Flow Visualization in Superfluid ^{4}He Using Metastable Helium Molecules as Tracers

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Flow visualization in superfluid 4He is challenging, yet crucial for attaining a detailed understanding of quantum turbulence. Two problems have impeded progress: finding and introducing suitable tracers that are small yet visible; and unambiguous interpretation of the tracer motion. Metastable He_2^* triplet molecules are promising tracer candidate due to their small size and their relatively simple behavior in superfluid helium. He_2^* molecules can be easily produced by electron bombardment of the helium or by field ionization. To detect and image the molecules, we have developed laser-induced-fluorescence techniques. At temperatures above 1 K, helium molecules follow the motion of the normal-fluid component without being affected by quantized vortices. We shall summarize our recent progress on studying the normal-fluid flow using He_2^* molecule tracers and present evidence showing that the normal fluid can become turbulent in a thermal counterflow at relatively large heat flux. The coexistence of turbulence in both the normal fluid and the superfluid components in thermal counterflow presents us with a theoretically challenging type of turbulent behavior that is new to physics.