Vortex dynamics in 2-dimensional soap film turbulence

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Introduction

The bubble and soap film are quasi-two-dimensional system which has many different scales of vortices. It can be driven by external electric field to generate turbulence. There are many complicated phenomena of the fluid dynamics and it is still an open issue.

Goal

The goal is to observe the emergence of small vortices from boundary, which combine as larger vortices. Also, we focus on the spatiotemporal evolution of soap film at different shapes.

Particle Image Velocimetry

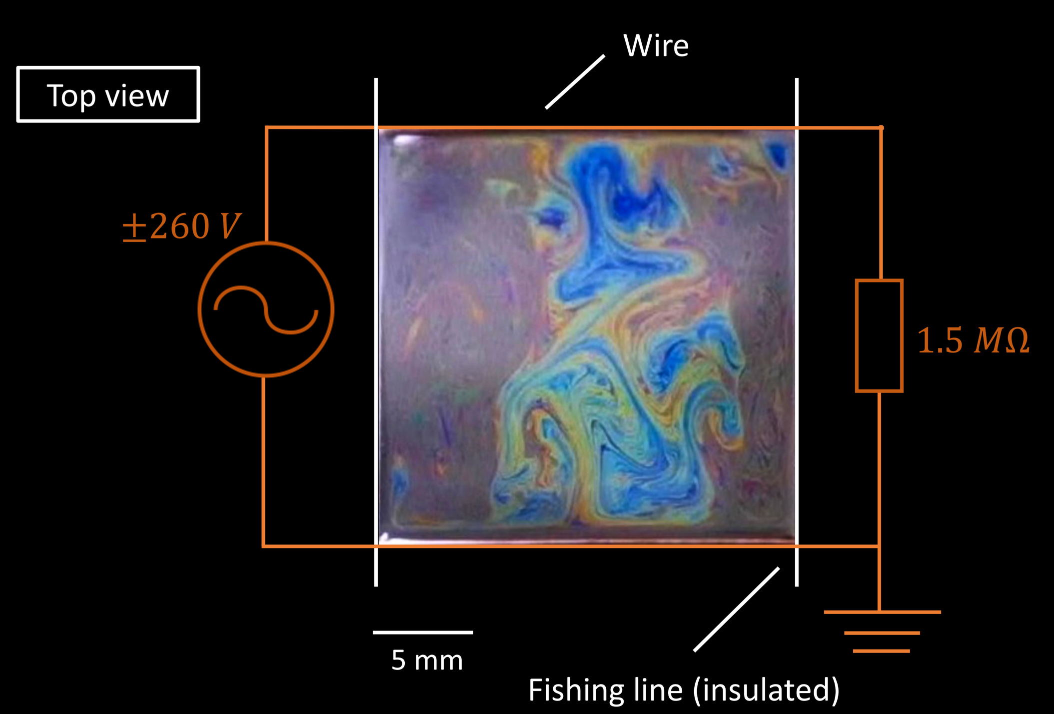
The PIV method can get the velocity and vorticity field. Comparing two images with a time interval at fixed frame size, and then find the displacement with maximum correlation.

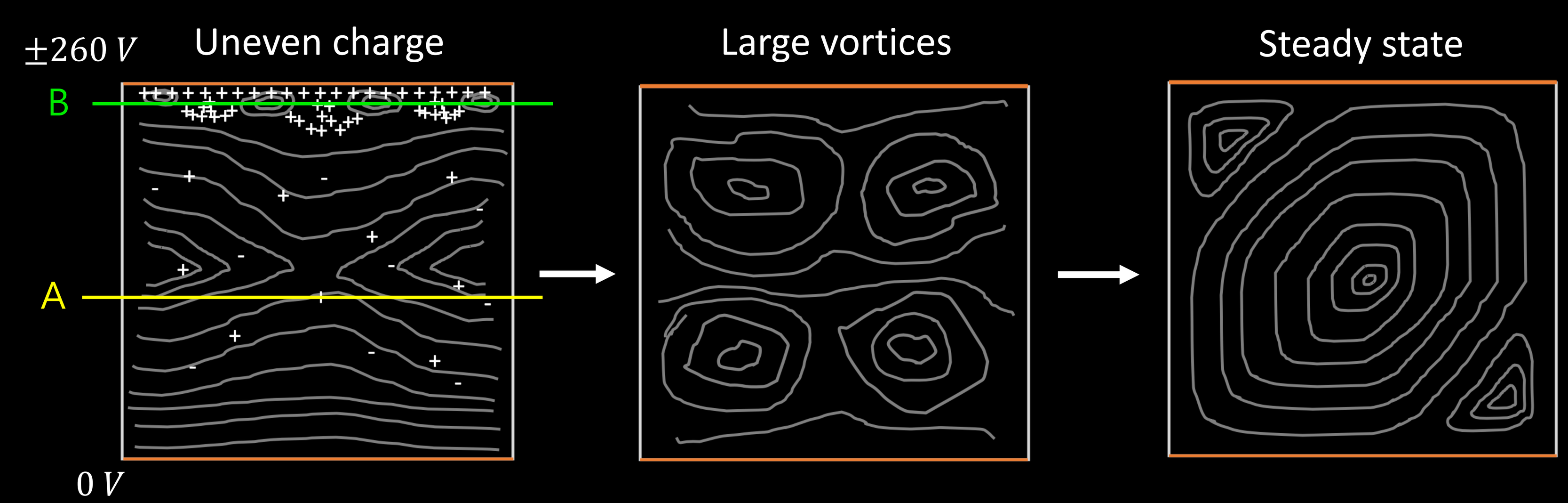
Setup

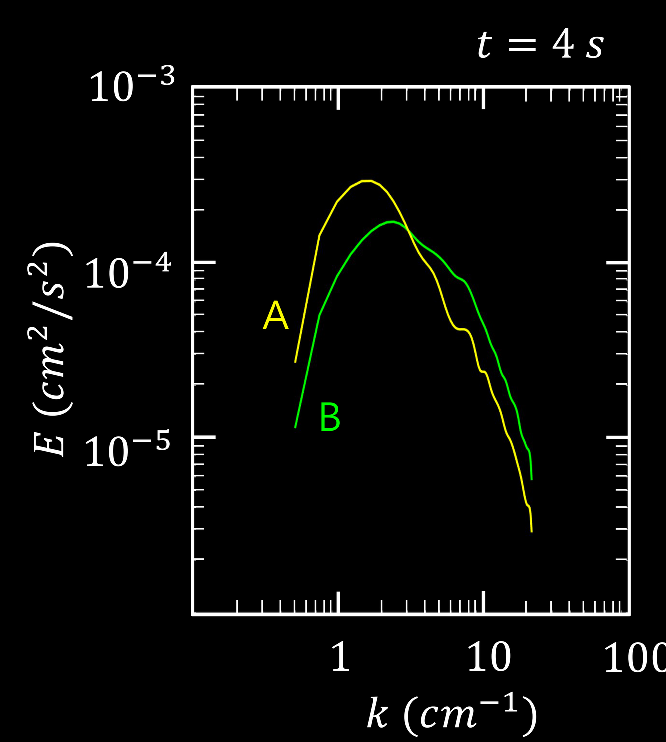
Two wires and two fishing lines are used to prop up the soap film at the cross region. The autotransformer with 260 volt AC drives the soap film with micrometer scale thickness.

Background

The turbulence on the soap film is generated by the electric force. At first, the boundary generates small disturbances with many small vortices. This phenomenon can be proved by the power spectrum. Then, the flow lets electric charges be uneven, so it starts to influence the fluid in the middle of the soap film. Furthermore, the non-uniform thickness of the soap film also causes the flow. Last, the vortices would merge into large vortices and reach the steady state.

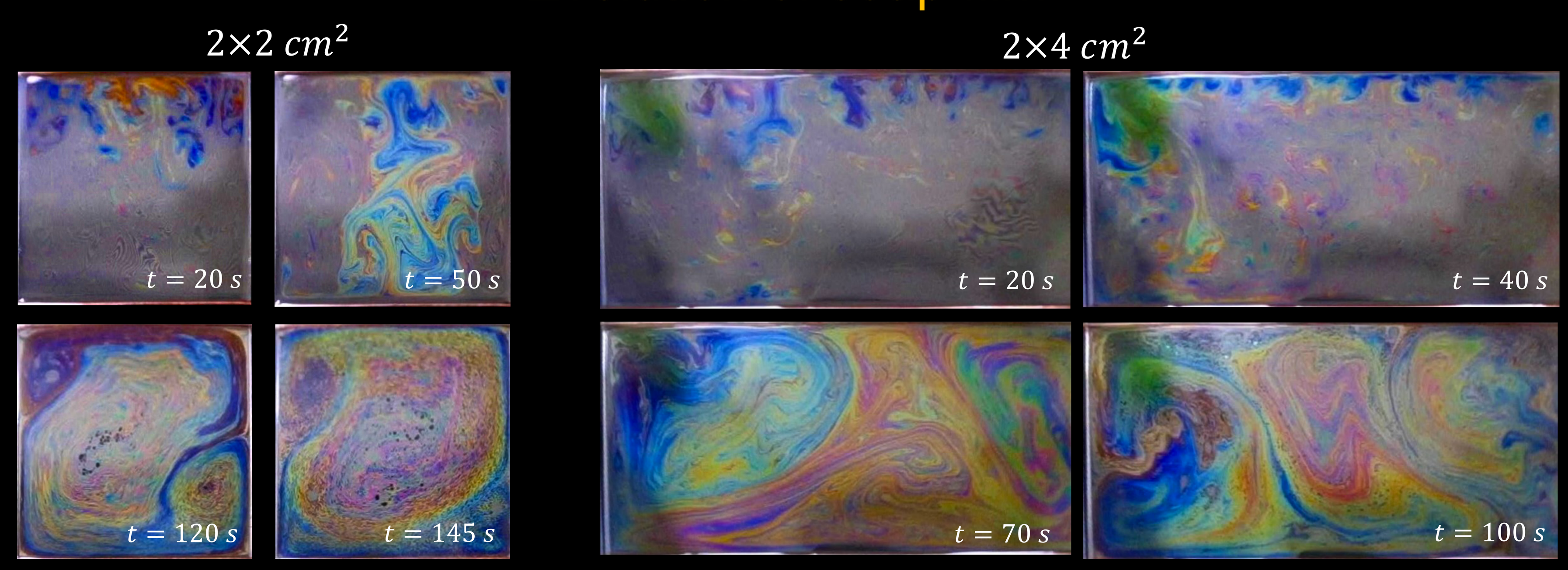




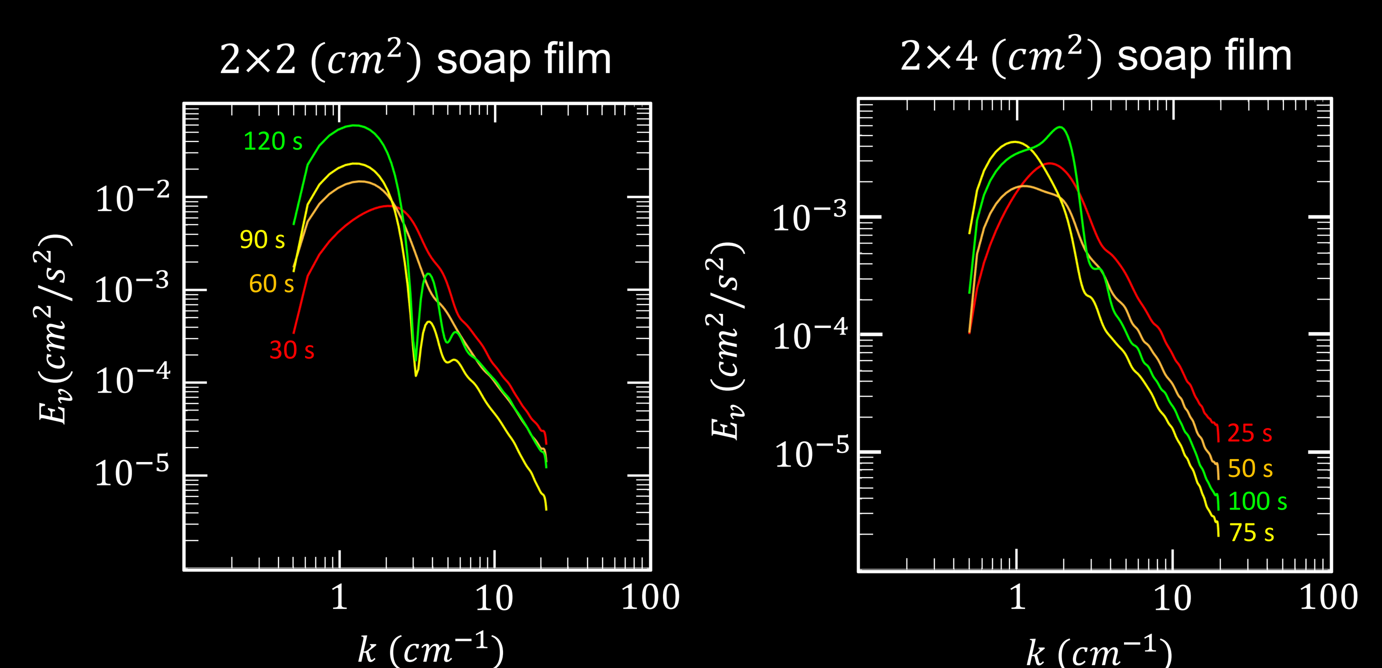


Power spectrum and spectrogram

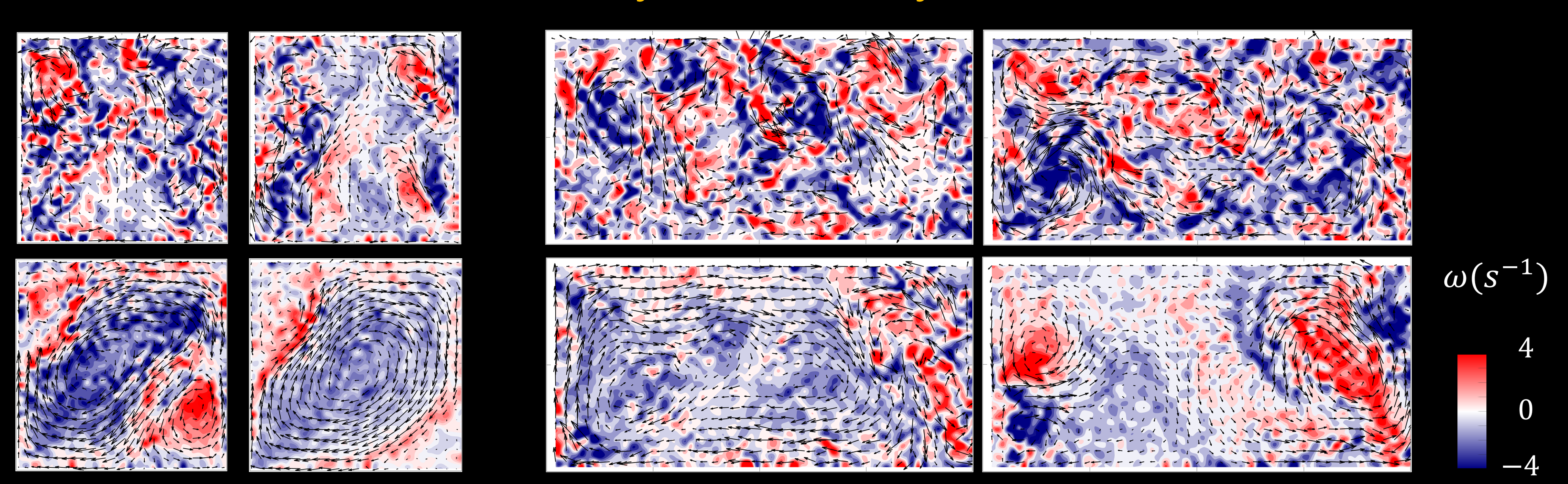
Evolution of soap film



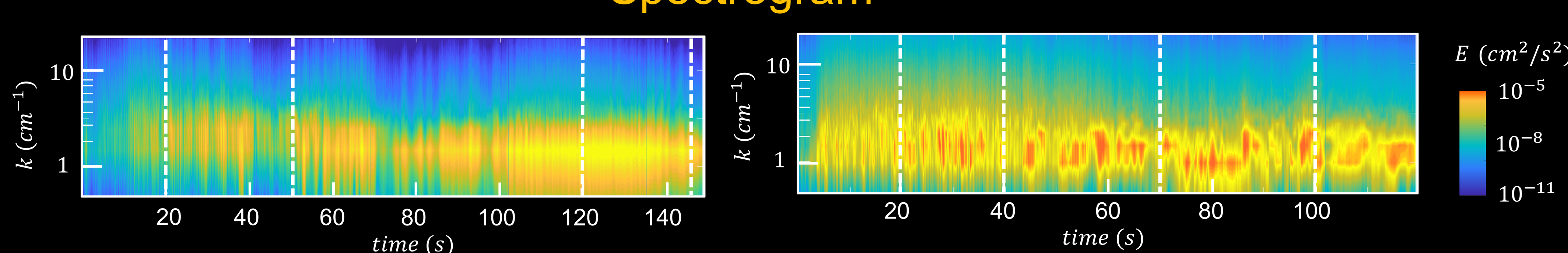
Evolution of power spectrum



Velocity and vorticity

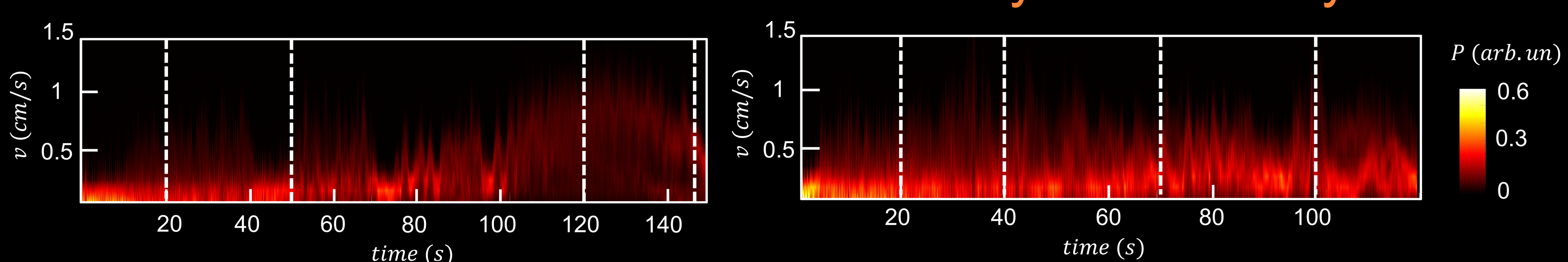


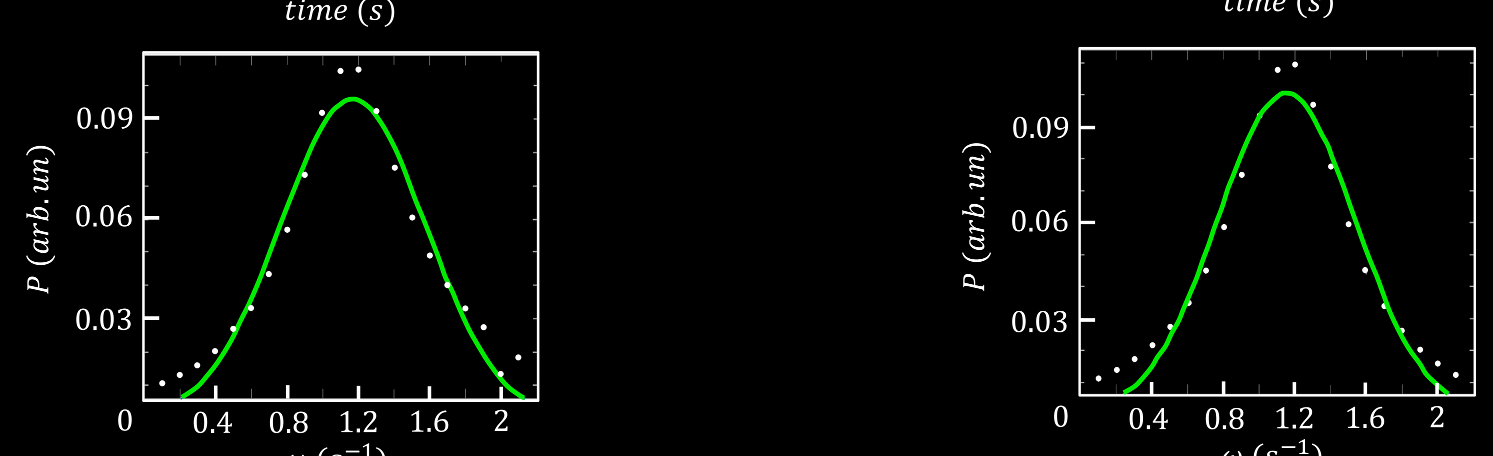
Spectrogram



The spectrograms of the two sizes of soap films have similar phenomenon. Take 2*2 for example. At t = 20s, when the AC voltage is just applied, there are some small vortices beside the boundary. The energy disperses in each scale. Later, at time t = 50s, those small vortices merge into larger vortices. At t = 120s, the velocity increases and forms a larger vortex. The energy gathers at $k_x = 0.5{\sim}1cm^{-1}$. The velocity of the fluid slows down and then the soap film breaks. The energy distribution of 2x2 soap film is stable when it forms a large vortex. However, the case of 2x4 soap film has energy transfer between different scales even if it forms a large vortex, which means the 2x2 soap film has larger effect of boundary than that of 2x4 one.

Velocity and vorticity distribution





The graphics is the velocity v and vorticity ω distribution. At the beginning, v and ω is centered in a range which is by injection. As time goes, it will diffuse to whole system and the distributions become uniform. Therefore, the system will become more stable.

Conclusion

1. The energy distribution gradually concentrates on the large scale.
2. The condensate effect of 2x2 soap film is more obvious than 2x4 one.
3. The velocity and vorticity will diffuse to the whole system.

Reference

- S. Mollaei, M. Nasiri, et al., PRE **97**, 043110 (2018)
- M. A. Rutgers, X. L. Wu, et al., Rev. Sci. Instrum. **72**, 3025 (2001)
- Chien-Chia Liu, Rory T. Cerbus, et al., PRL **117**, 114502 (2016)