## Appendix III: Comparison of flow generation performance of ArtC with other microfluidic pumps

For fully developed laminar flow in a channel with rectangular cross section of a width *w*, height *h* and length *L*, the pressure drop  $\Delta P$  and the flow rate *Q* can be computed as follows:<sup>1</sup>

$$\Delta P = \frac{\mu V_z(x,y) L \pi^3}{4h^2 \sum_{n=1,3,5...}^{\infty} \frac{(-1)^{\frac{n-1}{2}}}{n^3} \cos\left(\frac{n\pi y}{h}\right) \left[1 - \frac{\cosh\left(n\pi x/h\right)}{\cosh\left(n\pi w/2h\right)}\right]}$$
(1)  
$$Q = \frac{wh^3 \Delta P \left[1 - \frac{192h}{\pi^5 w} \sum_{n=1,3,5...}^{\infty} \frac{\tanh(n\pi h/2w)}{n^5}\right]}{12\mu L}$$
(2)

where  $\mu$  is the dynamic viscosity,  $V_z(x, y)$  is the flow speed at the point (x, y) in the cross section, with x being the width direction (-w/2 < x < w/2) and y the height direction (-h/2 < y < h/2). In our study,  $w = 500 \ \mu$ m and  $h = 420 \ \mu$ m, and a flow speed at the center of the channel  $V_z(0,0)$  was measured to be 120  $\mu$ m/s with the configuration of  $5 \times 5$  ArtC at the actuation frequency of 20 Hz in water. Using Eq.1 and 2, a flow rate Q about 0.7  $\mu$ L/min can be obtained.

The self-pumping frequency is defined as follows:<sup>2</sup>

$$f_{sp} = \frac{Q}{S_p} \tag{3}$$

with  $S_p$  being the size of the pump. If we take the size of the cilia chamber as  $S_p$ , which is 4  $\mu$ L,  $f_{sp}$  is then roughly 0.2 min<sup>-1</sup>.

Compare with the other means of microfludic pumping reviewed by Laser and Santiago,<sup>2</sup> our ArtC generated comparable flow rate with electroosmotic and electrohydrodynamic pumps, and the self-pumping frequency is also in the medium range of the reported micropumps.

## References

[1] F. M. White, Viscous Fluid Flow, McGraw-Hill, 1991.

[2] D. J. Laser and J. G. Santiago, Journal of Micromechanics and Microengineering, 2004, 14, R35–R64.



**Figure 1** Comparison of the the flow rate of ArtC with electrohydrodynamic and electroosmotic pumps. Figure reproduced, with permission, from Laser and Santiago<sup>2</sup>, with our data inserted.



**Figure 2** Comparison of the the self-pumping frequency of ArtC with other microfluidic pumps. Figure reproduced, with permission, from Laser and Santiago<sup>2</sup>, with our data inserted.