# Optofluidic gradient refractive index resonators using liquid diffusion for tunable unidirectional emission

## Electronic Supplementary Information

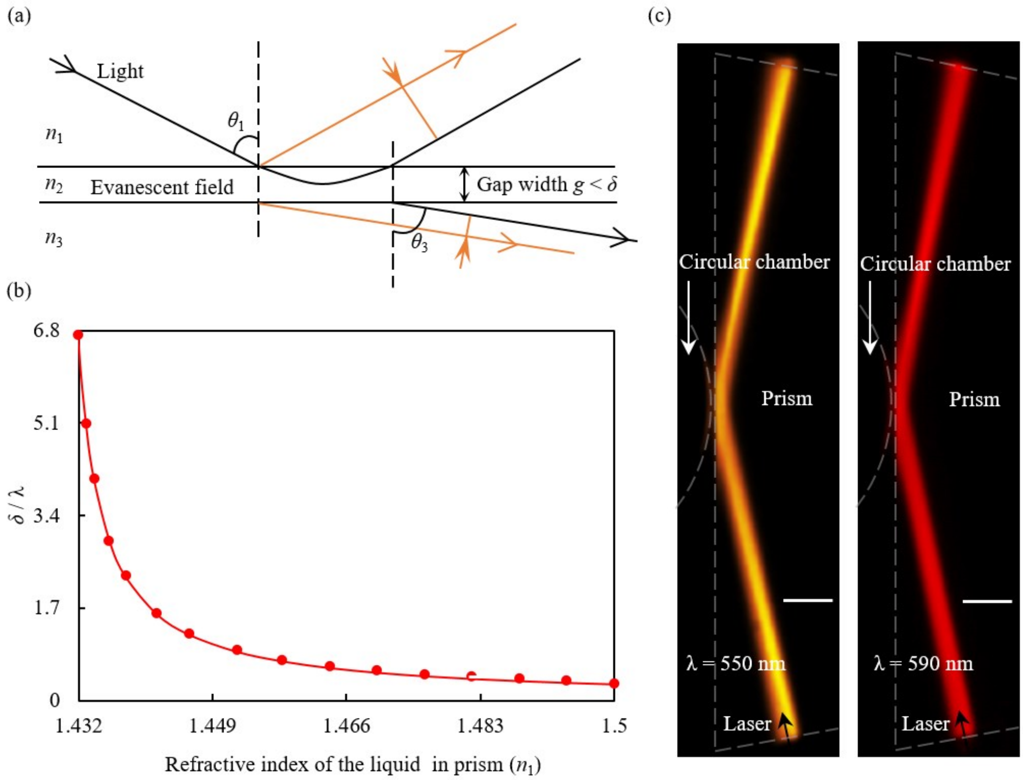


**Fig. S1** Coupling between the prism and gradient-index resonator. (a) Total internal reflection for coupling process. Here, $\theta_1 = 79.5°$; gap width $g = 600$ nm (the shortest distance between the prism and resonator); $n_1$, $n_2$, and $n_3$ are the refractive indices of the prism, PDMS (1.405) and ethylene glycol (1.432). To ensure total internal reflection, $n_1 > n_2/\sin\theta_1 = 1.429$. When $g <$ penetration depth, $\delta$, $n_1\sin\theta_1 = n_3\sin\theta_3$. Solid black arrows represent the light path while the orange arrows show the light displacement caused by total internal reflection. (b) The fraction $\delta/\lambda$ (where λ is wavelength) as a function of the refractive index of the liquid in prism. The value of $\delta$ can be modulated by the refractive-index difference, $n_1 - n_2$. (c) Experimental total internal reflection for incident wavelengths of 550 and 590 nm. The scale bars represent 20 μm.

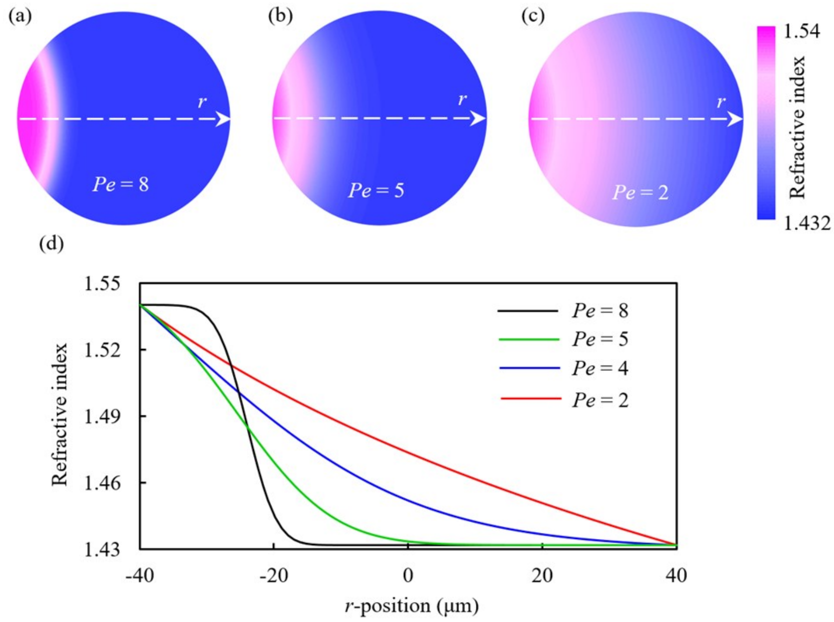


**Fig. S2** Dependence of refractive index distribution on flow rates (*Pe*) for $R$ = 100 μm. (a)-(c) Refractive-index profiles at *Pe* = 8, 5 and 2, respectively. (d) Refractive index on *r* axis. When the flow rates are low enough such as *Pe* = 2, the diffusion is complete to form gradient-index profile.

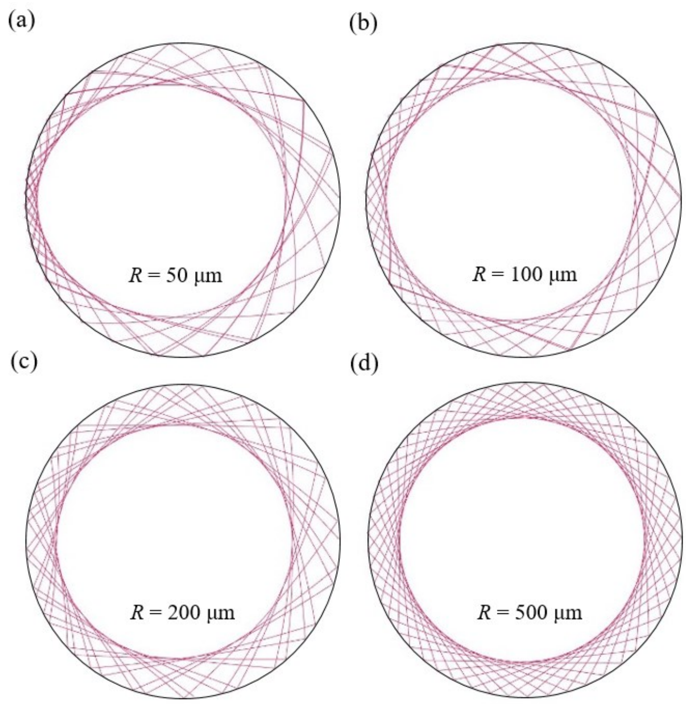


**Fig. S3** (a)-(d) Simulated ray trajectory for different bending radii. It clearly shows that the "squeezing" of light is pronounced for smaller bending radius. When the bending radius is larger enough such as $R$ = 500 μm, the special squeezed performance disappears, meaning that this gradient-index resonator losses its characteristics.

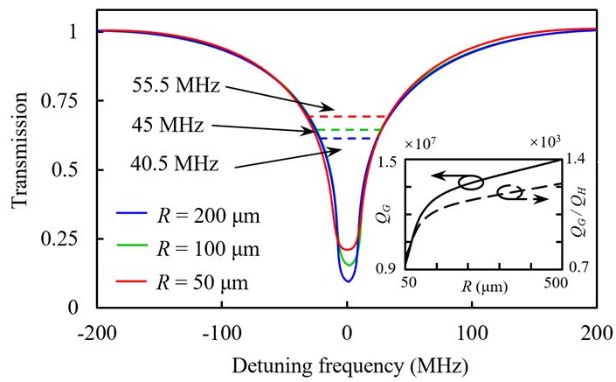


**Fig. S4** Simulated transmission spectra at incident wavelength of 550 nm. According to the formula $Q = f / \Delta f$, where $f$ is the resonant frequency and $\Delta f$ is the bandwidth, we can obtain the quality factor is on the order of $10^7$. In details, the bandwidth is relatively smaller as $R$ increases, resulting in higher quality factor for large bending radii R, which may be caused by the reduction of the squeezing of high refractive-index region or light prolife. Inset shows the dependence of quality factor on bending radii. $Q_G$ is for this gradient-index resonator and $Q_H$ is for homogeneous counterparts, showing nearly one thousand times higher of this resonator than conventional models.

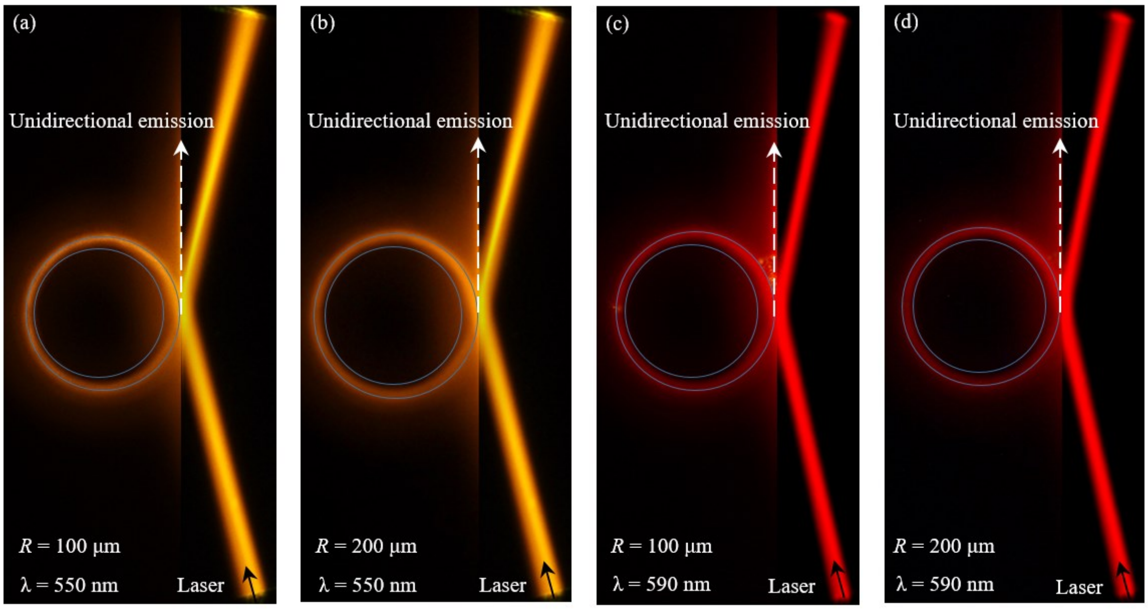


**Fig. S5** Light propagation for different bending radii $R$ and incident wavelengths $\lambda$. The liquids in the resonator (left side of each figure) and prism (right side of each figure) are both dyed with Rhodamine 640 to visualise the light. The green and red filters are used to filter out excitation light of wavelengths 550 and 590 nm, respectively. (a), (b) Optical resonance at 550 nm for $R$ = 100 and 200 μm, respectively. (c), (d) Optical resonance at 590 nm for $R$ =100 and 200 μm, respectively.