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System Modeling of kJ-class Petawatt Lasers at LLNL

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Advanced Radiographic Capability (ARC) [1] project at the National Ignition Facility (NIF) [2] is designed to produce energetic, ultrafast x-rays in the range of 70-100 keV for backlighting NIF targets. The chirped pulse amplification (CPA) laser system will deliver kilo-Joule pulses at an adjustable pulse duration from 1 ps to 50 ps. System complexity requires sophisticated simulation and modeling tools for design, performance prediction, and comprehension of experimental results. We provide a brief overview of ARC, present our main modeling tools, and describe important performance predictions.

The laser system (Fig. 1) consists of an all-fiber front end, including chirped-fiber Bragg grating (CFBG) stretchers. The beam after the final fiber amplifier is split into two apertures and spatially shaped. The split beam first seeds a regenerative amplifier and is then amplified in a multi-pass Nd:glass amplifier [3]. Next, the preamplified chirped pulse is split in time into four identical replicas and injected into one NIF Quad. At the output of the NIF beamline, each of the eight amplified pulses is compressed in an individual, folded, four-grating compressor. Compressor grating pairs have slightly different groove densities to enable compact folding geometry and eliminate adjacent beam cross-talk. Pulse duration is adjustable with a small, rack-mounted compressor in the front-end.

We use non-sequential ray-tracing software, FRED [4] for design and layout of the optical system. Currently, our FRED model includes all of the optical components from the output of the fiber front end to the target center (Fig. 2). CAD designed opto-mechanical components are imported into our FRED model to provide a complete system description. In addition to incoherent ray tracing and scattering analysis, FRED uses Gaussian beam decomposition to model coherent beam propagation. Neglecting nonlinear effects, we can obtain a nearly complete frequency domain description of the ARC beam at different stages in the system.

We employ 3D Fourier based propagation codes: MIRO [5], Virtual Beamline (VBL) [6], and PROP [7] for time-domain pulse analysis. These codes simulate nonlinear effects, calculate near and far field beam profiles, and account for amplifier gain. Verification of correct system set-up is a major difficulty to using these codes. VBL and PROP predictions have been extensively benchmarked to NIF experiments, and the verified descriptions of specific NIF beamlines are used for ARC. MIRO has the added capability of treating bandwidth specific effects of CPA. A sample MIRO model of the NIF beamline is shown in Fig. 3. MIRO models are benchmarked to VBL and PROP in the narrow bandwidth mode.

Developing a variety of simulation tools allows us to cross-check predictions of different models and gain confidence in their fidelity. Preliminary experiments, currently in progress, are allowing us to validate and refine our models, and help guide future experimental campaigns.

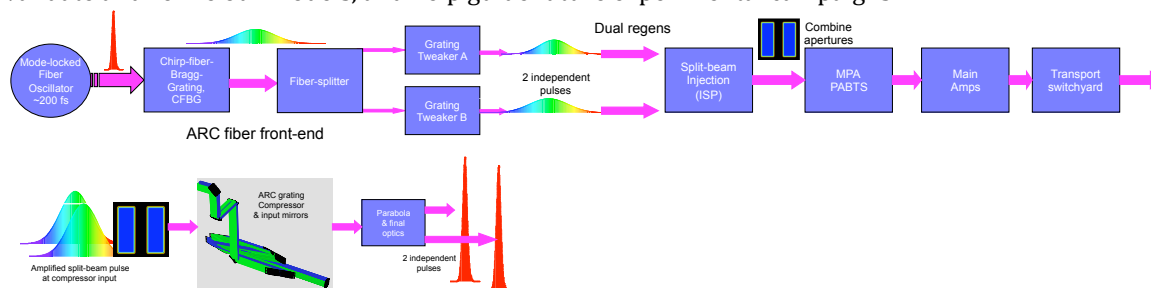


Fig. 1: Overview of the ARC system highlighting a unique version of CPA architecture to produce two intense pulses in one NIF beamline.

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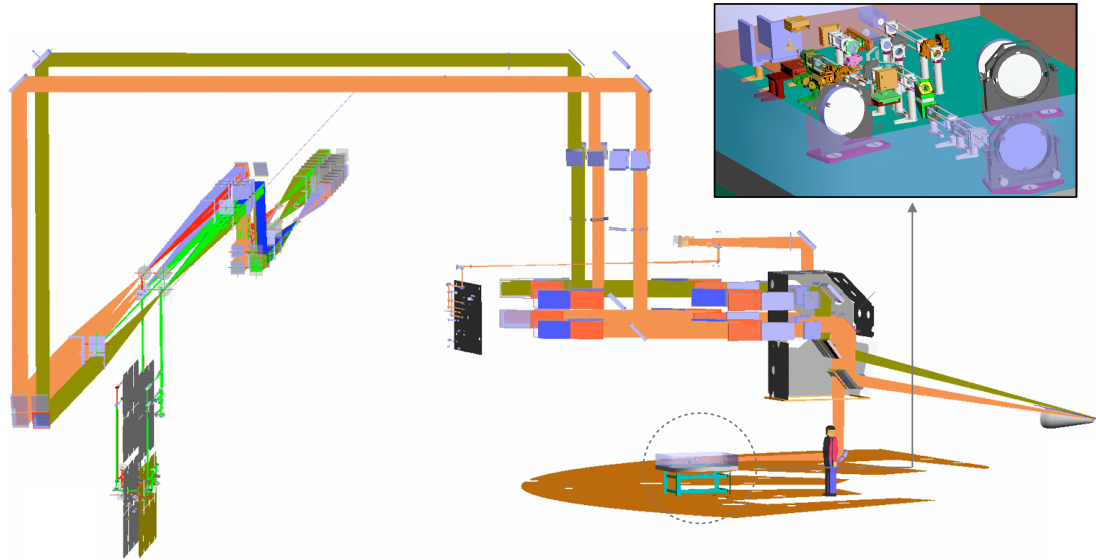


Fig. 2: FRED model of ARC system provides both a system level overview and specific component-by-component description.

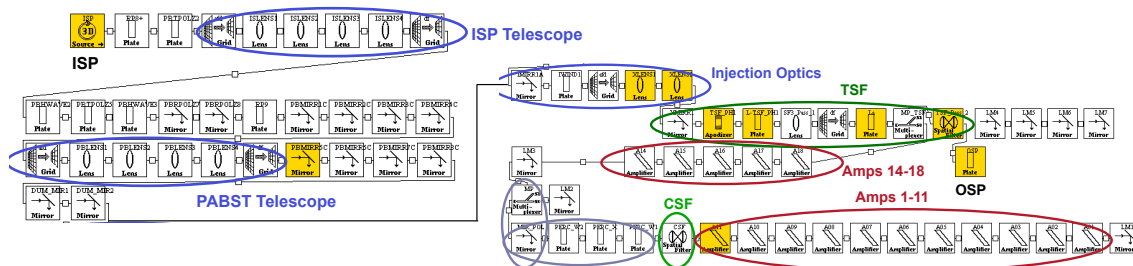


Fig. 3: MIRO model of ARC enables physical optics system description.

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