Supplementary figures and text:

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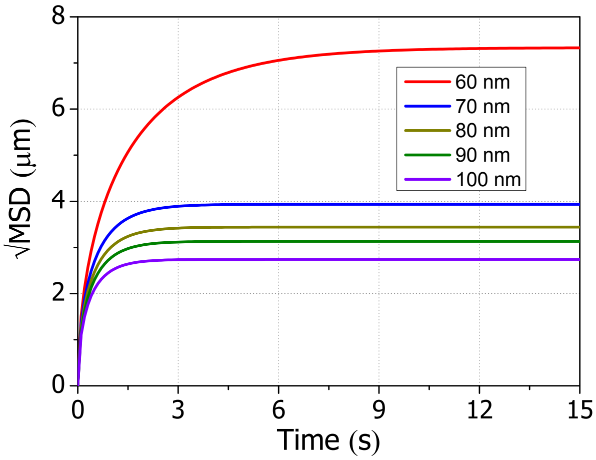

Fig. S1 Calculated Mean amplitude of vibration of gold nanoparticles in trapped positions.

Supplementary Table S1 | Trapping positions and oscillating movement of the nanoparticles

Size (nm)	**Trapping position (μm)**	**Stiffness ($N\ s^{-1}$)**	**Measured $\overline{D}$ (μm)**	**Calculated $\sqrt{MSD}$ (μm)**
60	32	-2.45×10^{-10}	7.1	7.31
70	74	-8.42×10^{-10}	5.8	3.93
80	104	-1.09×10^{-9}	3.7	3.44
90	112	-1.32×10^{-9}	5.3	3.13
100	132	-1.66×10^{-9}	6.3	2.74

Supplementary Note 1 | Dynamic trapping of the nanoparticles in a light field

A particle moving in a force field satisfies

$$m\ddot{x} = 6\pi\eta r\left(v_f - \dot{x}\right) + F_{opt} + F_{Brownian} \tag{S1}$$

where m, r, x, $\dot{x}$ and $\ddot{x}$ are the mass, size, displacement, velocity and acceleration of the particle, respectively; η and v_f are the viscosity and velocity of the fluid, respectively; and F_{opt} and F_{Brownian} are the optical and Brownian forces on the particle, respectively.

Let $\dot{x} = C + Be^{-\omega t}$,

then

$$\ddot{x} = -B\omega e^{-\omega t} \tag{S2}$$

Next, substituting these into equation (S1), we obtain

$$-m\omega Be^{-\omega t} + 6\pi\eta rC + 6\pi\eta rBe^{-\omega t} = F_{opt} + 6\pi\eta rv_f \tag{S3}$$

Equation (S3) holds because F_{opt} is constant over a very short time. When $t = +\infty$, we obtain

$$6\pi\eta rC = F_{opt} + 6\pi\eta rv_f \tag{S4}$$

Therefore,

$$C = v_{end} = \frac{F_{opt} + 6\pi\eta rv_f}{6\pi\eta r} \tag{S5}$$

By substituting equation (S5) into equation (S4), we obtain

$$-m\omega Be^{-\omega t} + 6\pi\eta rBe^{-\omega t} = 0 \tag{S6}$$

$\therefore\ \omega = 6\pi\eta r / m$.

Meanwhile, when $t = 0$,

$$m\dot{v}(t = 0) = 6\pi\eta r v_f + F_{opt} - 6\pi\eta r v_0 \tag{S7}$$

From equation (S2), we obtain that

$$\dot{v}(t = 0) = -B\omega e^0 \tag{S8}$$

By substituting equation (S8) into equation (S7), we obtain

$$-m\omega B = 6\pi\eta r v_f + F_{opt} - 6\pi\eta r v_0 \tag{S9}$$

Therefore,

$$B = \frac{6\pi\eta r\left(v_0 - v_f\right) - F_{opt}}{m\omega} = v_0 - v_{end} \tag{S10}$$

We assume the particle has a constant velocity when $r / B = 0.1\%$, that is,

$$C + Be^{-\frac{6\pi r\eta}{m}t} - v_{end} = 0.001B \Rightarrow Be^{-\frac{6\pi r\eta}{m}t} = 0.001B \tag{S11}$$

If *m*, *r* and η are given, the time from the initial velocity to the final velocity can be determined. For a 60-nm gold nanoparticle, given *r* = 30 nm, *m* = 2.185×10^{-18} kg and η = 0.001, the calculated time for the particle to reach its final velocity is 26.69 ns. Therefore, given an initial velocity small enough to satisfy the condition that F_{opt} is constant, the particle requires roughly 27 ns to reach the final velocity resulting from the combined effect of the optical field and the flow. The nanoparticle velocities are limited by the strong damping of the liquid flow exerted by the optical field. As a result, every location in the microchannel has a specific velocity for a given nanoparticle. In our experiments, the nanoparticles decelerated as they approached their positions of force equilibrium, and their velocities fell to zero upon reaching the equilibrium positions.

Supplementary Note 2 | Calculation of the optical forces with different stress tensors

Several stress tensors, including those of Maxwell, Einstein–Laub, Minkowski and Abraham, are available for the calculation of the optical forces in a liquid [43−46]. They give identical results for particles embedded in air, but differ for particles embedded in a medium. The Maxwell stress tensor is expressed as [1]

$$T_{ij} = \varepsilon_0 E_i E_j + \mu_0 H_i H_j - \frac{1}{2}\left(\varepsilon_0 E^2 + \mu_0 H^2\right)\delta_{ij} \tag{S12}$$

The Minkowski stress tensor is expressed as [2]

$$T_{ij} = E_i D_j + H_i B_j - \frac{1}{2}\left(\mathbf{E}\cdot\mathbf{D} + \mathbf{H}\cdot\mathbf{B}\right)\delta_{ij} \tag{S13}$$

The Abraham stress tensor is expressed as [3]

$$T_{ij} = \frac{1}{2}\left(E_i D_j + E_j D_i + H_i B_j + H_j B_i\right) - \frac{1}{2}\left(\mathbf{E}\cdot\mathbf{D} + \mathbf{H}\cdot\mathbf{B}\right)\delta_{ij} \tag{S14}$$

The Einstein–Laub stress tensor is expressed as [4]

$$T_{ij} = E_i D_j + H_i B_j - \frac{1}{2}\left(\varepsilon_0 E^2 + \mu_0 H^2\right)\delta_{ij} \tag{S15}$$

Note that the Minkowski and Abraham stress tensors are identical in an isotropic medium. Thus, we only calculate the Minkowski stress tensor in this paper. The force calculated with the Minkooowski stress tensor is biggest on each particle, while the smallest using Maxwell stress tensors. We calculated the trapping positions of the different-sized nanoparticles using the forces given by each of those stress tensors, and compared them with the measured positions.

References

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