A Low- Cost Microfluidic Concentrator for Cyanobacteria Harvesting

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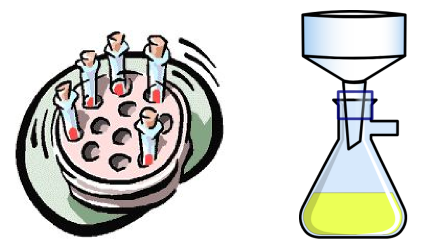
Abstract

❖ Problem needs to be solved

Cyanobacteria Harvesting in Biofuel production **30%**

Current solutions: **$$$$$$**



	Continuous Flow Centrifugation	Cross Flow Microfiltration
Process ability	300 L/h	300 L/h
Device Cost	$270,000	$175,000
Installation Cost	$54,000	$25,000
Annual Maintenance cost	$25,000	$40,000
Total	$349,000	$240,000

In order to **reduce capital investment of biofuel production**, there is a great interest to develop new economical feasible harvesting methods.

❖ Our solution

Inertial Focusing Microfluidics:

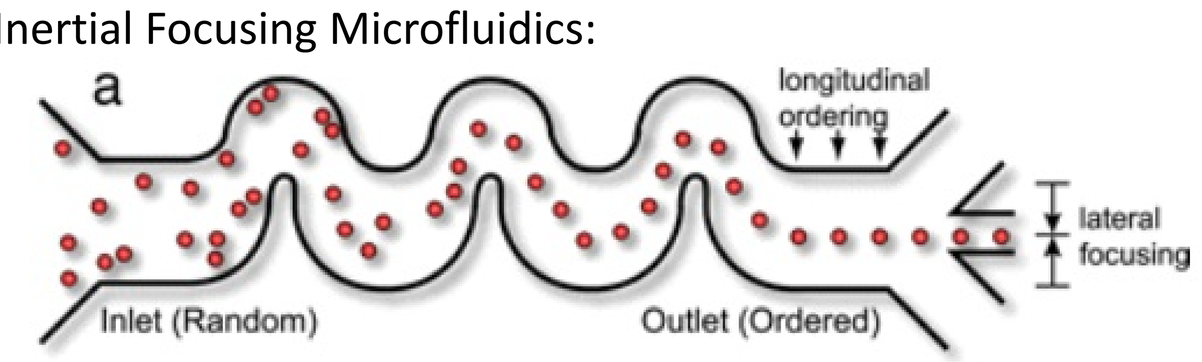


Image source:
D.D. Carlo, et al., PNAS, 104, 18892-97 (2007)

Current usage
✓Focusing
mammalian cell (size≥8μm)

Our usage
✓Focusing
Cyanobacteria (size≈**2μm**)

Physics of inertial focusing

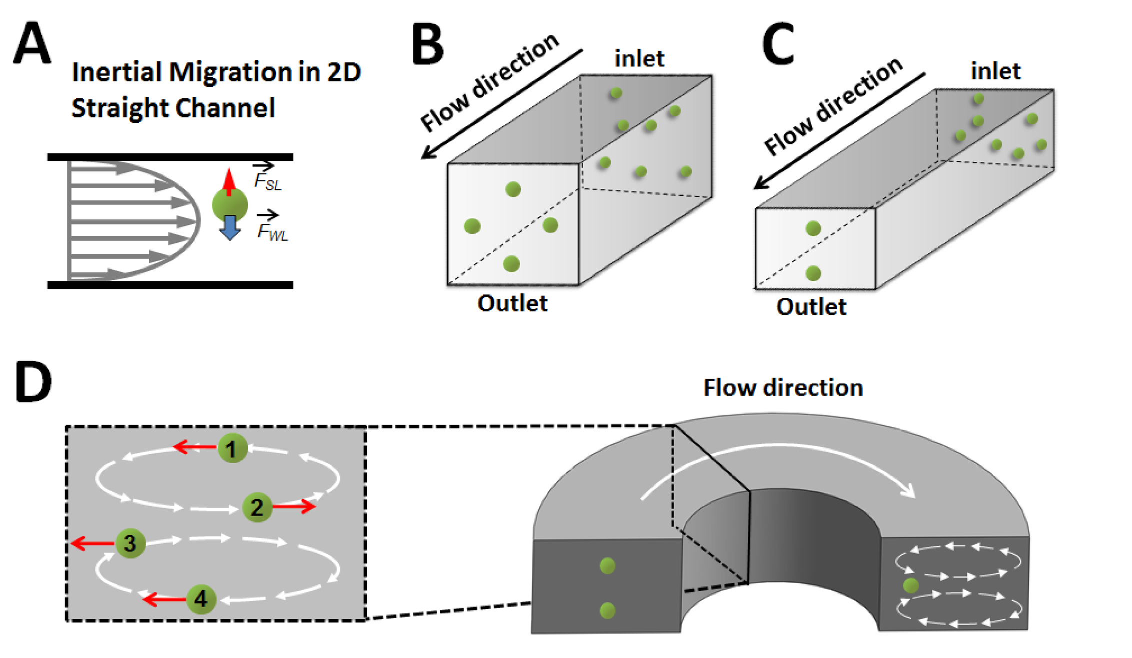


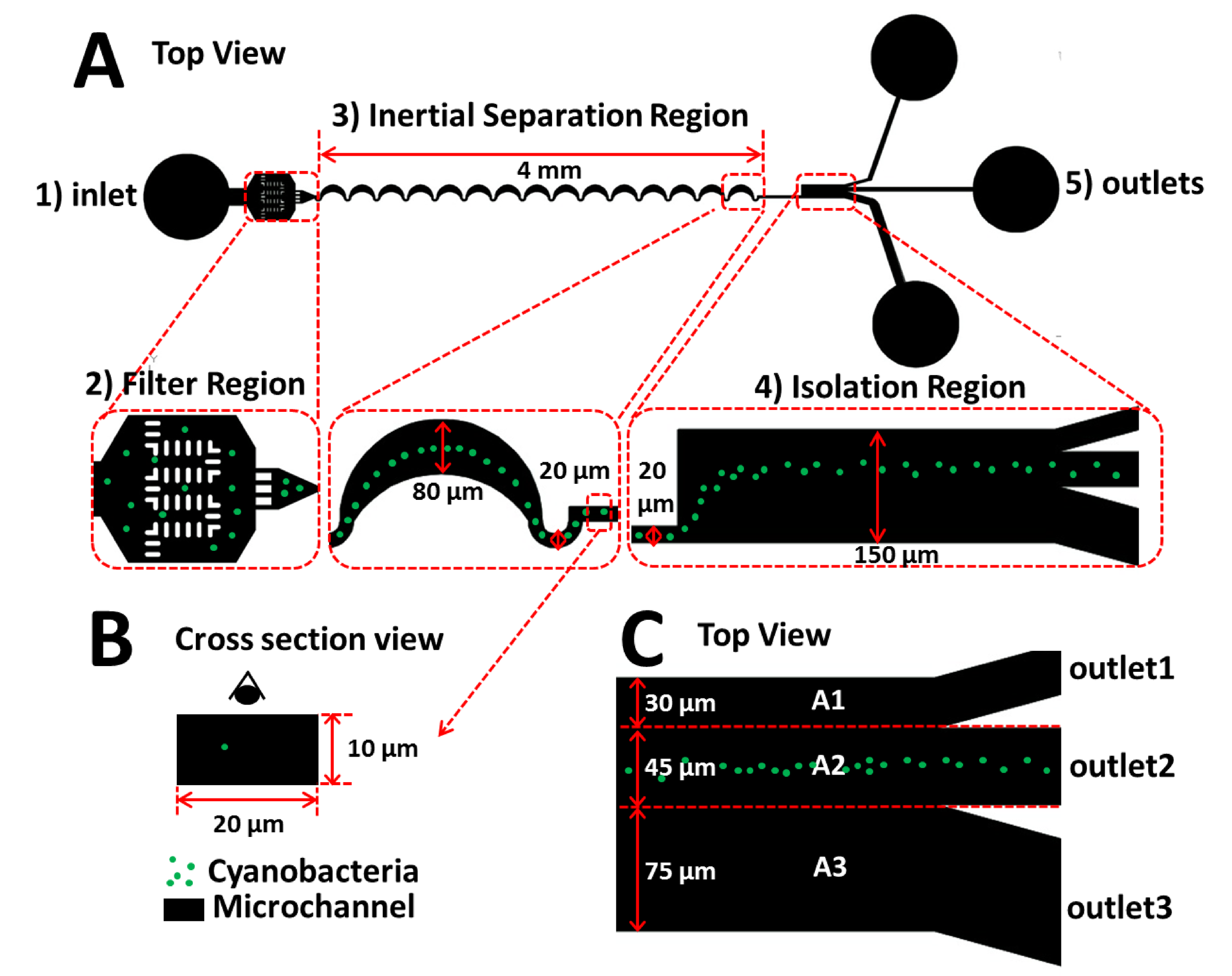
Image source:
L Wang, et al., Algal research, 26, 481-489 (2017)

Shear Induced Lift Force: F_{IL}
Wall Induced Lift Force: F_{WL}
Inertial Lift Force: F_L

$$\overline{F_L} = \frac{4\rho \overline{U}_f^2 C_L a_p^4}{D_h^2}$$

Inertial lift forces. (A) In two-dimensional or axisymmetric geometries, particles in flow experience opposing forces associated with shear gradient lift (F_{SL}) and wall-effect lift (F_{WL}) that balance when the particles reach equilibrium lateral positions. (B) In a square channel, the randomly distributed inlet suspension will be focused into four equilibrium regions centered at each face. (C) For rectangular channels, the randomly distributed particles migrate to two equilibrium positions which are located near the middle of the long channel faces. (D) Dean flow creates two counter-rotating vortices (white arrows) perpendicular to the primary flow direction.

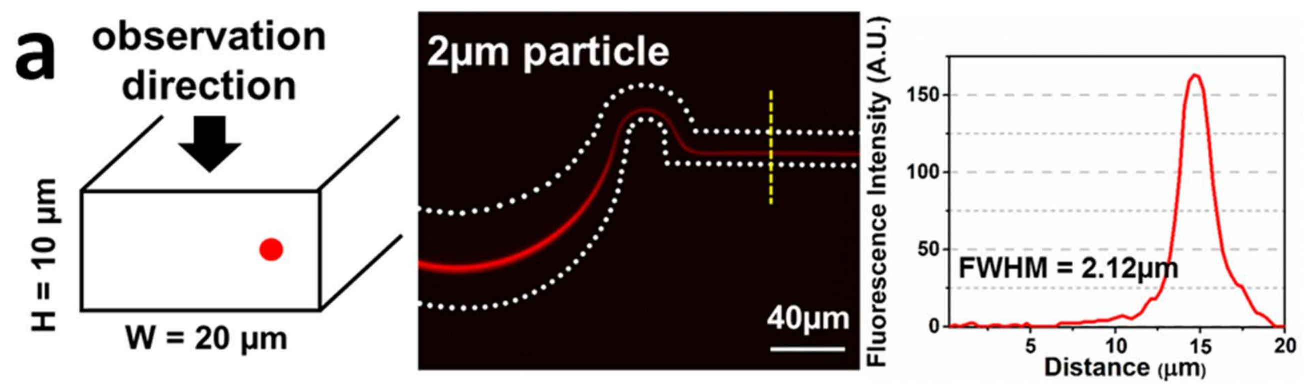
Device design



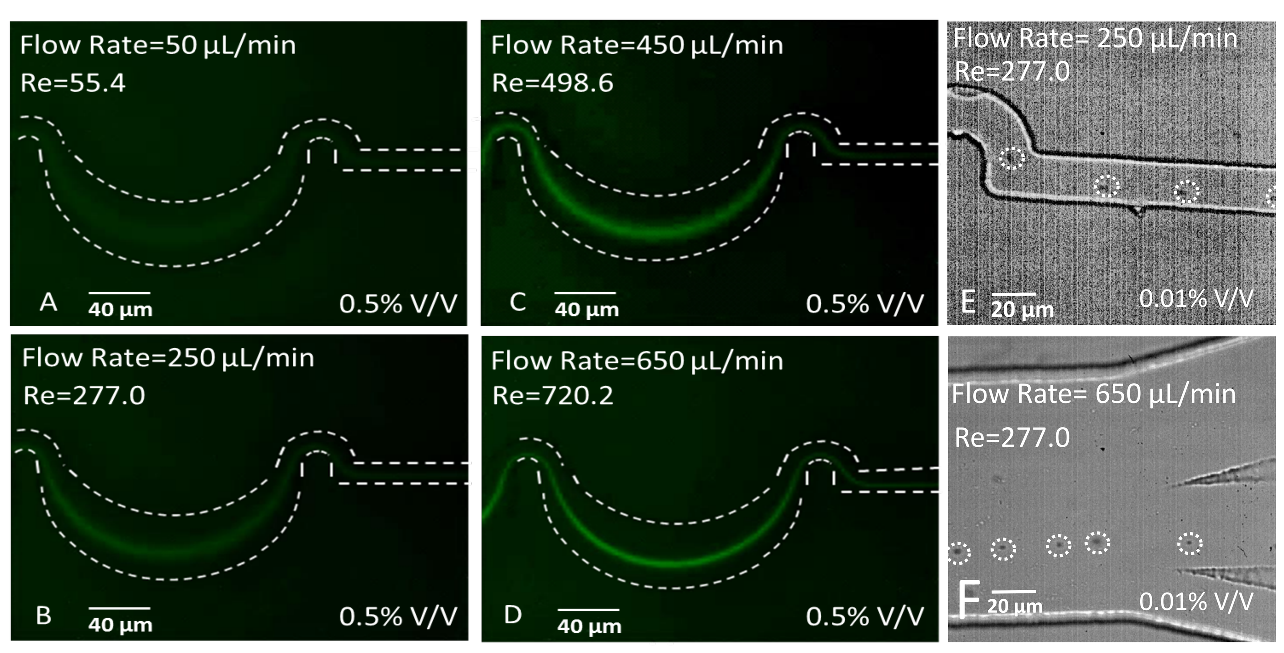
Design of the microfluidic device for concentrating cyanobacteria. (A) Top view of the design and enlarged images for each region. (B) Cross section view of cyanobacteria focusing in the straight channel after the last curve. (C) Detailed view and scale of the isolation region. The A1 and A3 regions carried the waste streams, and A2 fed outlet 2, which was intended for collecting the concentrated cyanobacteria product stream.

Results

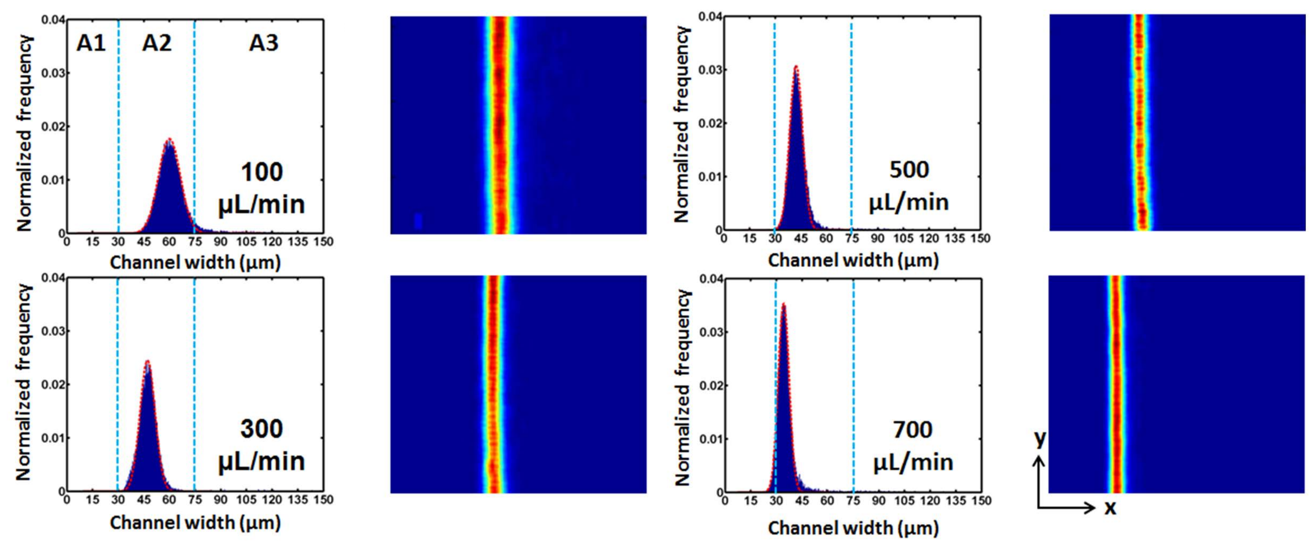
❖ 2 Micron red fluorescence particle focusing

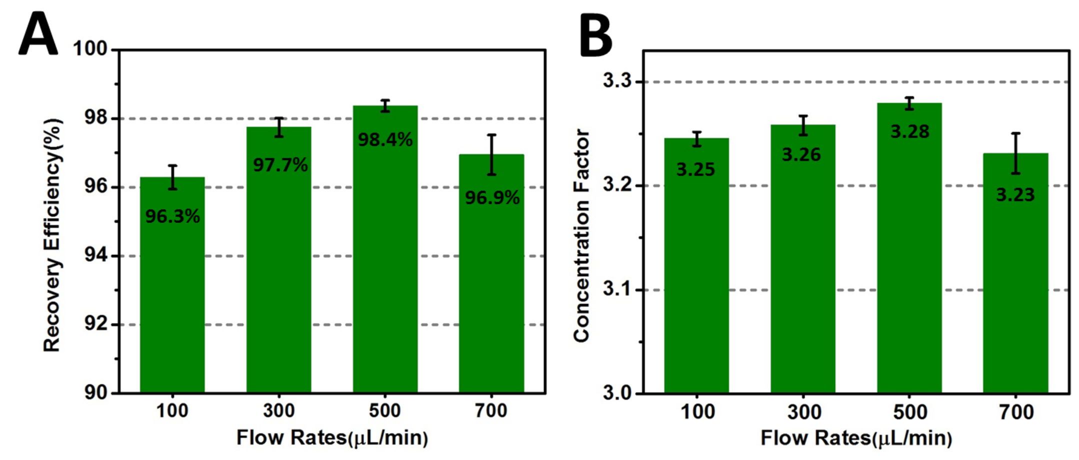


❖ Cyanobacteria focusing



❖ Effect of flow rates on cyanobacteria concentration





Recovery efficiency: 98.4±0.2%
Concentration factor: 3.28 (98.5% of the maximum possible value)

❖ Power consumption

Harvesting technology	Concentration factor (vol. in/vol. out)	Energy consumed per unit volume (kWh·m^{-3})
Decanter bowl centrifuge [1]	11	8.0
Self-cleaning, disc-stack centrifuge [1]	120	1.0
Nozzle discharge centrifuge [1]	20-150	0.9
Microfluidic Concentrator	3	1.6
	11	3.2
	36	4.8
	118	6.4
	390	8.1

Reference
[1] E. Molina Grima et al. Biotechnol. Adv. 20, 491-515, 2003

Significance & limit

•This is a promising alternative approach for harvesting at commercial scale, and may help with overall process economics and feasibility.
•Lowering microalgae harvesting costs using microfluidics technology lies in the trade-off resulting from the inverse relationship between operating energy requirements and capital cost.

Conclusions

•A powerful tool has been designed, constructed, and validated for inertial focusing of micron- and submicron-sized particles and bioparticles with potential for high throughput.
•Performance is evaluated by recovery efficiency, concentration factor, and power consumption.
•This represents a promising alternative approach for economical feasible large-scale industry algae harvesting.

Acknowledgement

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