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Diffraction-limited, high average power phase-locking of four 30J beams from discrete Nd:glass zig-zag amplifiers

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ABSTRACT: A single Nd:YLF oscillator beam is amplified in four discrete Nd:glass, flashlamp-pumped, zig-zag amplifiers. The resulting four 30J beams are phase-locked using SBS phase conjugation, resulting in near diffraction-limited 120J pulses from a single aperture at up to a 10Hz pulse repetition frequency.

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In many applications of high average power solid state laser systems, the laser is required to emit relatively high energy pulses greater than 25J/pulse. Examples of these applications, among many, are long range illumination for coherent imaging, laser shock processing for material strengthening, and point source x-ray generation for lithography and medical imaging. In this paper we report the performance of a 120J/pulse Nd:glass amplifier system developed as a long coherence length, long range illuminator for high resolution coherent imaging. This application requires 120J/pulse in a transform-limited 600ns pulse with less than 2 times diffraction-limited output divergence. The laser we have developed can be operated at 3Hz pulse repetition frequency in steady state (over many hours) or can be operated at 10Hz in 5s bursts with a burst spacing of 10s. Based on extensive experience with these amplifier systems, these are very conservative operating parameters which will result in many years of consistent operation. We have also successfully demonstrated operation of this system at repetition frequencies of up to 5Hz resulting in a steady state average power of 600W.

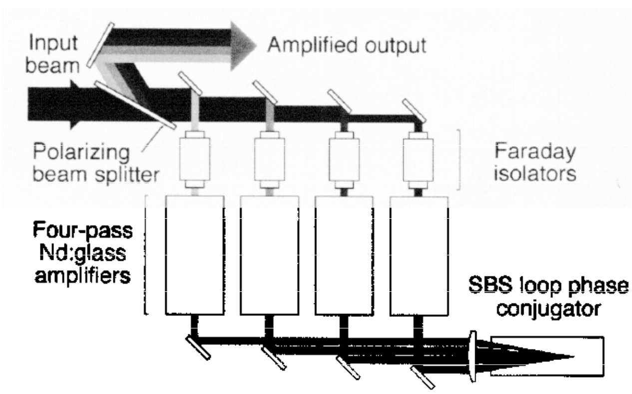

Fig. 1 - Conceptual chematic of the amplifier layout.

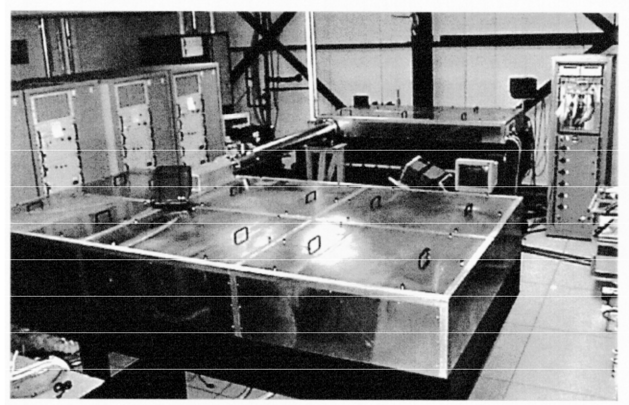

Fig. 2 - Photograph of the operating laser.

The unique feature of this laser system is the use of four separate flashlamp pumped Nd:glass zig-zag amplifiers to generate spatially and temporally coherent 120J output pulses emitted from a single aperture. The output beam from a Nd:YLF oscillator is anamorphically expanded and sheared into four square 25mm injection beams, as schematically depicted in Fig. 1. Each beam is then amplified by four passes through individual amplifiers before being rejoined and directed into a single SBS phase conjugate mirror. The SBS mirror uses a Brillouin-enhanced four wave mixing loop geometry, without which adequate phase locking stability of the four beams cannot be achieved. After four more amplifier passes, the now 30J beams are rejoined in the near field to form a single beam consisting of the four 25mm square beams with ~1mm interbeam gaps. Fig. 2 shows the measured far fields of the amplifier output for 1, 2, 3, and 4 beams at full pulse energy. The profiles are near textbook Fourier transforms of the rectangular near field patterns. Measured divergences in each case are well below 1.5 times the diffraction limit.

In summary, we are reporting the operation of a solid state laser system with 120J/pulse which can be operated at a steady state average power of 600W and a burst average power of 1200W. The output divergence is less than 1.5 times the diffraction limit and the pulses have been measured to have transform-limited bandwidth. The laser uses SBS phase conjugation to generate a single spatially and temporally coherent ouput beam using four separate and parallel amplifiers and does this with unprecedented accuracy. Work is presently ongoing to complete the construction of the second harmonic frequency converter which is expected to result in output at 527nm exceeding 80J/pulse at the full repetition frequency.

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