

Experimental investigation of vortex-ring cavitation

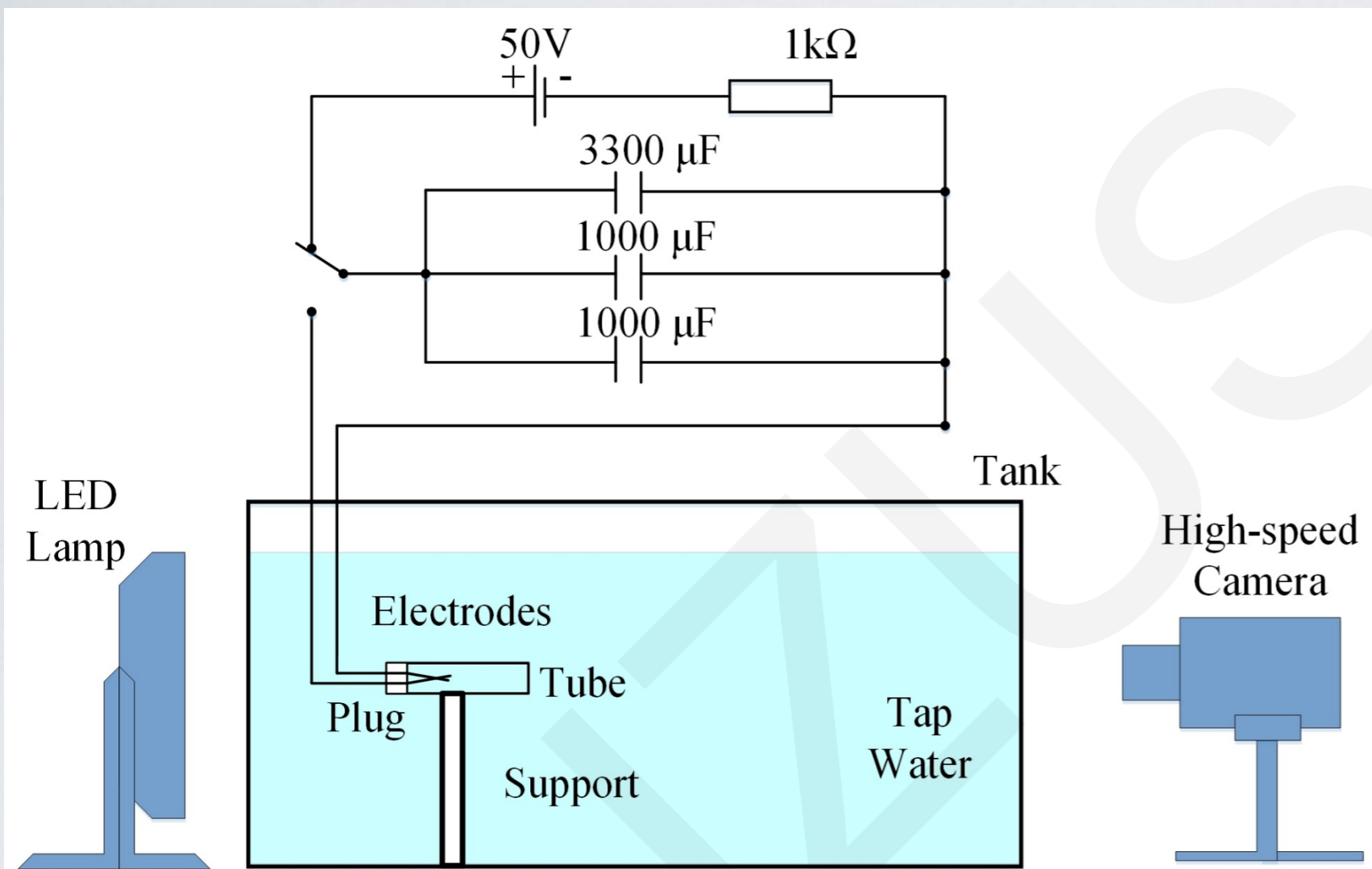
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Key words: Cavitation, Toroidal cavity, Oscillation period, Impinging on wall

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Experimental setup

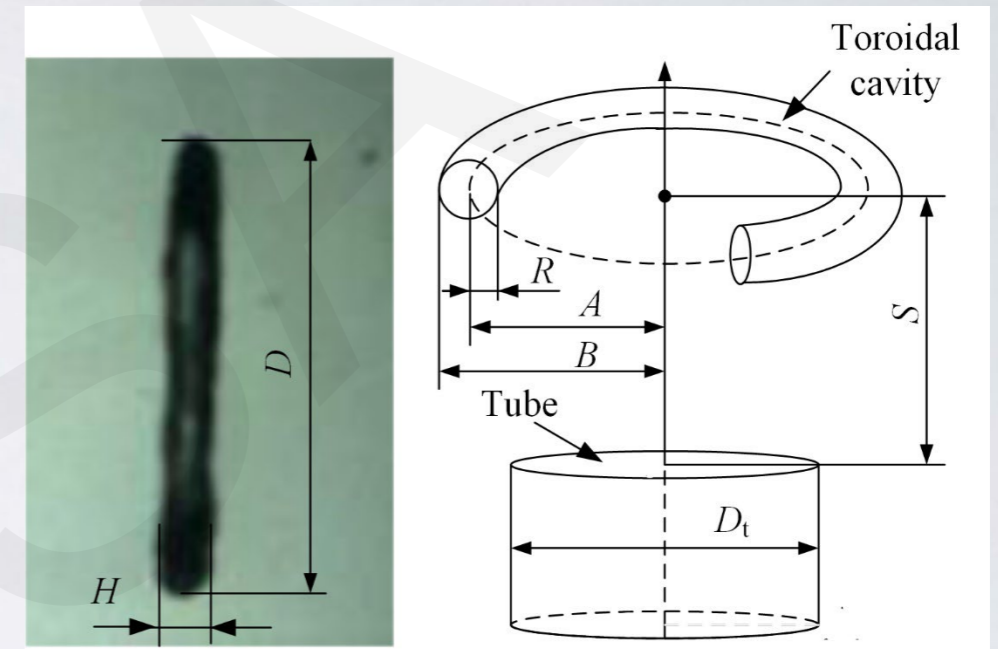
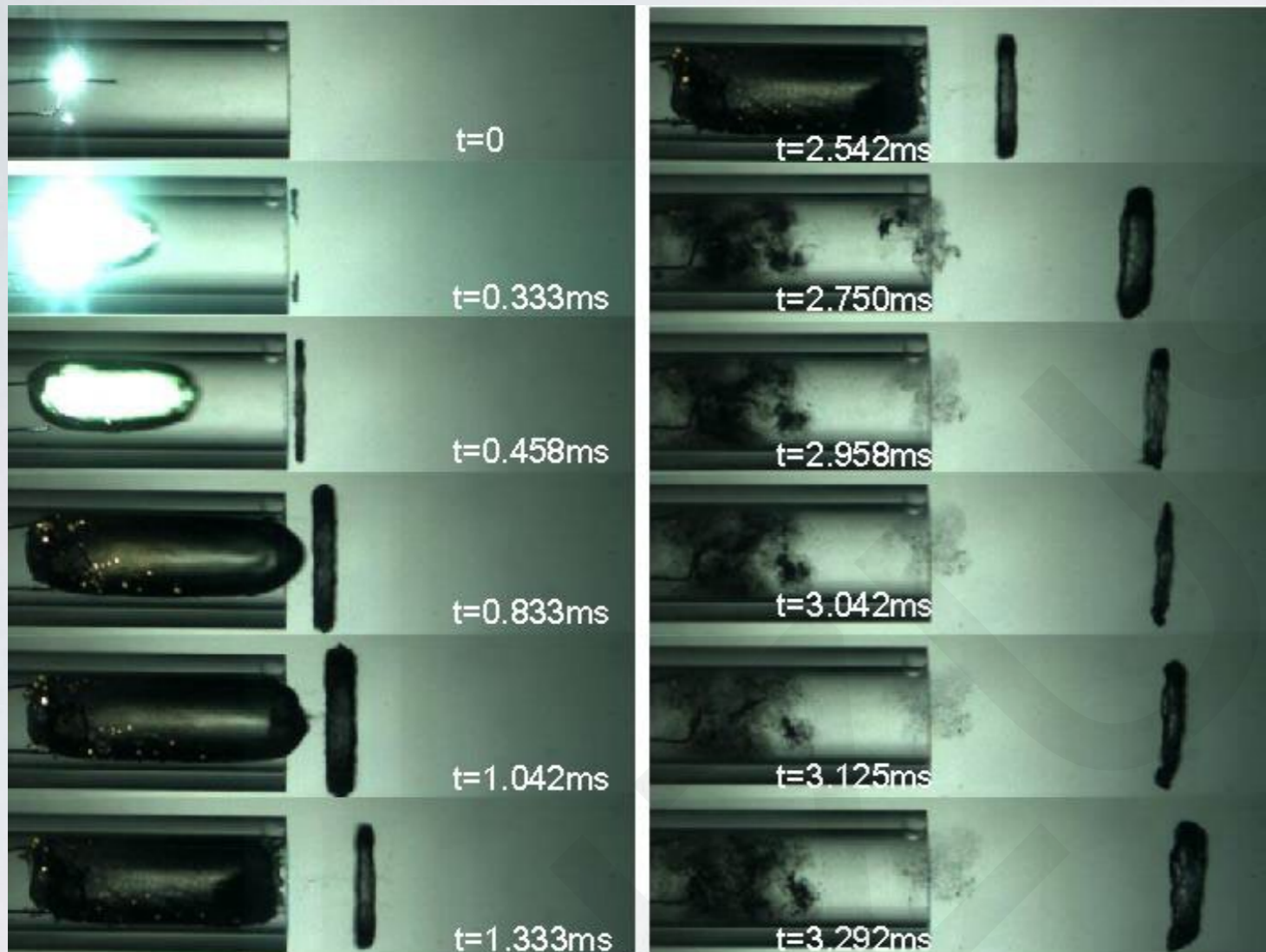


A circuit is used to induce a low-voltage electric spark in a transparent cylindrical tube immersed in tap water, to generate a cavitation bubble in the tube.

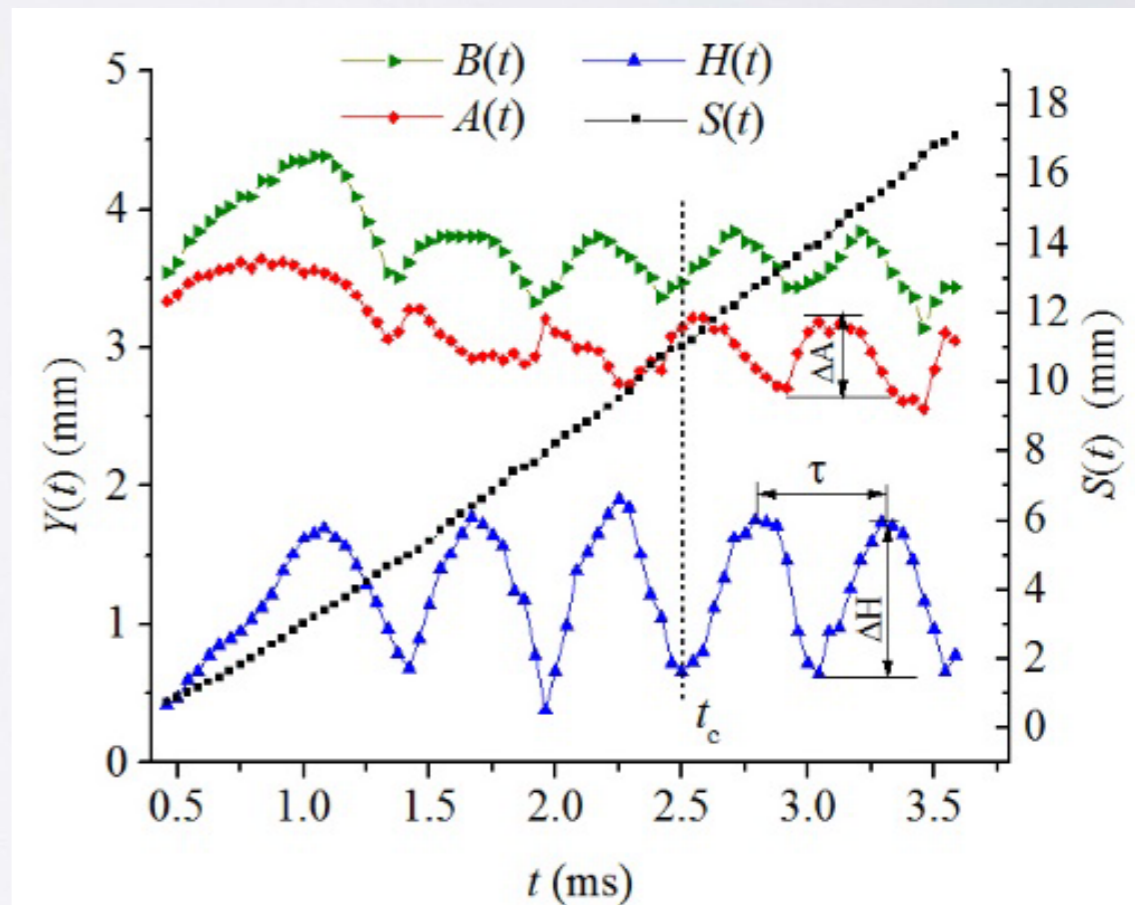
One open end of the tube is blocked by a silica gel plug pierced by electrodes, which encourages the formation of a toroidal cavity around the other open end.

Schematic diagram of the experimental setup

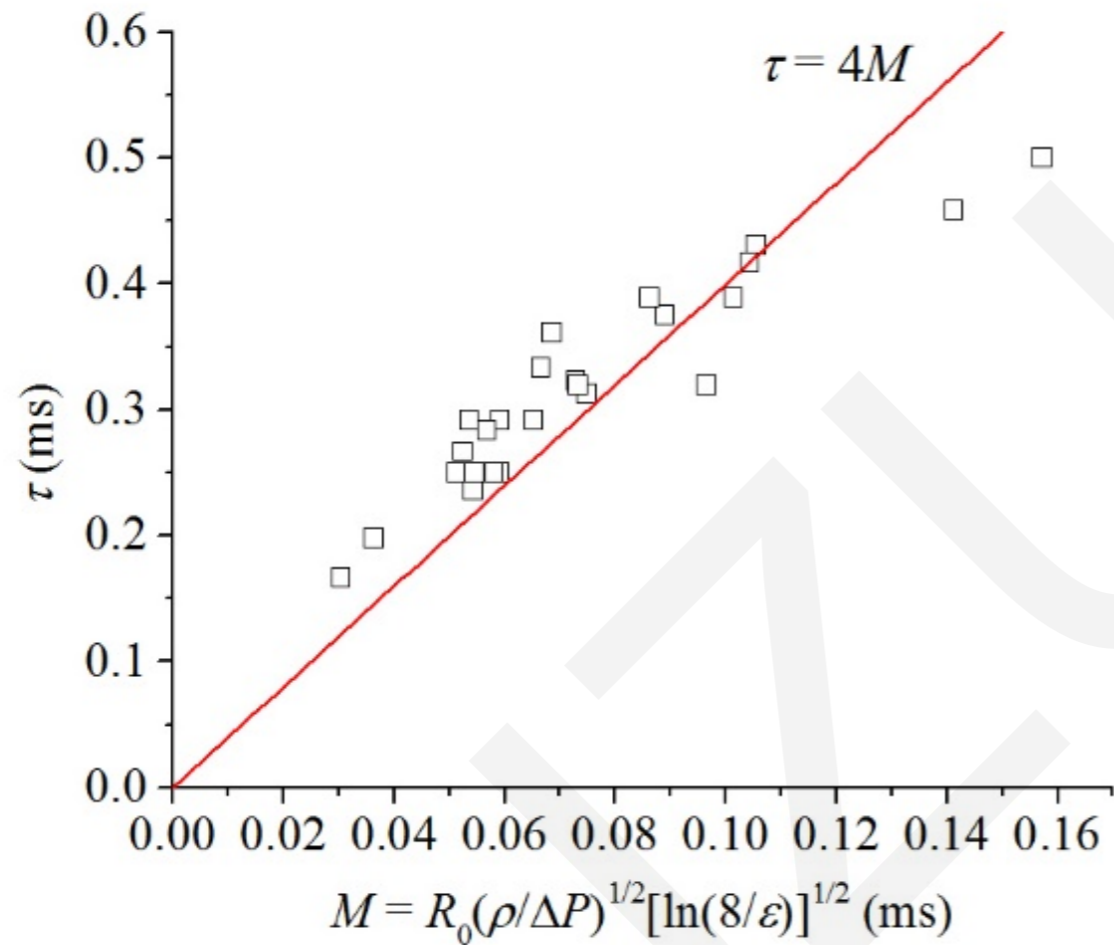
The oscillation of the toroidal cavity



The toroidal cavity oscillated periodically and moved with a constant velocity after the collapse of inner bubble



The oscillation period of toroidal cavities



The oscillation period of toroidal cavities follow the scaling law:

$$\tau \sim R_0(\rho/\Delta p)^{0.5}[\ln(8/\varepsilon)]^{0.5}$$

Oscillating model for a toroidal cavity

$$(R\ddot{R} + \dot{R}^2) \ln \frac{R}{8A_0} + \frac{1}{2} \dot{R}^2 = \frac{1}{\rho} \left[P_0 - \frac{\rho}{2} \left(\frac{\Gamma}{2\pi R} \right)^2 - P_v - P_{g0} \left(\frac{R_0}{R} \right)^{2k} + \frac{\sigma}{R} \right]$$

The circulation Γ is hard to measure



How to evaluating Γ ?



Circulation calculation

Line vortex model

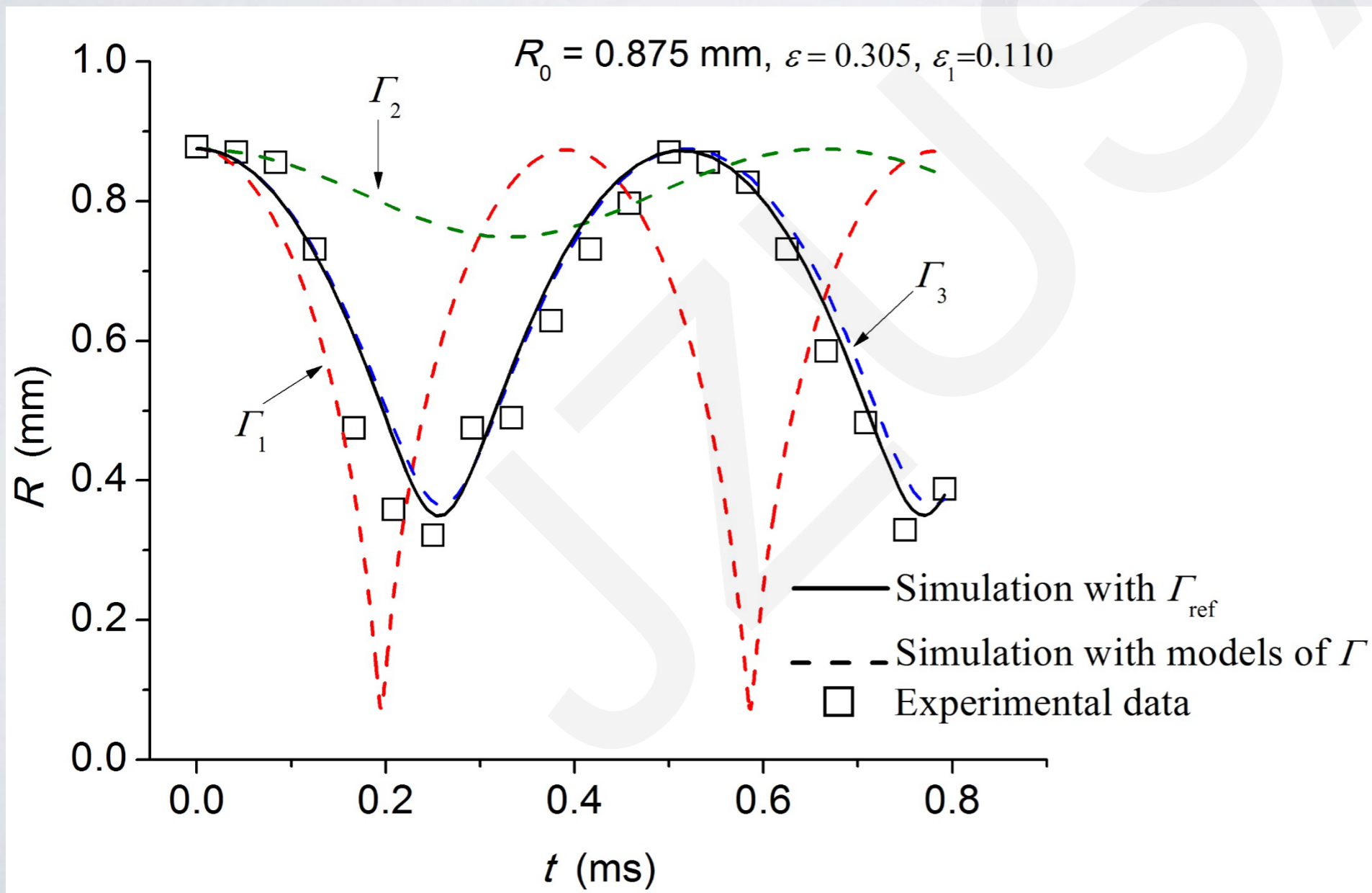
$$\Gamma_1 = 2R_0 V_z$$

Hollow core model with maximal core radius

$$\Gamma_2 = \frac{4\pi R_0 V_z}{\left(\varepsilon \log \frac{8}{\varepsilon} - \frac{1}{2} \varepsilon \right)}$$

Hollow core model with minimal core radius

$$\Gamma_3 = \frac{4\pi R_1 V_z}{\left(\varepsilon_1 \log \frac{8}{\varepsilon_1} - \frac{1}{2} \varepsilon_1 \right)}$$



Summary

- The oscillation of toroidal cavities induced by vortex rings is investigated experimentally.
- The experimental data agree well with the theoretical analysis: $\tau \sim R_0(\rho/\Delta p)^{0.5}[\ln(8/\varepsilon)]^{0.5}$
- An estimation model of circulation is proposed

$$\Gamma = 4\pi R_1 V_z / \left(\varepsilon_1 \log \frac{8}{\varepsilon_1} - \frac{1}{2} \varepsilon_1 \right)$$