Amplification of flat laser pulse train

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Abstract: We present modeling and measurements of flattop amplification of a laser pulse train in a diode pumped Nd:YLF system. We establish a theoretical model, accounting for the transverse Gaussian shape of an amplified laser beam, in order to explain remaining slopes in the pulse train energy. The influence of the transverse Gaussian shape on the train’s flatness has been experimentally verified. Based on the model we are able to increase the total amplification of a long train of infrared seed beam in the drive laser system at the Fermilab Accelerator Science and Technology facility. The single-pass amplifier improvements resulted in a gain of ∼7 with flat output pulse train for up to 1000 seed pulses.

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1. Introduction

High peak power lasers play an essential role in high-field science, requiring a high energy density. One common approach relies upon kilohertz-scale repetition rate laser systems for purely laser-based experiments and research [1]. Recently, higher repetition rate laser systems have been attracting considerable interest for use as drive lasers in photoinjectors [2, 3] as well as other applications that benefit from a MHz-scale repetition rate, such as the generation of widely-spaced frequency combs in the extreme ultraviolet region [4, 5].

One such photoinjector application can be found at Fermilab, which is used to generate short photo-electron bunches to be accelerated through a superconducting RF (SRF) LINAC at the Fermilab Accelerator Science and Technology (FAST) facility. The LINAC consists of a photoinjector, two SRF booster cavities, an ILC TESLA-style cryomodule, multiple downstream beam lines with various diagnostics and a high power beam dump. The primary purpose of this LINAC is to serve as the injector for the new Integrable Optics Test Accelerator (IOTA) [6], but it also provides an opportunity for advanced accelerator R&D beamline-based tests and experiments, such as the planned inverse Compton scattering experiment [7].

The drive laser is based on the one developed for use at the A0 Photoinjector at Fermilab [8], though the gain medium was changed from Nd-doped Glass to Nd:YLF rods, and the flash lamp pumps were changed to fiber-coupled laser diode pumps to get better stability and higher reliability [2].

While short bunch-trains consisting of fewer than 100 fast-repetition rate bunches can be achieved with relative ease to provide a flat intensity distribution through the pulse train, achieving this with a long train like the one the FAST drive laser was designed for, becomes more difficult. Ultimately, the FAST drive laser can achieve a flat intensity distribution through a pulse train of > 1000 pulses at 3 MHz, though this could conceivably also be achieved with a flash lamp pumped system [3].

In this study a theoretical model based on the diode pump is established to explain the experimental data quantitatively. Based on the model we are able to increase the total amplification of a long train of infrared seed beam in the drive laser system at FAST facility. The optimization includes a series of realignments, adjustments of optical components, and pump-diode timing parameters, along with beam spot analysis.