TOWED-GRID SYSTEM FOR PRODUCTION AND CALORIMETRIC STUDY OF HOMOGENEOUS QUANTUM TURBULENCE

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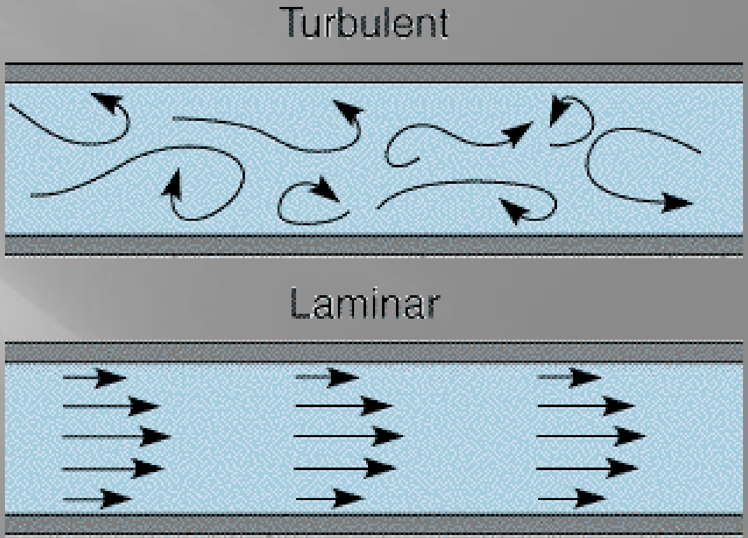
Classical Turbulence

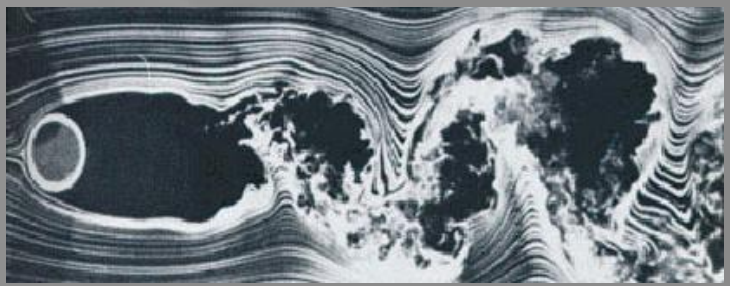
Laminar:
- No viscous shearing between streamlines
- Below Re = 2000

Turbulent:
- Vortices and eddies form
- Seen at high fluid velocities
- Everyday occurrence

Turbulent Decay:
- Energy dissipates via viscosity/friction on small scales

$$Re = \frac{\rho V D}{\mu}$$





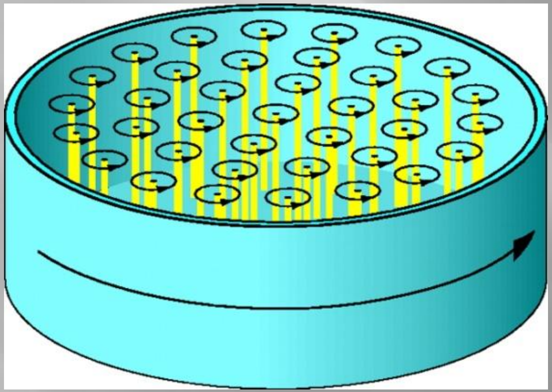
Quantum Turbulence

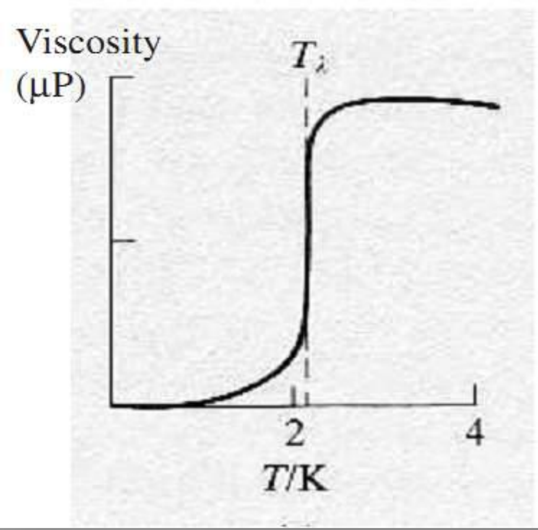
Turbulence in a superfluid:

- Classically, any motion with a nonzero velocity (V) in a fluid with zero viscosity (μ) would generate infinite Reynolds numbers; always turbulent

$$Re = \frac{\rho V D}{\mu}$$

- Quantized in form of quantized vortices with circulation (κ= nh/m)

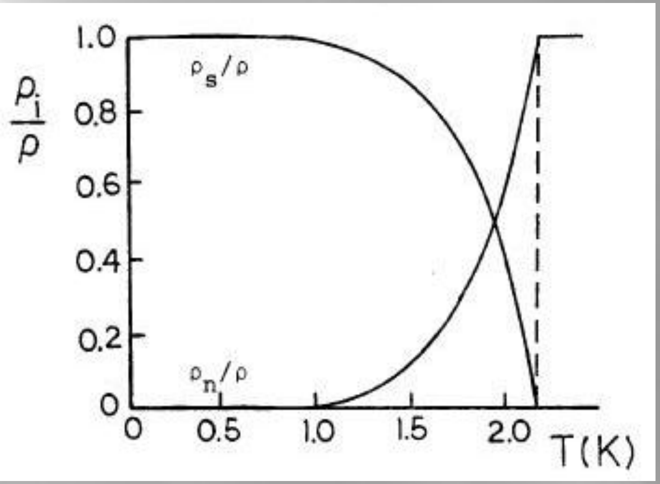




- Predicted a smooth transition from quantum to classical turbulence
- Studies in quantum turbulence might help us understand its classical counterpart

Below 1K

- Above 1K: decay of turbulence is due to mutual friction between normal and superfluid components



- What happens below 1K where there is no viscous normal component?
- Kelvin-wave cascade is thought to be responsible for dissipation
- Results in phonon radiation

- <u>Need experimental evidence</u>

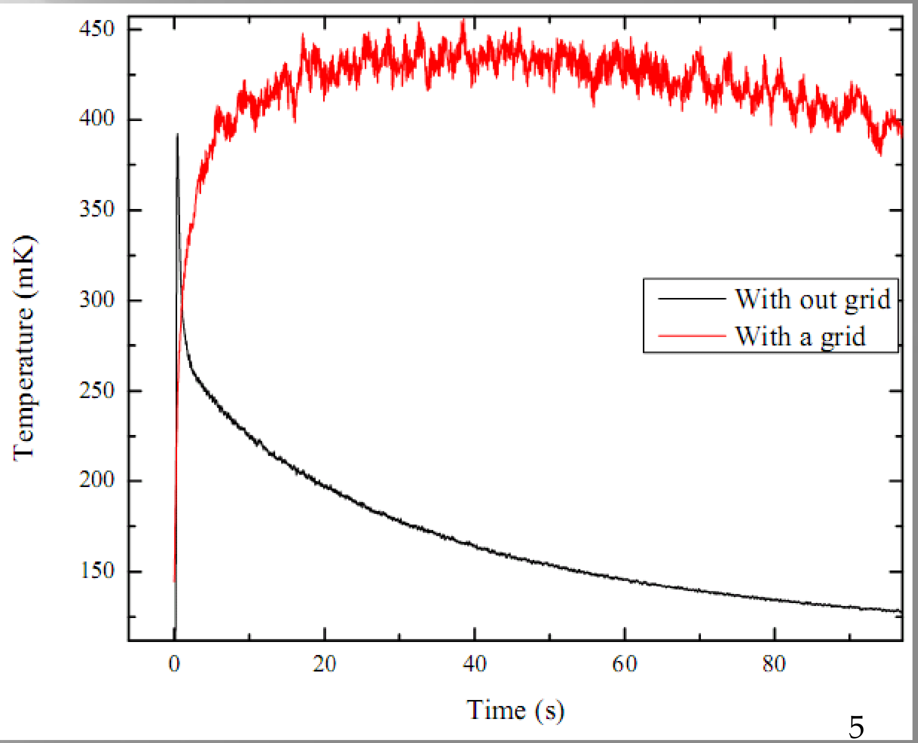
Observing the Decay

Problems with previous techniques

- Pressure fluctuations: currently available small transducers are not accurate or fast enough
- Attenuation of second sound: it does not propagate in helium at very low temperatures

Proposed technique:

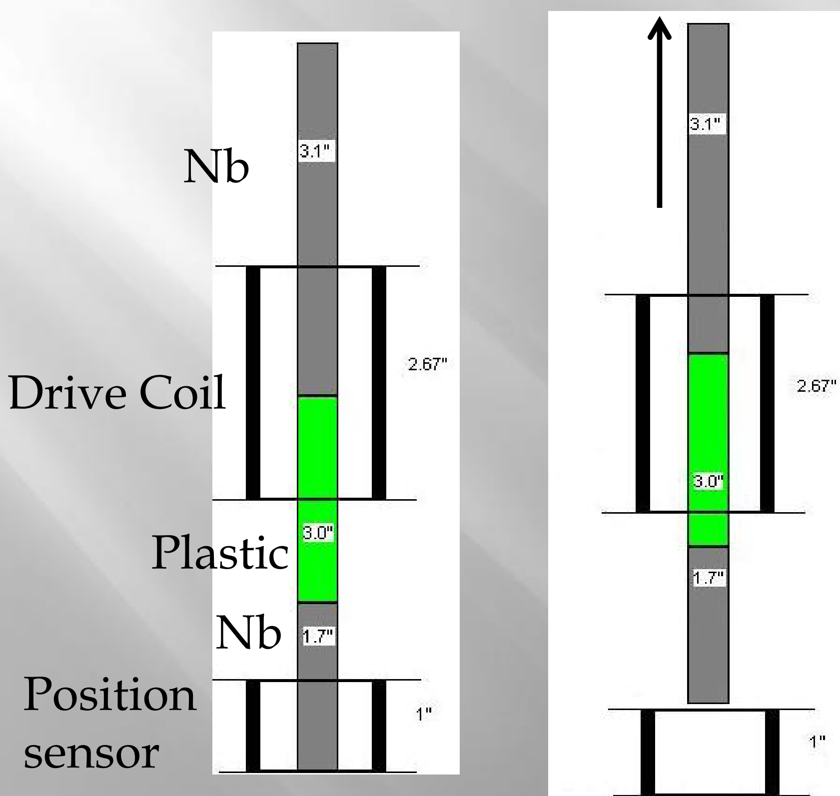
- Calorimetry: measure the rise in temperature of helium resulting from turbulent dissipation



Motor Design

Meissner effect-based motor:

- Divergent magnetic field provides lift without friction
- Remote control at mK temperatures



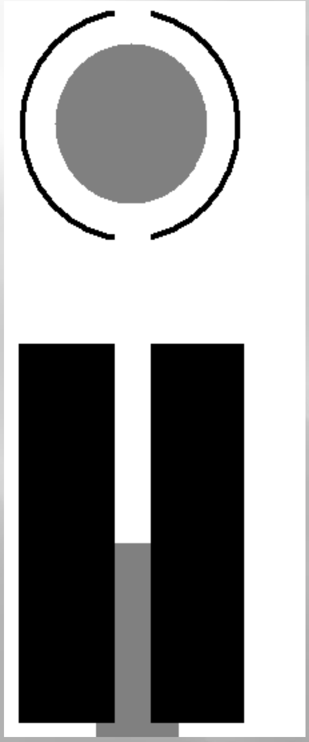
Moving a grid attached to Nb tube:

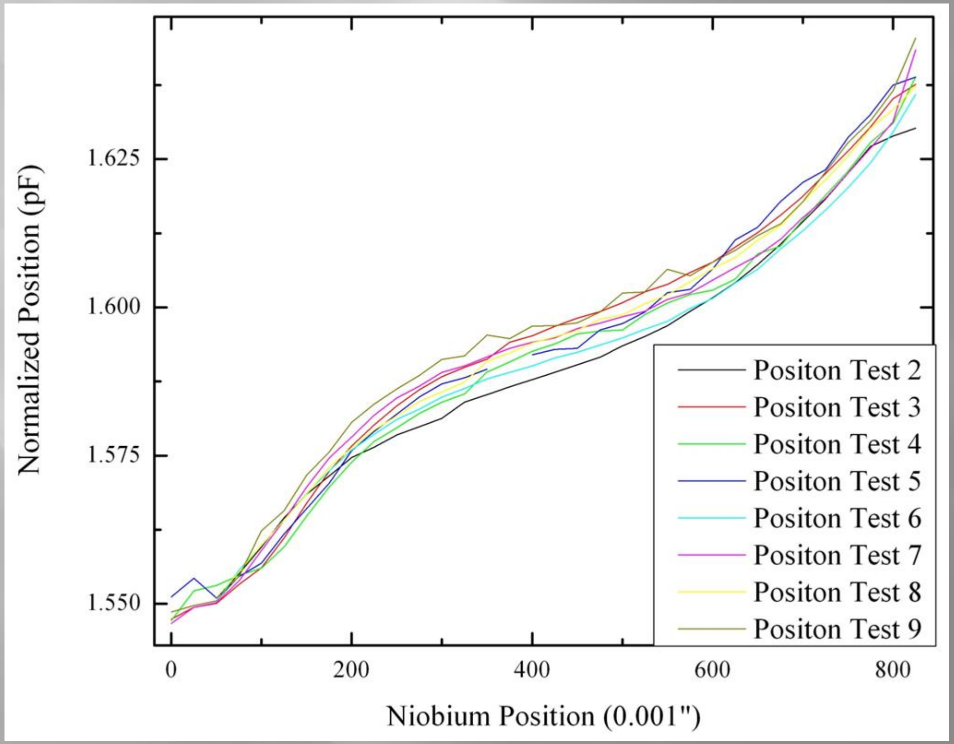
1. Current increases in the drive coil
2. Superconducting tube (Nb) experiences magnetic pressure
3. Superconductor moves to a new stable position where

   Fmag = mg

Previous Position Sensor

- Measured capacitance between two semi-cylindrical copper sheets
- Insertion of Nb tube changed permittivity ε
- Only geometry dependent





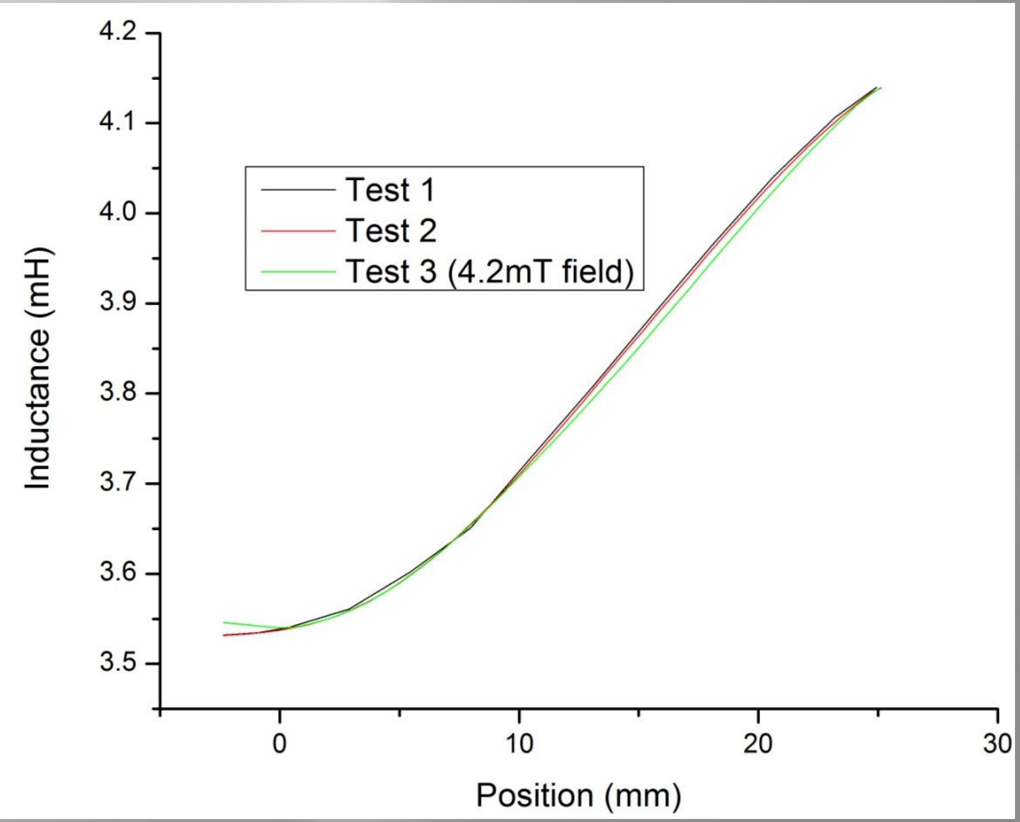
Nonlinear

Total ΔC= 0.1pF

Hard to reproduce

New Position Sensor

- Measured inductance of a copper coil $L = \mu AnN$
- Insertion of Nb tube changed permeability μ
- Depends on geometry, total number of turns (N), and turn density (n)



Results

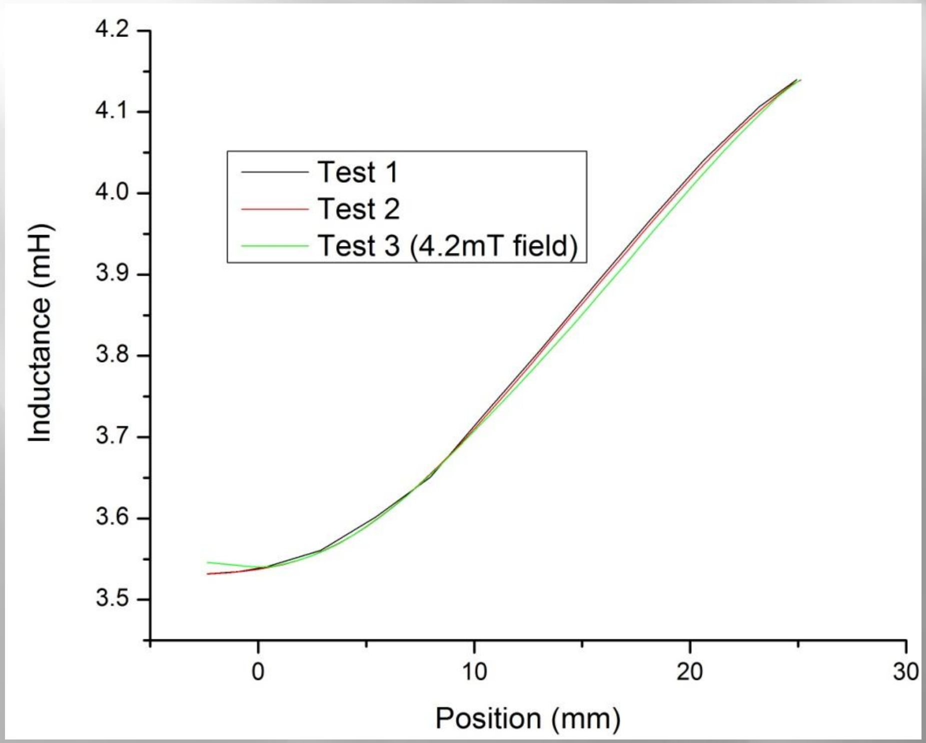
Many calibrations show that:

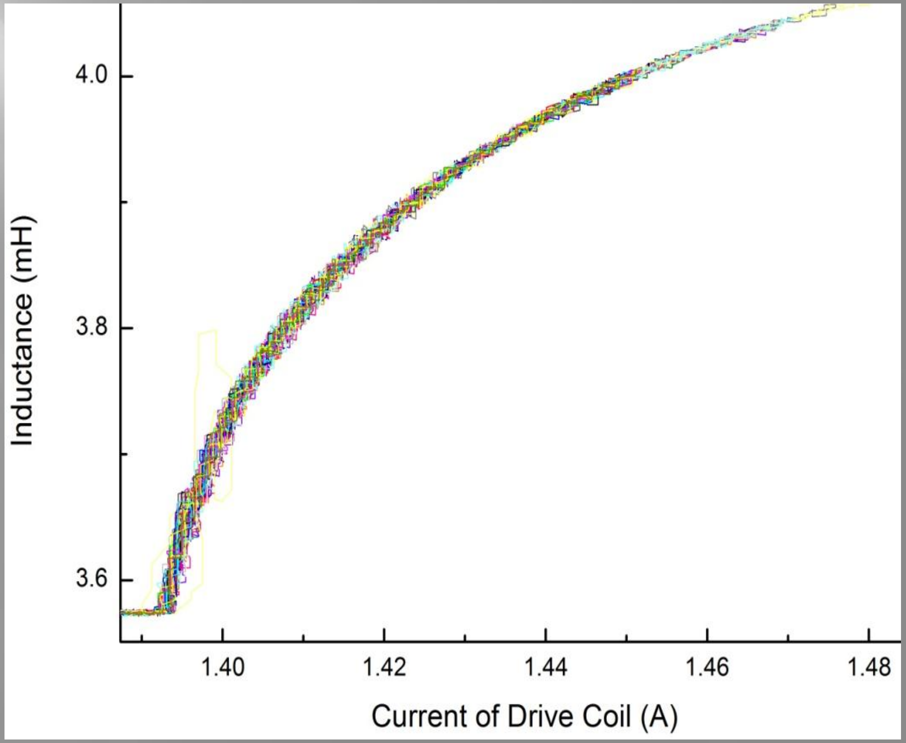
- It is mostly linear
- Reproducible
- Total change ΔL= 0.5mH
- Unaffected by small magnetic fields, similar to those that the sensor experiences from the drive coil
- Calibrations are temperature independent, perfect for use with calorimetry techniques

Precision Control

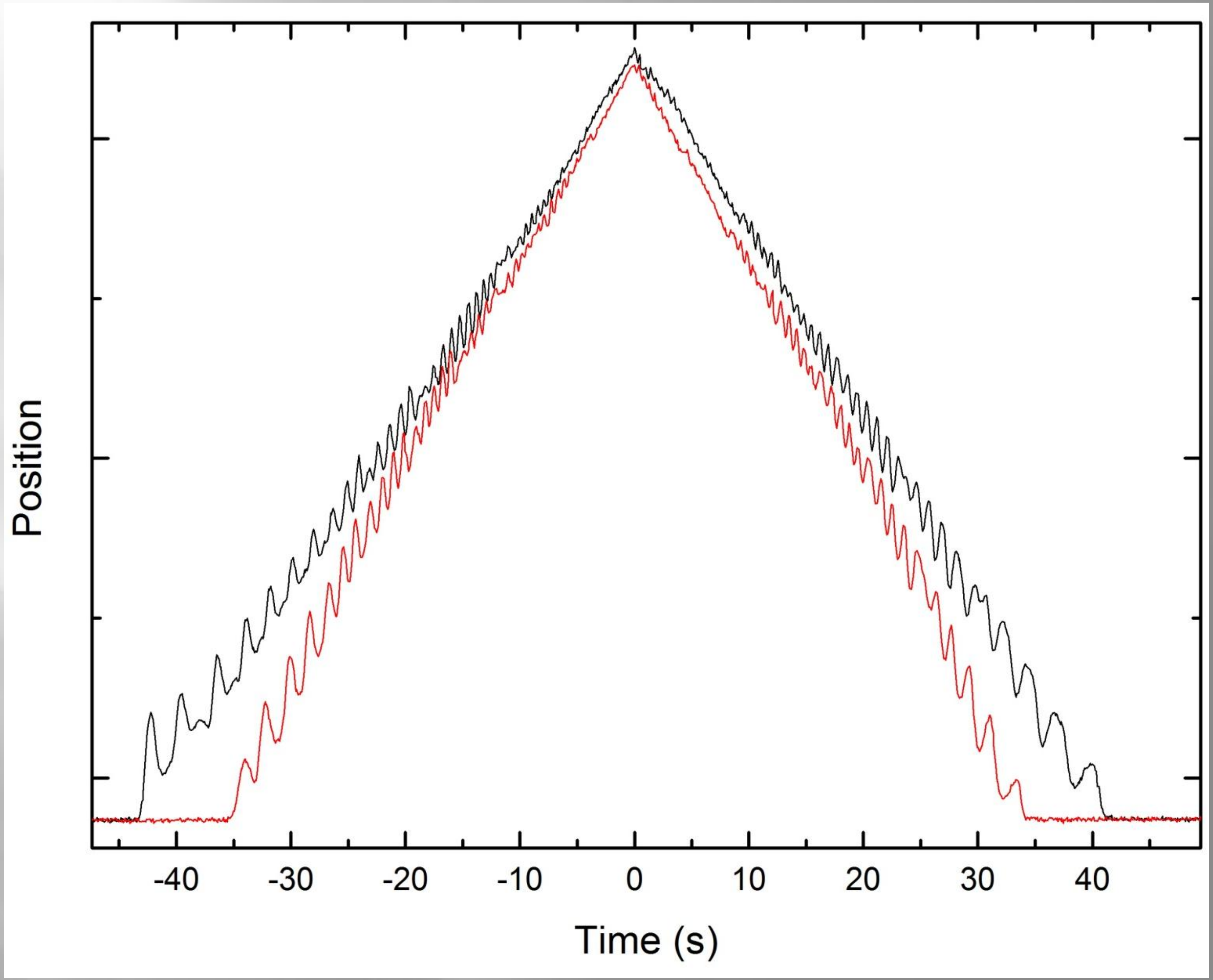
Mapping using calibration curves:

Desired Position -> Inductance -> Current -> Motion





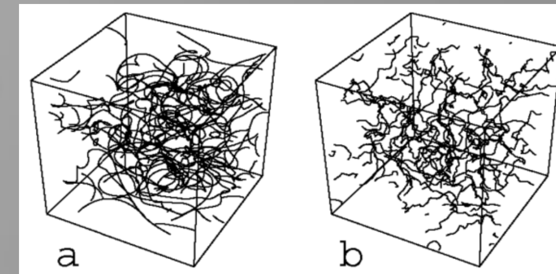
Actual Motion



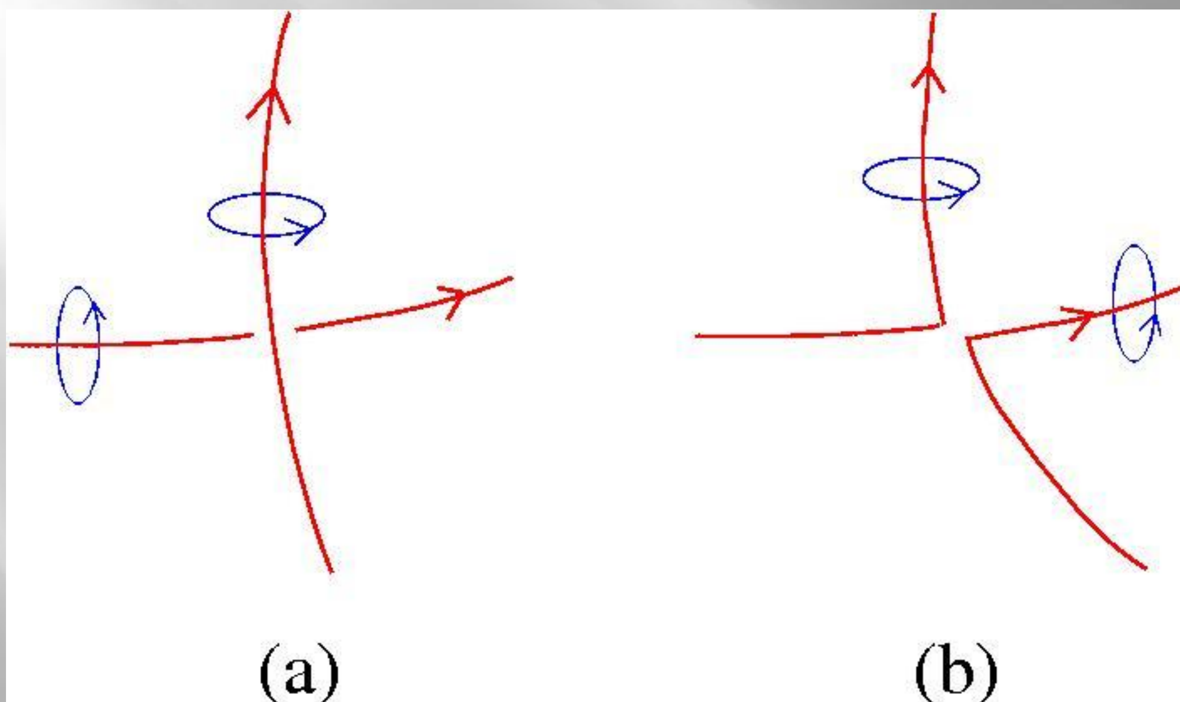
THE END

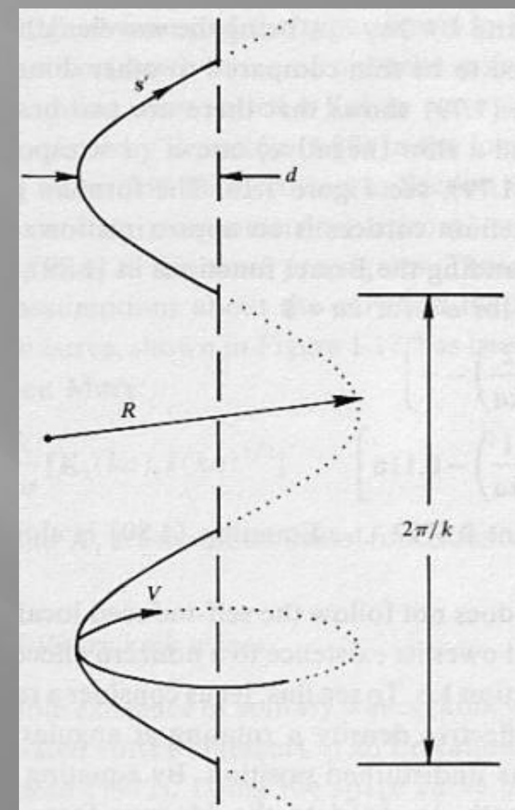
Thank You for your attention

Kelvin Waves



- Vortex line reconnections
- Induced waves on vortex lines





Calorimetric Cell