Plasma based amplification of short seed laser pulses via stimulated Raman or strongly-coupled (sc) Brillouin backscattering is receiving growing interest as these schemes may become a key technology for the next generation of ultra-high intensity lasers [1,2,3]. In order to reach intensities up to the Exawatt-Zettawatt level, the pump beam, delivering energy to the seed pulse, and the amplified seed pulse itself, will have large transversal diameters in order to stay within the weakly relativistic field intensity regime within the amplifier. As a result, the pulses will be vulnerable to transverse instabilities. Using multi-dimensional three-wave fluid models and kinetic (Particle-in-cell and full Maxwell-Vlasov) simulations we discuss the limitations of Raman and sc-Brillouin amplification with respect to seed pulse filamentation. Superluminal re-shaping of the seed pulse is observed during the nonlinear stage of Raman [4,5] and sc-Brillouin [6] amplification of finite-duration seed pulses. In case of Raman amplification this behavior can lead to the filamentation-free propagation of the first envelope oscillation of the seed. We demonstrate this effect by 2D and 3D simulations of the according three-wave envelope model. The results from these simulations are compared with PIC and Vlasov simulations. Although wave-breaking occurs, the kinetic simulations show that the leading pumped pulse develops a form similar to that obtained from the three-wave-interaction model. As a result the operational limits for a Raman amplifier may be less stringent compared to previous estimates based on plane-wave theory.

Filamentation of the pump pulse will be on the order of some 100 ps. This is usually longer than the interaction of pump and seed. However, imperfections of the pump will imprint on the amplification of the seed. In this context we discuss the possible influence of such imperfections on the quality of the amplified seed pulses.