

Optical Sorting and Spectroscopy of Micro and Nanospheres Containing Carbonyl Bonds with Mid-Infrared Optical Force

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Introduction Recent studies have explored the use of resonantly enhanced optical forces in the mid-infrared (mid-IR) spectral region for sorting particles based on molecular vibrational resonance with a single wavelength mid-IR laser.^[1,2] Herein, we employed a tunable continuous-wave quantum cascade laser (CW-QCL) to specifically target the carbonyl (C=O) bond vibrational mode in PMMA and cross-linked TPM (3-trimethoxysilyl)propyl methacrylate) micro- and nanospheres. By monitoring velocity variation across different wavenumbers, we were able to reconstruct the mid-IR spectra of the micro- and nanospheres (velocity spectra), demonstrating a novel approach to combine optical manipulation with molecular-level spectroscopy.

Experiment A 5.6 - 6.4 μm (1782-1562 cm^{-1}) CW-QCL was introduced into an attenuated total reflection (ATR) setup to generate an evanescent field on a silicon prism surface. The evanescent field can exert optical force and accelerate micro- and nanospheres along the laser propagation direction. We employed microspheres containing carbonyl bonds with an absorption peak at 1750 - 1650 cm^{-1} . The trajectories and velocities of individual microspheres were recorded using a camera, and the obtained videos were analyzed using the Trackpy Python package.

Results and Discussion We have experimentally demonstrated the optical force spectroscopy of PMMA and TPM micro- and nanospheres using a mid-infrared evanescent field that excites the carbonyl group's vibrational modes. The velocities of the manipulated PMMA and TPM spheres at different laser wavenumbers, along with their velocity spectra, correlate well with the absorbance spectra obtained from conventional ATR-FTIR spectrometers, as shown in Fig. 1. Notably, the relative magnitudes and peak positions of the spectra are accurately reproduced, allowing us to sort carbonyl bonds with different bond environments. This demonstrates that optical chromatography can identify carbonyl groups in diverse environments and enables single-particle mid-infrared spectroscopy by analyzing the macroscopic motion of the spheres.

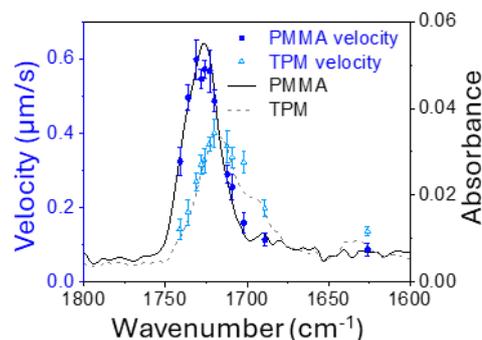


Figure 1. Velocity spectra of PMMA and TPM microspheres in the evanescent field and their respective ATR-FTIR spectra.

References

- 1) A. Statsenko, Y. A. Darmawan, T. Fuji, T. Kudo, Phys. Rev. Appl. **18**, 054041 (2022).
- 2) Y. A. Darmawan, T. Goto, T. Yanagishima, T. Fuji, T. Kudo, J. Phys. Chem. Lett. **14**, 7306-7312 (2023).