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Towards a Pre-Pulse Cleaning Method In Ultrafast, High Peak Power Fiber Laser Systems

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The application of ultrafast, high-peak power lasers for laser-driven plasma acceleration (LPA) can lead to more compact accelerators reaching sufficiently high-acceleration gradients and high particle beam energies. However, such accelerators often require tremendous electrical resources and modern commercial lasers often operate on wall-plug efficiencies less-than-30%. Coherently combined short-pulse fiber lasers offer competitive energies and repetition rates for LPA while operating on efficiencies above 30% [1], but there are challenges with the fiber-array approach, including the possible reduction of contrast due to pre-pulses. Our current work focuses on investigating approaches to eliminate pre-pulse during the amplification stage. We primarily look towards a nonlinear approach by propagating the pulses through a multicore fiber, which induces both strong reshaping of the pulse by selective coupling to adjacent cores, potentially leading to shortening and contrast improvement, as well as spectral broadening by high nonlinearity, which can be used to further compress the pulse and enhance peak-to-pedestal ratio [2]. We are currently building a custom source to test the concept and modeling the spatiotemporal dynamics of femtosecond pulses through the multicore fiber. Furthermore, we are also constructing a low-cost measurement device to measure the overall dispersion of the system after pre-pulse cleaning.

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[1] J. W. Dawson et al., "High average power lasers for future particle accelerators," AIP Conf. Proc., vol. 1507, no. 1, pp. 147–153, Dec. 2012, doi: 10.1063/1.4773687.
[2] A. V. Andrianov, N. A. Kalinin, M. Y. Koptev, O. N. Egorova, A. V. Kim, and A. G. Litvak, "High-energy femtosecond pulse shaping, compression, and contrast enhancement using multicore fiber," Opt. Lett., vol. 44, no. 2, pp. 303–306, Jan. 2019, doi: 10.1364/OL.44.000303.

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