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Novel criteria for efficient Raman and Brillouin amplification of laser beams in plasma

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Twenty years have passed since the seminal paper on Raman amplification in plasma by Malkin, Shvets and Fisch [1]. While Raman amplification has been explored very successfully in theory and simulations [2], no significant Raman amplification of a laser pulse beyond 0.1 TW or 6% efficiency has been achieved [3], and there exists only one report of Brillouin amplification beyond 1 TW [4]. In this paper, we investigate one aspect of Raman and Brillouin amplification that has been consistently overlooked until now: the parameters and quality of the initial seed pulse. We have developed new criteria for the initial seed pulse in Raman and Brillouin amplification, and show through analytic theory and numerical simulations, that the energy gain and efficiency of the amplification will be significant if and only if these criteria are met. We will analyze the plasma-based Raman and Brillouin amplification experiments carried out to date, and show that the input seed pulses in all but one of these experiments fall short of our criteria, which is the likely explanation for the poor efficiency obtained in them. Finally, we apply our findings to the results of the most promising Raman and Brillouin amplification experiments available [3, 4] to test how well those conform to our model. [1] V.M. Malkin, G. Shvets and N.J. Fisch, Phys. Rev. Lett. **82**, 4448 (1999). [2] R. M. G. M. Trines *et al.*, Nature Physics **7**, 87 (2011). [3] J. Ren *et al.*, Nature Physics **3**, 732 (2007). [4] J.-R. Marquès *et al.*, Phys. Rev. X **9**, 021008 (2019).