Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary Information

An integrated microwell array platform for cell lasing analysis

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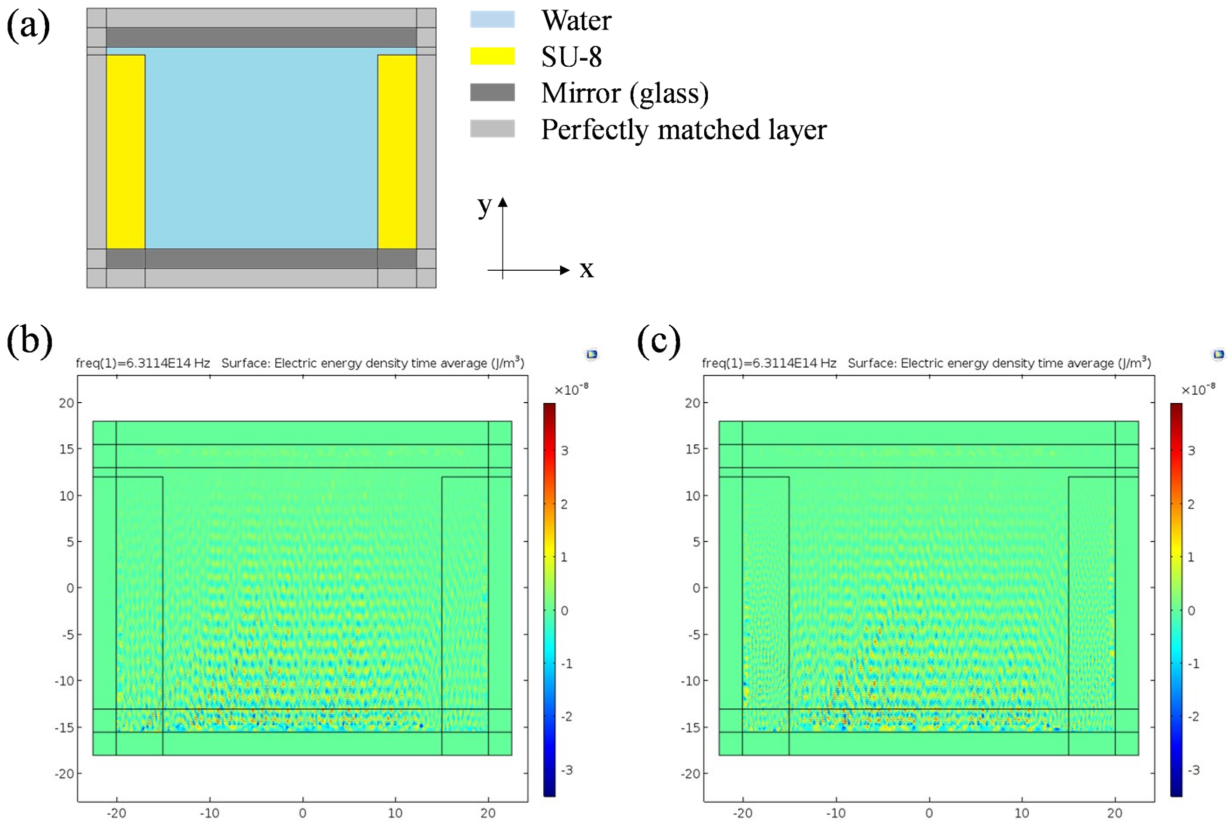
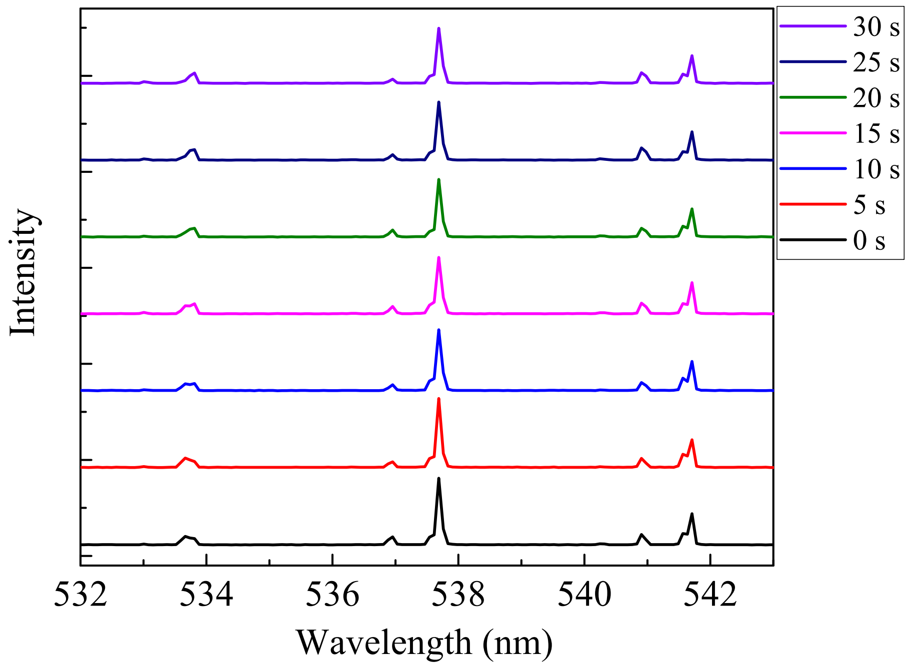
Figure S1. Simulation of the scattered field of the incident Gaussian beam



(a) The simulation geometry. n_{water}=1.33. n_{mirror}=1.45. A Gaussian beam along y-axis is set as the background field with an FWHM of 60 μm and the focal plane at the top interface between the mirror and water. (b) The distribution of the scattered field when there is no microwell structure (the SU-8 domain is set to be the same as the water domain, $n_{SU\text{-}8}$=1.33). (c) The distribution of the scattered field when the microwell is present ($n_{SU\text{-}8}$=1.60). The integration of the scattered field energy density over the water domain is 2.45e-19 and 2.60e-19 J/m^3 without and with the SU-8 microwell structure, respectively. The discrepancy is less than 10%, thus we conclude that the microwell structure does not have any significant effect on the excitation profile.

Figure S2. Lasing stability of a cell captured in a microwell



Lasing stability of a cell captured in a microwell. The cell was continuously excited for 30 seconds with a pump intensity of 100 μJ/mm^2 per pulse. The cell underwent up to 600 excitation pulses during the test, about twice the number of pulses that a cell might receive when it was scanned for 6 times in our work. As shown in Figure S2, no wavelength shift is observed in those lasing peaks.

The thermal effect on the microwell-integrated cell lasing array

Given that there is environmental temperature fluctuation during the experiment, the resulting lasing wavelength shift is examined as follows. The dependence of the lasing wavelength λ on temperature can be written as $\frac{\Delta\lambda}{\lambda} = (\frac{1}{n_{eff}}\frac{dn_{eff}}{dT} + \frac{1dL}{LdT})\Delta T$, where n_{eff} is the effective refractive index, $\frac{dn_{eff}}{dT}$ the thermal-optic coefficient, L the cavity length and $\frac{dL}{dT}$ the linear thermal expansion coefficient. A cell laser cavity consists of mainly water, DNAs and proteins, with an effective thermal-optic coefficient estimated to be $-1\sim4\times10^{-4}$/℃.[1-3] Since the SU-8 layer acts as the spacer for the laser cavity, the linear thermal expansion coefficient of SU-8 (52×10^{-6}/℃, MicroChem Corp.) is used to estimate $\frac{1dL}{LdT}$. Thus, for a temperature drift of 1℃, $\left|\frac{\Delta\lambda}{\lambda}\right| < 0.05\%$ and the corresponding lasing wavelength shift $\Delta\lambda$ around 540 nm is about 0.2 nm.

We also examine the thermal effect of the pump laser. At 120 µJ/mm^2 pump fluency, the total energy impinged on an area of 2×10^{-4} mm^2 (the area of a cell) is 2.4×10^{-8} J per excitation pulse. Typically, less than 10% of the total energy can be absorbed (absorption cross section of dyes at excitation wavelength $\sigma_a \sim 1\times10^{-16}cm^2$, dye concentration C ~1 mM, gain medium length L~ 10 µm, thus absorbance A = $\sigma_a CL = 0.06$) and only a fraction that non-radiatively dissipates turns into heat (assume to be 40%, since quantum yield of SYTO9=0.6). The resulting fluctuation in local temperature is estimated to be around 0.3 ℃ ($\Delta T = \frac{E_{heat}}{C_p m}$, E_{heat} the energy that turns into heat, C_p the specific heat (water: 4.184 J/(g·℃)), m the mass). The lasing wavelength might have a drift of 0.06 nm accordingly. However, no build-up effect is expected under continuous pulse excitation due to the small duty cycle (5 ns/50 ms) of the 20 Hz OPO laser.

References

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