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Challenges in the description and observation of the Schwinger mechanism

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The Schwinger effect, a long lasting prediction of quantum electrodynamics (QED), consists in the spontaneous creation of electron-positron pairs from a strong homogeneous electric fields. Many theoretical and experimental proposals using different field configurations have been put forward to verify this hypothesis, but so far, it has eluded all experimental investigations, mostly because the particle production rate is insignificant with actual electric fields generated in laboratories. Even in high intensity lasers, the typical field strength is many orders of magnitude below the Schwinger field (1.3e18 V/m) at which electron-positron pair production becomes important. Nevertheless, major improvements in laser technologies in the last few decades have stimulated a lot of efforts on the theoretical side and given some hope that the Schwinger effect could be detected in the near future.

To facilitate the detection of the Schwinger mechanism, a pulse-shape optimization technique is introduced. This method, based on the optimal control theory, can be used to enhance the pair production rate by the dynamically assisted mechanism or to control the direction of the emitted particles. Nevertheless, the predicted number of pairs obtained by using either this technique or other proposals, is still relatively small and an experimental observation would be challenging. Graphene and other Dirac materials, offer an interesting alternative as the theoretical description of charge carriers in these materials is analogous to QED. As a matter of fact, a quantum simulation of the Schwinger mechanism in graphene may be possible if one looks at the dynamics of electron-hole pairs.

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