Microfluidic HHG Sources for XUV Light Generation and Manipulation

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Capturing molecular dynamics has been a long-pursued target for ultrafast spectroscopy due to its importance in many fields, including fundamental physics, biochemistry, and quantum technologies. High Harmonic Generation (HHG) from the interaction of intense femtosecond laser pulses with noble gases provides a powerful tool, by enabling the realization of table-top sources of coherent Extreme Ultraviolet (EUV) and Soft-X ray ultrashort pulses. This ultrafast EUV emission allows extreme temporal resolutions, down to the attosecond regime, and chemical selectivity, offering insights into electron dynamics, and fundamental light-matter interaction processes [1].

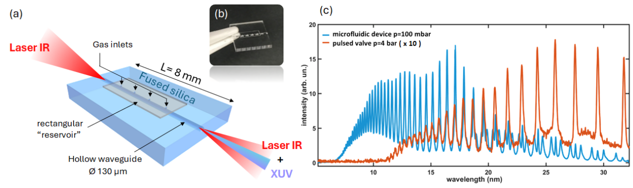

Figure 1: (a) Schematic of HHG in a microfluidic device. (b) View of a glass microfluidic device. (c) High harmonic spectrum generated with the microfluidic approach (blue) compared with the spectrum generated by a more standard approach based on gas-jet valve (red)

Time-resolved studies of light-excited molecular systems rely on techniques based on HHG-delivered EUV pulses, primarily pump-probe methods and self-probing HHG Spectroscopy (HHS). However, the full exploitation of these techniques is limited by the technological complexity and the low generation efficiency of the HHG sources, especially at higher photon energies.

We present an innovative and flexible technological platform for coherent EUV and Soft-X ray generation and manipulation. Our approach uses microfluidic devices for HHG, featuring hollow-core channels connected to customized microfluidic networks. This setup allows precise control over harmonic generation, resulting in high photon flux and effective phase matching for broadband harmonics, up to 200 eV, driven by 1kHz 800-nm ultrashort pulses [2].

Furthermore, the integrated microfluidic approach allows us to control the spatial properties of the HHG beam through the direct manipulation of the waveguide's modal characteristics, making it possible to generate structured EUV/soft-X light for application to ultrafast spectroscopy and high-resolution imaging.

This microfluidic approach can be extended to longer driving wavelength with the potential of approaching the soft X-ray region, up to the water-window (284–543 eV). Moreover, it is perfectly suitable for the manipulation of gas and liquid samples. By combining optical control on the HHG process and sample delivery manipulation, we foresee the possibility of realizing innovative optofluidic platforms for advanced applications in spectroscopy and high-resolution imaging of biologically relevant molecules, where the transparency of the aqueous environment is crucial.

References

[1] J Li, J Lu, A Chew, S Han, J Li, Y Wu, H Wang, S Ghimire and Z Chang, Nat. Commun. **11**, 2748 (2020)

[2] A G Ciriolo, R Martínez Vázquez, G Crippa, *et al.*, APL Photonics **7**, 110801 (2022)