Semester report

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Ph.D. Thesis title: ***"Interaction of noble gas clasters with ultrashort laser pulses"***

Introduction

High harmonic generation is not only a topic of interest for obtaining radiation sources in the ultraviolet, but it is a possible tool for investigating fast processes with femtosecond or attosecond resolution. High harmonics in clusters are not only – in some cases – more intense than those from gases, but they give insight into the structures of clusters in the same time. In recent works of the researchers of the Wigner FK [1,2] evidence was shown for the existence of nanoplasmas inside the clusters from the observation of a pressure-dependent red shift of the generated high-harmonics. However the necessary conditions for the existence of nanoplasmas was not cleared in full. My PhD work is therefore to carry out systematic investigations and demonstrating the nanoplasmas by alternative methods.

In the first semester of my studies – which was shortened by the quarantine after arrival – my aim was to generate experiences on the field and to clear theoretically the necessary conditions for the experiments. Unfortunately, due to the pandemics serious introductory experimental investigations were not possible, because the researchers of the Wigner RCP were mainly in home office, there was only a very limited laboratory operation.

Description of research work carried out in current semester

In order to get insight into the necessary experimental parameters one has to know the properties of clusters based on Rayleigh-scattering experiments which were carried out earlier by the research group [2]. Laser Rayleigh scattering diagnostics is commonly known to be an effective, relatively simple diagnostic tool for the investigation of gas properties and cluster formation in gas jets. From Rayleigh signals the absolute cluster size and density can be determined. In the experiment, a cw laser beam of 532 nm wavelength and 90mW power with its beam diameter of 25mm was focused into the cluster jet. The Rayleigh signal scattering from clusters were observed in 90° arrangement by a photomultiplier (Hamamatsu H6779 series) and a CCD camera. The output signal of the photomultiplier was recorded by a

digital oscilloscope. The valve had to be opened for at least 3 ms duration. This was longer than the opening applied earlier [1] when the nanoplasmas were observed, but it was needed to obtain a constant flow of gas. The investigations showed that the generally used semi-empirical Hagena-scaling cannot be applied for a correct estimation of the size of the clusters but the results give the basis for choosing correct valve parameters (backing pressure, opening time and gas type and delay between opening and arrival of the laser pulse).

In my PhD work based on these results I am intending to vary the cluster parameters in order to find the range in which the nanoplasma effects are becoming significant. One expects that in the case of nanoplasma inside the cluster the normal 3-step model of high-harmonic generation should be modified. In this case the electron will not necessarily recombine to the same mother atom from which it was released, but to the collective wave function of the nanoplasma.

Therefore I am intending to investigate polarization dependence of high-harmonic generation to investigate this effect. It is expected that in case of a collective wave function harmonics can be generated even with larger ellipticity than in case of atomic gases. Preliminary experiments in the Wigner Research Centre for Physics with a laser intensity higher and pulse duration longer than expected for nanoplasma generation the ellipticity dependence could not be seen [3]. However, I think that by more systematic investigation varying also the laser intensity the optimum range can be found.

As mentioned in the introductions the pandemics hindered the experimental work. At present the experiment is moved into a new laboratory in which the laser provides up to 30 mJ in 40 fs pulses. Now the vacuum chamber and the optical table are prepared, the laser beamline is being modified to obtain good coupling into it.

References

[1] Aladi, M. et al., *High harmonic generation and ionization effects in cluster targets;* High Power Laser Science and Engineering **2**, e32 (2014)
[2] Aladi, M., et al., *Cluster size distributions in gas jets for different nozzle geometries.* Journal of Instrumentation, **12**(06): p. C06020 (2017)
[3] Bódi B. et al., *High Harmonic generation on noble gas clusters*; Optics Express 27, No. 19, 26721 (2019)