Electronic Supplementary Material (ESI) for Chemical Communications.
This journal is © The Royal Society of Chemistry 2014

Supplementary Information

Optical trapping of particles can lead to particle heating through absorption of the laser radiation incident on the particle. The extent of the heating depends upon the characteristics of the laser beam (wavelength, power and beam profile) and the absorption characteristics of the particle and surrounding medium[1,2]. The increase in particle temperature above the ambient conditions, caused by absorption of the 514.5 and 1064 nm laser beams, is estimated using an approach similar to Knox and Reid[3]. The equation used is shown in Equation 1.

$$\Delta T = \frac{(1 - exp(- 2r\varepsilon c))P_p}{4\pi rK} \qquad \text{E1}$$

where ΔT is the steady state rise in particle temperature, r is the particle radius, ε is the molar extinction coefficient, c is concentration of the particle (for pure water c = 55.5 M, for pure salbutamol sulphate c = 2.3 M), Pp is the laser power available for absorption in the particle: $P_p = P_0 \times (1\text{-Q}) \times f_p$, where P_0 is the total laser power, Q is the Q-factor of the optical configuration[4] and f_p is the fraction of the laser power incident on the particle.

The heating is estimated for both pure salbutamol sulphate particles and pure water droplets. The absorption coefficients used for water were 5.4×10^{-6} and 2.2×10^{-3} M^{-1} cm^{-1} at 514.5 and 1064 nm, respectively[5]. Values for the crystalline salbutamol sulphate absorption coefficients were not available in the scientific literature and are therefore assumed to be the same as the aqueous phase absorption coefficients (0.83 and 0.15 M^{-1} cm^{-1} at 514.5 and 1064 nm, respectively) which were measured using a UV-Vis-NIR spectrometer (Shimadzu UV-1800).

At the typically used laser powers (24 mW of 1064 nm and 2 mW of 514.5 nm), it is estimated that a pure salbutamol sulphate particle of 2 μm diameter would be 1.4 °C warmer than the ambient conditions. A water droplet of the same diameter would be 0.3 °C warmer. These temperature increases are small but non-negligible. To check for any heating effects on trapped particles we levitated a droplet of aqueous solution of NaCl and were able to observe the characteristic broad liquid water peak centred at ~3400 cm^{-1}. This water peak did not change with prolonged (several minutes) exposure to either of the 1064 or 514.5 nm laser beams, indicating that the particle was not dried out by laser heating.

To check that the calculated laser induced temperature increases did not affect the ambient RH at which the deliquescence occurred, the total 1064 nm laser power was varied between 20-40 mW, whilst the 514.5 nm laser was held constant at 2 mW, which corresponds to a temperature increase estimate of 1.3-2.1 °C. The variation in the laser power caused no significant variation in critical RH value obtained for the deliquescent phase transition and hence we conclude that any localised heating effect is of negligible importance to these experiments.

References

1 E. J. G. Peterman, F. Gittes and C. F. Schmidt, Biophys. J., 2003, 84, 1308 – 1316.
2 H. Mao, J. R. Arias-Gonzalez, S. B. Smith, I. Tinoco and C. Bustamante, Biophys. J., 2005, 89, 1308 – 1316.
3 K. J. Knox and J. P. Reid, J. Phys. Chem. Lett, 2008, 1123, 10439 – 10441.
4 L. Rkiouak, M. J. Tang, J. C. J. Camp, J. McGregor, I. M. Watson, R. A. Cox, M. Kalberer, A. D. Ward and F. D. Pope, Phys. Chem. Chem. Phys., 2014, 16, 11426 – 11434.
5 J. A. Curcio and C. C. Petty, J. Optics Soc. America, 1951, 41 (5) 302 – 304.