Optical focusing of isolated particles for diffractive imaging experiments

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Synopsis Diffractive imaging experiments using single isolated particles require particle beam sizes matched to the x-ray focal spot of only a few 100 nm diameter, in order to avoid wasting sample and ensure high hit-rates. Here, we report on the development of optical control methods to steer and guide nanoparticles *in vacuo* using hollow-core laser beams essentially acting as "pipelines of light".

The development of x-ray free electrons lasers (XFELs) has led to a paradigm shift in atomically-resolved structure determination. The advance of the serial femtosecond crystallography (SFX) technique [1] has pushed the required crystal sizes for diffractive structure determination to only a few hundred unit cells. The next step is to extend this methodology to the imaging of isolated single-particles. These methods require the efficient delivery of reproducible target particles into the narrow focus of the FEL beam. For SFX applications, this is typically done with focused liquid jets, as the Bragg scattering from the cyrstals is significantly stronger than the scattering background from the liquid jet. However, this is not the case in single-particle imaging applications. Here, one is looking at weak diffuse scattering from isolated molecules, rendering the liquid jet approach not feasible. Instead, particles have to be delivered into the interaction point *in vacuo* to avoid background scattering signal. This is achieved by aerosolizing target particles and introducing them into the vacuum chamber through aerodynamic lenses [2, 3] or convergent-nozzle focusing injectors, which produce a tightly collimated or focused particle beam [4]. However, even the best aerosol injectors currently used still produce particle beams orders of magnitude larger than the spot size of the nano-focused x-ray beam. This leads to excessive sample consumption and low hit-rates, leading to prohibitively long measurement times.

To overcome these issues, we are developing methods to optically manipulate particle streams produced by aerodynamic lenses using hollow-core vortex laser beams. Through light pressure and photophoretic interactions, these laser beams can be used to steer particles, confine them within the hollow core, and even compress the particle beams, essentially acting as "pipelines of light", guiding particles into the x-ray interaction region [5, 6].

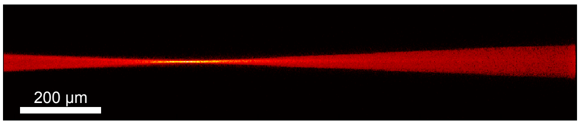

Figure 1. Beam of nanoparticles imaged in-flight as it emerges from a convergent nozzle injector.

To diagnose and optimize our particle vaporization and control mechanisms away from the XFEL, we have developed novel characterization techniques that allow direct visualization of particles (as shown in Fig. 1) and gas streams, as well as the absolute determination of the particle concentration and velocity [7, 8, 9].These tools significantly aid in alignment of tightly focused beams with the XFEL beam in single-particle diffractive imaging experiments.

References

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