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Classical and quantum approaches to extreme laser-plasma physics[1]

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Current laser facilities explore a wide range of key parameters, such as intensity, energy, pulse length, and spectral and phase properties. The development of new laser systems will make it possible to further tailor such parameters. Surpassing the one petawatt level for laser systems takes us into a regime where previously suppressed processes become important, involving complex processes over a wide range of spatial and temporal scales. Microscopic and macroscopic processes, single-particle and collective effects, and classical and quantum physics come together in such scenarios, e.g., electron-positron pair creation. Our understanding of the interplay between optical fields, matter, and high-frequency radiation has largely depended on the use of classical methods. However, experimental and modeling activities for stepping outside the classical domain has increased tremendously over the last decade. We are now able to perform experiments on the quantum behavior of matter in strong lasers, and self-consistently model extreme plasmas, such as strong field pair plasmas or the plasma generation of multi-GeV photons. It is the aim of this talk to present where we are coming from, where we are at the moment, and what we can expect from future developments in this research field.

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