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Modern tests of Quantum Electrodynamics in the strong-field regime

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Quantum electrodynamics (QED) is a well-established physical theory and its predictions have been confirmed experimentally in various regimes and with extremely high accuracy. However, there are still areas of QED that deserve theoretical and experimental investigation, especially when physical processes occur in the presence of intense background electromagnetic fields, i.e., of the order of the so-called “critical” field of QED [1–3].

After a broad introduction on strong-field QED and I focus on two prominent theoretical examples of currently open problems in the field: The problems of radiation reaction and that of vacuum polarization [1–3]. Then, I will show how a newly-developed technology, “flying focus laser beams” (FFBs), can be employed as a tool to test QED in the strong-field regime and, in particular, its predictions on radiation reaction and vacuum polarization. In FFBs, in fact, the velocity of the focus can be “programmed” and it is independent of the group and the phase velocity of the beam itself.

Specifically, by considering either an ultrarelativistic electron beam or a high-energy photon beam counterpropagating with respect to a FFB, whose focus copropagates with the electrons/photons at the speed of light, we show that radiation-reaction [4] and vacuum-polarization [5] effects can be rendered measurable at much lower intensities than conventionally required in a similar setup.

In the last part of the talk, I will describe the main features of a multipetawatt laser facility which is currently under design in Rochester: NSF OPAL [6].

[1] A. Di Piazza et al., *Rev. Mod. Phys.* 84, 1177 (2012).

[2] A. Gonoskov et al., *Rev. Mod. Phys.* 94, 045001 (2022).

[3] A. Fedotov et al., *Phys. Rep.* 1010, 1 (2023).

[4] M. Formanek et al., *Phys. Rev. A* 105, L020203 (2022).

[5] M. Formanek et al., *Phys. Rev. D* 109, 056009 (2024).

[6] National Science Foundation Optical Parametric Amplifier Lines (NSF OPAL), <https://nsf-opal.rochester.edu/>.