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Laser Stability Lessons Learned at ATLAS-3000

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Laser-driven plasma-based particle acceleration has achieved impressive results over the last decades, demonstrating a large variety of experimental schemes. These studies were possible even though the available instrumentation mostly had prototype-like character, often introducing considerable jitter and drift in the experimental results. Currently, the interest in improving the reproducibility of plasma-based acceleration is growing in the community, with the prospect of facilitating explorative studies and enabling real-world applications.

In this endeavor, the properties of the laser driver, in particular its wavefront, have been shown to play a crucial role in the stability of laser-based acceleration. This also holds for ATLAS-3000, a petawatt laser system hosted at CALA in Garching. In this contribution, we characterize its fluctuations and systematically explore their possible origins as well as their effect on LWFA performance. This includes a detailed analysis of the frequency components present in the pointing jitter, the dynamics and origin of defocus fluctuations, as well as higher-order wavefront fluctuations driven by air turbulence. Special emphasis is put on the pre-focal region, where intensity fluctuations tend to be larger than in the focus itself. We hope that sharing our insights with the community will help address similar issues at other facilities.

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