FORMATION OF MINI VORTEX RINGS ARISING FROM A VORTEX PAIR IMPINGING ON A WAVY WALL

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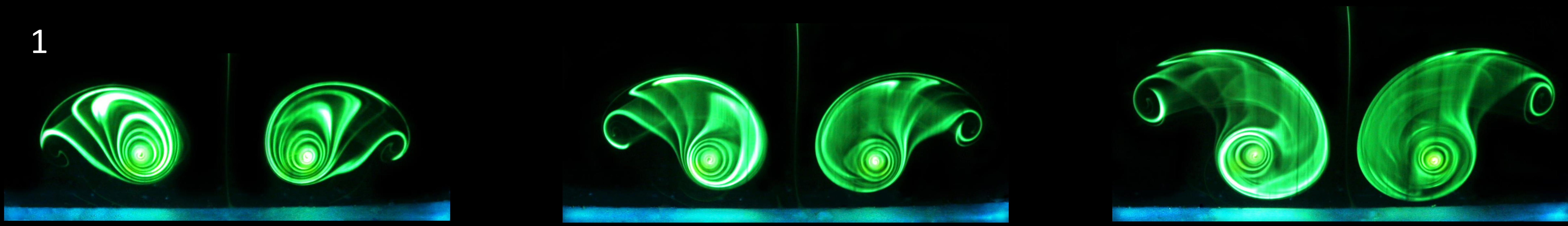
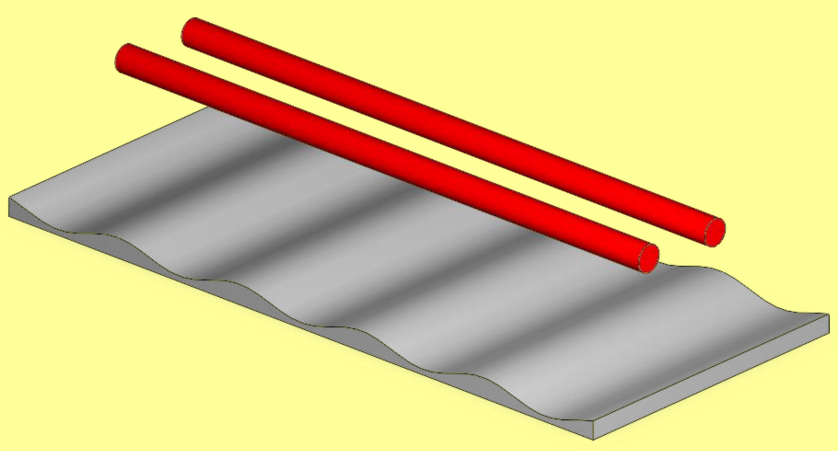
1



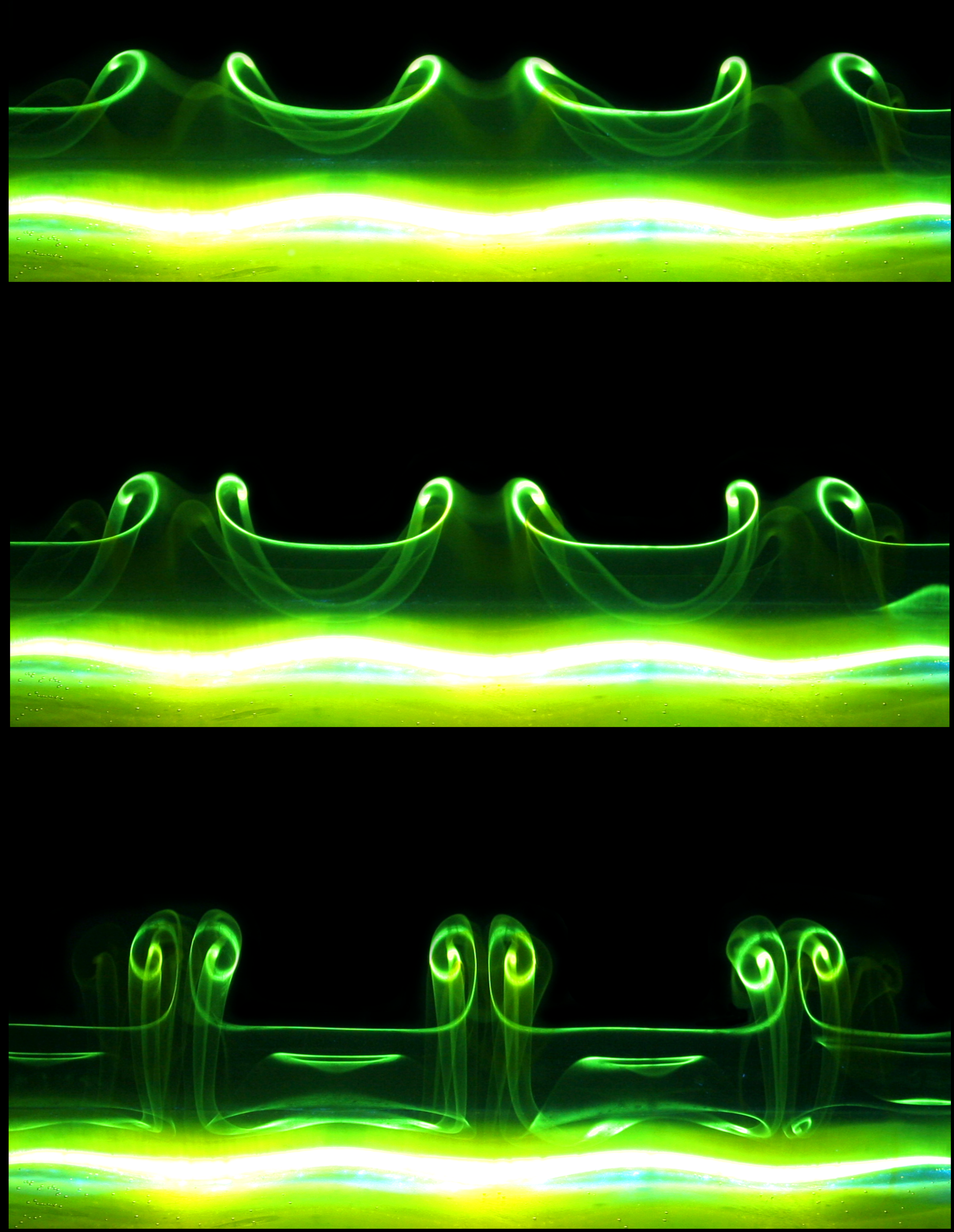
In this work, we examine the impingement of a counter-rotating vortex pair onto a wavy wall* (See Figure 4 below). *When a vortex pair with the long-wave "Crow" instability interacts with a flat boundary, the topology of the pair changes. This results in rebounding vortical structures whose form is dependent on the extent of the instability prior to wall interaction (Asselin & Williamson, Accepted JFM, 2016). By considering the "complementary" experiment of a straight vortex pair encountering a wavy wall (rather than a wavy vortex pair impinging on a flat wall), certain critical features of the two flows are found to be similar. Such research has applications in fundamental turbulence, and in flows such as wingtip vortices generated behind aircraft.

4



We employ two long, computer-controlled flaps that are lowered into a water tank and closed to generate a counter-rotating vortex pair, which travels downward under its own induced velocity. The vortices then impinge upon transparent hillocks that are custom casted with Crystal Clear 200 acrylic resin, which sits upon a transparent acrylic ground plane that fits the length of the tank. When the vortex pair encounters the wall, the boundary layer that forms on the surface separates, generating secondary vorticity and causing the primary pair to 'rebound'.

2



A key feature of this experiment is the ability to visualize the primary and secondary vortices either independently or concurrently. The flow is illuminated using an argon ion laser. The primary vortex pair is made visible by directly painting the flaps with fluorescein dye, while dye is carefully pooled (prior to the experiment) on the surface of the hillocks to visualize the secondary vortices.

Two principal effects are discovered in this flow:

- The 2D vortex pair first interacts with the "hills" of the wavy wall, triggering accelerated vorticity cancellation in this area compared to the corresponding "valley" regions. An axial pressure gradient forms between the two regions, giving rise to strong axial flow.

- This leads to the interaction of primary and secondary vortices in the valleys, wherein reconnection results in "rebounding" vortex rings.

Figure 1. The development of the primary vortex pair at three different times is shown as a transverse cross section through the "valley". The vortex core remains in the same location, while the secondary vorticity is swept around the primary vortex and entrains primary dye into the outermost region of secondary vorticity. The cross section of the hillock is illuminated blue by the laser.

Figure 2. In this series the secondary vorticity of the back vortex is shown as a cross section of the longitudinal plane, where the waviness of the wall can be seen. Secondary vortex tubes can be observed developing around the primary vortex, resulting in the formation of rebounding vortex ring structures.

Figure 3. In this image, both the primary and secondary vortices of the back vortex are visualized simultaneously. The secondary dye (brighter green) is nested within the primary dye. Once again the rebounding vortex rings can be observed, and the hillock is illuminated bright blue by the thin laser sheet passing through.

3