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DESIGN OF LIQUID INJECTION DEVICE FOR THE HARD X-RAY ULTRAFAST SPECTROSCOPY EXPERIMENT STATION

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INTRODUCTION

The Shanghai high repetition rate XFEL and extreme light facility (SHINE) is equipped with a high-quality electron beam continuous wave superconducting linear accelerator with an energy of 8 GeV. The energy wavelength coverage of this device is 0.4-25 keV, and the pulse repetition rate can reach up to 1 MHz. The main experimental platform of the Hard X-ray Ultrafast Spectroscopy Experiment Station (HXS) located in FEL-III is the high-energy resolution X-ray photo-in-photo-out (PIPO) spectrometer, which can achieve femtosecond time resolution by combining pump-probe technology. The reactions involved in the liquid phase state of matter are currently an important research area in the fields of chemistry and biology, and are also an important research direction of HXS. Therefore, it is necessary to build a liquid sample injection device that meets the requirements of the experiment station.

Requirements for the in-situ environment of liquid samples: Firstly, due to the high repetition rate and radiation damage characteristics of X-ray free-electron lasers, sample replacement is necessary. Therefore, we need to establish a system that can continuously deliver samples to ensure that the pulse of the X-ray free-electron laser is not wasted. Secondly, in order to control the impact of liquid film thickness on the pump-probe time resolution within 66 fs, the liquid film thickness must be less than 20 μm. At the same time, the outline of the liquid sample should be much larger than the light spot of the X-ray beam to ensure that the detector receives the signal after passing through the liquid sample.

This work designs and implements a super-thin liquid film generation device, and verifies the stability and thickness of the generated liquid film through the construction of a test optical path, which meets the experimental requirements. This research provides an important experimental foundation for subsequent research in related fields.

EXPERIMENTAL METHODS

•Liquid film generation device

Based on the principle of liquid flow collision, this study built an experimental platform as shown in Figure 1. Using an HPLC pump to provide power for liquid transport and control the liquid flow rate, a liquid pipeline was constructed at the output end of the pump, using PEEK tubes, liquid-phase connectors, T-shaped tees, stainless-steel tubes, and other parts.

(Tips: **Liquid flow collision**. This method utilizes two liquid flows that collide with each other to form a liquid film through interaction, and has high stability. This method has broad application prospects in pump-probe ultrafast spectroscopy experiments.)

•Liquid Film Characterization System

The thickness of the liquid film is characterized by reference to the Lambert-Beer law, which calculates the film thickness based on the intensity absorption of light by the liquid film. Using HL-2000 as the light source, the light beam is emitted from a fiber with an inner diameter of 600 μm, and a monochromatic light source with a desired wavelength band is obtained through an optical filter. Since the light source is a point light source, it needs to be focused and aligned, and an experimental optical path as shown in the figure is constructed. After the converged light is received by the fiber probe, a PG-2000 fiber spectrometer and its supporting spectral testing software Morpho are used for spectral analysis.

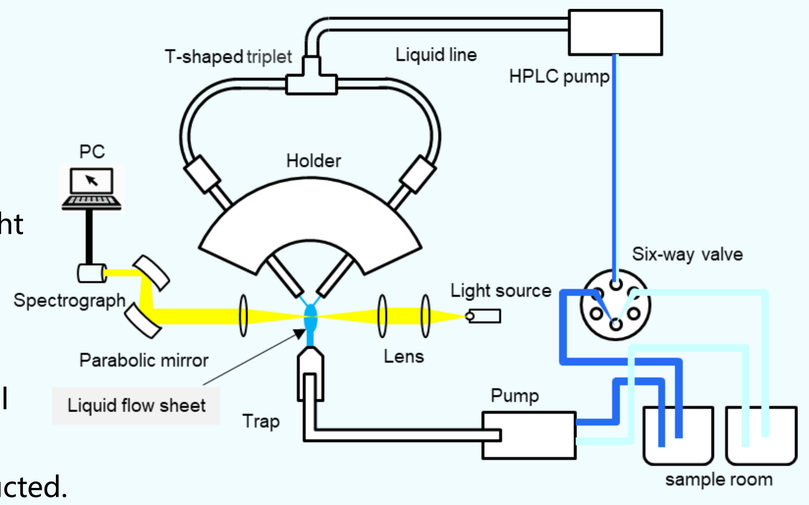


Figure 1: Liquid Film Generation Device and Characterization System

RESULTS

• Liquid Film Characterization System

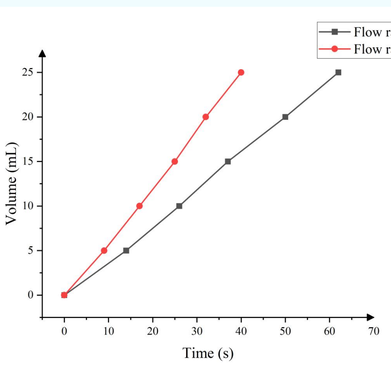


Figure 2: Flow Rate Test

• Calculation of liquid film thickness

$$\frac{hr}{R^2} = \frac{sin^3\theta}{(1-\cos\phi\cos\theta)^2} \quad thickness$$

$$\frac{r_e}{R\,We} = \frac{sin^3\theta sin^2\psi}{4(1-\cos\phi\cos\theta)^2} \quad shape$$

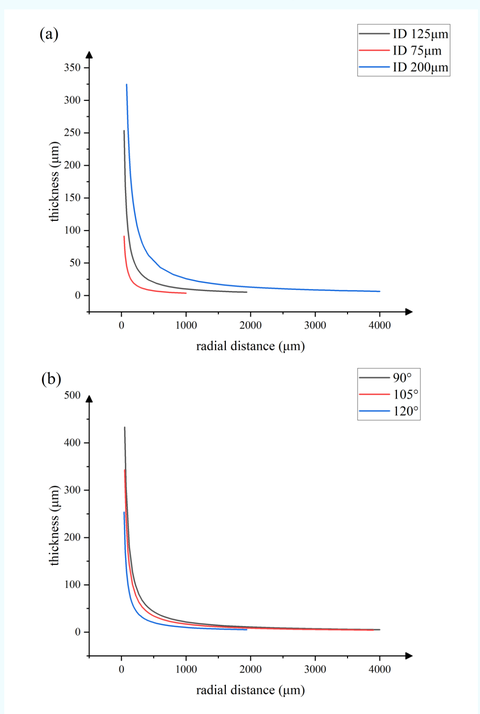


Figure 3: Simulation Curve of Liquid Film Thickness: (a) Jet Diameter Factor (b) Collision Angle Factor

• Characterization of liquid film thickness

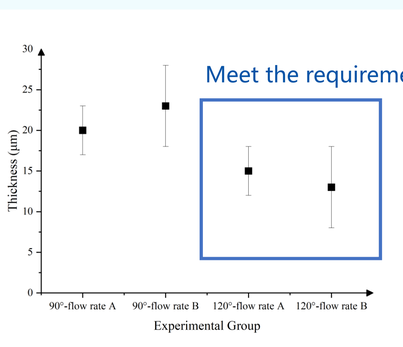
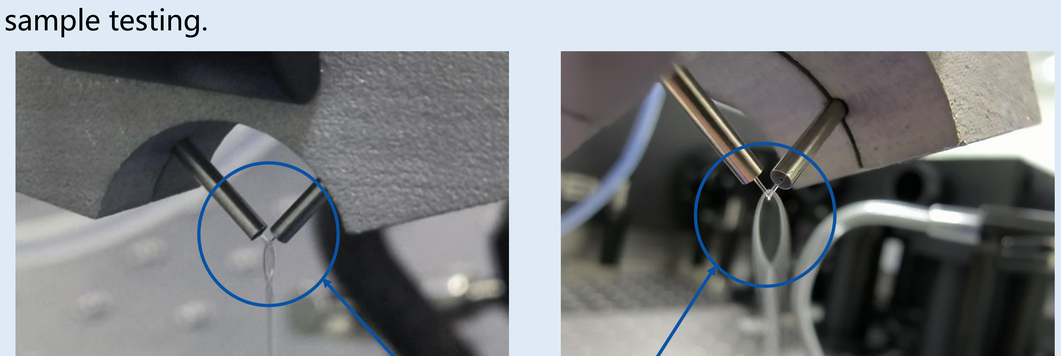


Figure 4: Liquid Film Thickness Data Chart

SUMMARY

The work studies a liquid sample injection device applied to the hard X-ray ultrafast spectroscopy experiment station of the Shanghai high repetition rate XFEL and extreme light facility . The device is based on the principle of liquid flow collision, which can form a liquid film that meets the experimental requirements, and is equipped with a thickness measurement device for the liquid film. By designing a specific optical path, the precise measurement of the liquid film is achieved. In the experiment, methylene blue solution is used as the sample solution to test the device. The results show that the size and thickness range of the liquid film are consistent with the theoretical calculation results, meeting the needs of the ultrafast spectroscopy experimental station for liquid sample testing.



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