Flapping in the Wind

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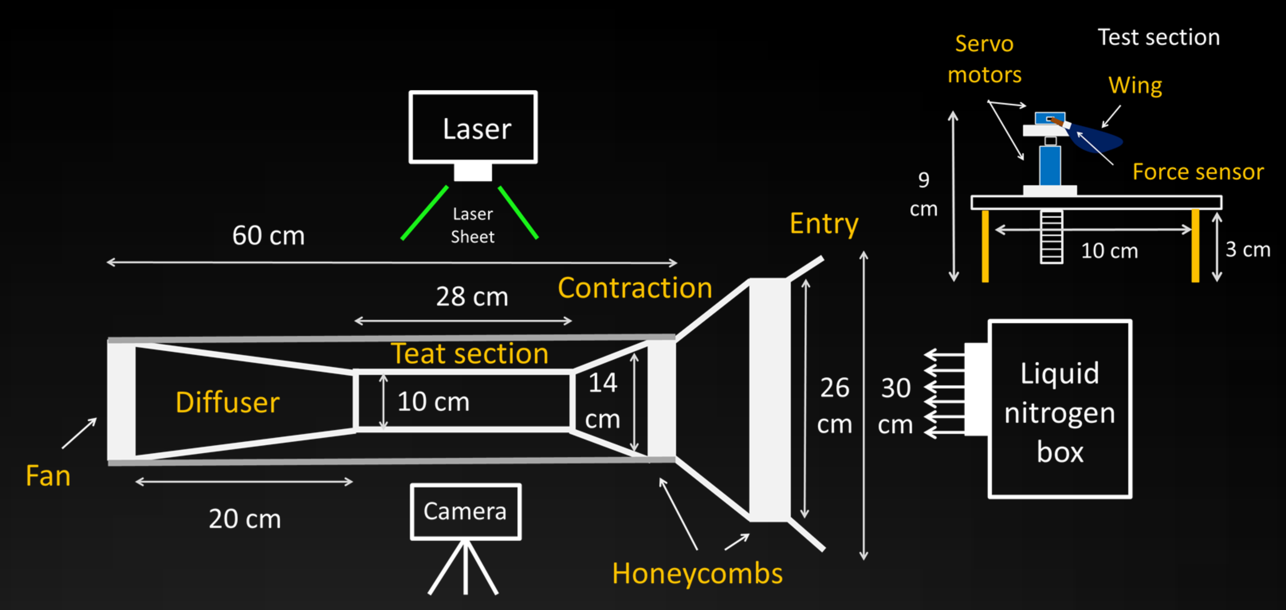
Introduction

Insects fly like clouds in the sky with large angles of attack. During hovering, insects receive enough lift to be supported. It is the wing motions, translation and rotation, that support insects. Image that there is a strong wind blowing, how are the airflow fields like?

Our work

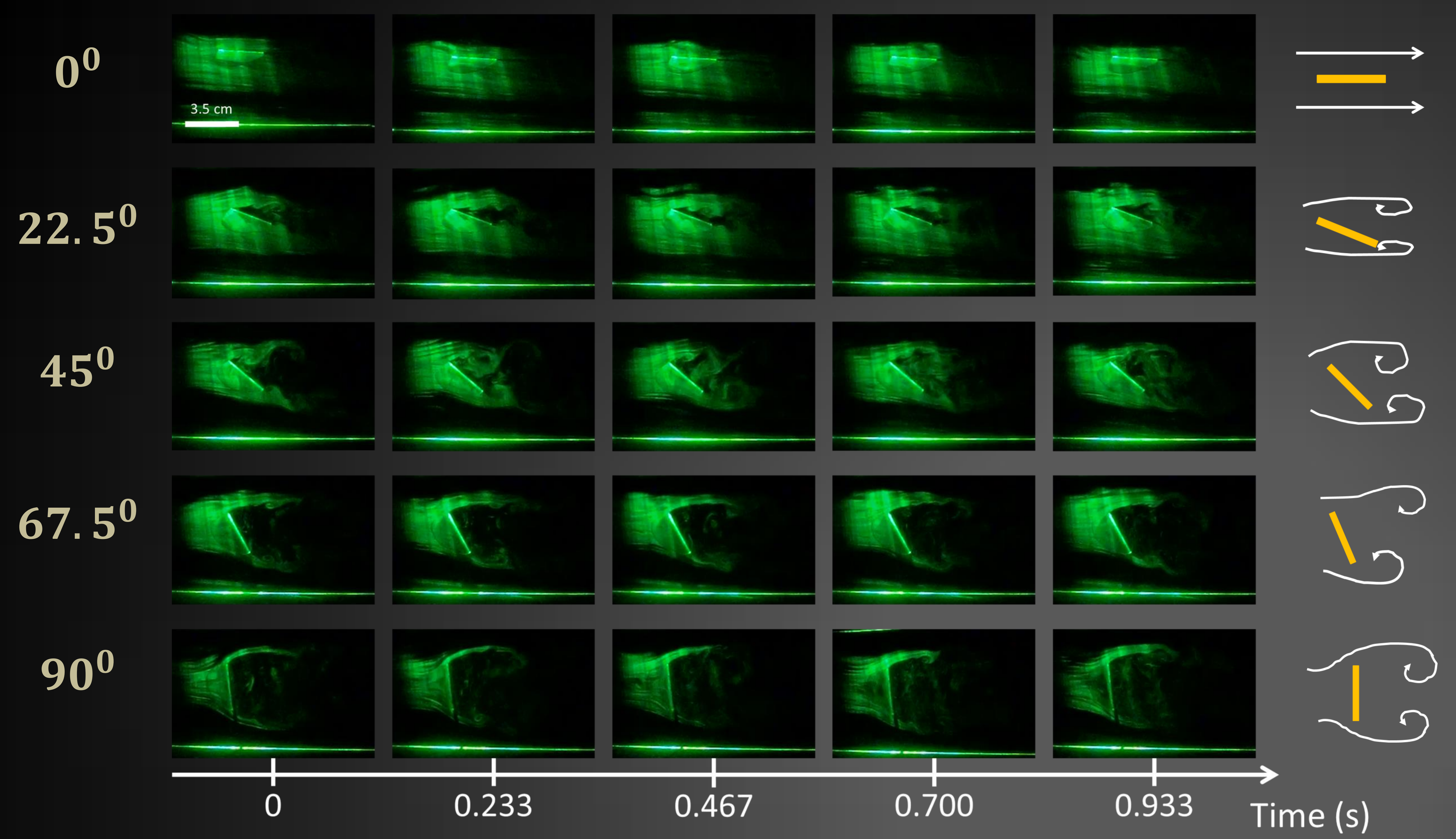
We observe the airflow fields with five different angles of attack, 0^0, 22.5^0, 45^0, 67.5^0, and 90^0. Additionally, we designed a wing motion process. Then, we analyze the airflow field with the wing flapping in the wind which is about 0.035 m/s.

Experimental setup



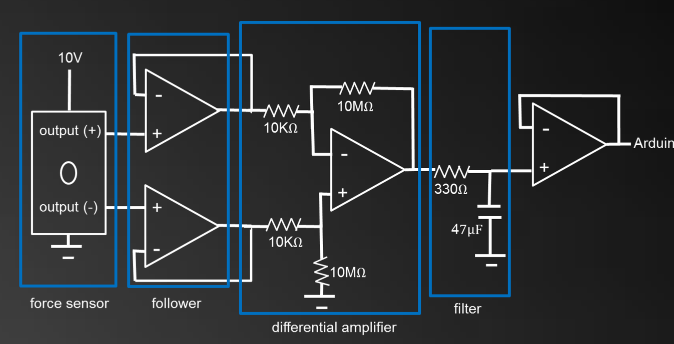
We use open return wind tunnel. Honeycombs divide the air vortices into tiny eddies. By conservation of mass, the air is smoothly accelerated through the contraction. The diffuser allows the wind to restore with normal pressure. In the test section, two servo motors simulate wing motions. One motor controls the angle of attack and the other controls the position of the wing.

Airflow fields with different angles of attack



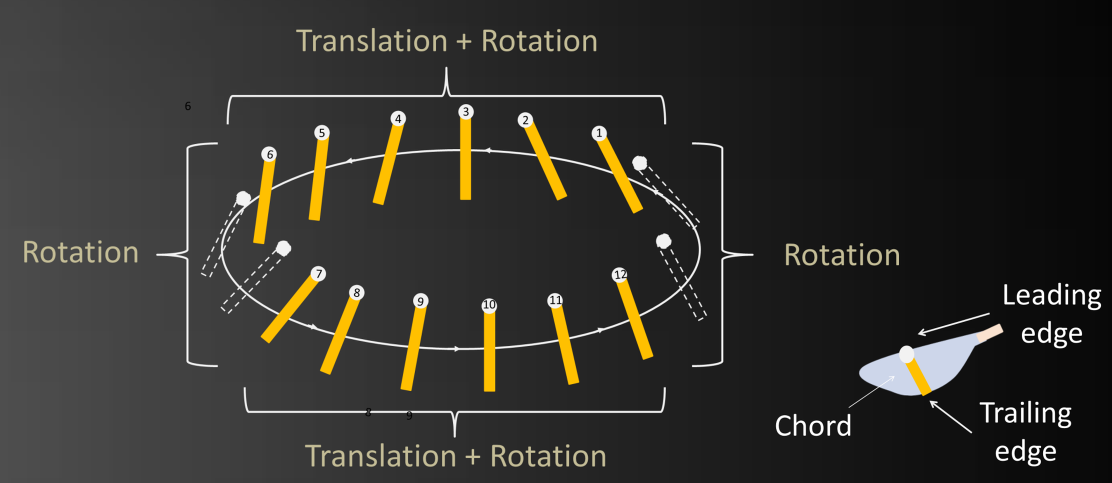
With the angle of attack being larger and larger, the vortex tends to separate from the wing. Hence, lift is unstable.

How to get Lift?



0.24mV = 1gw
The original signals are amplified in 1000 times with the differential amplifier. Then, we use Arduino to sample the amplified signals.

Wing Motion Process

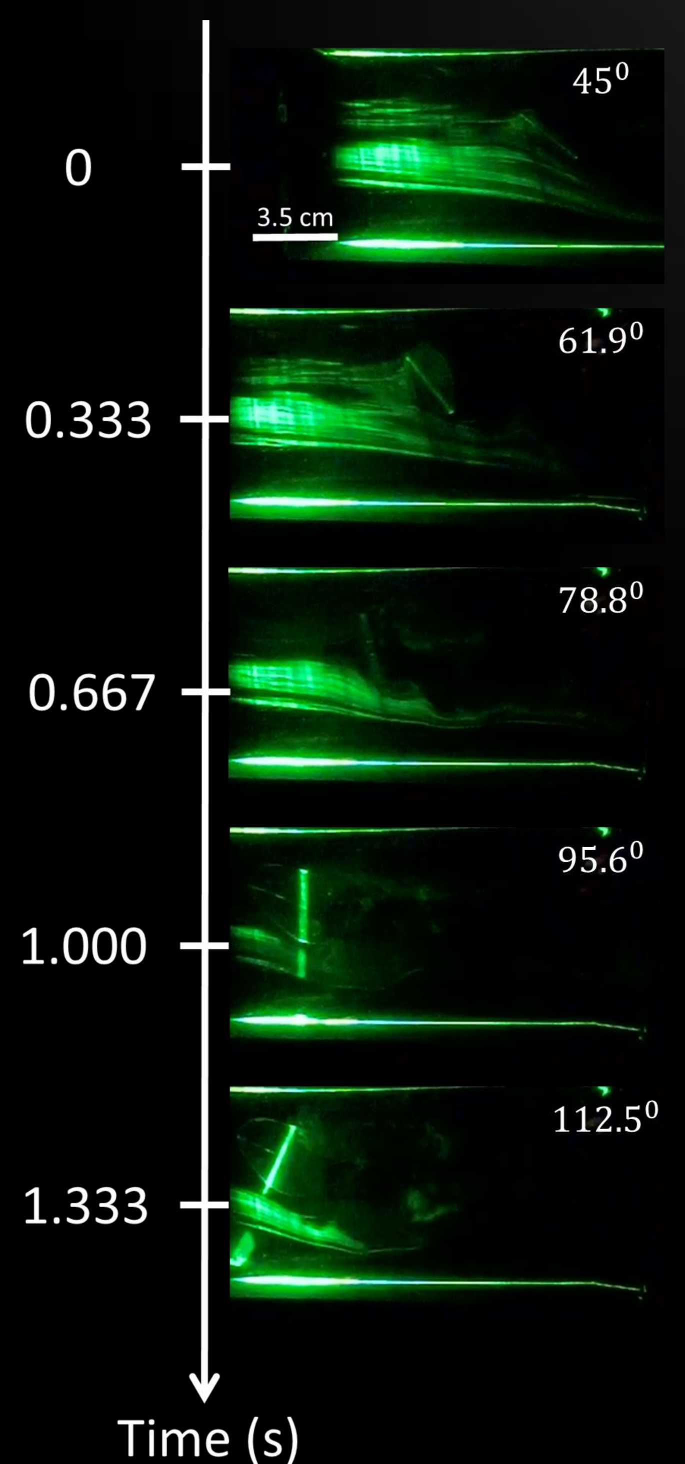


At first, the wing translates and rotates simultaneously. Just when the wing rotates to -45^0 does the wing starts to do the same process from 45^0 to -45^0. The stroke amplitude is 60^0.

Lift force and airflow field during the wing motion process

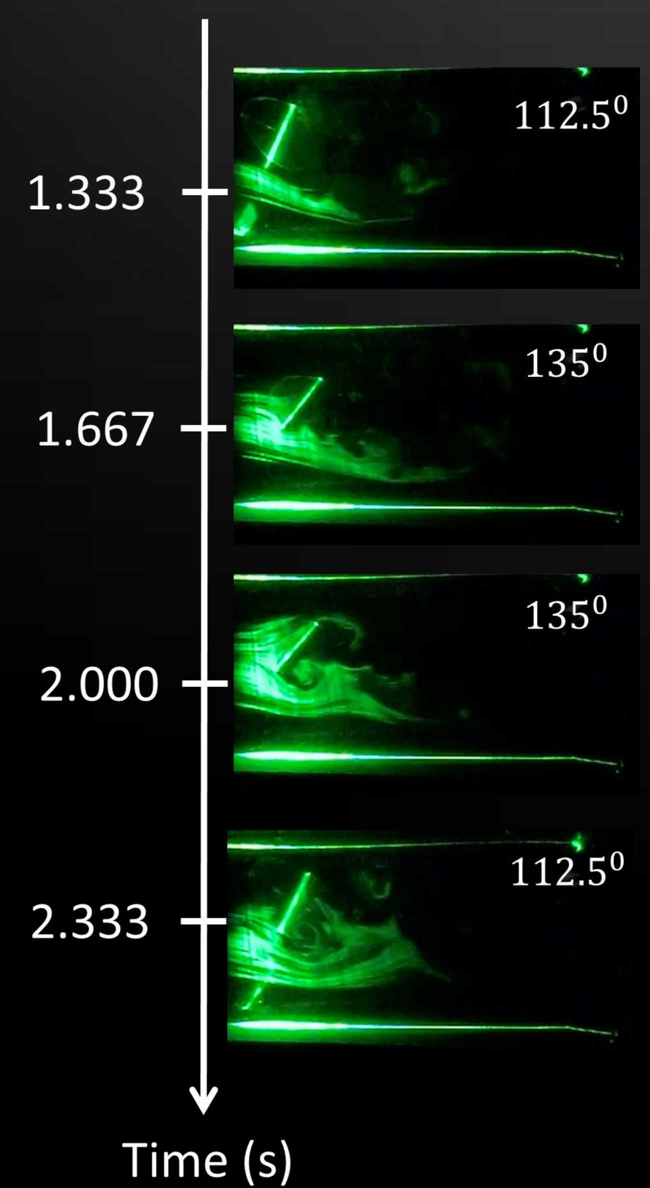
Translation + Rotation

The airflow keeps attaching to the wing during translation. There is am empty space behind the wing.

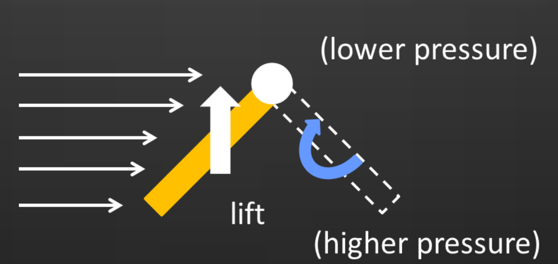


Rotation

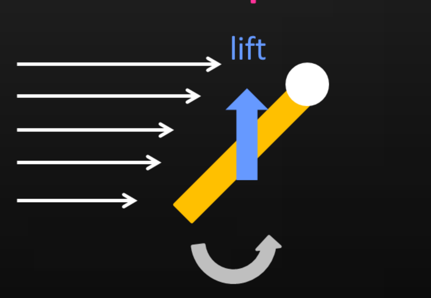
There is a vortex at the trailing edge hitting the wing.



Pressure difference

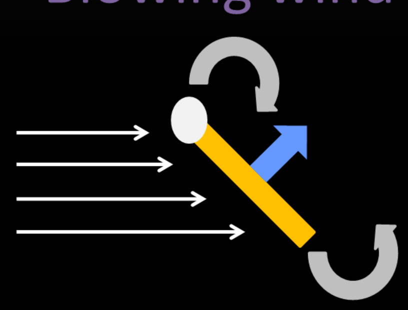


Wake capture

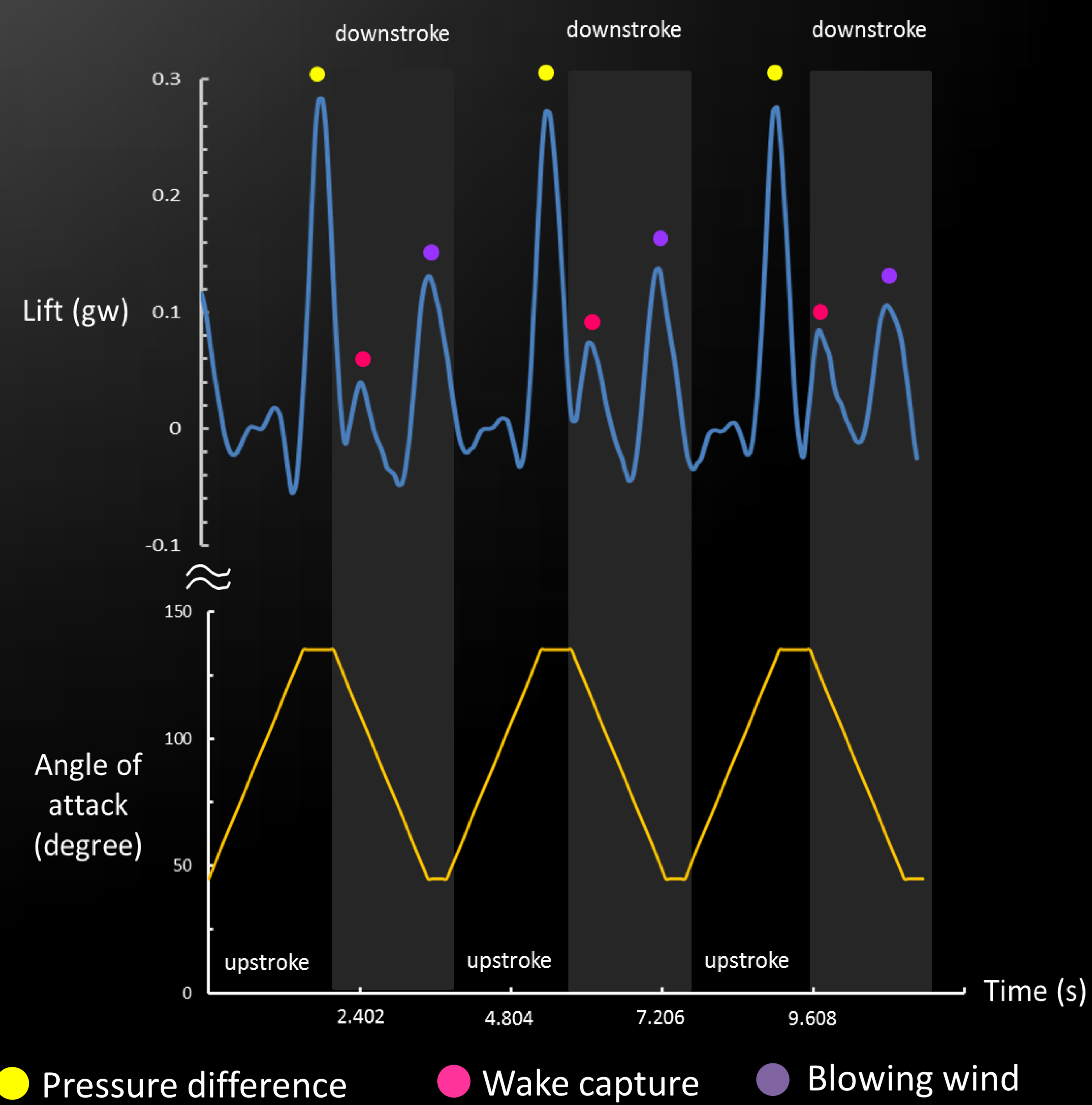


Lower vortex hits the wing

Blowing wind



Wind gives the wing a lift



Lift force

Conclusion

- Windward lift is stronger than leeward lift.
- The vortex hit the wing so that the lift is strong once the wing starts to translate.

Reference

*Z. J. Wang, PRL **99**, 148101 (2007)*
*W. J. Maybury, J. Exp. Biol. **207**, 4707-4726 (2004)*