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Spectral dependencies of **GHz electromagnetic emission** from **Hall thrusters**

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CONTEXT

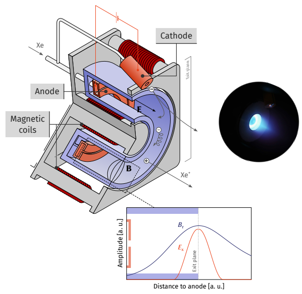
- **Pulsed electromagnetic emission** from Hall thrusters in the **GHz range**
- Unclear **physical origin**
- Source of electromagnetic **noise**

- Where does this emission **come from ?** Is it **independant** from the **discharge dynamics** ?

→ Investigations of a **connection** with **low-frequency oscillations** of the discharge

Hall thruster

- **Most proven technology** for **electric propulsion** of satellites
- **Thrust** generated by **acceleration of ions**

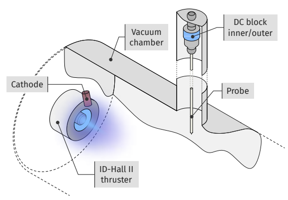


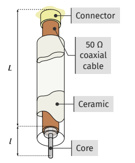
- Combination of **E** ⊥ **B** : **closed electron drift** with velocity :

$$V_d = \frac{\|\mathbf{E}\times\mathbf{B}\|}{B^2} \simeq \frac{E_x}{B_r}$$

Experimental setup

- **ID-HALL II** [1] double-stage Hall thruster, used in **single stage** operation





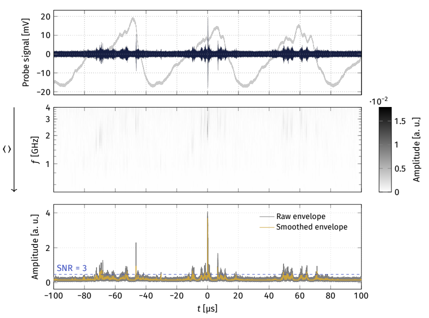
- Detector is an **open-ended coaxial cable** [2], positioned **inside the metallic vacuum chamber**
- Acts as an **electrically small antenna** on a]0,4] GHz range
- Simultaneous recording of : **probe signal** and **discharge current** I_d

Data processing

- Time-frequency analysis based on **Continuous Wavelet Transform** (CWT)
- Adapted to **2 different objectives**

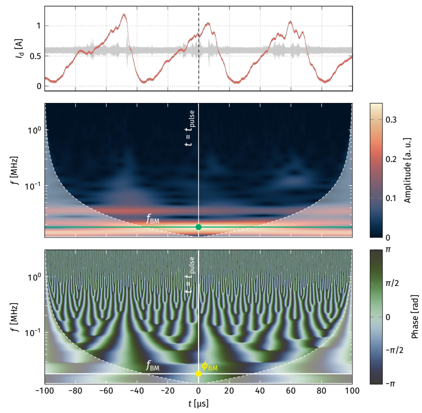
Pulse detection

- Detection based on the **HF envelope** of the probe signal
- **Threshold** for detection following a fixed value of **Signal to Noise Ratio** (SNR)



Phase retrieval of *Breathing Mode*

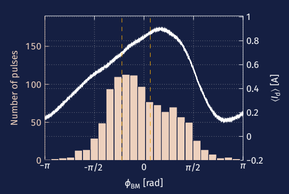
- **Amplitude** of CWT gives the value of the **BM frequency** when a pulse occurs
- The **phase of the BM** ϕ_{BM} is retrieved from the **argument of CWT** at the same time and BM frequency



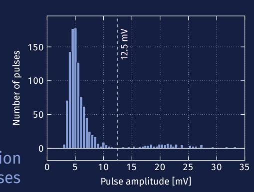
Main findings

- Recorded **99** samples of 200 µs each
- **1089 pulses** detected for SNR = 3

Mean frequency of occurence : **55 000 pulses.s**$^{-1}$



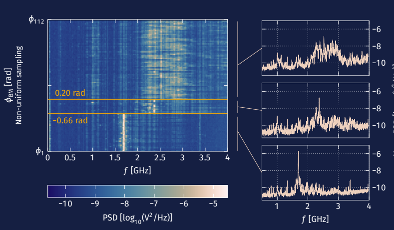
- Pulse **appearance** dependent on the **phase** of the **Breathing Mode** : few pulses for low I_d values



- **Amplitude** distribution of the pulses

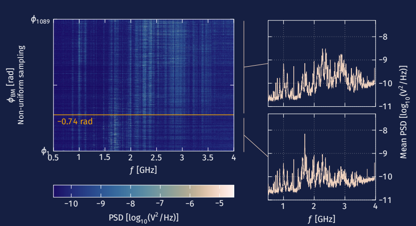
Spectral dependence

- Search for a spectral dependency : pulse **spectra stacked** by **increasing values of** ϕ_{BM}



Pulses of **highest amplitude**

- **Explicit classification** of the pulse spectra following **3 phase ranges** of BM oscillations
- In particular, **quasi-monochromatic** character for ϕ_{BM} < −0.66 rad at **1.7 GHz**



Total set of pulses

- Classification less obvious, but still discernible
- 2 phase ranges for ϕ_{BM} rather than 3
- Similar behavior and value of phase boundary

Discussion

- Recorded pulses are the result of a **convolution** by the **impulse response** of the **measuring system**
- Inf uence of **resonance frequencies** of the metallic **vacuum chamber**
- **Does not contradict** the spectral dependency revealed

CONCLUSION

- First evidence for a **dependency** of the pulsed GHz emission on **Breathing Mode oscillations** regarding :
  - Pulse **appearance**
  - Pulse **spectra**
- Valuable **insight** into the **physical origin** of this emission

[1] Dubois L. et al., *Physics of Plasmas* **2018**, 25, 093503.
[2] Mazières V. et al., *Physics of Plasmas* **2022**, 29, 072107.

Other relevant references :
[3] Beiting E. J. et al., *46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit*, **2010**.
[4] Beiting E. J. et al., *ISPC-2008-070*, **2008**.
[5] Beiting E. J. et al., *IEPC-2009-072*, **2009**.

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