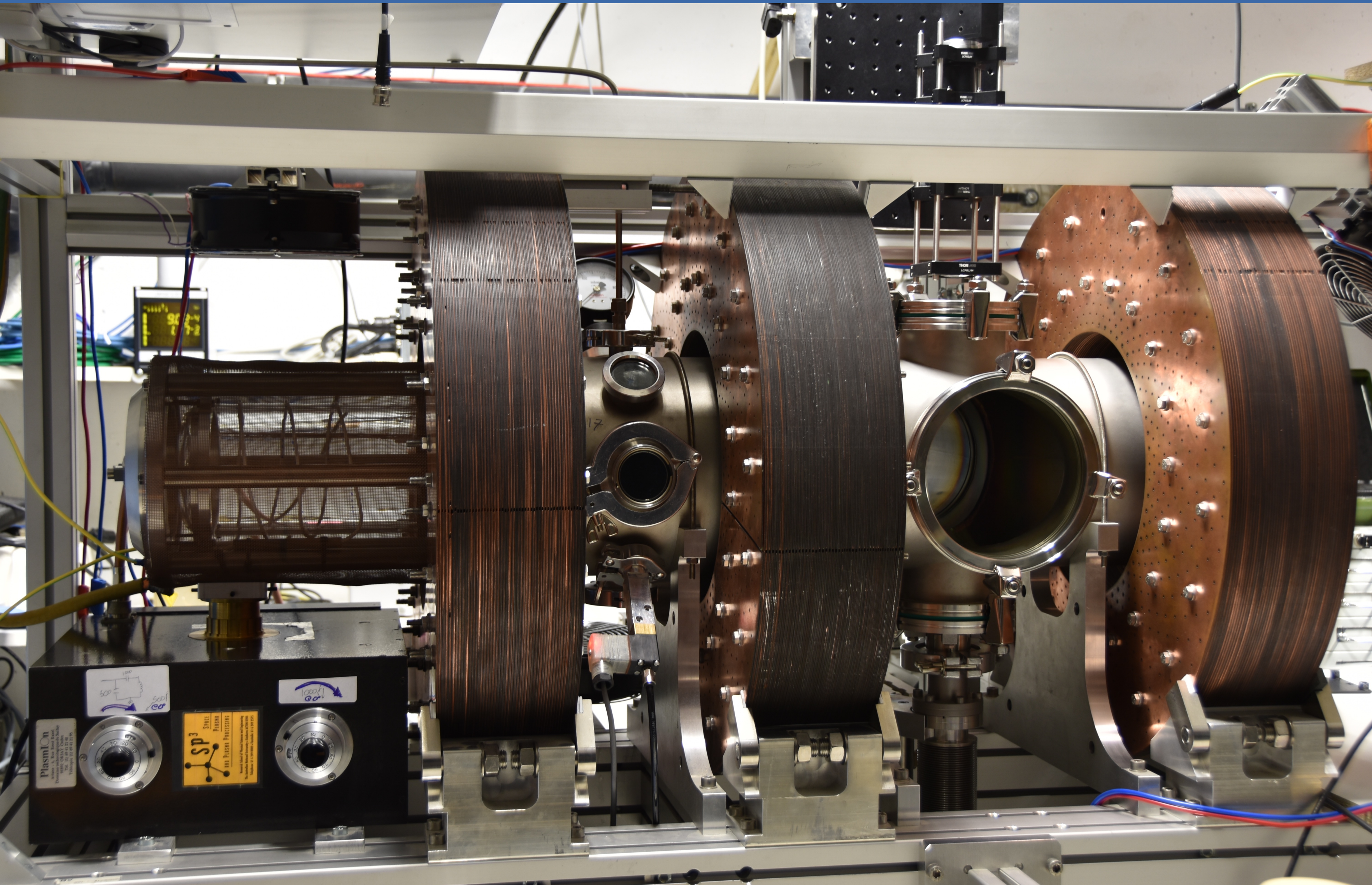

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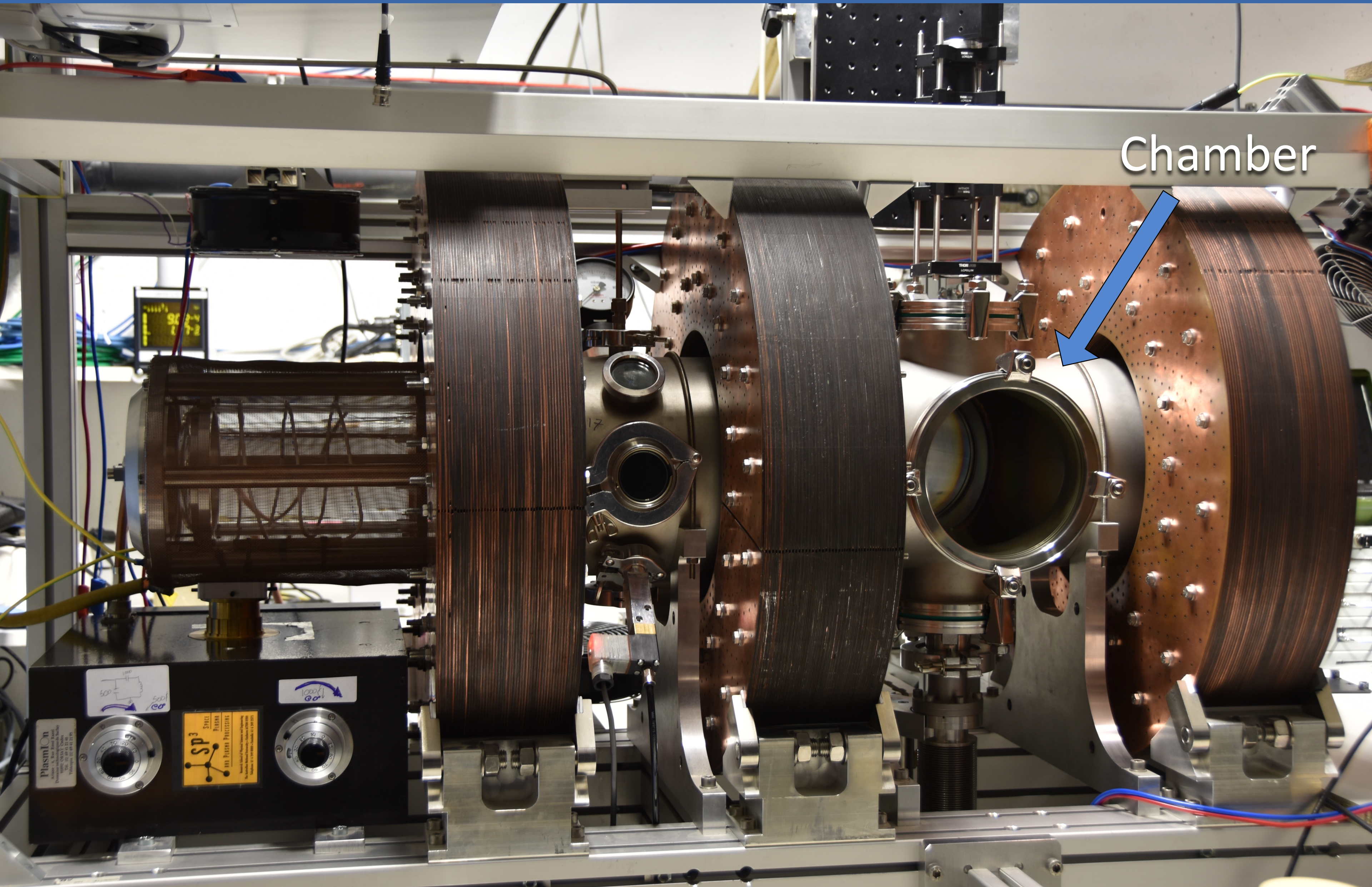

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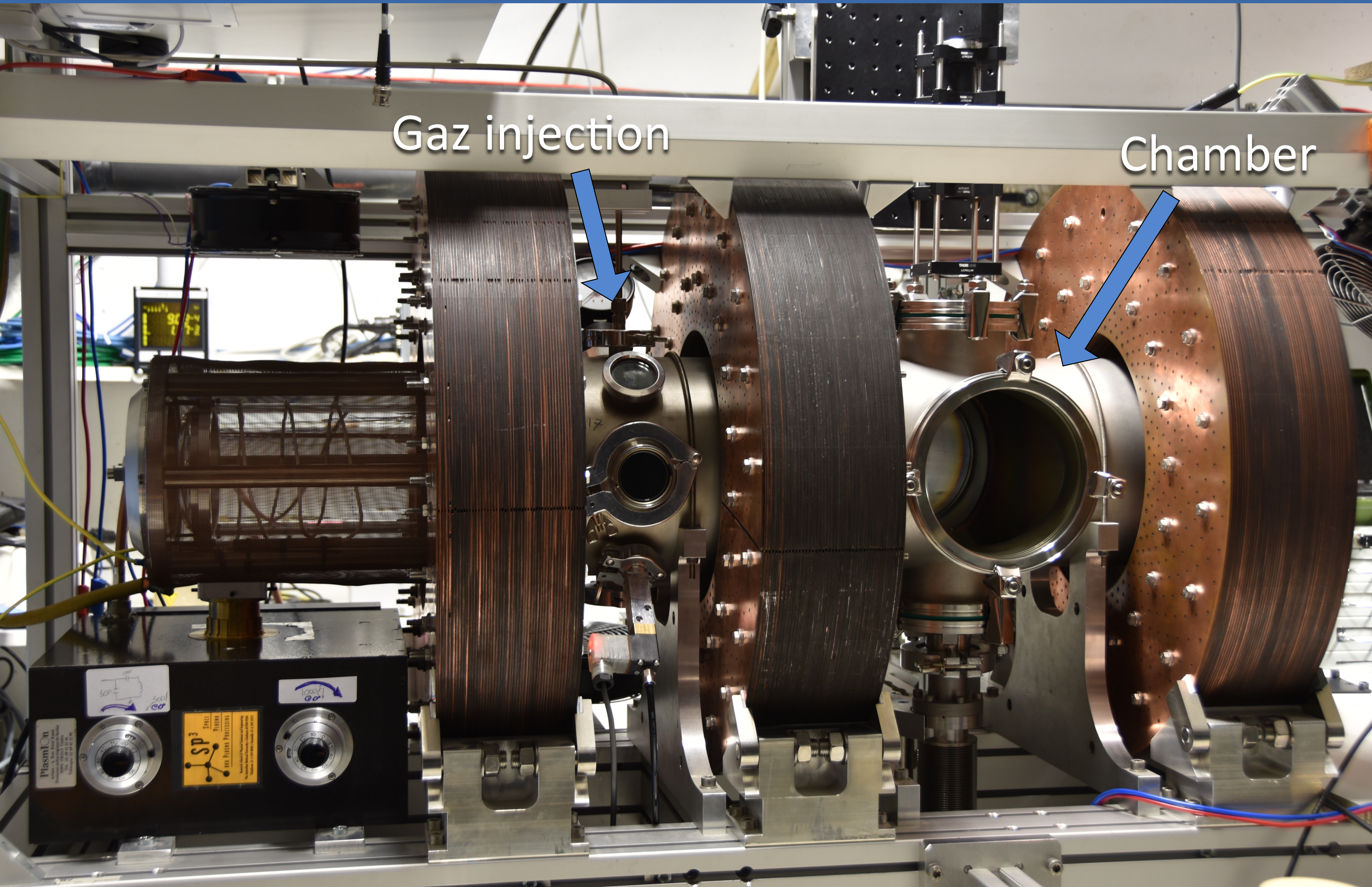

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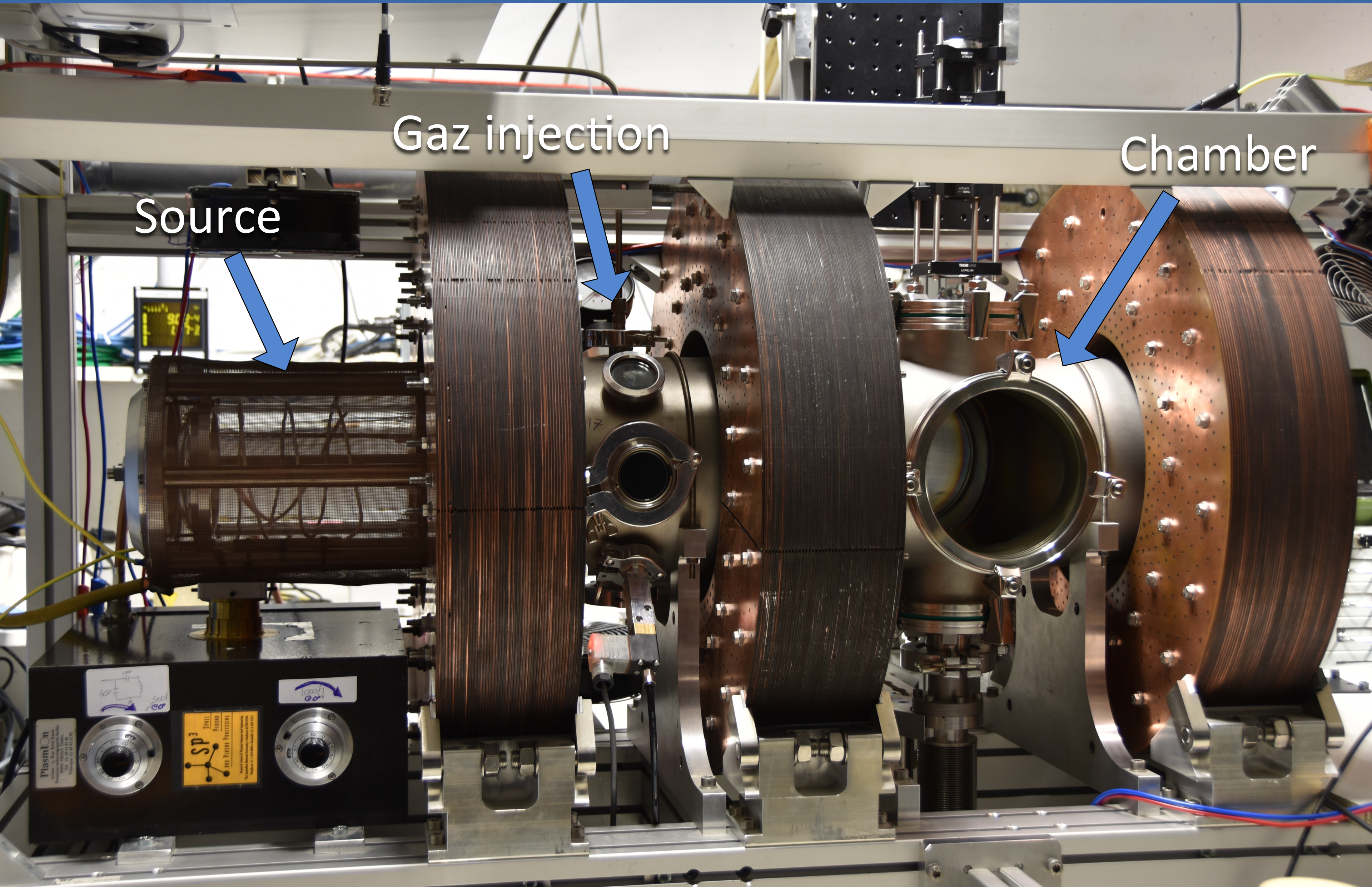

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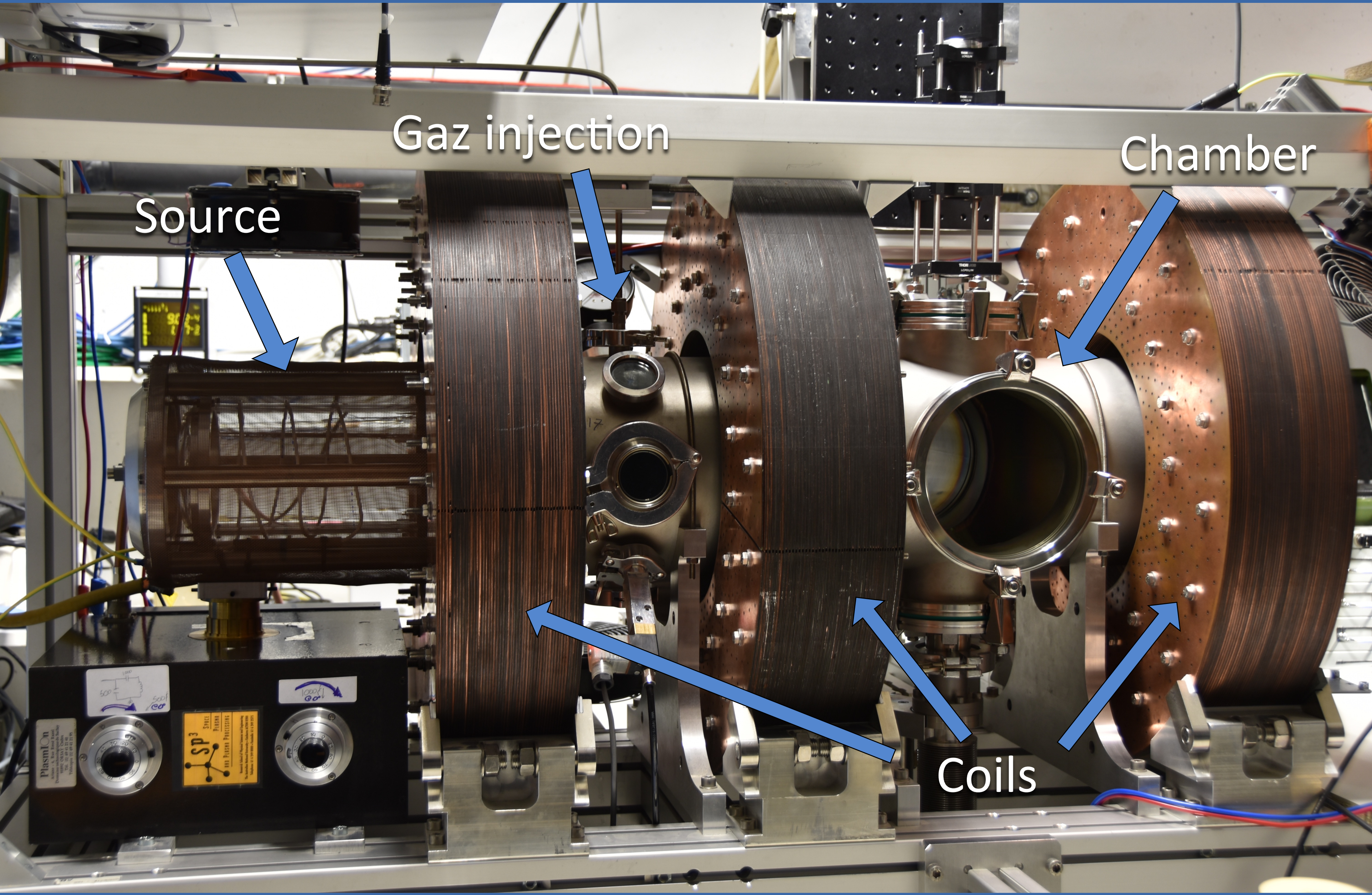

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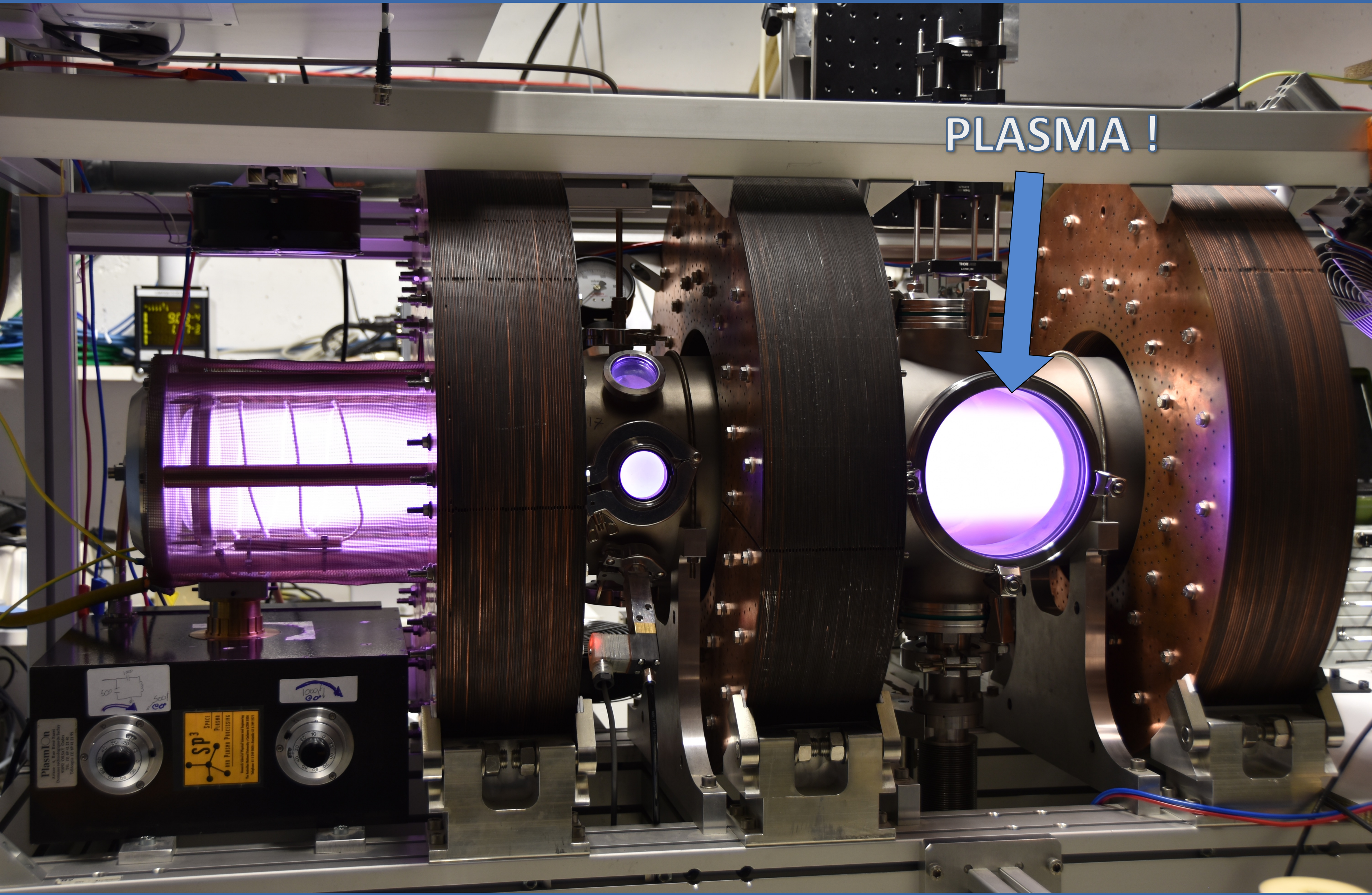

WHY ?

WHY ? – Thermonuclear fusion

Stars : energy production by fusion reactions

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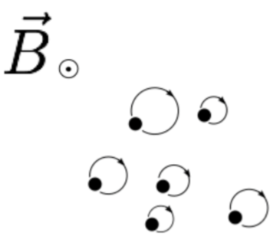

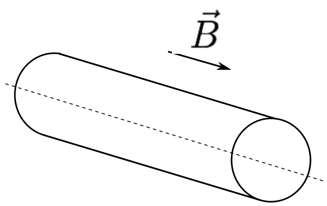

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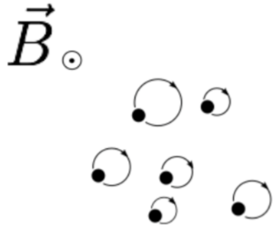
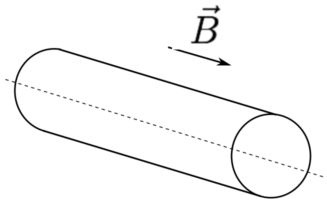
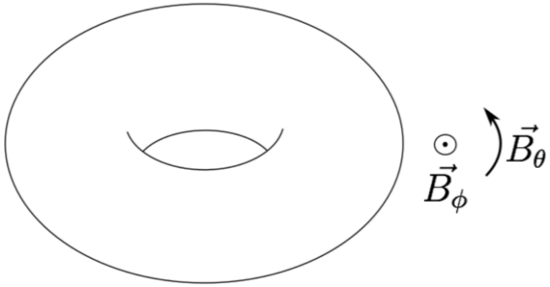


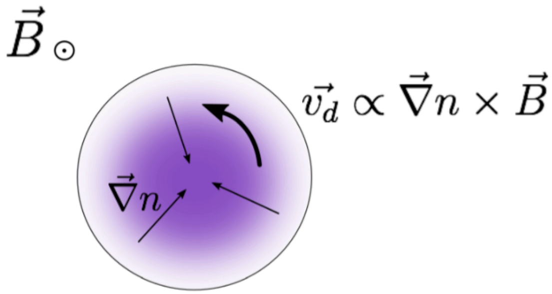


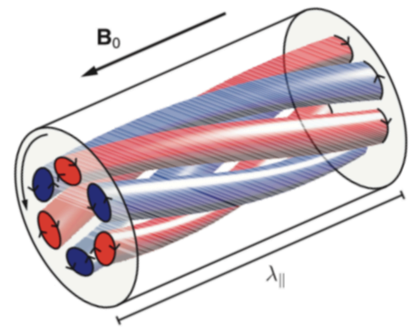


« Tokamak »

WHY ? – Drift waves

Drift waves come from : Density gradient + B





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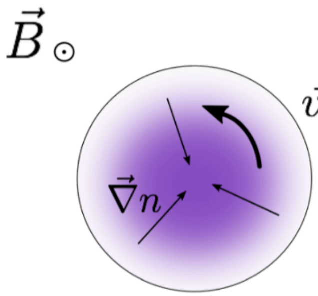
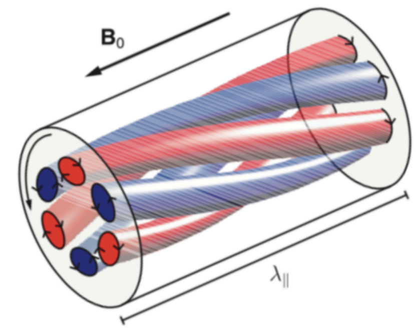
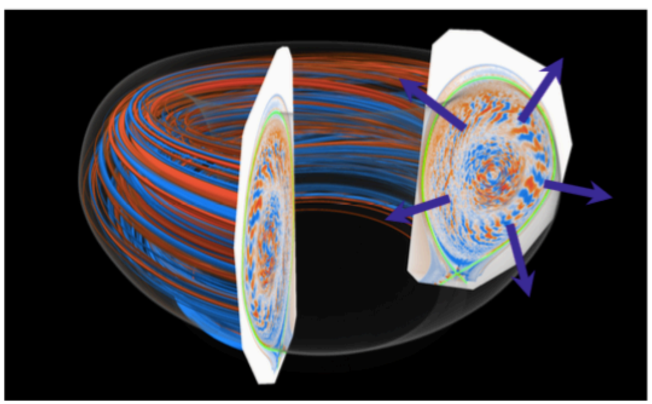


$\vec{v_d} \propto \vec{\nabla} n \times \vec{B}$



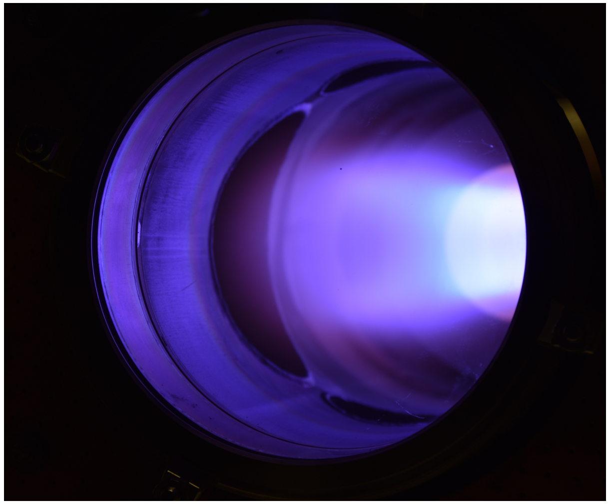
→ Turbulent transport

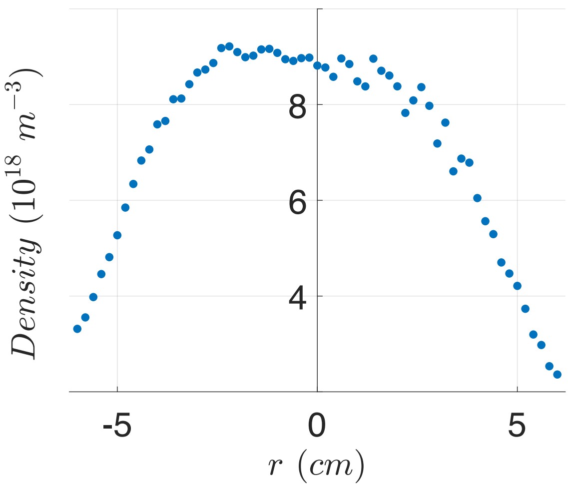


C.S. Chang, Princeton Plasma Physics Lab

$$\langle \Gamma_r \rangle = \langle n \rangle . \langle v_r \rangle + \underbrace{\langle \widetilde{n}\, \widetilde{v_r} \rangle}_{\textit{dominant}}$$

WHY ? – Link to our plasma column





$$P_W \sim 1 \text{ kW}$$
$$B \in [100, 1600] \text{ G}$$

$$p_0 \sim 10^{-6} \text{ atm}$$
$$n \sim 10^{18}\ m^{-3}$$
$$T_e \sim 4 \text{ eV}$$

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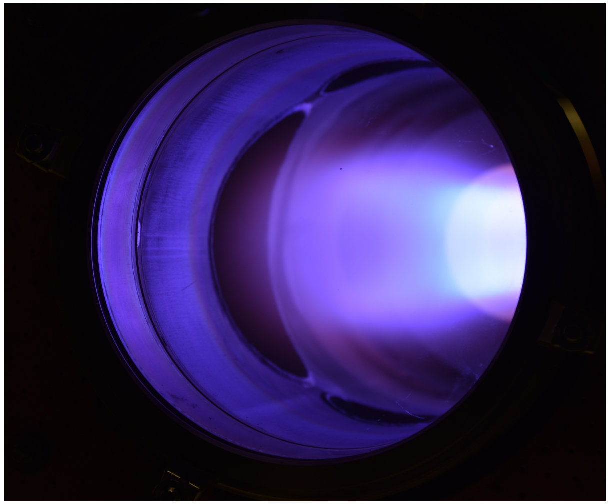

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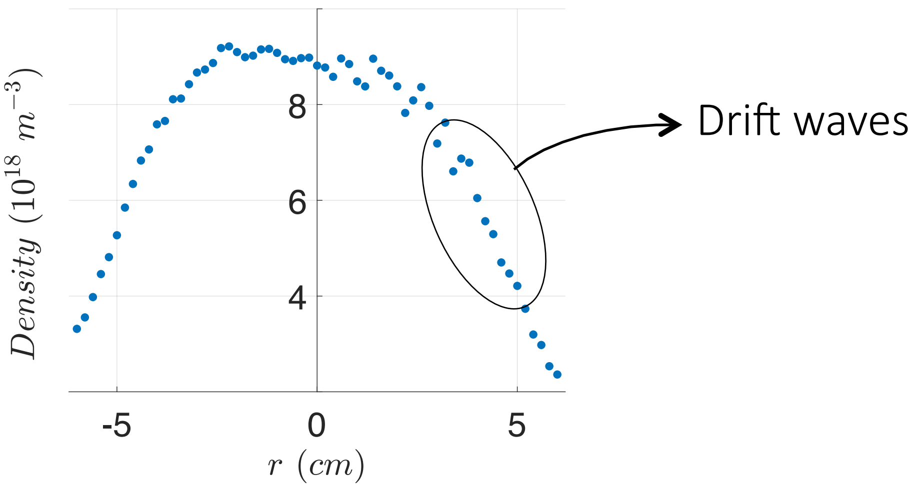
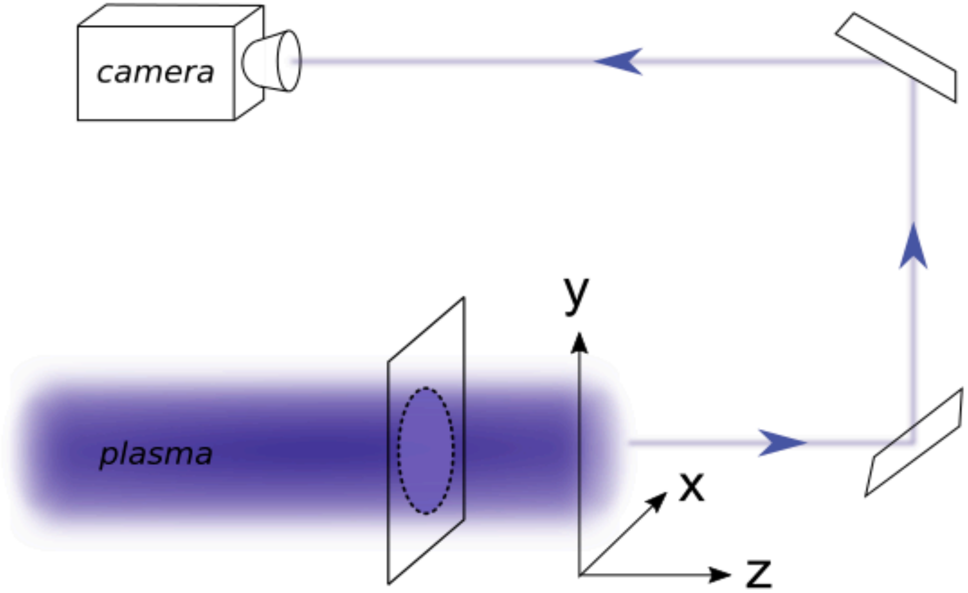


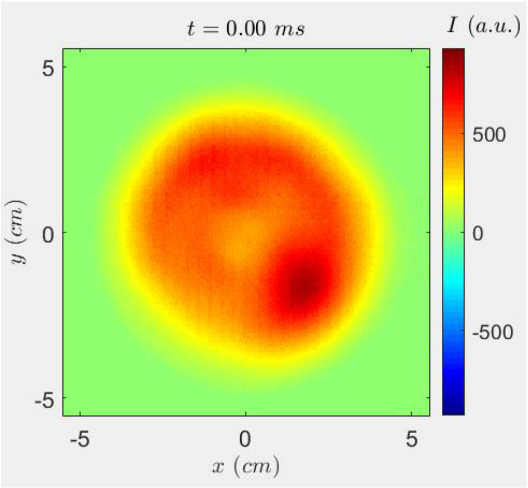
DETECTING DRIFT WAVES

DETECTING DRIFT WAVES – Fast camera imaging

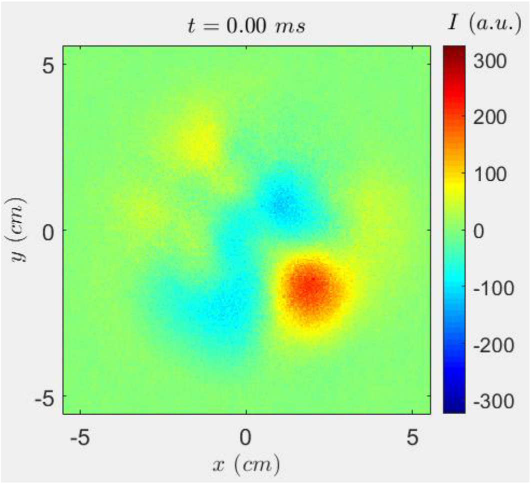


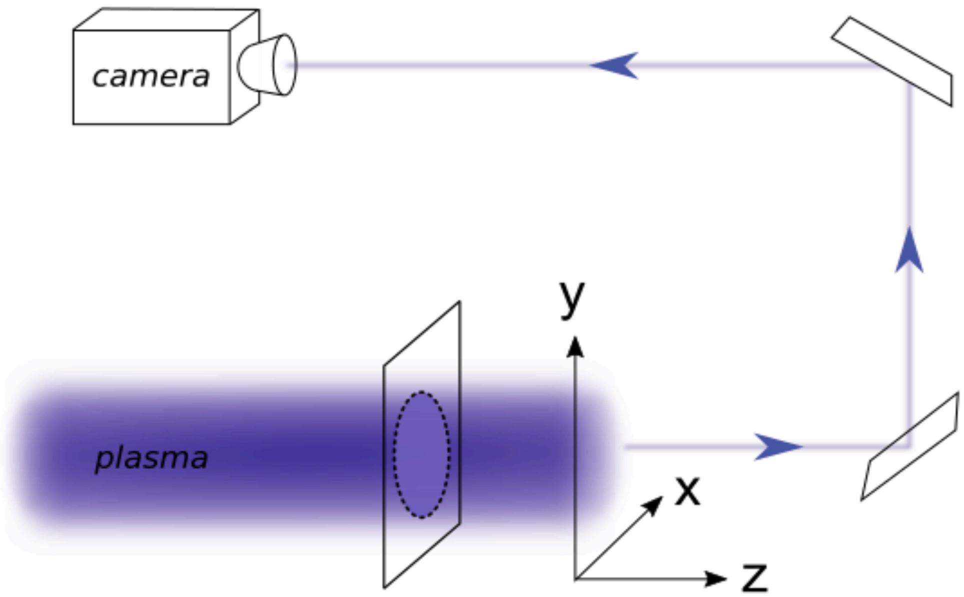
Acquisition frequency : 200 000 Hz
Resolution : 256x256 px

Light intensity



Fluctuations



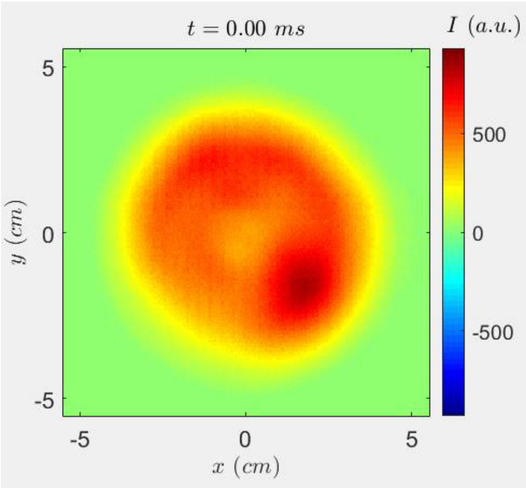


Acquisition frequency : 200 000 Hz
Resolution : 256x256 px

$\tilde{I} \propto \tilde{n}$ (Oldenbürger *et al.* 2010)

→ Observation of density fluctuations

Light intensity



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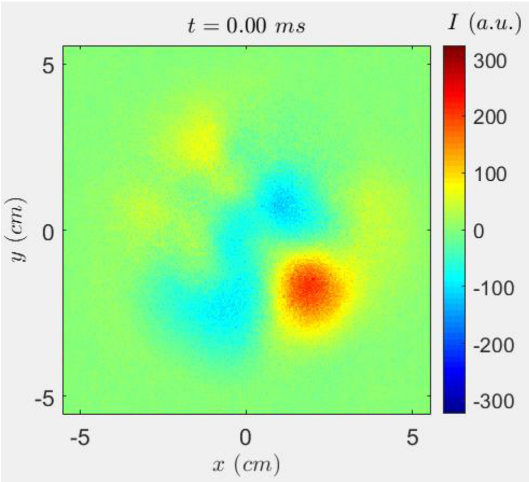
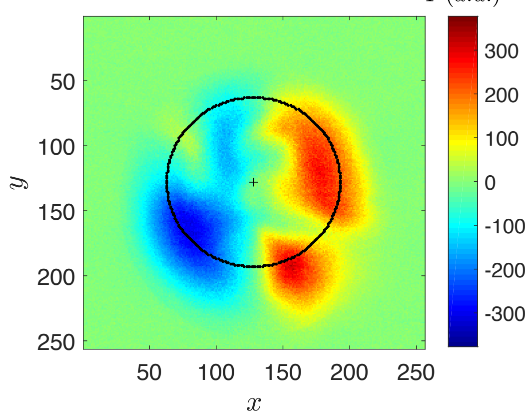
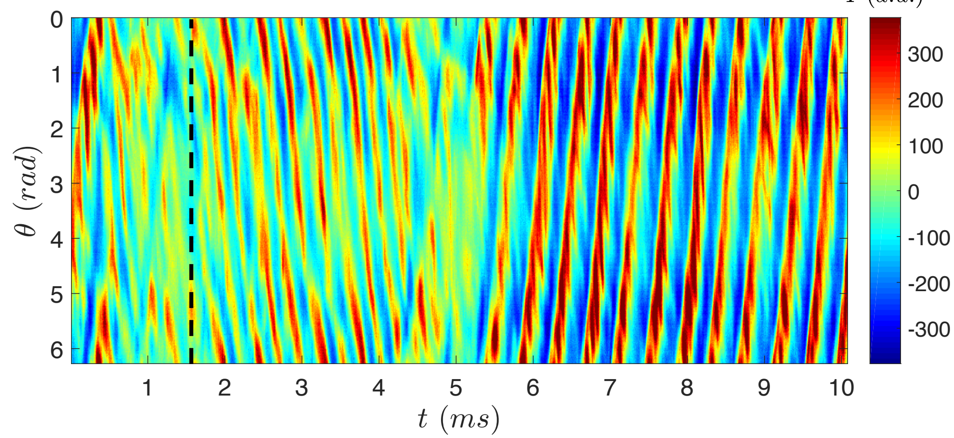


DETECTING DRIFT WAVES – 2D Fourier Transform

Snapshot



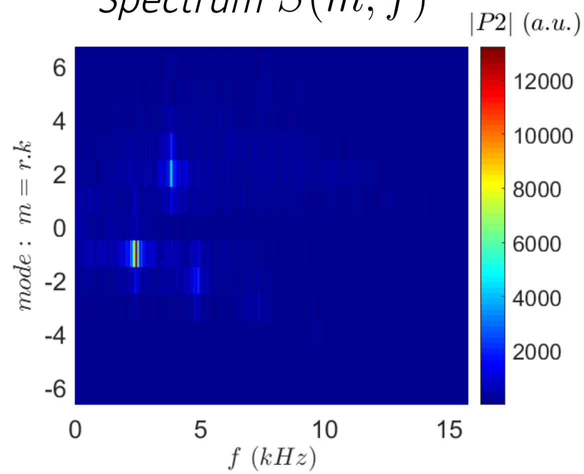
Temporal fluctuations $I(\theta, t)$



2D - FT

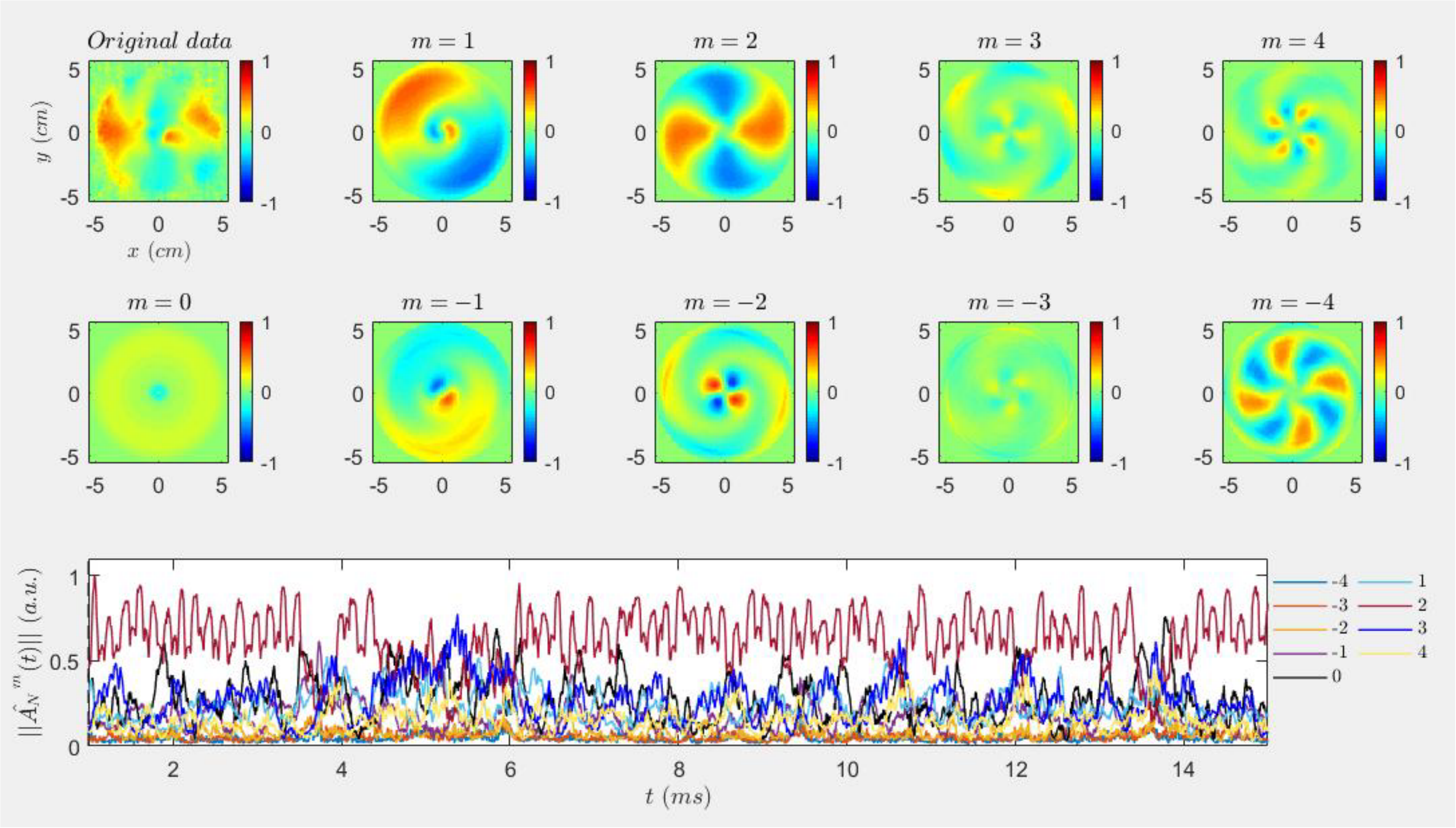
Spectrum $S(m, f)$

For each radius R:



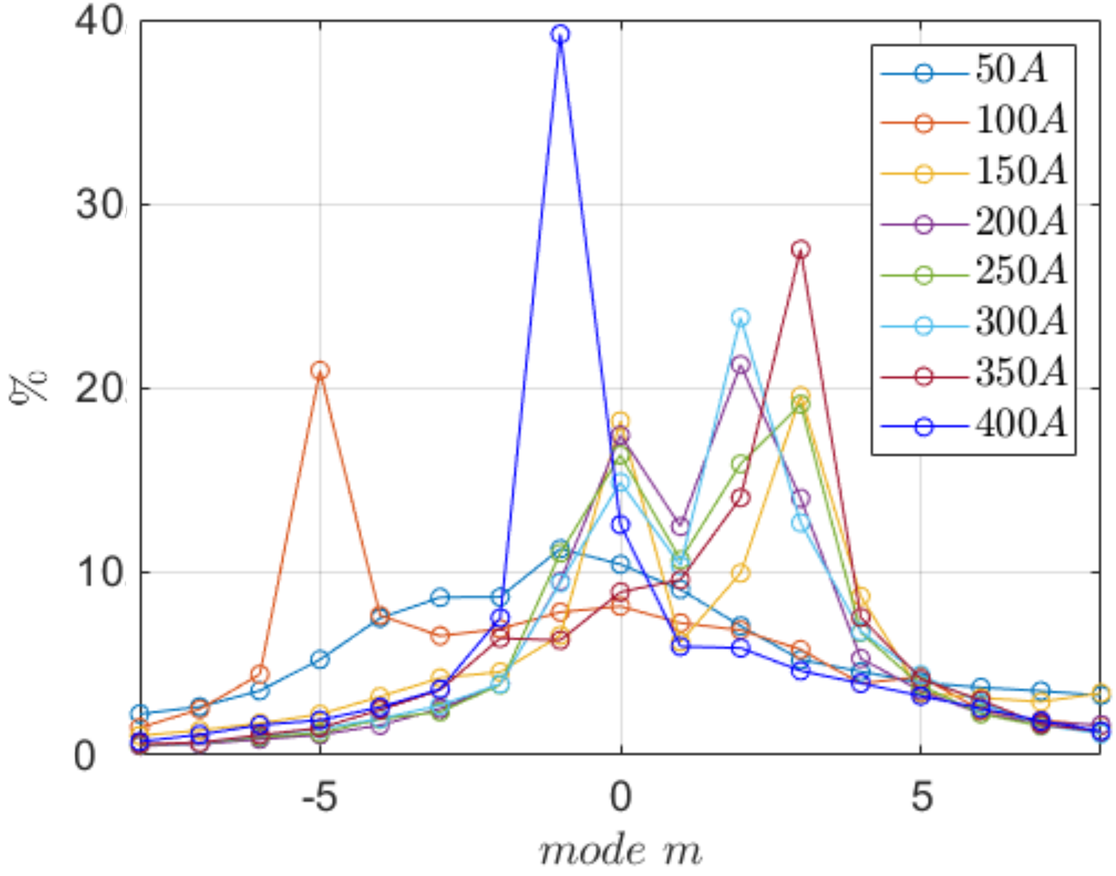
DETECTING DRIFT WAVES – 2D Fourier Transform

Time evolution of m-modes amplitudes (B = 360 G)



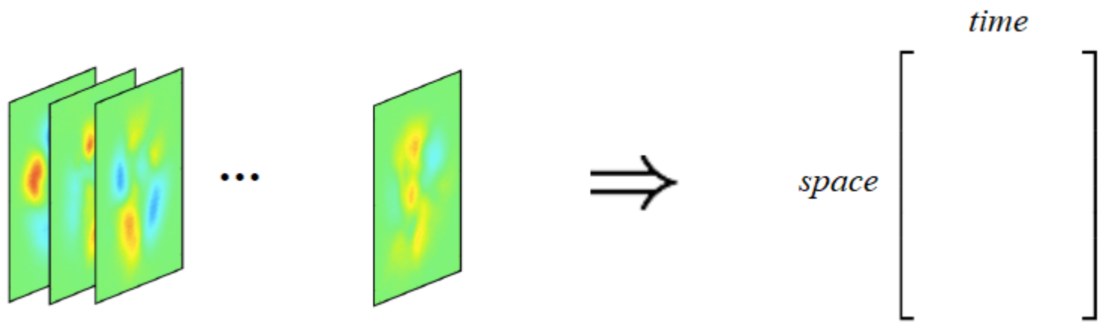
DETECTING DRIFT WAVES – 2D Fourier Transform

Average amplitude of the modes



DETECTING DRIFT WAVES – Proper Orthogonal Decomposition

Rearrange data :



Perform a **Singular Value** decomposition :

$$\text{Space}\left\{\overbrace{\begin{bmatrix} & & \\ & (A)_{ij} & \\ & & \end{bmatrix}}^{\text{Time}}\right. = \begin{bmatrix} \vdots & \vdots & & \vdots \\ u_1 & u_2 & & u_m \\ \vdots & \vdots & & \vdots \end{bmatrix} \begin{bmatrix} \sigma_1 & & \\ & \ddots & \\ & & \sigma_n \end{bmatrix} \begin{bmatrix} \cdots & w_1^T & \cdots \\ \cdots & w_2^T & \cdots \\ & & \\ \cdots & w_n^T & \cdots \end{bmatrix}$$

Spatial modes

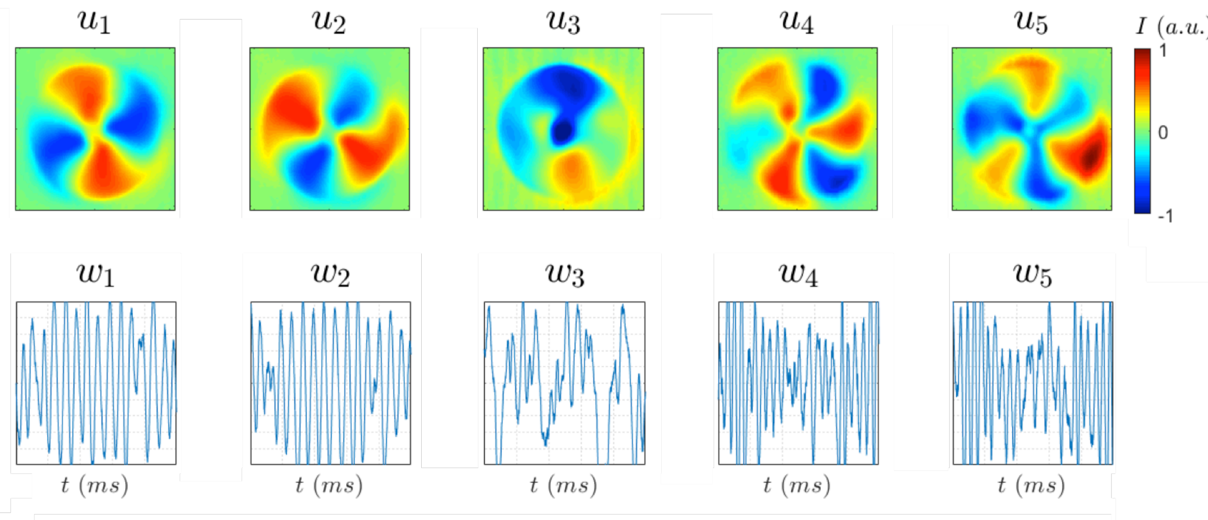
Singular values

Temporal modes

POD

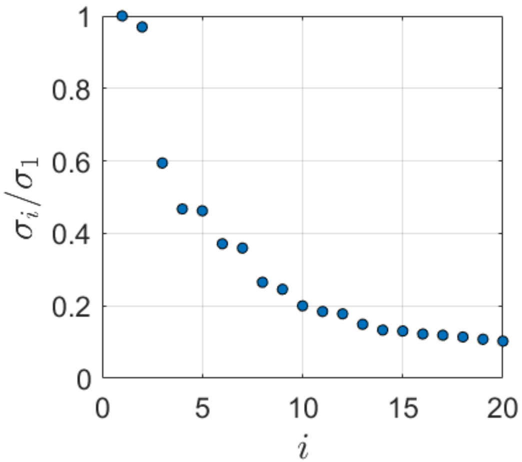
Spacial modes

Temporal modes



Singular values

(importance of the mode)

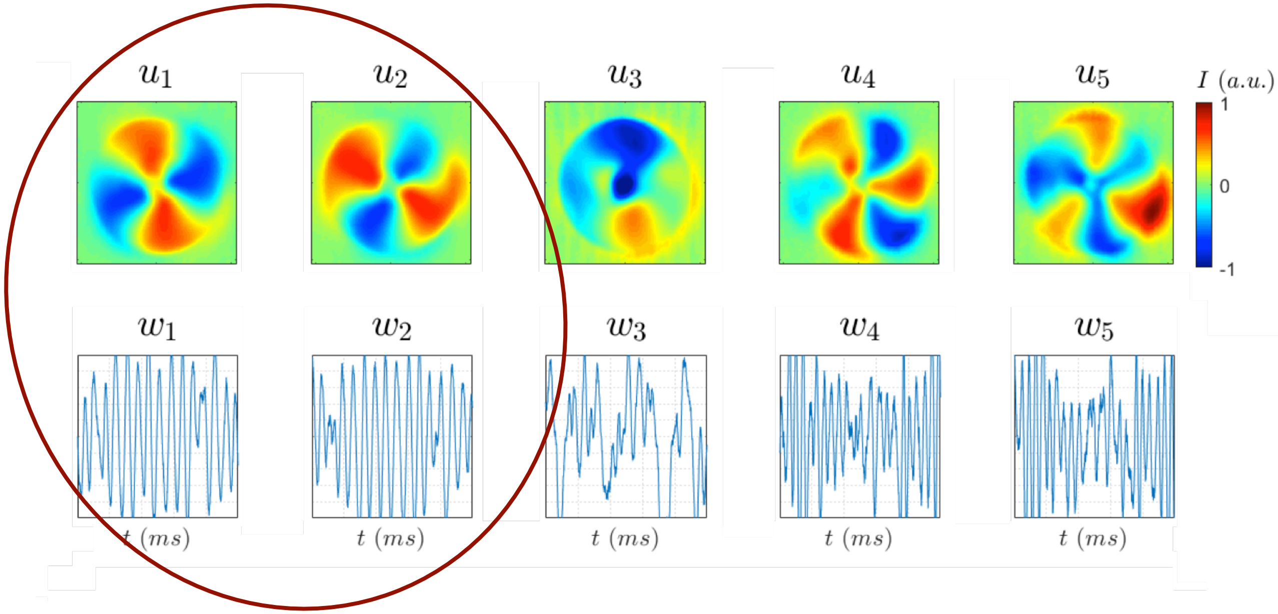


DETECTING DRIFT WAVES – Proper Orthogonal Decomposition

POD

Spacial modes

Temporal modes



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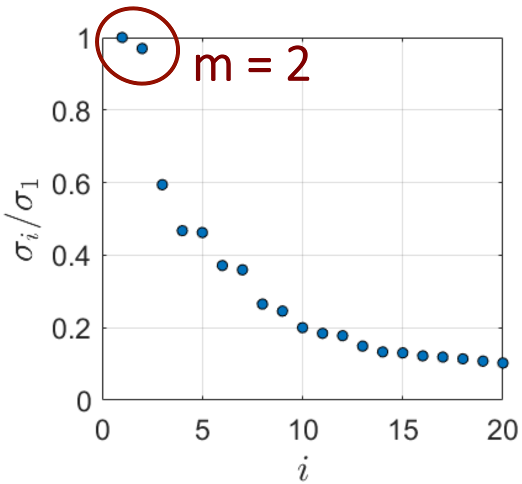

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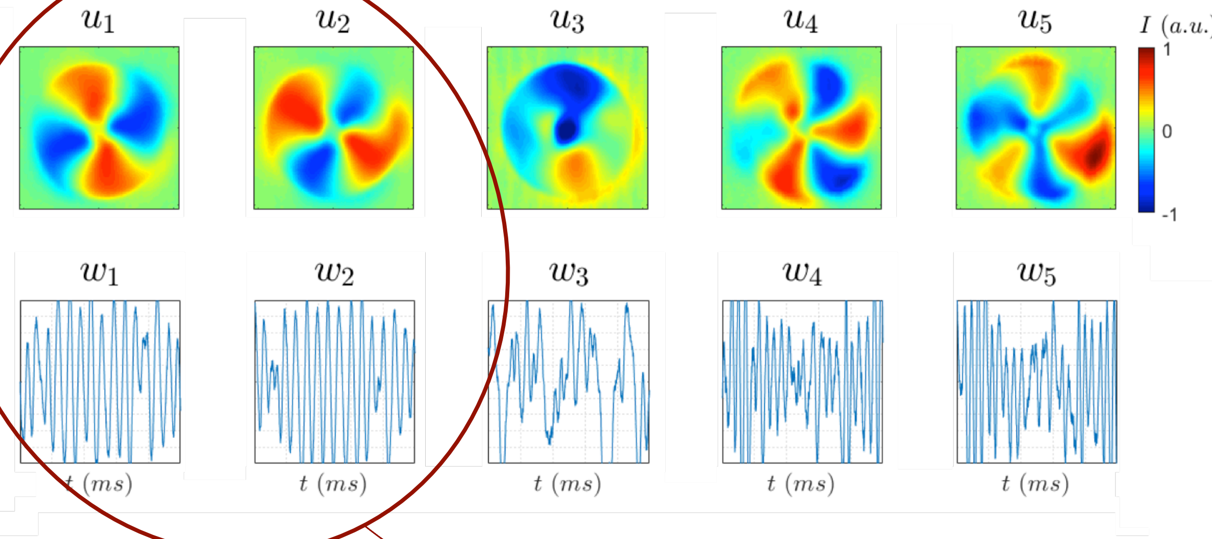

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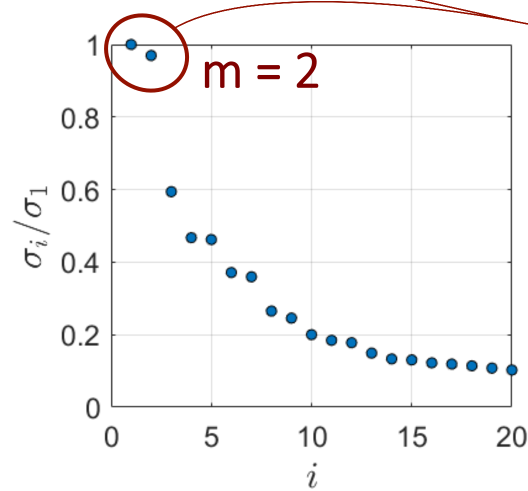
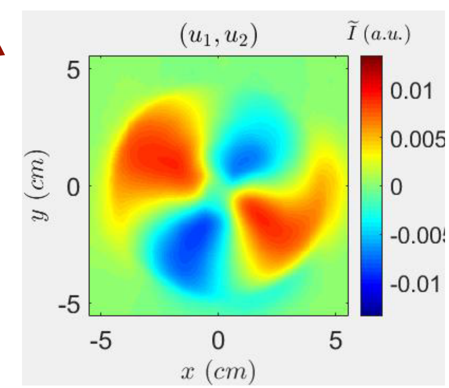
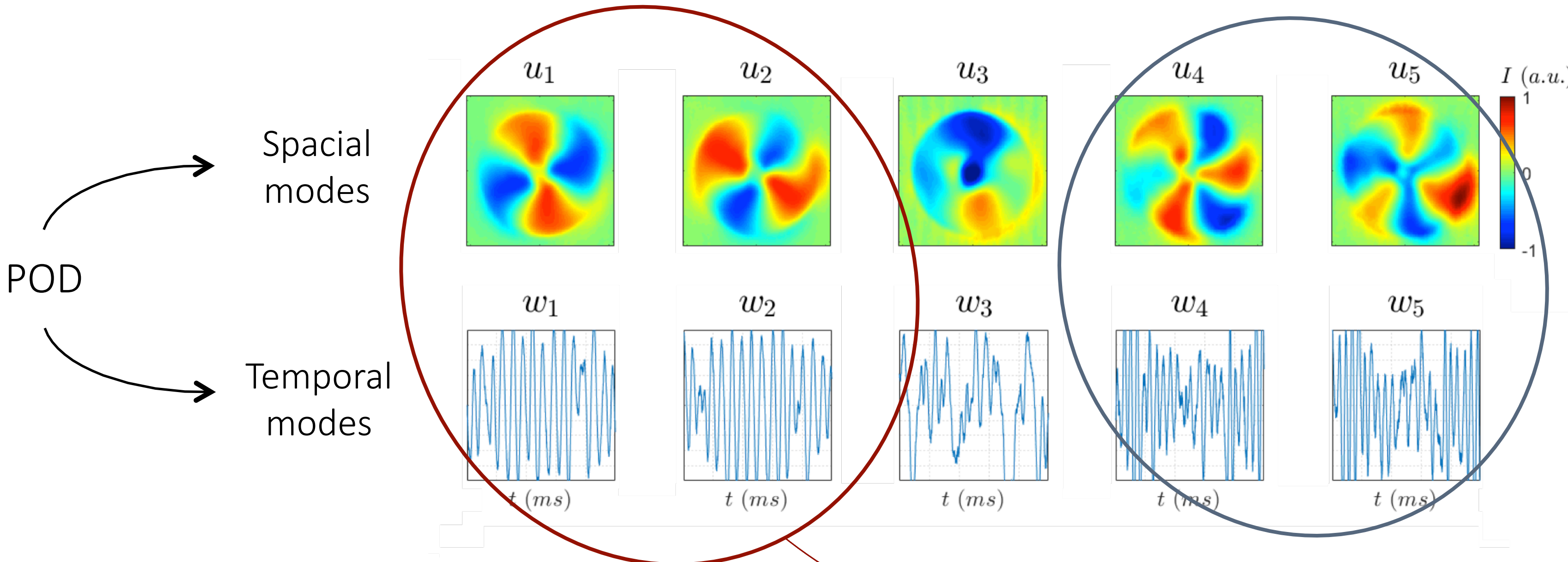


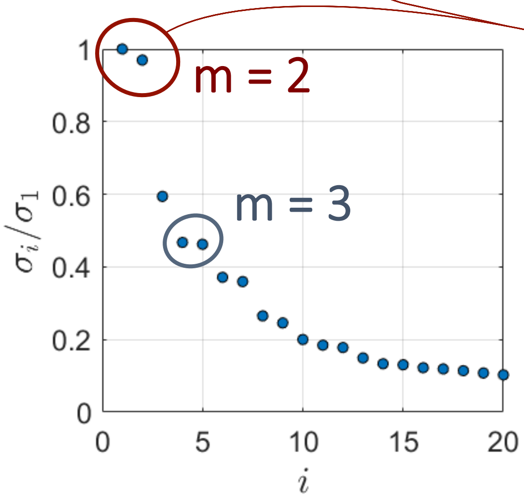


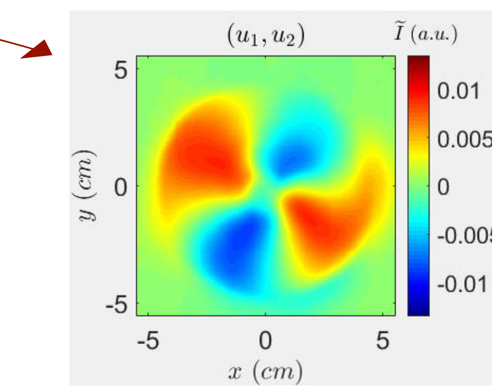
Reconstructed m-mode



Singular values

(importance of the mode)





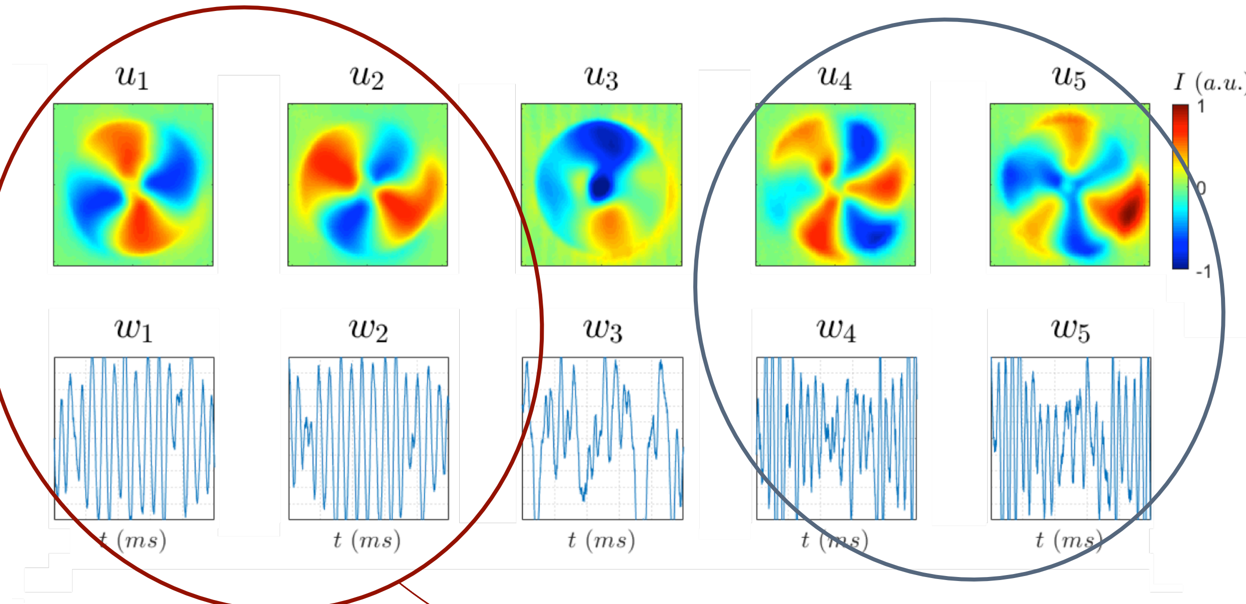
Reconstructed m-mode

DETECTING DRIFT WAVES – Proper Orthogonal Decomposition

POD

Spacial modes

Temporal modes



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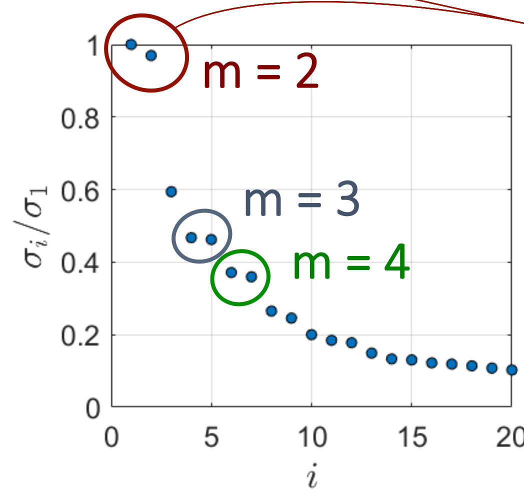
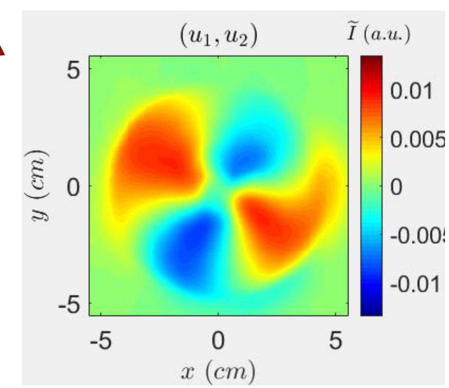
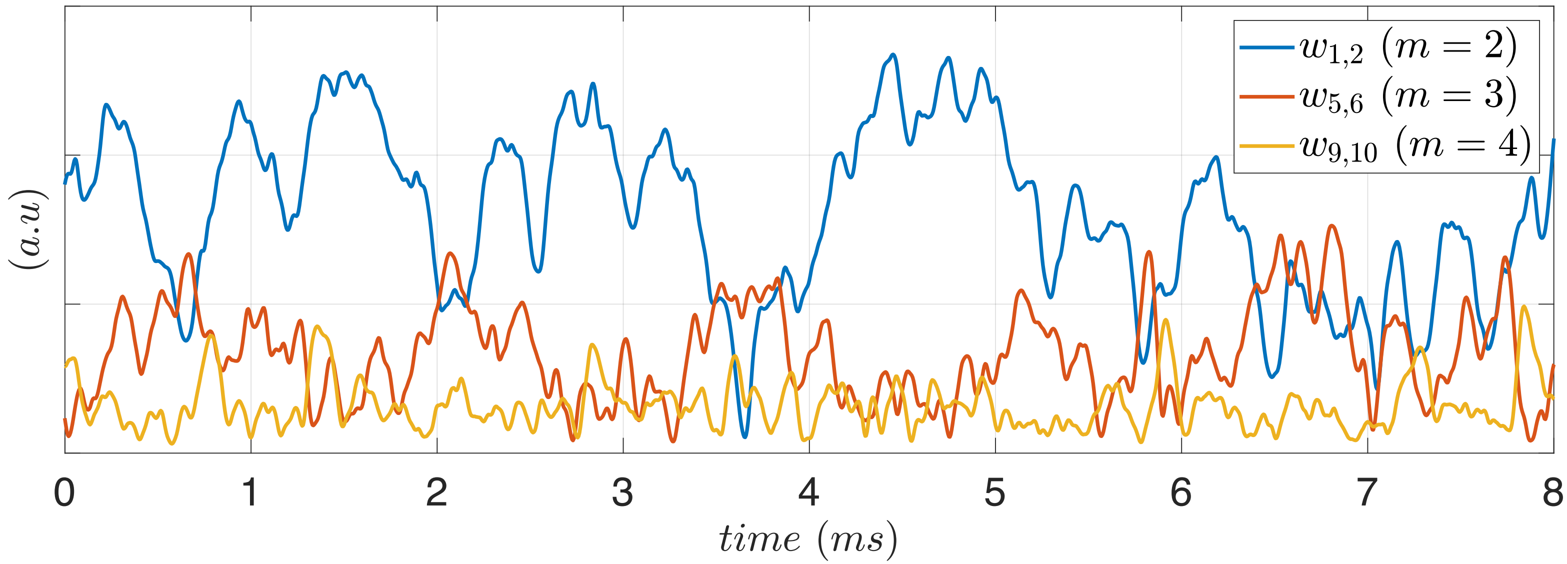




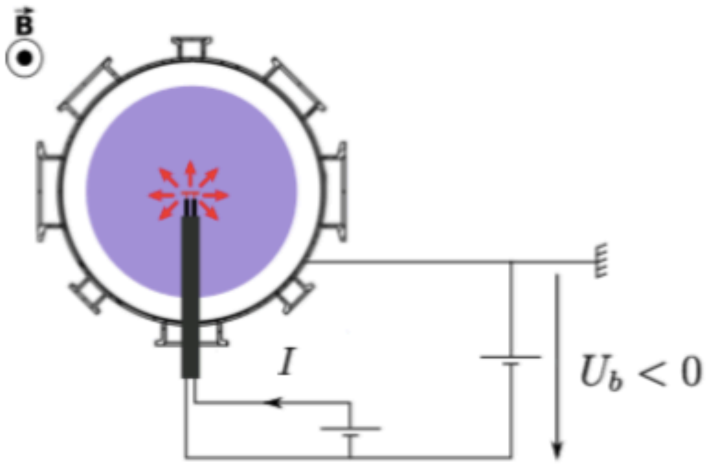
Reconstructed m-mode

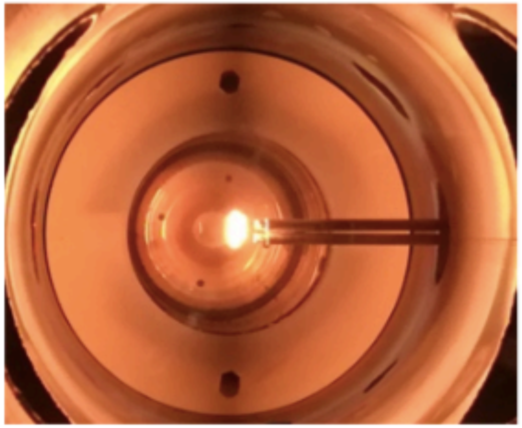
Mode interactions during time :



PLAYING WITH DRIFT WAVES

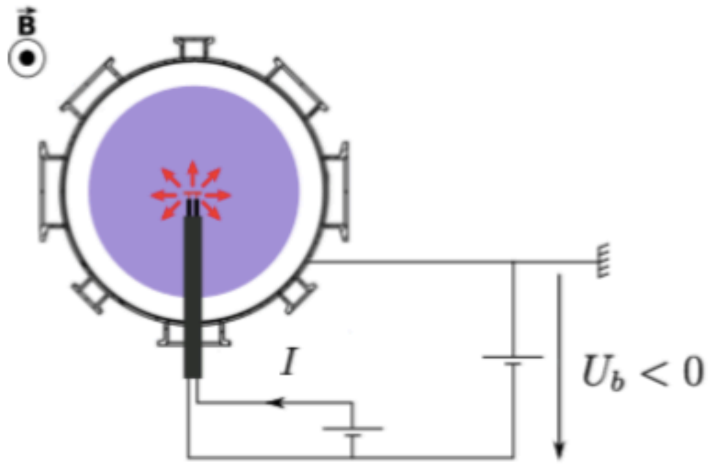
PLAYING WITH DRIFT WAVES – Emissive cathode

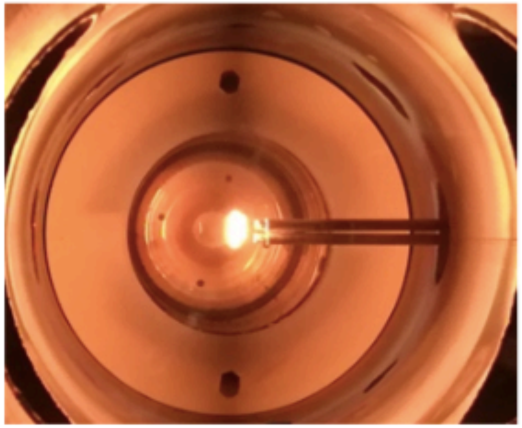




Hot cathode, without plasma

PLAYING WITH DRIFT WAVES – Emissive cathode

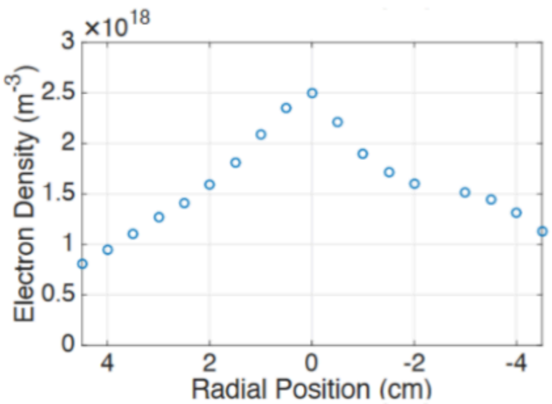




Hot cathode, without plasma

⟶ Modification of the velocity profile (phd thesis V. Desanglés)

⟶ Modification of the density profile

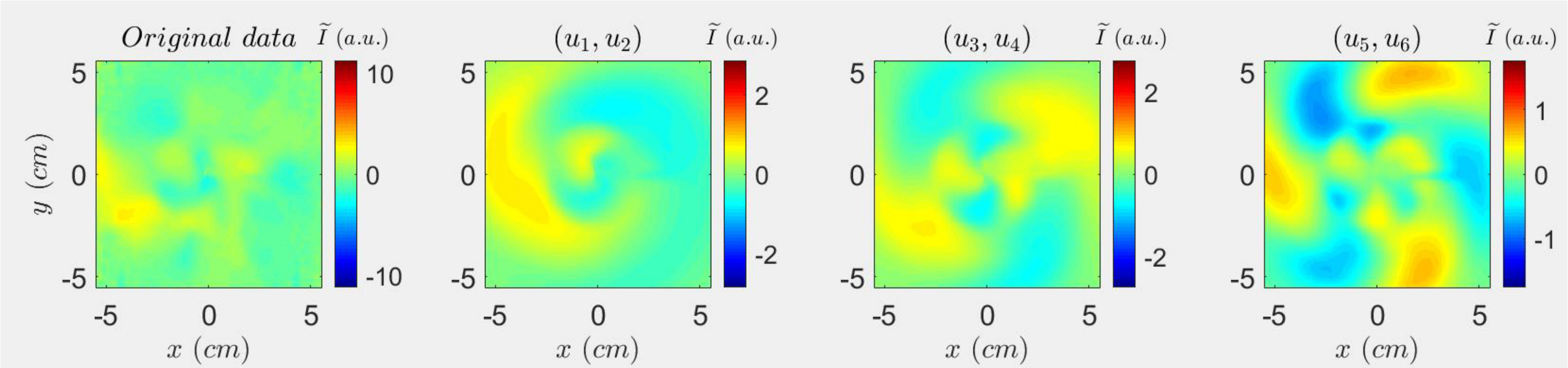


(Measure : V. Désangles)

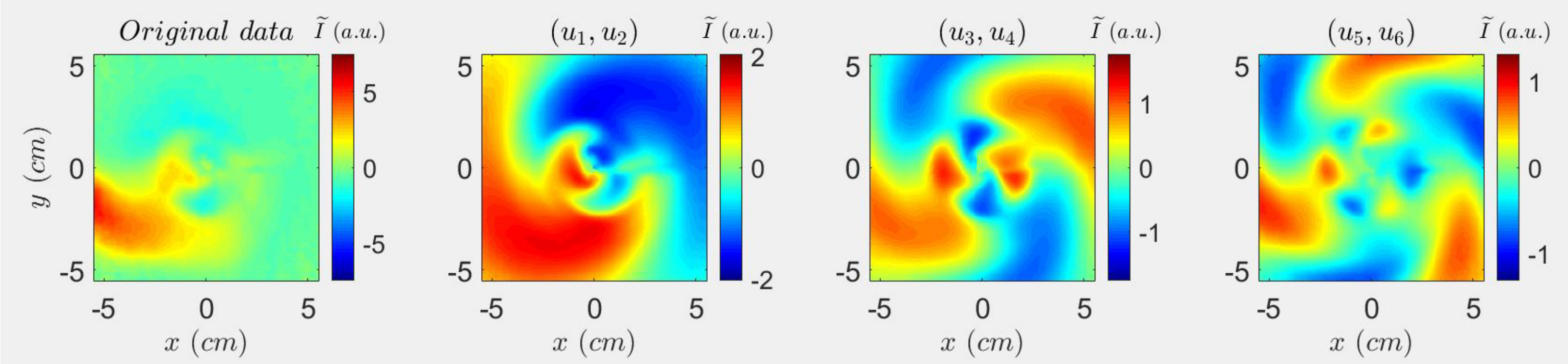
PLAYING WITH DRIFT WAVES – Emissive cathode

Density fluctuations & POD decomposition :

$I_{cathode}$: 10 A



$I_{cathode}$: 15 A

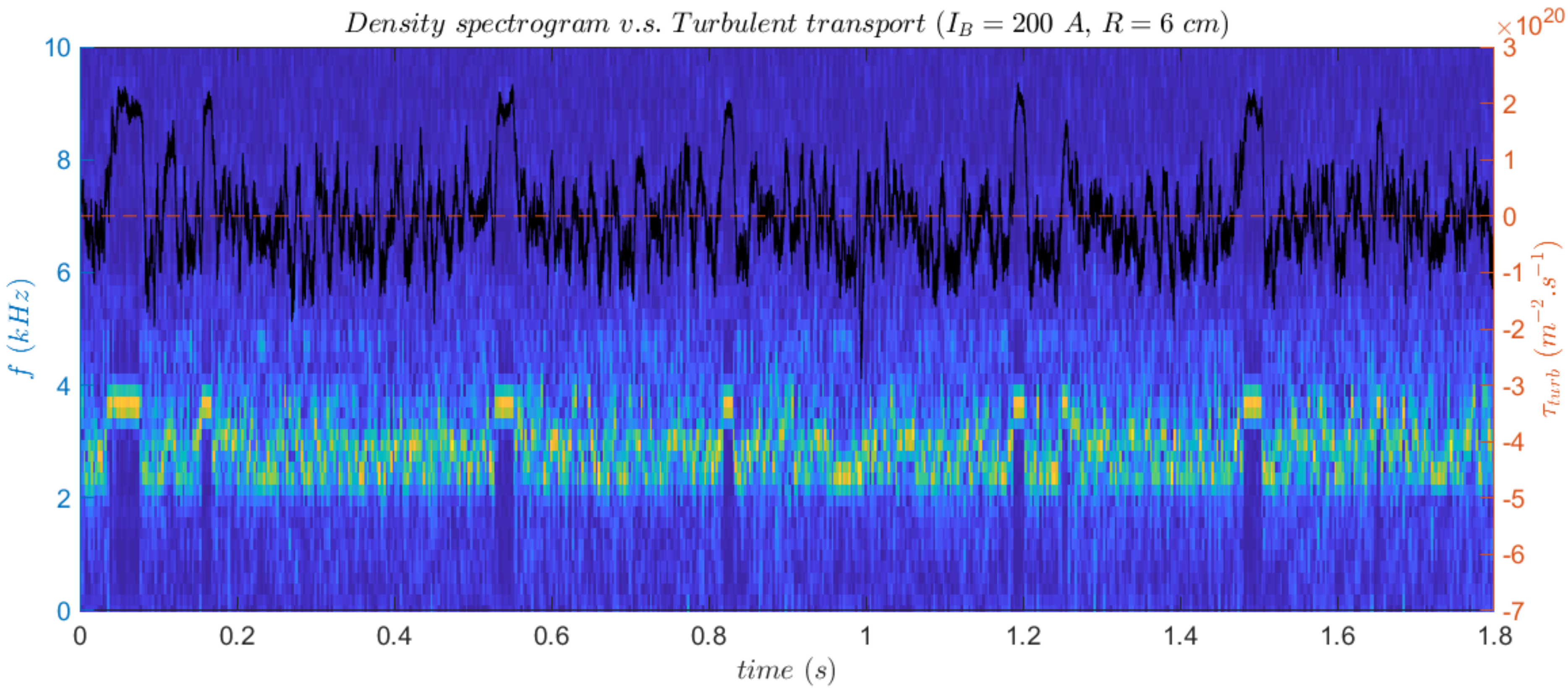


$\longrightarrow$ Apparition and enhancement of drift waves

PERSPECTIVES

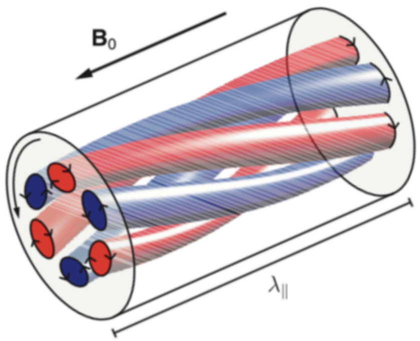
- Quantitative characterisation of the cathode's influence on DW

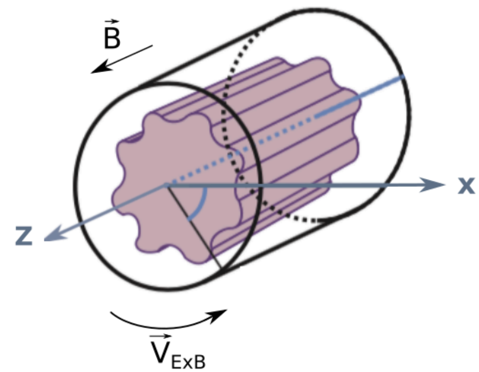
- Turbulent transport measurements

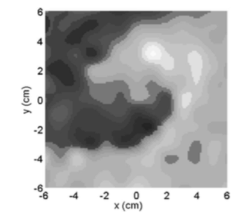


Low frequency waves

Drift wave	Rayleigh-Taylor	Kelvin-Helmholtz
Density gradient (+ B)	Centrifugal force (+ B)	Velocity shear (with or w/o B)







$$v_\phi^{DW*} = \frac{1}{1+k_\perp^2\rho_s^2} v_{d,e} + v_{E\times B}$$

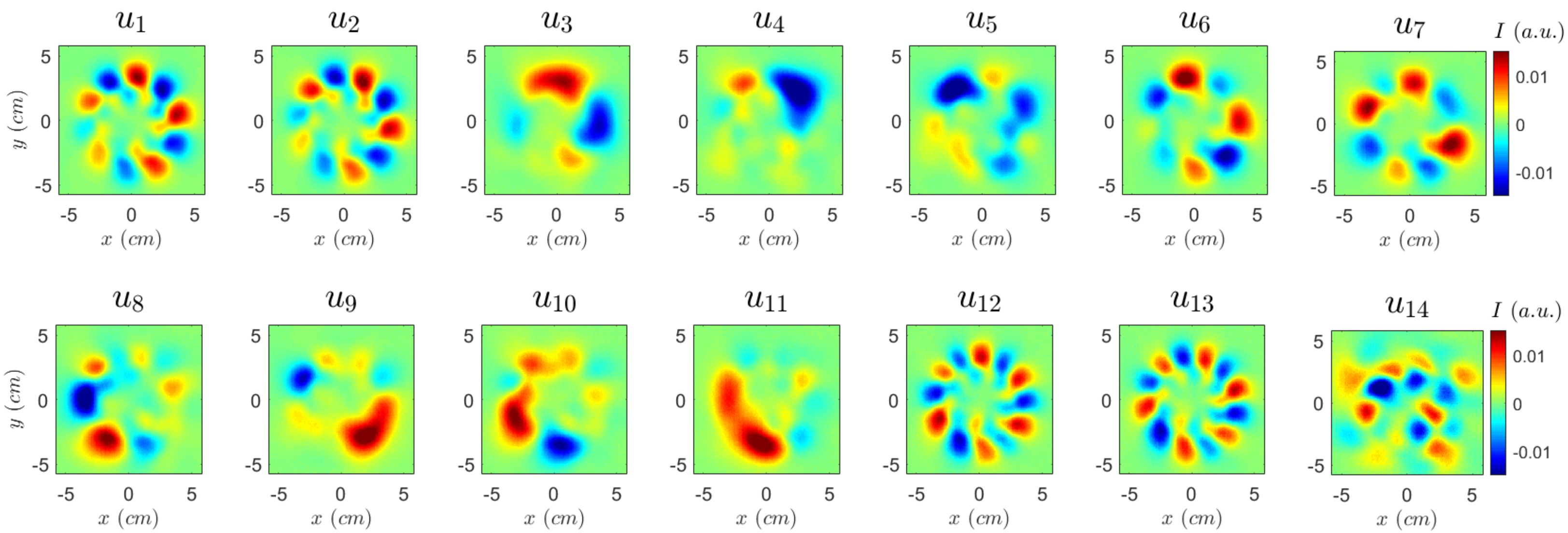
$$v_\phi^{RT} = v_{E\times B}$$

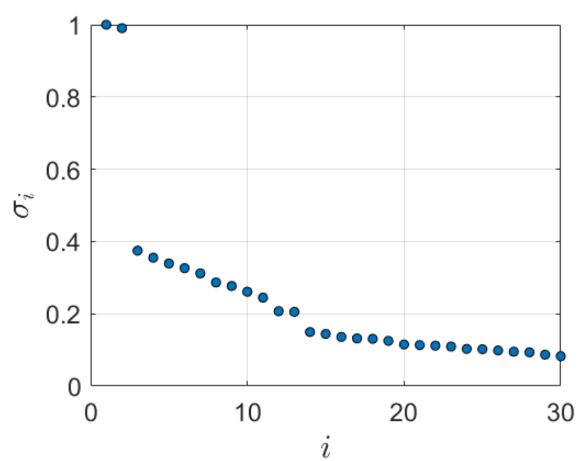
$$v_\phi^{KH} \propto (0.2\text{-}0.6) v_{E\times B}$$

(images : thesis C. Brandt, thesis S. Oldenbürger, Brochard et al. 2005)

MODES IDENTIFICATION – Low magnetic field (250 G)

POD results :





(adequation POD / FT-2D)