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P4.2026 Towards separated Doppler harmonics through the lighthouse effect

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When an ultra-intense, femtosecond laser irradiates a solid target, an over dense plasma is generated at the target surface, acting as a non linear reflective media for the incident laser (known as a plasma mirror) that reflects the incident fields and emits a train of attosecond pulses of X-UV radiation . For ultra-high laser intensities (I >= 10^19W.cm^-2 for λ = 0.8μm), the laser field induces a relativistic motion of the plasma surface, leading to a strong and periodic Doppler shift of the laser field, each optical laser cycle. This periodic modulation in the form of an attosecond pulse train is associated to a high-harmonic spectrum in the frequency domain. To generate isolated attosecond pulses instead of trains of such pulses, which are more convenient for time-resolved experiments, an approach has recently been proposed in [1], known as the attosecond lighthouse effect. This technique consists in introducing a controlled spatio temporal coupling (STC) on the incident laser field. This STC leads to a wave front rotation at focus. Hence, attosecond beams are emitted in different directions and a single pulse can be spatially filtered in the far field. This approach has been successfully applied to harmonics in gases and solid targets in non-relativistic regime (through Coherent Wake Emission process) using a fewcycle lasers(~5 fs). Nevertheless, it has never been successfully applied to Doppler harmonics as those are usually generated with many cyle laser beams (typically ~25 fs) which leads to a drop of pulse separation. Moreover, separating attosecond pulses in the relativistic regime supposes very short gradient lengths, which leads to a significant drop in harmonics generation efficiency. In this study, we propose an optimized scheme to separate Doppler attosecond pulses based attosecond lighthouse effect with realistic experimental setup. For this purpose we have conducted an extensive numerical and theoretical study in order to assess optimal parameters for pulse separation in the relativistic regime. Our study shows that pulse separation efficiency can be improved by introducing a spatial shift between the target and the laser focus, in order to reduce harmonics divergence. This study also shows that maximizing wave front velocity is not necessarily optimal for pulse separation. A numerical model that predicts optimal separation parameters has been developed and confronted to first principle Particle In Cell simulations.

References

[1] H. Vincenti, F. Quere. Phys. Rev. Lett. 108, 113904 (2012).

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