Experimental Issues and Developments for the Search of Axion-Like Particles in Four-Wave Mixing Approach with High-Intensity Laser System at ELI-NP

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The recent development of high-intensity laser technology creates an opportunity to generate the extremely brilliant pulsed light at sub-PW outputs or beyond in a compact volume with 10 μm^3 scale. Such high-photon density gives the potential to produce axion-like particles (ALPs) in the mass range below 1eV in quasi-parallel photon-photon collision system in laboratory. Our experimental approach is, in particular, to utilize the four-wave mixing process by Ti:Sapphire high-intensity laser for the creation field and Nd:YAG high-power laser for the inducing field under the vacuum condition. ALPs search in this approach was developed in mJ/sub-mJ laser pulse energy [1, 2]. In contrast to typical astrophysical experiments such as Helioscope CAST experiment [3–5] and Haloscope ADMX experiment [6–10], the experiment with four-wave mixing of the lasers can probe a resonance state with ALPs as well as the real-state ALPs production. Our approach has a benefit in that the initial condition can be determined by operating the laser systems, on the other hand, handling the experiments gets complicated and even challenging especially for the case which requires high laser-shot statistics, as the magnitude of the laser systems and experimental setups are increased.

The commissioning experiment with a 100 TW laser system took place at ELI-NP in 2021 and 2022. Based on the basic data taken in the commissioning experiment, key challenging issues and up-to-date developments for ALPs search with high-intensity laser system at ELI-NP are addressed with the performance evaluation of the subsystems such as vacuum control system, trigger system, detection system and so forth. As well, the results to characterize the quality of Ti:Sapphire creation laser and Nd:YAG inducing laser are shown with the optimization of the setups for the ALPs search.

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