

# Dynamics of twisting and releasing elastic filaments

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## Introduction

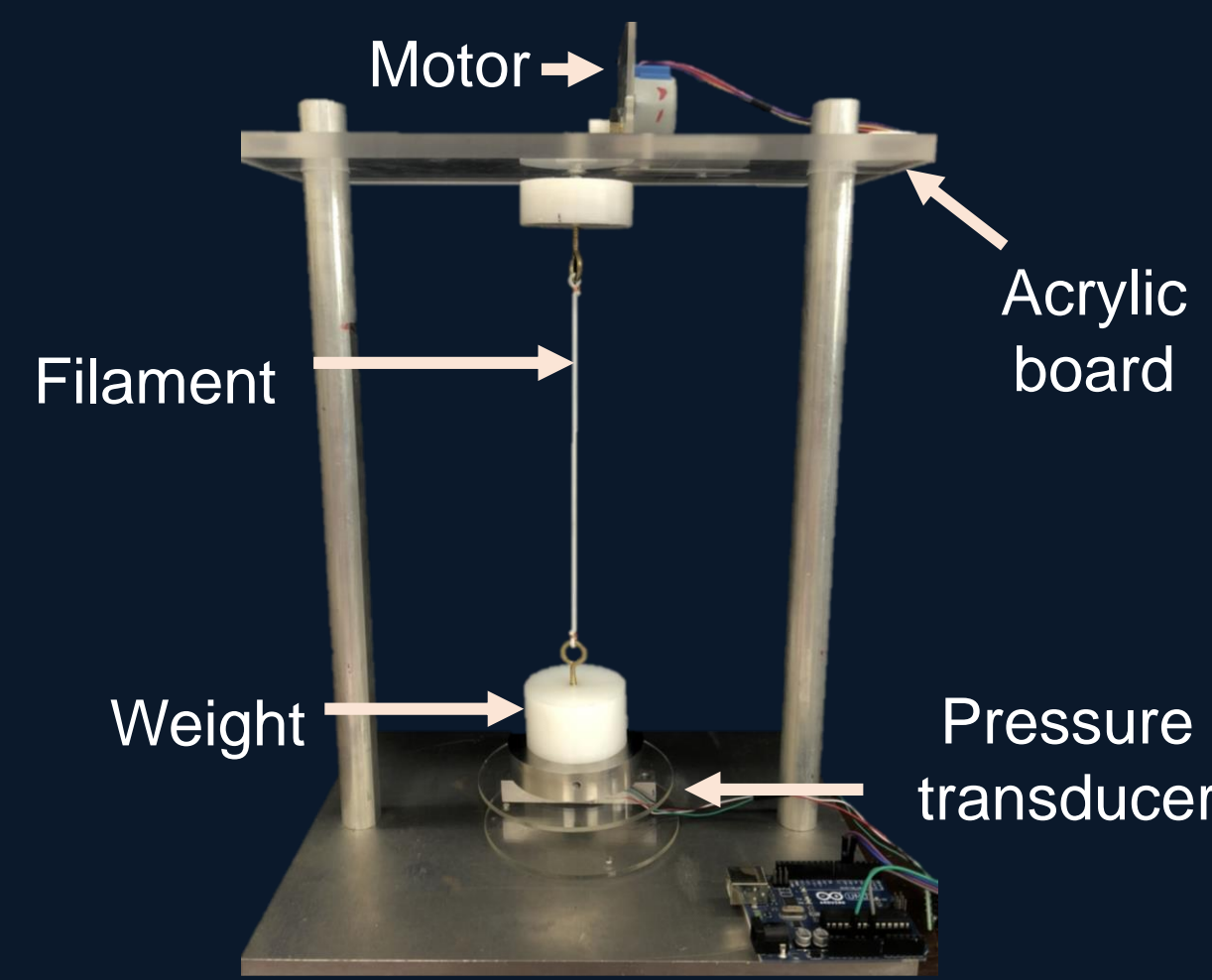
Filament is everywhere in daily life, such as DNA, textile, and rope. There are three kinds of deformation structures: straight, plectoneme, and solenoid, determined by different twist angle and stretching force.



## Goal

- Measure the force evolution when twisting and reverse twisting the filament with fixed length.
- Release one end of the filament and observe its deformation.

## Setup

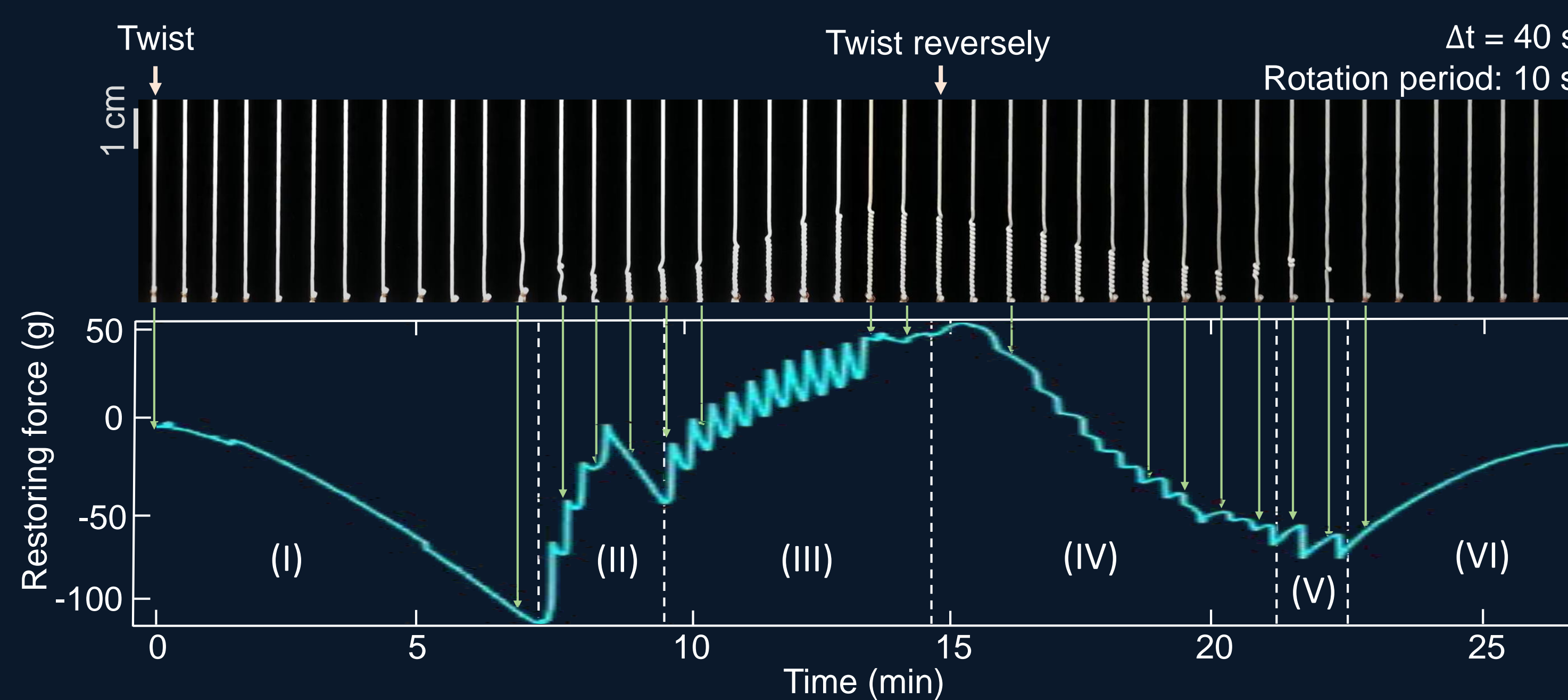


## Wavelet transform

Wavelet transform is a method that can observe the frequency composition in each time step. It uses the wavelet in different scales to see the similarity between the wavelet and the original signal.

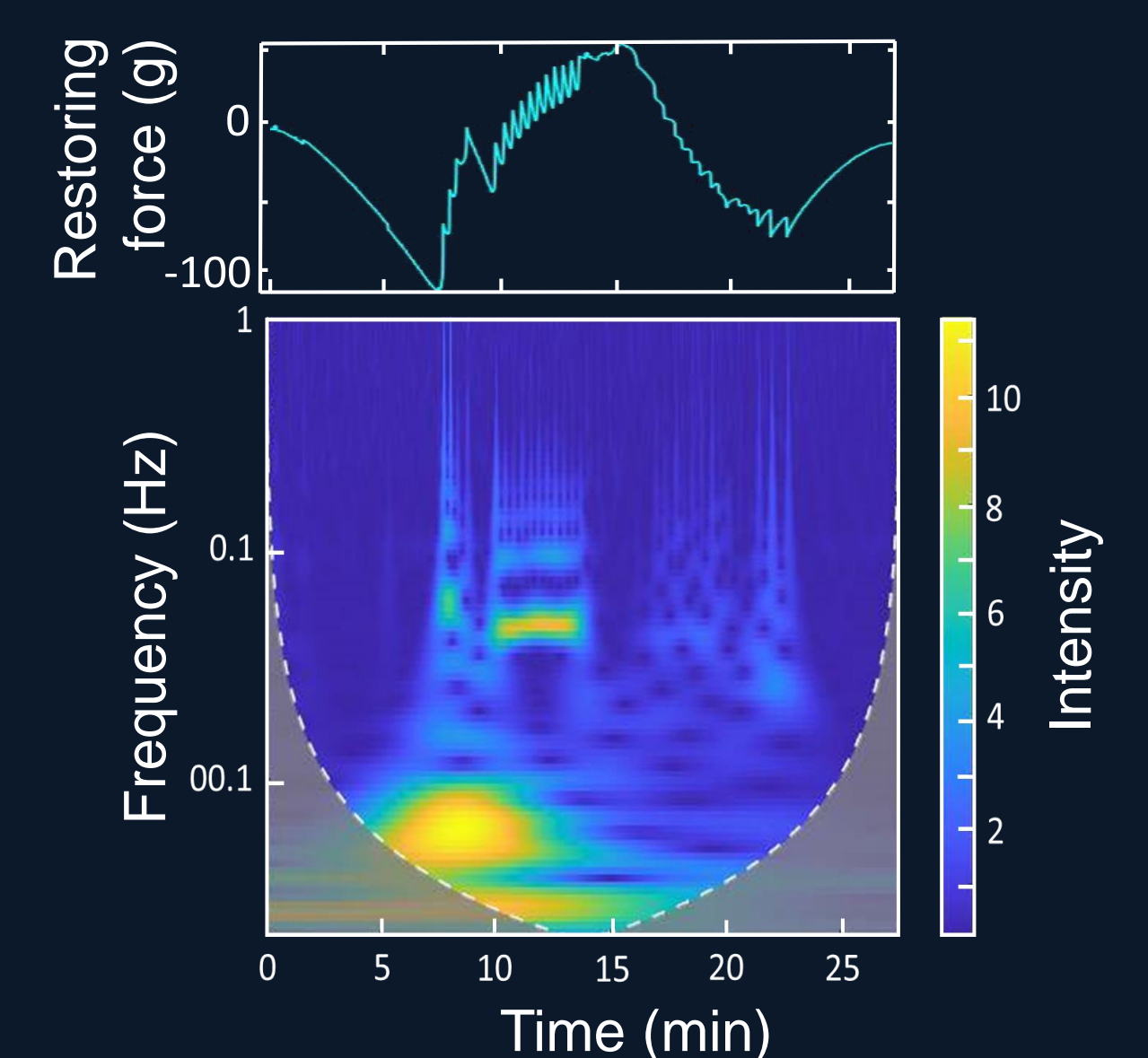


## Evolution of filament structure



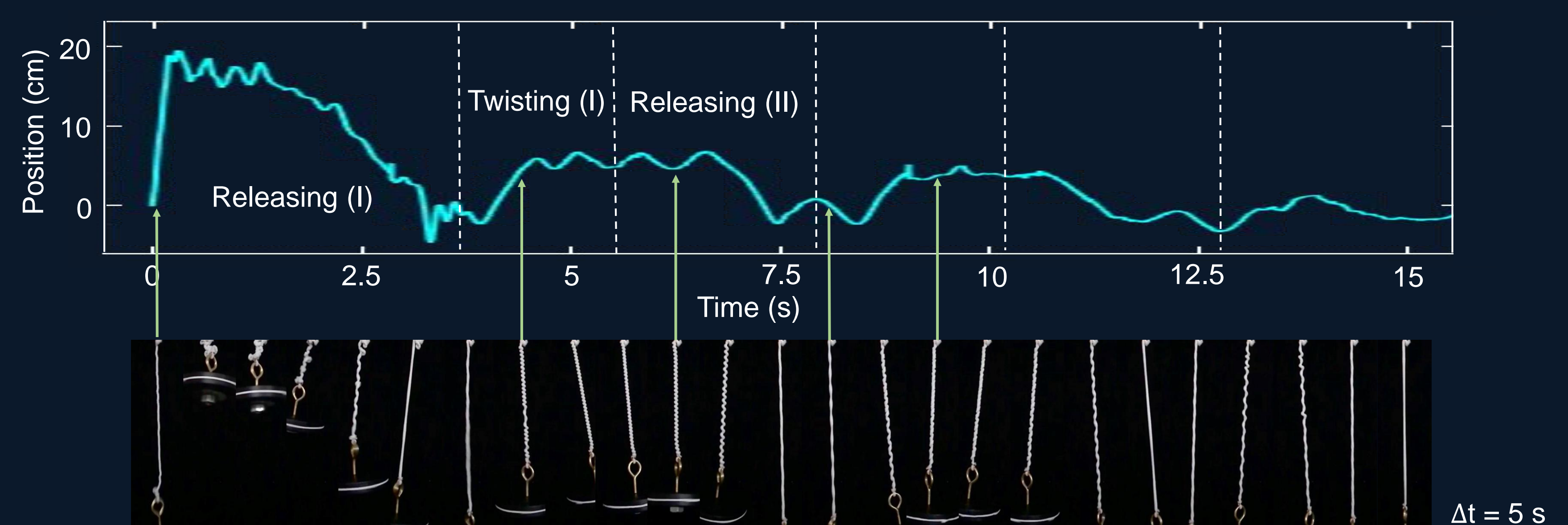
(I) After the onset of twisting, the force becomes smaller because the longer filament through deformation leads to smaller restoring force. (II) If the straight part cannot afford the twisting force, the filament forms solenoids to replace twisted part. Then, the force increases after forming the solenoids. When we twist the filament reversely, the force is opposite from forming the solenoid.

## Wavelet transform



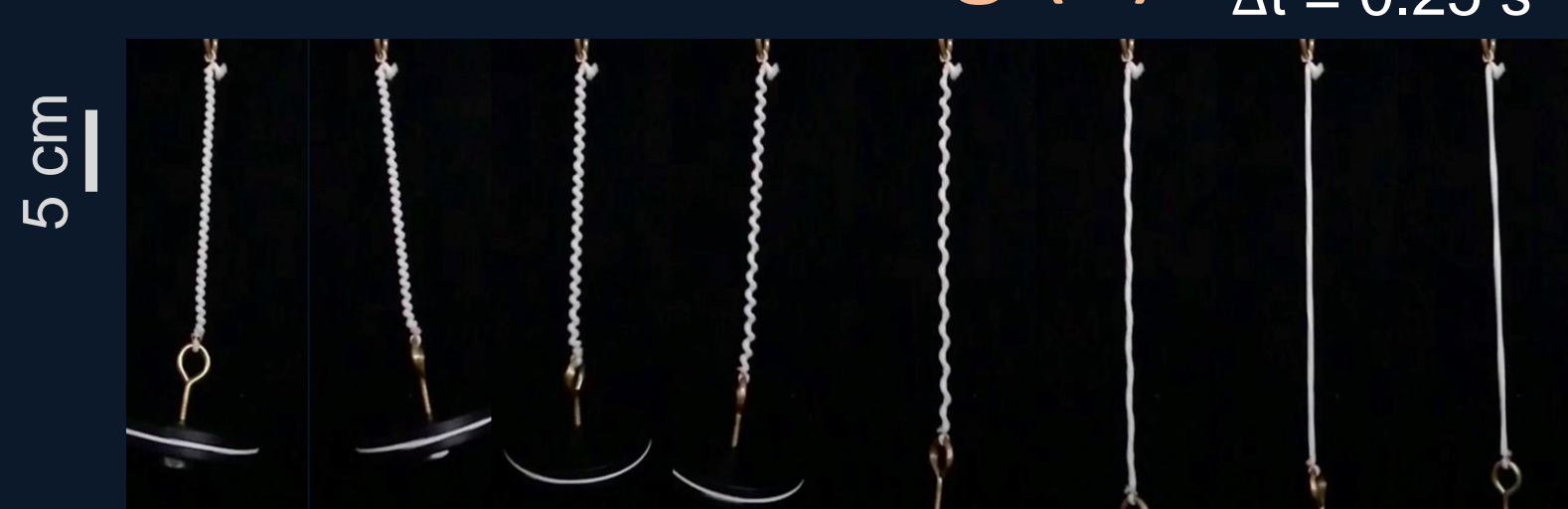
Several harmonics are corresponded to the sawtooth force evolution. Moreover, there exists high frequency when the solenoids form.

## Releasing one end of twisted filament



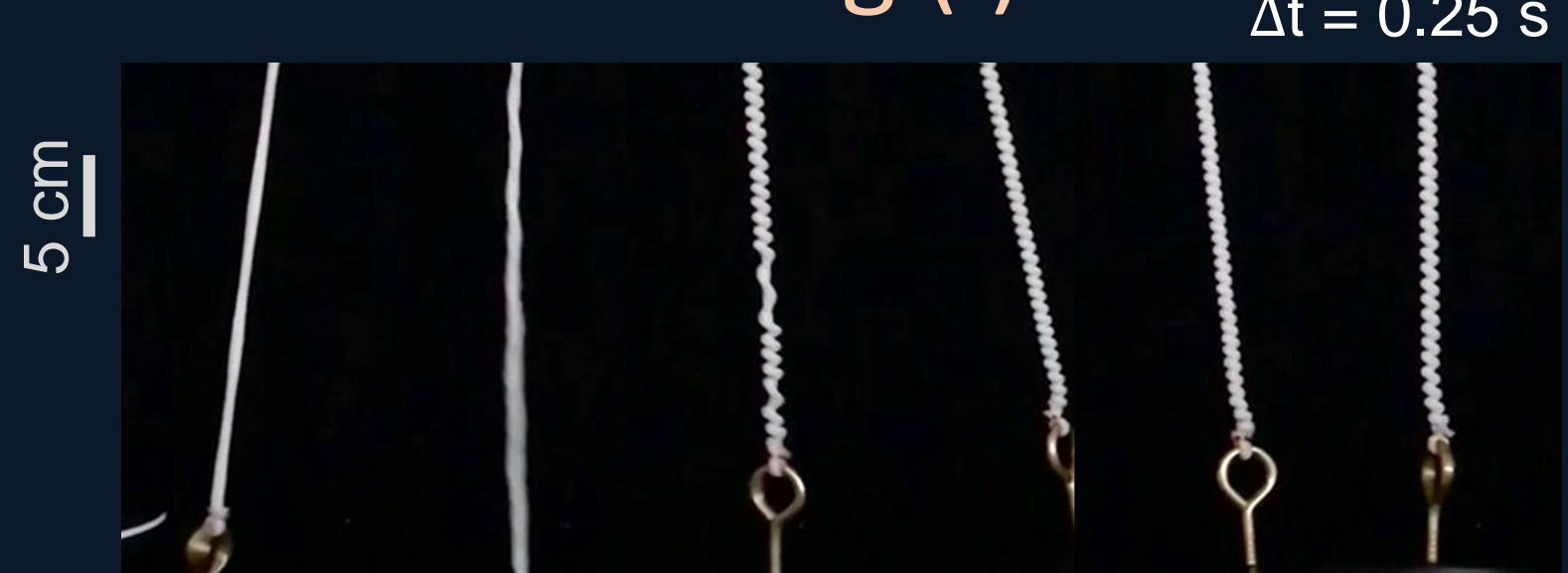
When we release one end to unwind the filament, the stretching force becomes smaller and causes the plectonemic structures. After unwinding all the knots, the inertia of the weight will cause the filament to keep twisting and unwinding the solenoidal structures.

### Releasing (II)



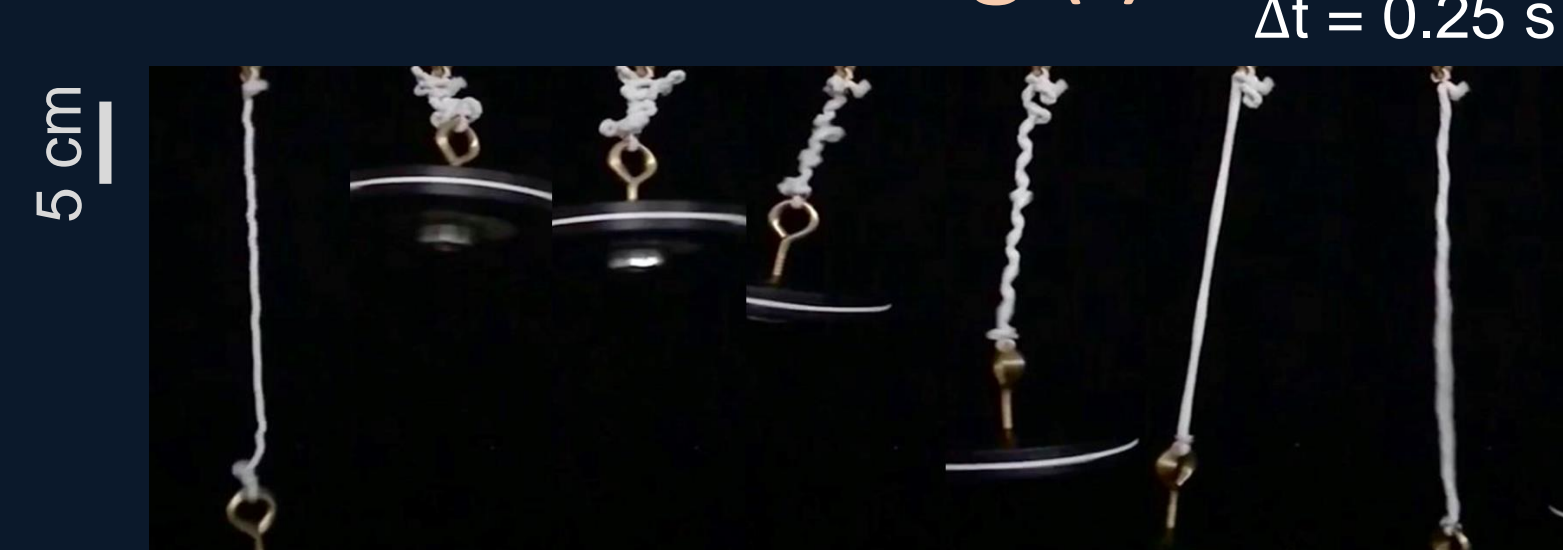
After the whole filament becomes solenoid, it starts to unwind solenoid evenly because the filament tends to be straight.

### Twisting (I)



Because there is one fixed end, the filament will pass the energy from the free end to the fixed end. Thus, the filament forms solenoid unevenly.

### Releasing (I)



When the filament is released, the stretch becomes smaller and the filament forms the plectoneme. After forming, it starts to unwind the knot.

## Conclusion

- When the filament is twisted, the force becomes smaller first due to the Poynting effect.
- When the straight part of filament cannot afford the twist, it transfers twist into solenoidal structures.
- When the solenoid forms, the restoring force exhibits sawtooth shape. One sawtooth shape corresponds to one solenoidal knot.
- In the releasing experiment, the process of forming solenoids is uneven, but the process of unwinding solenoids is even.

## Reference

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- [2] A. Panaitescu et al., Phys. Rev. Lett. **95**, 052503 (2017)
- [3] A. Panaitescu et al., Phys. Rev. E. **123**, 208003 (2019)