Fourier-Bessel based Image Analysis for Multi-Parameter Particle Characterization

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Abstract

We demonstrate a novel particle characterization method based on decomposition of conventional microscopy images in Fourier-Bessel (FB) components. This allows the simultaneous measurement of size, refractive index, 3D position and orientation of single colloidal particles.

Method

Setup

A particle is illuminated with a white light source under a microscope. Scattered light is captured with a high magnification (100x) objective on a CCD camera.

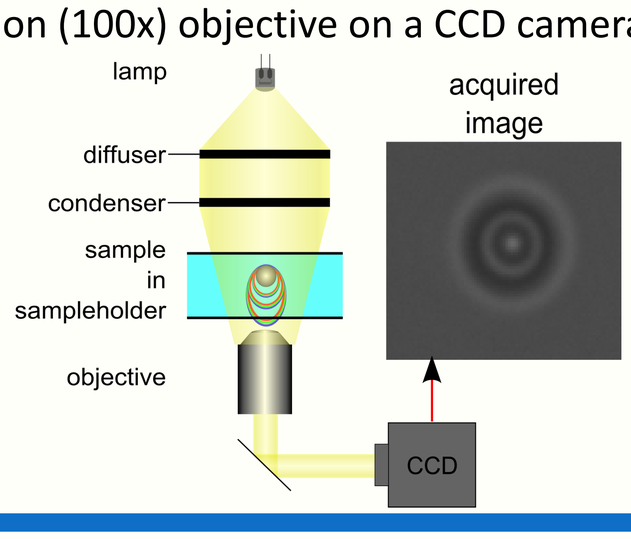
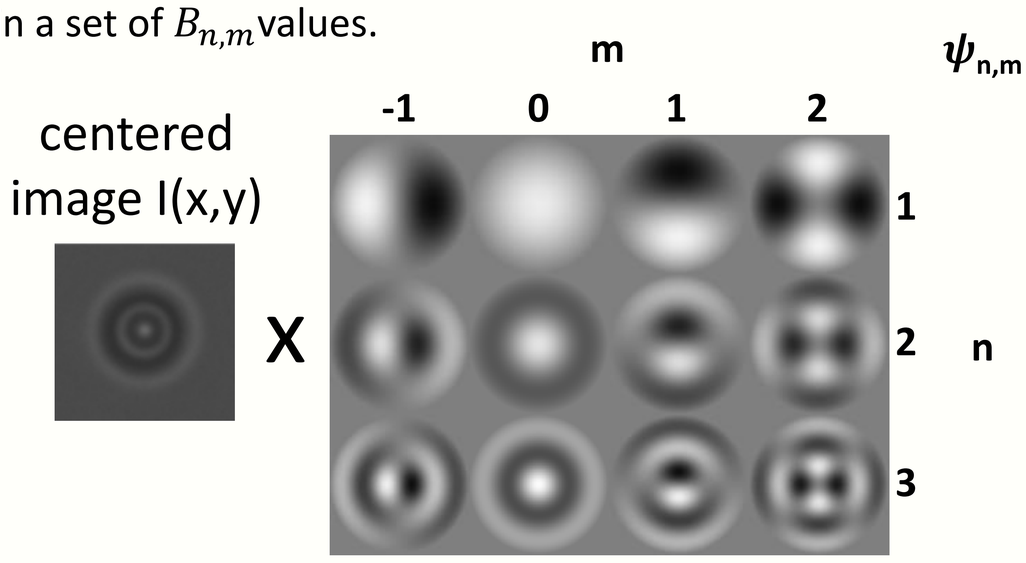


Image analysis

The centroid is tracked and the centered image is decomposed in Fourier-Bessel image moments resulting in a set of $B_{n,m}$ values.



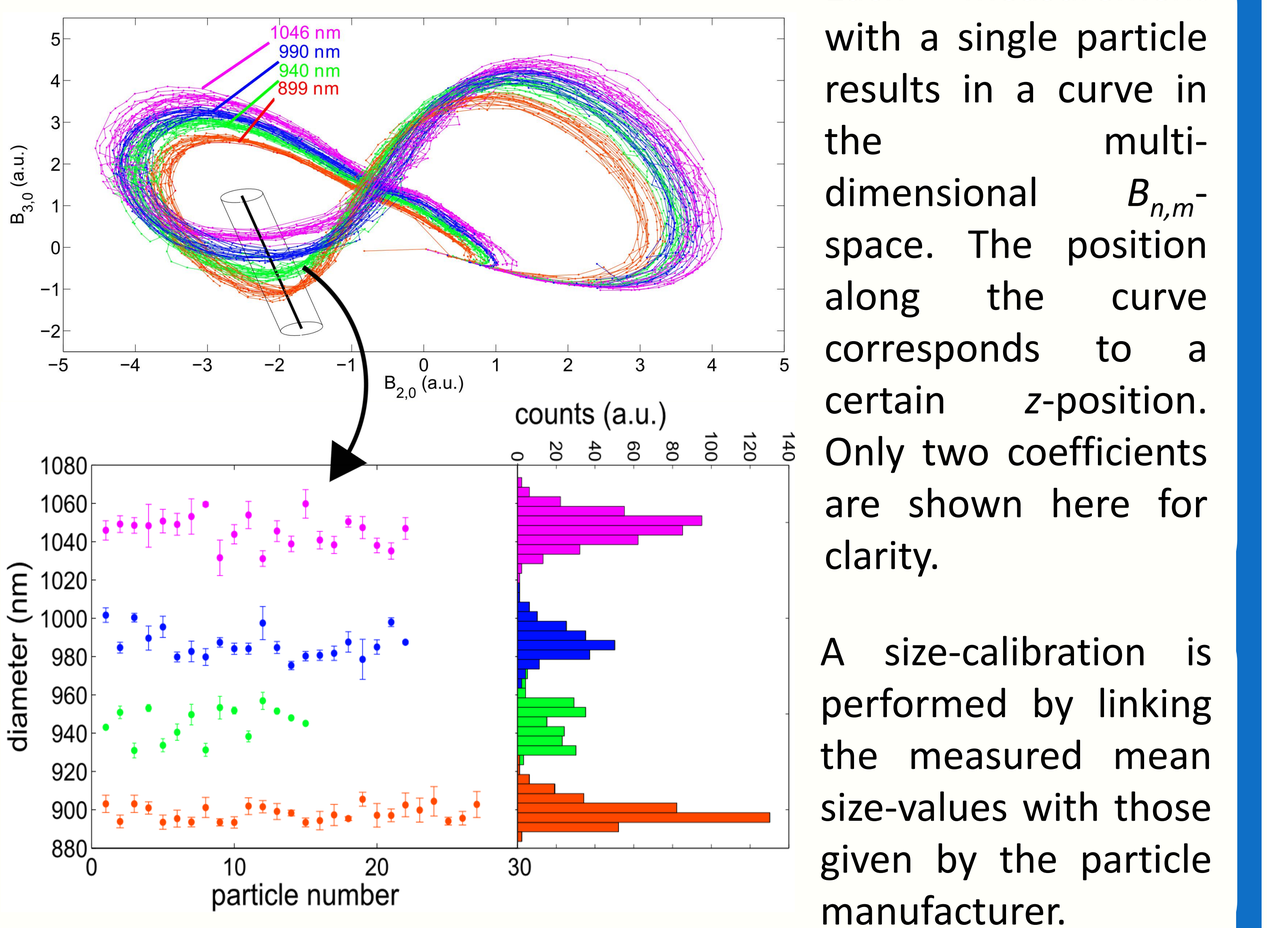
$$B_{n,m} = \int_0^a \int_0^{2\pi} I(r,\varphi)\psi^*_{n,m}(r,\varphi) r\,dr\,d\varphi$$

$$\psi_{n,m}(r,\varphi) = \frac{1}{\sqrt{2\pi N_n^{(m)}}} J_m\left(\frac{x_{mn} r}{a}\right) e^{im\varphi}$$

Results

Size extraction

Four different samples with monodisperse polystyrene particles (d = 899, 940, 990 and 1046 nm) were characterized with the first 10 radial $B_{n,m}$ moments .



Each measurement with a single particle results in a curve in the multi-dimensional $B_{n,m}$-space. The position along the curve corresponds to a certain z-position. Only two coefficients are shown here for clarity.

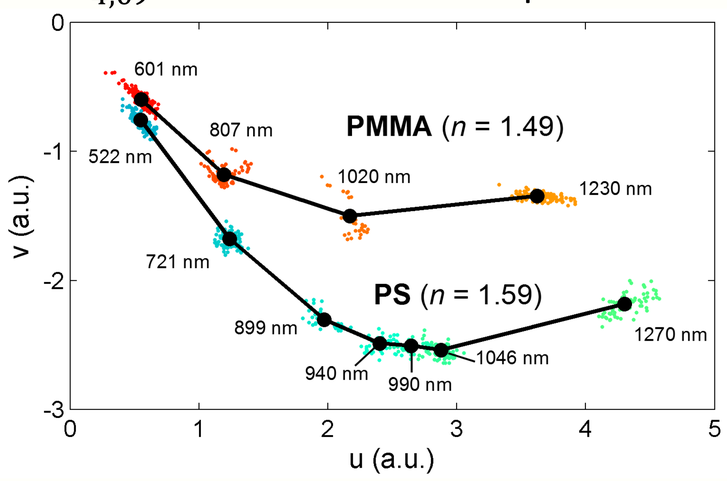
A size-calibration is performed by linking the measured mean size-values with those given by the particle manufacturer.

The measured standard deviation on the diameter per particle is ± 5 nm (≈1%). Results show that the four size distributions can be resolved well, which was not possible with Dynamic Light Scattering (σ = 100 nm).

Refractive index extraction

The refractive index (RI) is extracted by projecting three $B_{n,m}$ coefficients ($B_{2,0}$, $B_{3,0}$ and $B_{4,0}$) on a well chosen plane with orthogonal basis u and v.

Results show that the RI and diameter can be resolved simultaneously for PS and PMMA samples. The RI resolution is ± 0.0025 for d = 1000nm.



Conclusions

We conclude that the analysis using FB image decomposition can be used for simultaneous characterization of the size, refractive index and 3D position of single colloidal particles.

Future prospects

In a next step we will demonstrate its applicability for tracking the orientation of non-spherical particles by including higher-order angular moments in the analysis. Additionally we will use this technique to measure local changes in RI of the medium.