X-ray photon correlation spectroscopy (XPCS) study of nanospheres in parabolic microflow

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Introduction

The combination of microfluidics with small angle X-ray scattering (SAXS) and X-ray photon correlation spectroscopy (XPCS) is used to investigate the dynamics of 200 nm SiO₂-colloids in microflow with different geometric constraints. Especially for SAXS produced microfluidic devices provide a quasi-2D parabolic flow in curved, straight and constraint channels. The flow is controlled by syringe pumps. A coherent X-ray beam of small size (10 𝜇m x 10 𝜇m) allows us to measure static and dynamic properties at different positions within the microchannels. Using a fast 2D readout detector, autocorrelation functions are measured at a wide q-range in a temporal regime of 4 x 10⁻³ – 10² s. Analysis of the autocorrelation function provides us with information about advective and diffusive transport within the microfluidic flow of different velocities and in different channel geometries.

Results

Autocorrelation functions $g_2$ at different $q$-values show a decrease of correlation with increasing $q$. An ideal $q$-value of 0.0016 nm⁻¹ was therefore chosen for further autocorrelation analysis.

Figure 1: Scattering intensity curve with marked (red arrow) ideal $q$-value ($q = 0.0016$ nm⁻¹) for autocorrelation calculations (left) and autocorrelation functions $g_2$ at different $q$-values (right).

Figure 2: Autocorrelation functions $g_2$ at different positions across the channel. In flow direction (left) and perpendicular (right) to flow direction.
Figure 2 shows the difference between the autocorrelation function in flow direction and perpendicular to it. The left hand picture shows a faster decay of the correlation in the middle of the channel in comparison with positions closer to the walls, nicely correlating to a parabolic flow profile. On the right hand picture we see an almost constant behaviour of the correlation function perpendicular to the flow indicating a constant diffusion with hardly any influence from the flow velocity.

Not only correlation functions of angles parallel and perpendicular to the flow direction are measured but also in between. Figure 3 shows correlation functions of all angles at three different positions at the exit of a constriction. Here, not only the advection and diffusion differences can be observed, but also an influence of the channel geometry as the position of the slowest and fastest decaying correlation function are shifted (1 and 3 in comparison to 2).

Figure 3: Autocorrelation functions $g_2$ at three different positions across the channel in a constriction. The circular plots show the autocorrelation functions for 16 different angles, x-axis is parallel, y-axis perpendicular to flow direction in channel.

**Conclusion**

We use coherent synchrotron radiation and a fast 2D readout detector for XPCS measurement of particles in a microfluidic flow. Like this, autocorrelation functions can be obtained for several $q$-values and angles simultaneously. Calculating and analysing these autocorrelation functions gives us information about advective and diffusive transport in flow as well as about the impact of channel geometries.