Particle Assembly with Synchronized Acoustical Vortices

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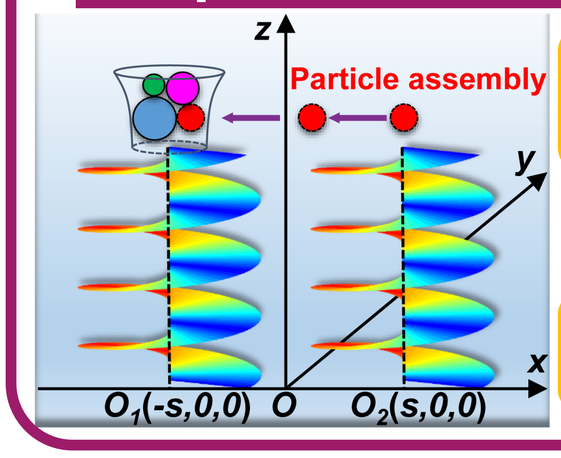
Graphic abstract



Single Vortex[1,2]: Selective trapping; NO assembly.

Two Vortices: 2D assembly[3].

Gor'kov potential theory and drag force

Gor'kov potential: [4] $U = 2\pi a^3 \rho_0 \left[f_1 \left\langle p^2 \right\rangle / \left(3\rho_0^2 c_0^2 \right) - f_2 \left\langle \mathbf{v}^2 \right\rangle / 2 \right]$

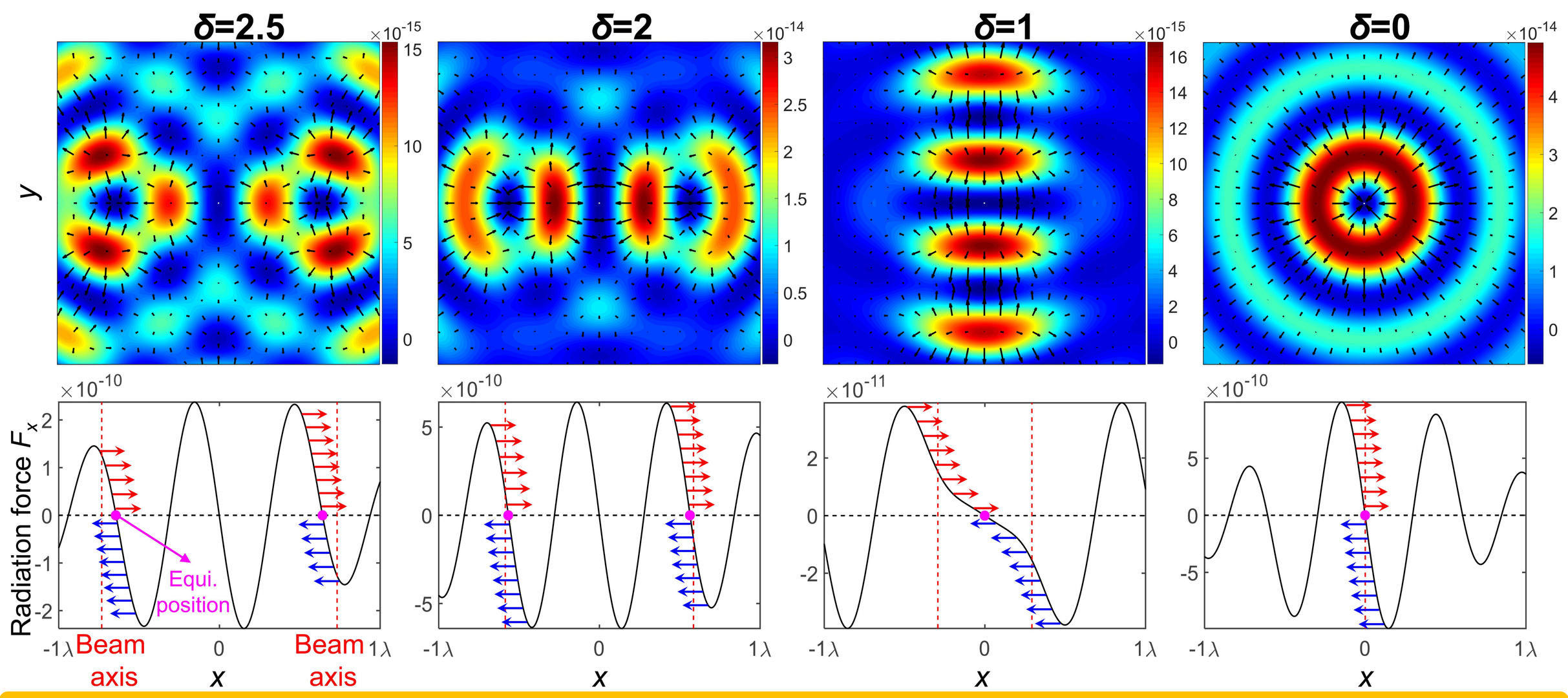
Total pressure field: $p = \sum_{j=1,2} A_j J_m \left(k_\perp r_j \right) e^{i\left(m\theta_j + k_\square z \right)} e^{i\beta_j}$ $\begin{cases} k_\perp = k \sin(\gamma) \text{ with } \gamma \text{ cone angle} \\ \beta\text{: original phase angle} \end{cases}$

Radiation force: $\mathbf{F} = -\nabla U$

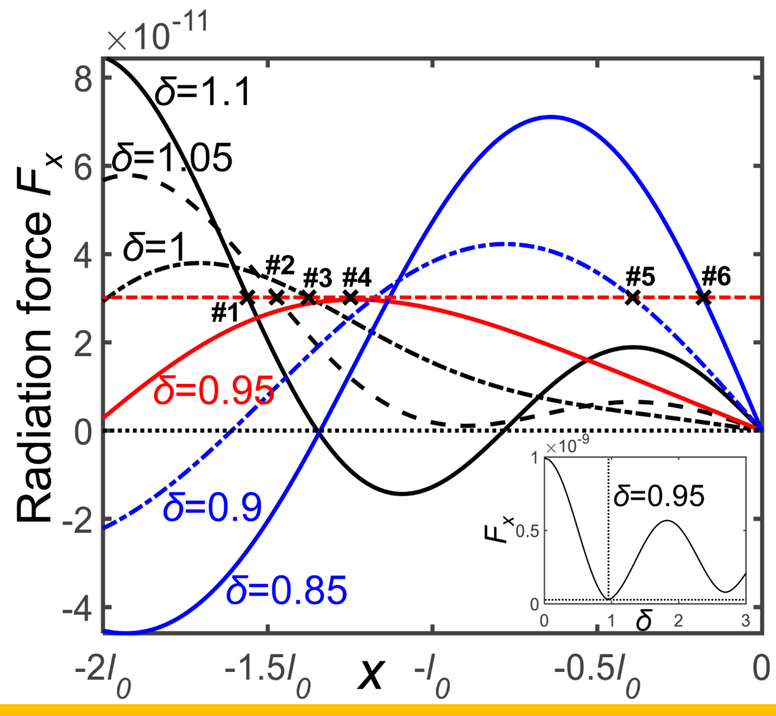
Stokes' drag force: $F_d = -6\pi\eta a v$

Parameters: Particle size: a=5 μm; $A_{1,2}$=10^6 Pa; Frequency: f=5 MHz; m=1; γ=90° (nonpropagating); Lateral offset ratio: $\delta = s/l_0$ (l_0: first peak distance)

Simulation results: 2D assembly & critical moving speed



2D particles assembly with two synchronized vortices. Magenta solid spheres denote the static equilibrium positions.



Critical radiation force for moving speed

- **Successfully assembling particles initially trapped at the center of two separate acoustical vortices by creating an attractive path between two interfering *cylindrical* Bessel vortices;**
- **Critical moving speed [determined by keeping the balance between the critical radiation force (here δ=0.95) and drag force, ~ 300 μm/s for PS sphere in water] agrees with the typical particle velocity in microchannel (5 – 500 μm/s);**
- **Potential for selective patterning, enrichment of particles.**

Conclusion

We demonstrate theoretically the ability to assemble two small particles in 2D by using two synchronized vortices. The critical speed at which particles can be assembled has been further investigated to meet the criterion for typical particle velocity in microchannels. More versatile applications of acoustic vortices are reviewed in Ref. [5].

References & Acknowledgement

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J.-L. Thomas