Birefringence in large-aperture high-power solid-state laser systems for fusion research is a potential limit to achieving efficient frequency converted performance to the second and third harmonic wavelengths. Even intrinsic levels of stress-induced birefringence in optical components can produce regions of depolarization in the output beam. Intensity-dependent ellipse rotation effects in the laser glass and intervening air paths increase the depolarization which can seriously degrade the efficiency of type II KDP frequency converters. Repolarization of the fundamental output beam has shown high conversion efficiency and good pulse fidelity but requires the use of a large-aperture high-rejection ratio thin-film polarizer that can be operated at fluences of >5 J/cm². We report here an alternative method for frequency-tripling solid-state lasers that do not require beam repolarization. Experiments using the LLNL Nova laser have successfully demonstrated that a large-aperture two-crystal type I/type II system can achieve 89% energy conversion to the third harmonic with an imperfectly polarized 1053-nm beam. Temporal records of the drive and 3rd converted pulses show that a fundamental pulse shape is maintained in the process.

The experiments were conducted in a 20-cm subaperture of the 74-cm Nova beam. Average depolarization in the chosen region was measured to be ~2.5%. Third harmonic pulses were generated with 1.2-cm thick type I and 0.985-cm thick type II AR coated KDP crystals oriented as shown in Fig. 1. The type I doubler was angularly detuned 200 µrad (internal crystal angle) to obtain the correct ratio of 1ω to 2ω energy for efficient 3ω generation in the type II mixer. Note that in this scheme, the depolarized (vertical) electric-field component of the drive beam does not enter the conversion process.

The third harmonic energy conversion results plotted in Fig. 2 are in good agreement with theory. The theoretical calculations include the intensity-dependent ellipse rotation effects that the beam undergoes in both the laser chain components and a 20-m air path by assuming an electric-field ellipticity of 0.15 and ellipse rotation rate of 3.4°/GW/cm². These parameters are consistent with the 2.6% depolarization measured in these experiments and with earlier Nova 3ω experiments at 2.5- and 25-cm subapertures. An eighth-power super-Gaussian profile was used in the computations to model the temporal shape of the nominally flat 1-ns drive pulse.

To obtain the flat temporal 1ω drive pulses at large-output energies, it is necessary to compensate for the gain saturation effects in the Nova amplifier. This is done by injecting a ramp shaped pulse into the chain. The effect of propagating the ramped pulse is that the intensity-dependent ellipse rotation angle in the output pulse is not constant but increases monotonically in time through...
Fig. 1. Crystal axis orientation for third harmonic frequency conversion with a type I phase-matched doublet and type II tripier crystal. Input beam polarization is nominally horizontal. The depolarized (vertical) component does not interact in the conversion process.

Fig. 2. Theoretical conversion efficiency curves and experimental data points for type I/type II third harmonic conversion of an imperfectly polarized drive beam. Crystal lengths are 1.2 cm for the doubler and 0.985 cm for the tripier. An ellipticity of 0.15 and ellipse rotation rate of 3.4°/GW/cm² is assumed (see text).

Fig. 3. Typical frequency converted pulse shapes for the type I/type II 3ω process (solid) compared with the type II/type II 3ω process (dashed) curve for 1ω drive intensities >2 GW/cm².