Liquid phase experiments at FERMI

The FERMI free electron laser (FEL) source provide ultrafast photon pulses in the extreme ultraviolet (EUV) and soft x-ray range, with a high degree of coherence and full control of the photon output, thanks to the unique seeding scheme adopted at the facility. FERMI presently offers a portfolio of five instruments, which have achieved cutting-edge scientific results in different fields. Furthermore, as a general outlook for the facility, it is foreseen to extend the photon energy range of the FEL source deeper into the soft x-ray range, in order to fully access the so-called "water window" (280-550 eV). This would enable a number of ultrafast experiments in aqueous environments, hence permitting to study, e.g., structural relaxations in water and complex liquids, real time dynamics of bio-molecules and chemical reactions [1-3].

In this context, we are going to develop dedicated sample environments to be implemented at the FERMI end-stations, capable of enabling studies of liquid phase samples. The high absorption of EUV and soft x-ray radiation calls for devising windowless sample holder/delivery systems compatible with a high vacuum environment. Such constraints are essentially the "worst conditions" for handling a liquid. However, a few strategies have been developed in the recent years to address this situation. Most of them are based on microfluidic technology, where small channel (10s of µm diameter) are used to inject liquid micro-jets in vacuum. Among various options, the recently developed flat-jet technology ensures sub-micrometer thick liquid sheets, compatible with the absorption length of EUV radiation [4]. However, this approach requires the availability of large amount of samples, which is not always the case. An alternative strategy is to generate a sequence of small (≈ 10 µm) droplets matching the repetition rate of the FEL. The bottleneck of this approach is the low hit rate due to the difficulty of aligning and synchronizing photon and particle beams. We propose to implement a laser manipulation by means of optical tweezer technology. Namely, we envision using counter-propagating laser beams to take a single droplet [5], move it into the interaction region, hold it in position for a suitable time to allow the interaction with the beam(s), release it after the interaction and then pickup iteratively the next droplets. The target is to achieve almost 100% hit rate at about 100 Hz repetition rate.

The project will be developed in three phases. In the first stage the PhD student will work on the realization of the two microfluidic setups. A flat-jet testing stand is already partially set at the FERMI facility. The student will be in charge of the offline commissioning of the device, meaning characterizing the operation parameters and thickness of the liquid sheet. He/she will also implement the system for permitting operation in vacuum. In parallel the student will be trained in optical tweezing techniques at the NanoBio Laboratory and will design the aforementioned laser manipulation setup of the liquid droplets at 100 Hz repetition rate. In the second phase, the PhD student will carry out a campaign of laboratory experiments with the two setups, aimed at understanding the performances and limits of both approaches. The outcome of these investigations will be the basis for designing pilot experiments, which will be carried out at the FERMI FEL in the last phase of the project. For this last stage a suitable amount of FEL beamtime will be reserved.

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References

[1] F. Mallamace, C. Corsaro and H. E. Stanley, PNAS **110**, 4899–4904 (2013)
[2] K. H. Kim et al.v Science **358**, 1589–1593 (2017)
[3] C. Kupitz et al., Nature **513**, 261–265 (2014)
[4] J. D. Koralek at al., Nat. Commun. **9**, 1353 (2018)
[5] A. Ashkin, Phys. Rev. Lett. **24**, 156–159 (1970)