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Single-Shot Multiplex SRS: High-Throughput Chemical Imaging for Industrial Quality Control and Environmental Monitoring

Digital chemical imaging via Stimulated Raman Scattering (SRS) microscopy provides label-free, reagent-free vibrational maps of biological and material samples. However, conventional dual-band or single-frequency narrowband systems form images at only one vibrational frequency at a time, resulting in a lack of the broad spectral information required for the rigorous identification demands of industrial quality control (QC) and complex environmental analysis [1]. We present a multiplex SRS methodology based on an all-fiber, triple-wavelength self-synchronized laser combined with a compact multichannel lock-in amplifier, achieving simultaneous acquisition of the C–H stretch and fingerprint regions at the pixel level in a single shot (down to 2 μ s per pixel). This broad spectral window enables the high-throughput, automated detection, classification, and size-distribution mapping of micro- and nanoplastics both on filtration substrates and within active flow cells, addressing a critical need in environmental water monitoring [2]. Furthermore, the rapid acquisition of full vibrational spectra makes this platform uniquely suited for industrial pharmaceutical QC, where multiple precise wavenumbers must be tracked simultaneously to differentiate chemical variations. It allows for the non-destructive, real-time chemical mapping of active pharmaceutical ingredients (APIs) and excipients, ensuring polymorph identification and blend uniformity without sample preparation [3]. By coupling multiplex SRS data with advanced chemometric deconvolution and machine-learning pipelines, we deliver highly reproducible, automated chemical maps without chemical labeling [4]. This unified approach bridges ultra-fast imaging with deep chemical specificity, moving Raman microscopy from a specialized laboratory tool into a robust, standardized solution for high-throughput industrial inspection and environmental screening.

References

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