**Microfluidics of Sample Delivery Systems for Free Electron Lasers**

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The advent of X-ray free electron lasers (XFELs) enabled serial femtosecond crystallography, which revolutionized the field of X-ray crystallography. Short and intense X-ray pulses created by XFELs enable protein macromolecule determination even with micron or submicron protein crystals. A common way of delivering samples into the X-ray beam is through a liquid jet with dispersed crystals focused by the coaxially flowing gas. The goal is to achieve thin (micron to submicron), long (> 50 microns) and fast (~ 100 m/s) jets. The formation of such jets is prone to dripping, spurting, and whipping instabilities. We will present an overview of our developments in the computational modelling and experimental validation of new sample delivery designs. The solution procedures will be introduced based on the one-domain phase-field formulated multiphase system, solved by a strong form collocation meshless method, and the front tracking approach, based on the boundary meshless method of fundamental solutions. We will show the experimental validation of the computational models and sensitivity studies of microfluidic systems concerning process parameters, fluid rheology and gas type. Modelling of the new sample delivery systems, including the deposition of the samples on the tape (appropriate for serial crystallography done at synchrotrons), gas and liquid focusing nozzles, nozzles producing thin liquid micro-sheets, as well as the design of newly developed convergent-divergent supersonic nozzles and nozzles with liquid acceleration in an electric field that create even thinner micro-jets will be discussed.

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