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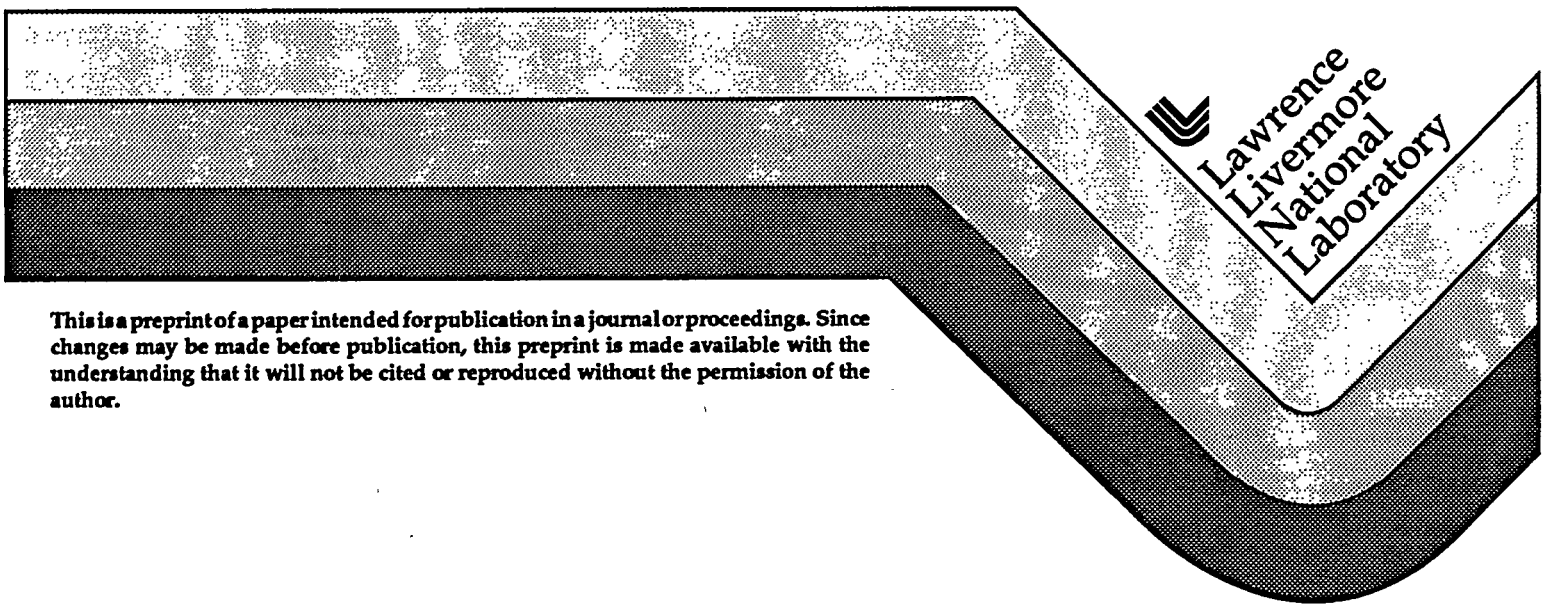

Amplification of Femtosecond Pulses to 1 J in Cr:LiSrAlF$_6$

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Abstract:

Using a large aperture (19 mm) flashlamp-pumped Cr:LiSrAlF$_6$ (LiSAF) amplifier, we have demonstrated the amplification of hundred femtosecond pulses to an energy of 1.0 J. Chirped pulse amplification in LiSAF results in recompressed pulses of 125 fsec at a repetition rate of one shot every 20 seconds.

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Summary

The development of the solid state laser material, Cr^{3+}:$LiSrAlF_6$ (LiSAF)[1], offers an important alternative for short pulse laser applications. Using the technique of chirped pulse amplification we have developed a one hundred femtosecond laser system capable of producing pulses with energies in excess of 1 J. The system utilizes compact, large aperture, flashlamp-pumped LiSAF amplifiers. Recompression after amplification yields 125 fsec, transform limited pulses at a repetition rate of one shot every 20 seconds.

The optical layout of the LiSAF system is shown in Fig 1. We start with a commercial self mode-locked Ti:Sapphire oscillator tuned to 825 nm. These 110 fsec pulses traverse a grating pair stretcher which broadens the pulses to 400 psec. The pulses then enter a TEM_{00} stable LiSAF ring regenerative amplifier cavity.[2] The pulse transits the regenerative amplifier 34 times before it is switched out, yielding a net gain of $> 10^7$. Up to 10 mJ can be extracted from this regenerative amplifier. The pulse is then passed through a serrated aperture and the image of this aperture is then relayed with magnification through the remainder of the amplifier system resulting in a super-gaussian beam at the output. After being clipped in the serrated aperture, the pulse is amplified in a second 4 mm LiSAF amplifier and is passed through an air spatial filter.

The pulse is then amplified in two 9.5 mm LiSAF amplifiers. We have optimized the performance of our large LiSAF flashlamp pumped heads to increase the maximum single pass gain. These amplifiers each utilize a flashlamp pulse forming network that delivers a 140 μsec

flashlamp pulse. By optimizing the flashlamp pulse width to match the upper state lifetime of the LiSAF we have achieved electrical to stored energy efficiencies of >1.5% in these amplifiers.[3] The pulse is first double passed through a 9.5 mm diameter LiSAF rod and single passed through a second yielding a net gain of 100. These amplifiers are each pumped with four flashlamps by 600 J of electrical energy. The output energy at this stage in the system is 400 mJ.

A vacuum spatial filter expands the pulse for amplification in a 19 x 110 mm LiSAF amplifier. This head uses 8 flashlamps in a cylindrical pump cavity and can deliver up to 3 kJ of pump energy in a 160 μsec flashlamp pulse. The gain of this amplifier as a function of input electrical energy is shown in figure 2. At low pump energies, the pump efficiency is high (1.6%) but at the higher pump energies this efficiency drops and the small signal gain grows roughly linearly with increasing pump energy. We attribute this behavior to the shift of the Xe flashlamp light spectrum toward the UV at these high pump energies. This shifts the flashlamp light away from the LiSAF absorption bands and lowers the excitation efficiency. Up to 1.6 J can be extracted from this amplifier head at a repetition rate of once every 20 seconds.

A second vacuum spatial filter further expands the beam for injection into a grating pair pulse compressor. The 65% through-put of the compressor yields pulses with energy of up to 1.05 J. The autocorrelation of the recompressed pulse, is shown in figure 3. It has a full width at half max. pulse width of 195 fsec which implies a pulse width of approximately 125 fsec if a $sech^2$ deconvolution is assumed.

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2 M. D. Perry, D. Strickland, T. Ditmire, and F.G. Patterson, Opt. Lett. **17**, 604 (1992).

3 T. Ditmire, H. Nguyen, and M. D. Perry, J. Opt. Soc. Am. B, **11**, 580 (1994).

Figure Captions:

Figure 1: Optical schematic of the 1 J, 125 fsec LiSAF laser system.

Figure 2: Measured single pass gain of the 19 mm LiSAF amplifier as a function of electrical pump energy.

Figure 3: Measured autocorrelation function of the amplified laser pulse.

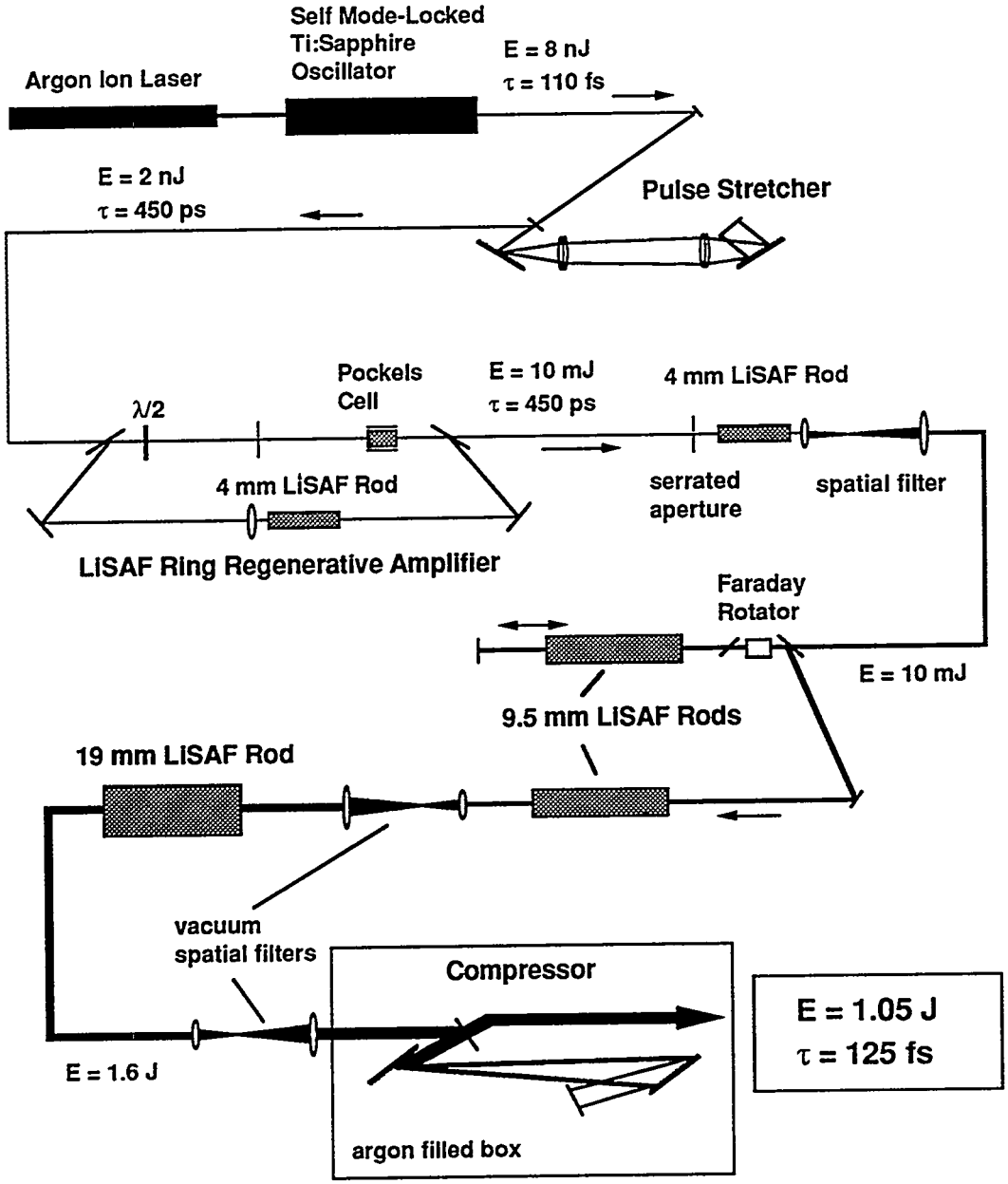
Self Mode-Locked
Ti:Sapphire
Oscillator
Argon Ion Laser
E = 8 nJ
τ = 110 fs
E = 2 nJ
τ = 450 ps
Pulse Stretcher
Pockels
Cell
E = 10 mJ
τ = 450 ps
4 mm LiSAF Rod
λ/2
4 mm LiSAF Rod
serrated
aperture
spatial filter
LISAF Ring Regenerative Amplifier
Faraday
Rotator
E = 10 mJ
9.5 mm LISAF Rods
19 mm LISAF Rod
vacuum
spatial filters
Compressor
E = 1.05 J
τ = 125 fs
E = 1.6 J
argon filled box

Figure 1

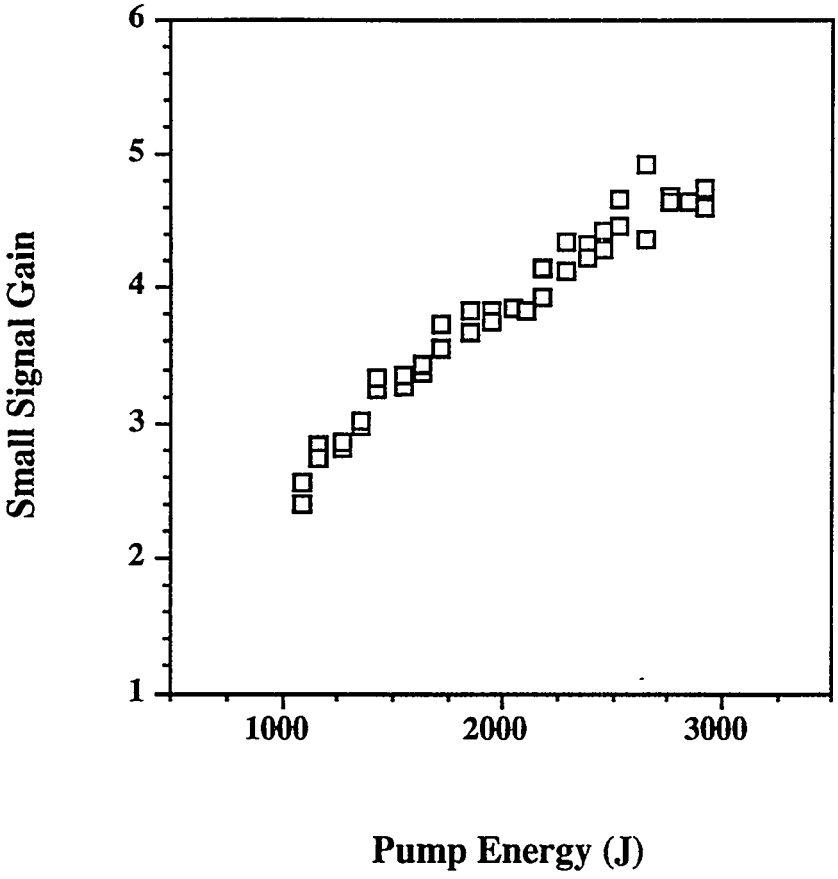

Figure 2

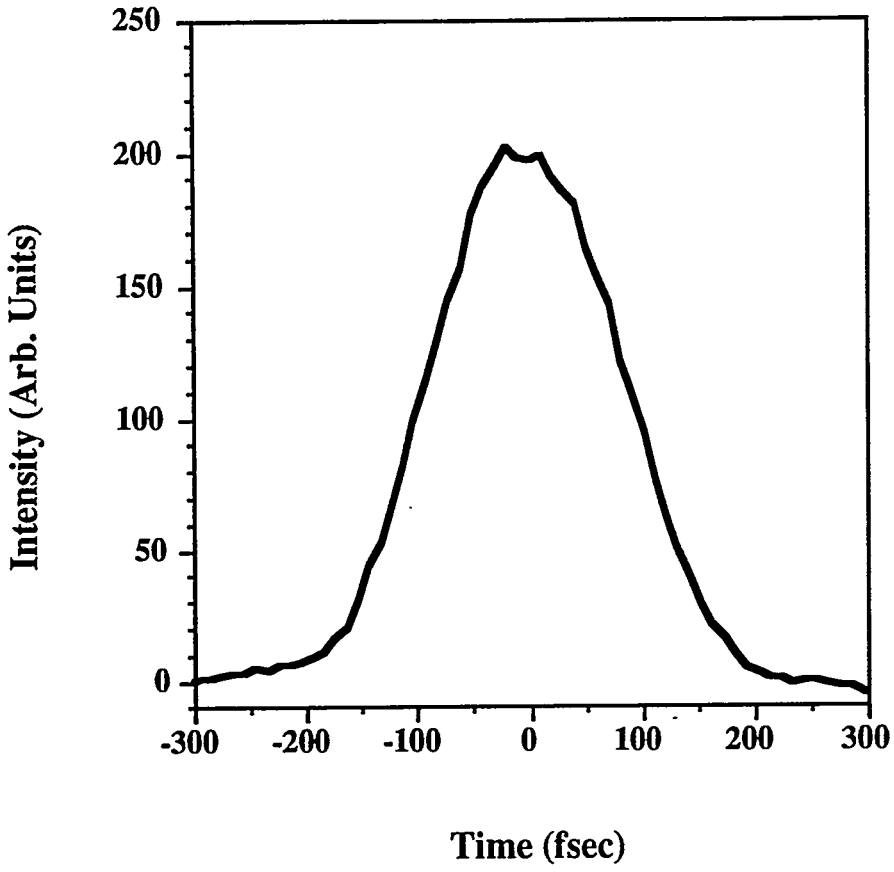
250
200
150
100
50
0
Intensity (Arb. Units)
-300
-200
-100
0
100
200
300
Time (fsec)

Figure 3