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Ultrahigh-brightness, Short Pulse Excimer Laser System at 193 nm

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Abstract

An ultrahigh-brightness ArF excimer laser system is described that is capable of generating pulse energies of 60 mJ (700 fs). The system utilizes a seed pulse generation scheme based on spectrally compensated sum-frequency mixing in BBO. Femtosecond gain characteristics of ArF are also discussed.

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Summary

Recent advances in high power, ultrashort pulse ArF excimer laser technology have led to development of ArF laser systems with peak powers in the 2-10 GW range [1-4]. This paper reports on the design and performance of an ultrahigh-brightness ArF excimer system operating at the 0.1 TW level, based on a discharge pumped preamplifier and an electron-beam pumped power amplifier. For the generation of subpicosecond injection pulses at 193 nm a spectrally compensated sum-frequency mixing scheme using β–barium borate (BBO) as a

nonlinear crystal is utilized [5]. The input signals to the sum-frequency mixer are provided by an amplified hybridly mode-locked dye laser at 707 nm (300 fs) and by fourth harmonic radiation of an Nd:YAG regenerative amplifier with a pulse duration of 50 ps. By using 0.8 mJ and 3 mJ pulse energies at 707 nm and 266 nm, respectively, the pulse energy at 193 nm is 12 μJ.

This injection source has been used to study the small-signal gain and the saturation energy density of a discharge pumped ArF excimer amplifier module in the subpicosecond regime. The measurement of the ArF excimer gain saturation was performed by injecting the femtosecond seed pulses into a Lambda Physik EMG 101 excimer laser with a gain length of 40 cm. The seed pulses were first preamplified in a single pass and then reinjected into the same excimer laser for the measurement of the gain characteristics. The results for two different time delays of the seed pulse with respect to the excimer amplifier are shown in Fig. 1. Since the nonlinear losses in the window material may distort the measured gain saturation curves, both the input and output energy values are corrected for window transmission. The average small signal gain and saturation energy density is found to be 0.17 cm^{-1} and 3.65 mJ/cm^2. Neglecting the window losses the same data would provide a saturation energy density of 2.3 mJ/cm^2. A measured autocorrelation trace of the amplified 193 nm pulses is presented in Fig. 2. showing a pulse duration of 710 fs assuming a Gaussian pulse shape.

The layout of the high power laser system utilizing an electron beam pumped ArF excimer amplifier as a power amplifier stage is shown in Fig. 3. The system generates pulse energies of up to 60 mJ at a pulse duration of ~700 fs, with less than 10 % ASE background. Since both the seed pulse generation scheme and the gain bandwidth of the ArF is expected to maintain pulse durations as short as 50 fs, assuming the same output energy density it seems to be feasible to increase the power up to above 1 TW in future experiments.

References

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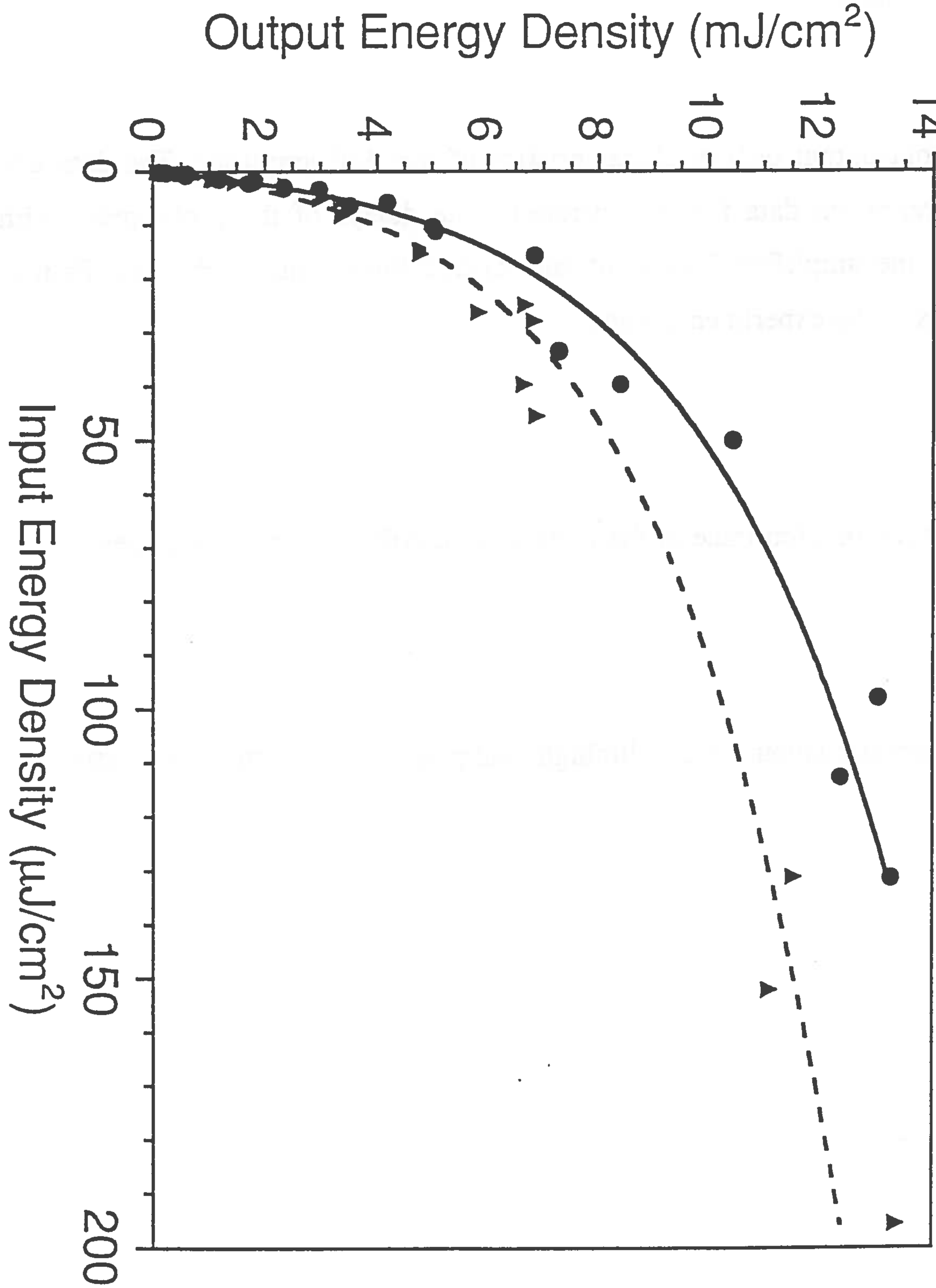
Figure captions

Fig. 1. Input-output energy characteristics of the ArF amplifier. The dots and triangles represent data for two different time delays of the probe pulse with respect to the amplifier. The solid and dashed lines indicate the best Frantz-Nodvik fits to the experimental data.

Fig. 2. Autocorrelation trace of the femtosecond ArF excimer laser pulses.

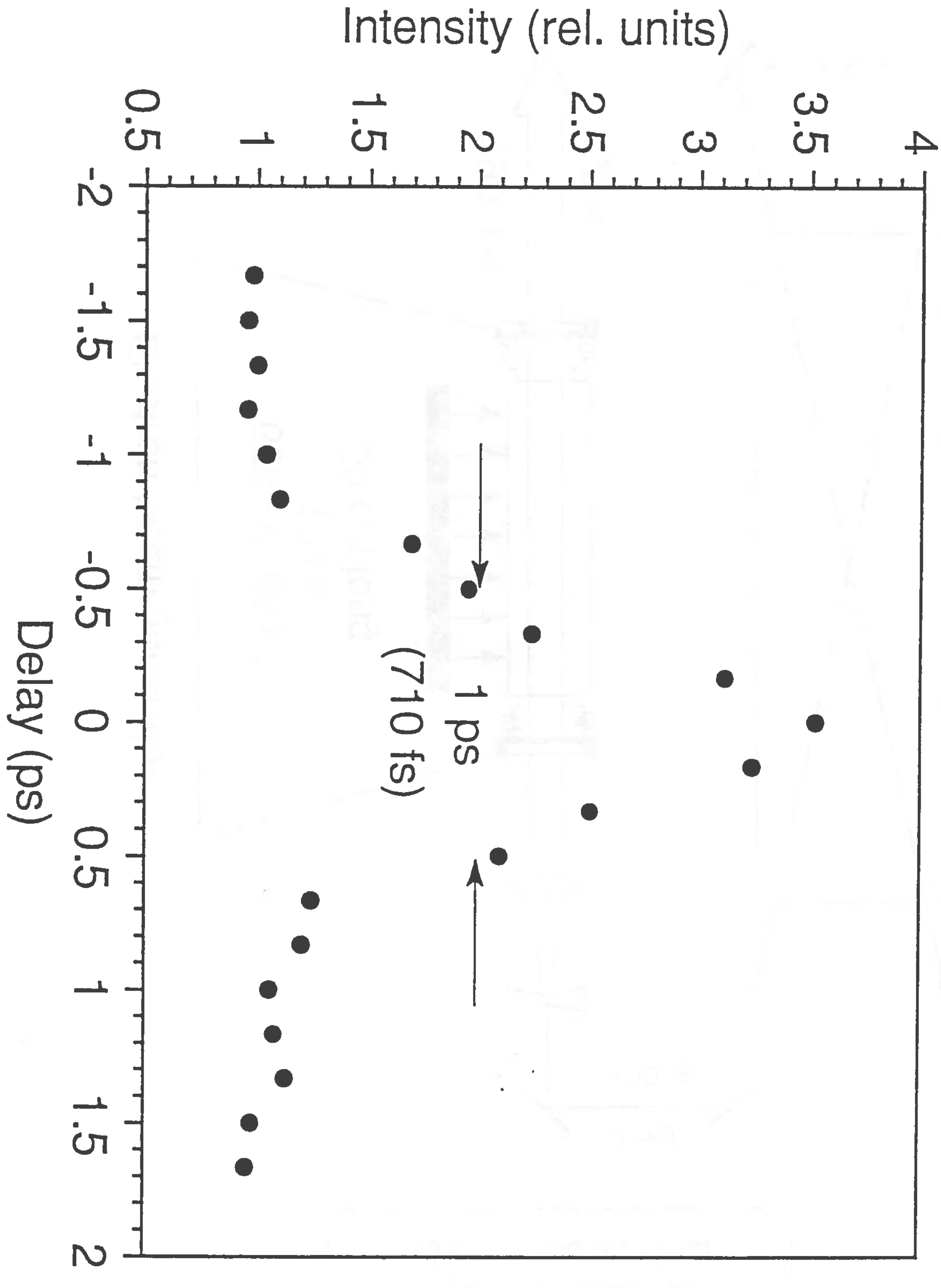
Fig. 3. Schematic layout of the ultrahigh-peakpower ArF excimer laser system.

Fig. 1

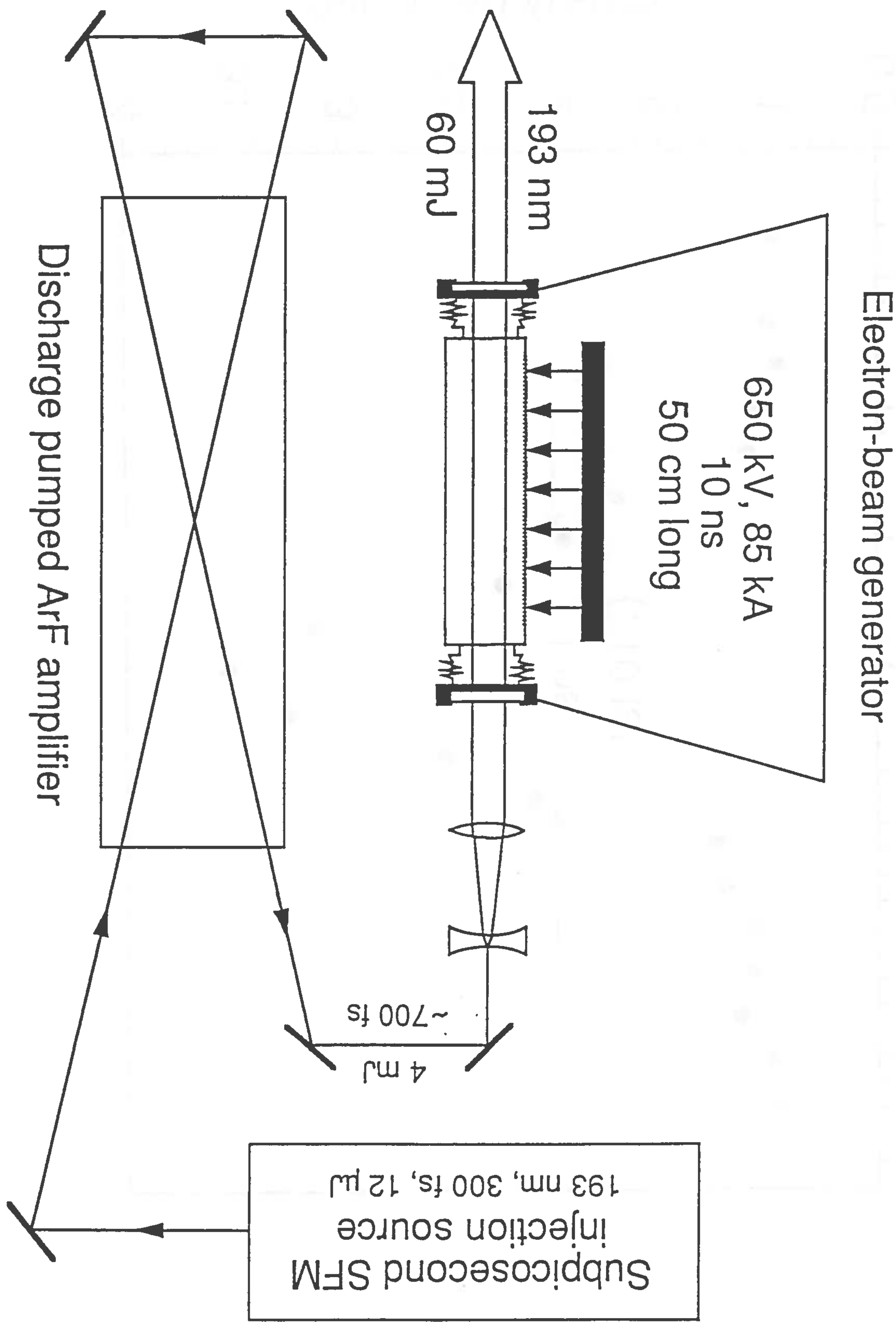


Output Energy Density (mJ/cm²)
0
2
4
6
8
10
12
14
Input Energy Density (µJ/cm²)
0
50
100
150
200

Fig. 2



Intensity (rel. units)
0.5
1
1.5
2
2.5
3
3.5
4
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Delay (ps)
1 ps
(710 fs)


Electron-beam generator
650 kV, 85 kA
10 ns
50 cm long
193 nm
60 mJ
Discharge pumped ArF amplifier
~700 fs
4 mJ
Subpicosecond SFM
injection source
193 nm, 300 fs, 12 µJ