Phase-locking of nanocontact vortex oscillators

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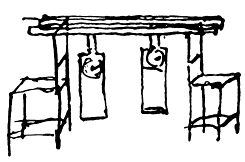
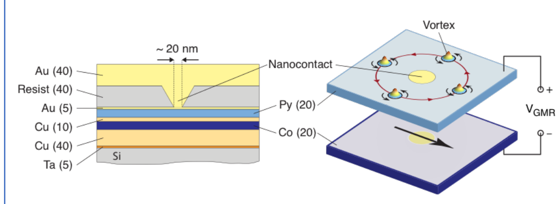
INTRODUCTION

Phase Locking

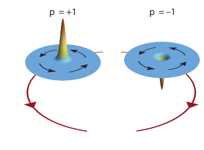

Huyghens synchronization figure [1]

First recorded synchronization observation was reported by C. Huyghens between two clocks. Since then, we have discovered many systems that can be synchronized, such as spin-torque nano-oscillators (STNO) [2]. Synchronization consists of at least two auto-oscillators that interact to oscillate at the same frequency. Such non-linear devices can then exhibit more complex behaviors [3]. Phase locking occurs when an oscillator reacts to an external signal.

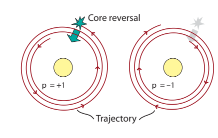
Geometry and core reversal



Spin-valve stack [4]



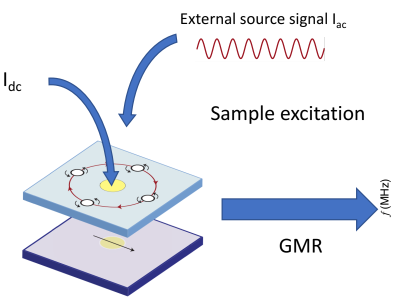
Core reversal [5]



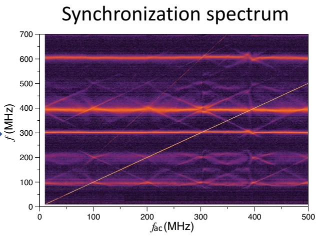
Vortex core trajectory

A core reversal leads to a change of position and giration direction

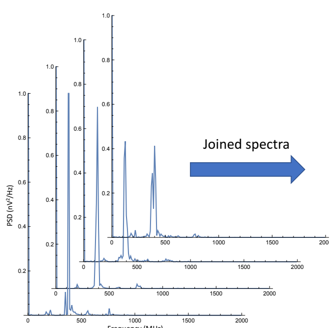
PHASE-LOCKING WITH EXTERNAL SIGNAL



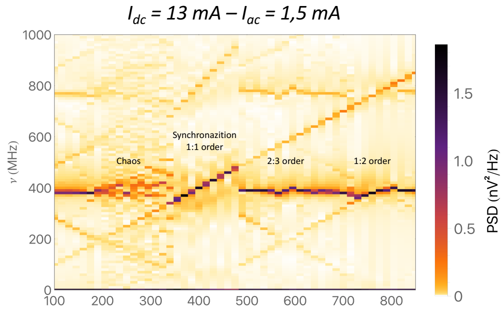
Experimental data
Synchronization spectrum



Frequency sweep



Simulated map
I_{dc} = 13 mA – I_{ac} = 1,5 mA

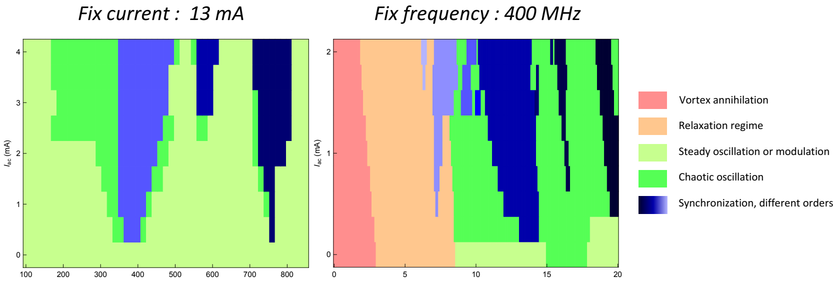


- Phase-locking seen between oscillator and external signal
- 1:1, 2:3, 1:2 orders of synchronization
- Steady to chaotic behavior

ARNOLD TONGUES

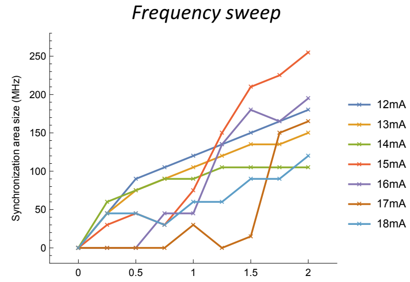
Frequency sweep
Fix current : 13 mA

Current sweep
Fix frequency : 400 MHz

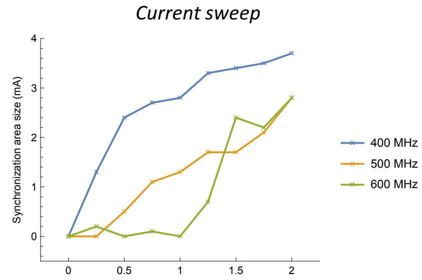


Size of 1:1 synchronization window

Frequency sweep

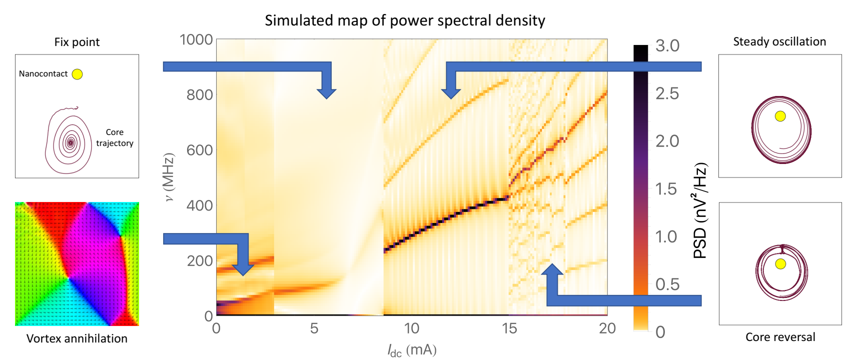


Current sweep

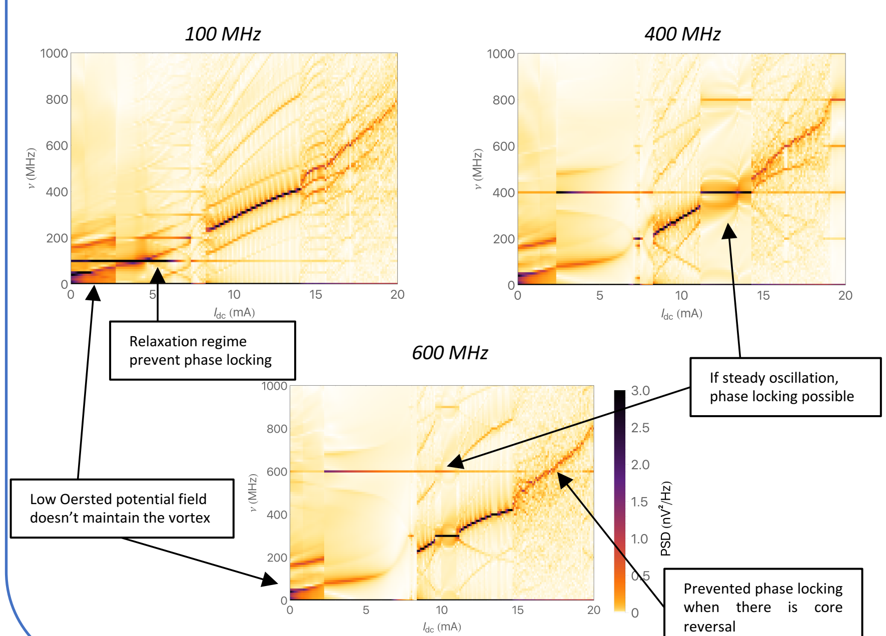


MICROMAGNETICS SIMULATIONS

DC Current



AC+DC Current



CONCLUSIONS

- Different behaviors : relaxation, oscillation and core reversal
- Phase locking easier in steady oscillation regime
- An external signal can turn a steady oscillation regime into a chaotic one, and vice-versa

REFERENCES

[1] C. Huyghens, *Œuvres complètes, Tome V : Correspondance 1664-1665* (1893)
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