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HiPER+
EUROPEAN LASER FUSION ENERGY

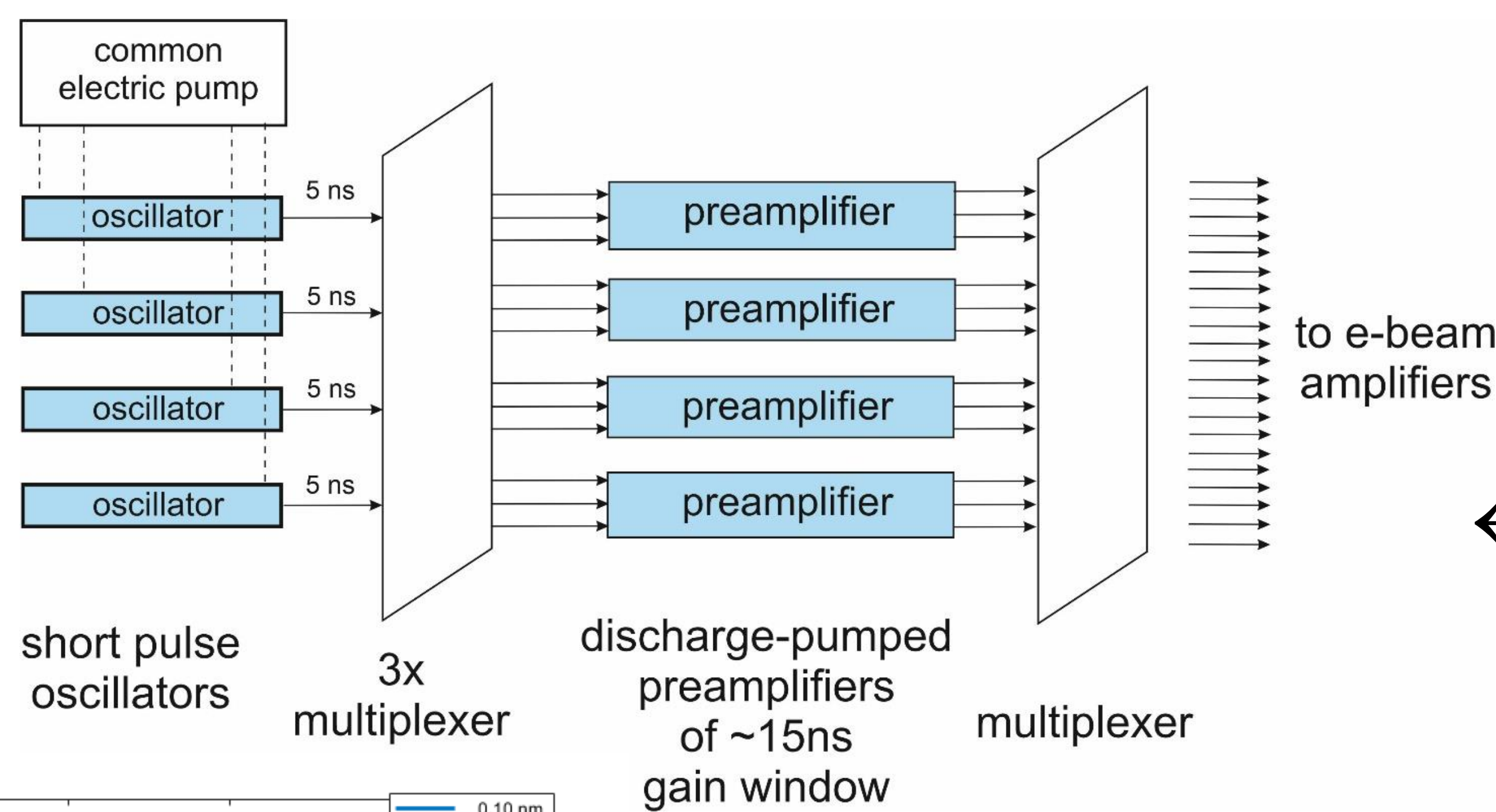
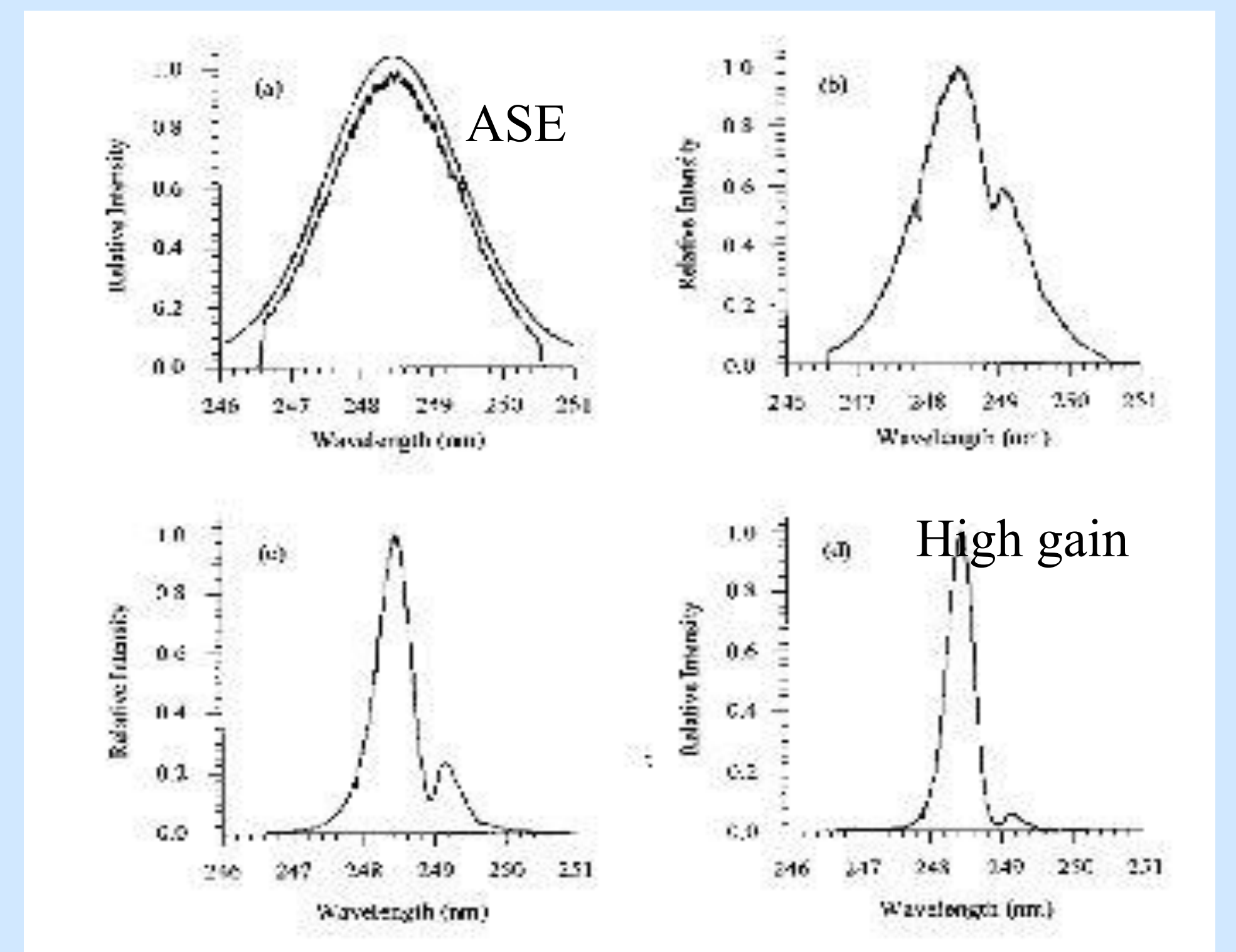
ABSTRACT

Most schemes for IFE are based on solid state lasers, and they use the third harmonics of Nd:YAG. A promising alternative of solid state laser systems is the excimer laser, as ELECTRA or the scheme suggested by the XCIMER company. The short wavelengths and broad bandwidth of excimer lasers are preferential parameters to avoid parametric instabilities. Excimers have intrinsically shorter wavelengths, and their overall gain bandwidth can surpass that can be produced by harmonic conversion of IR pulses. Herewith we propose a scheme for broadband KrF laser systems which helps to mitigate nonlinear phenomena. Due to gain narrowing the typical laser bandwidth of a free running oscillator is an order of magnitude less than the overall gain width. We propose a scheme in which several laser oscillators are detuned from each other. This can be realized in a single oscillator surrounded with multiple, detuned resonators, thus making synchronization easier. After amplification in separate preamplifiers the narrow bandwidth pulses are unified and then amplified in the main amplifiers. In this approach besides the temporal incoherence of the pulse even the spatial incoherence will not require the use of ISI schemes. The calculations show that an output pulse of 1 nm bandwidth can be obtained with a smooth spectral shape, serving as a potential candidate for the KrF alternative in IFE.

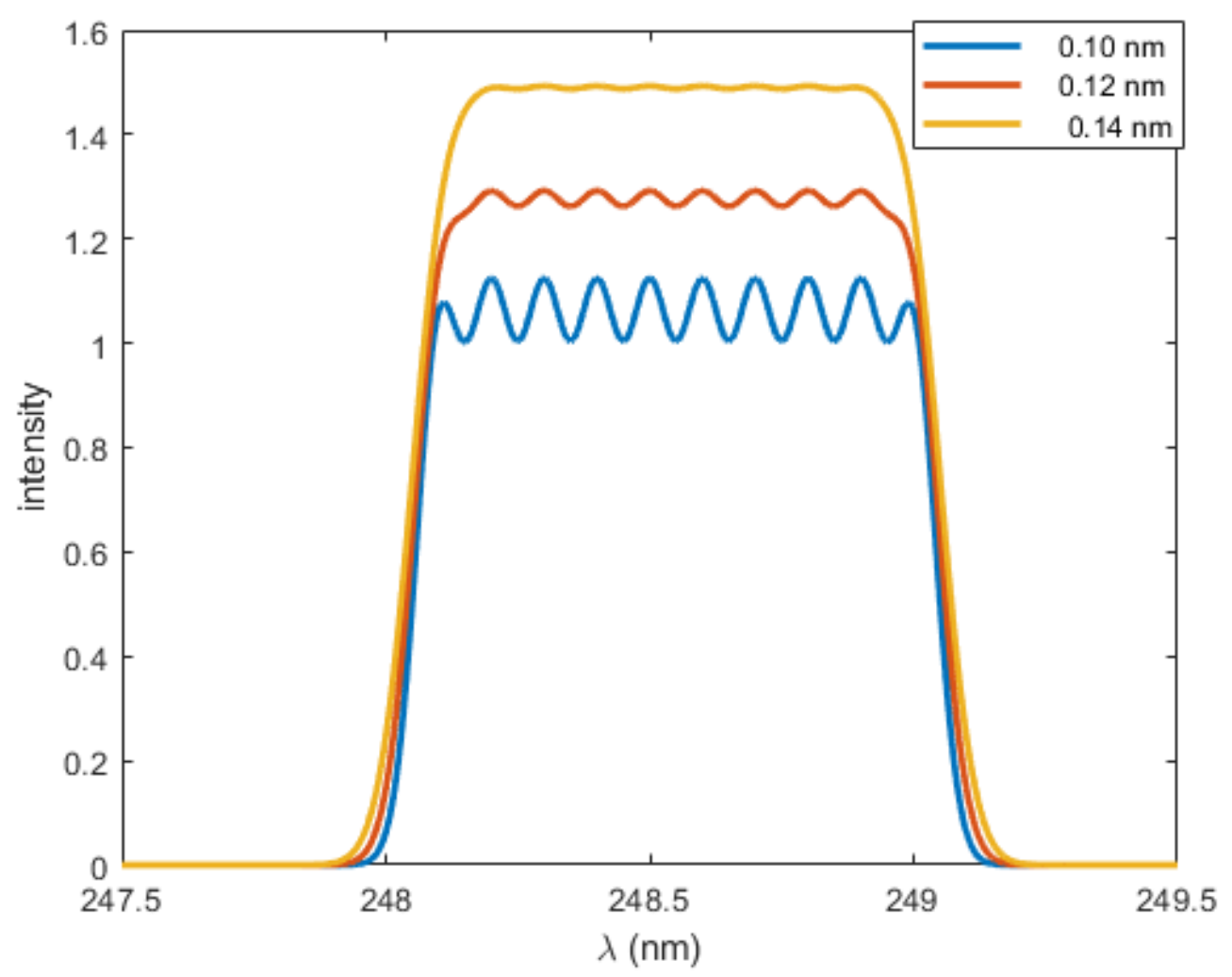
The success of direct drive scheme of IFE by shock ignition greatly depends on the mitigation of parametric instabilities of the short pulse, therefore short wavelength and broad bandwidth lasers are preferred. Alternative of the DPSSL laser harmonics is the direct radiation by excimer systems which may be more efficient [1], especially ArF on 193 nm [2]. A new arrangement is suggested which is applicable both for KrF and ArF lasers and which provides besides broad bandwidth spatial incoherence without the required difficulties of ISI imaging systems.

MULTI simulations were carried out. Results are given for the Al targets illuminated by 10^{14} W/cm² intensity sin² pulse corresponding to the experiments. Whereas the shock waves penetrate into the target much deeper than the 10 μm front side thickness of the Al layer, the plasma corona is long, allowing amplification of the instabilities.

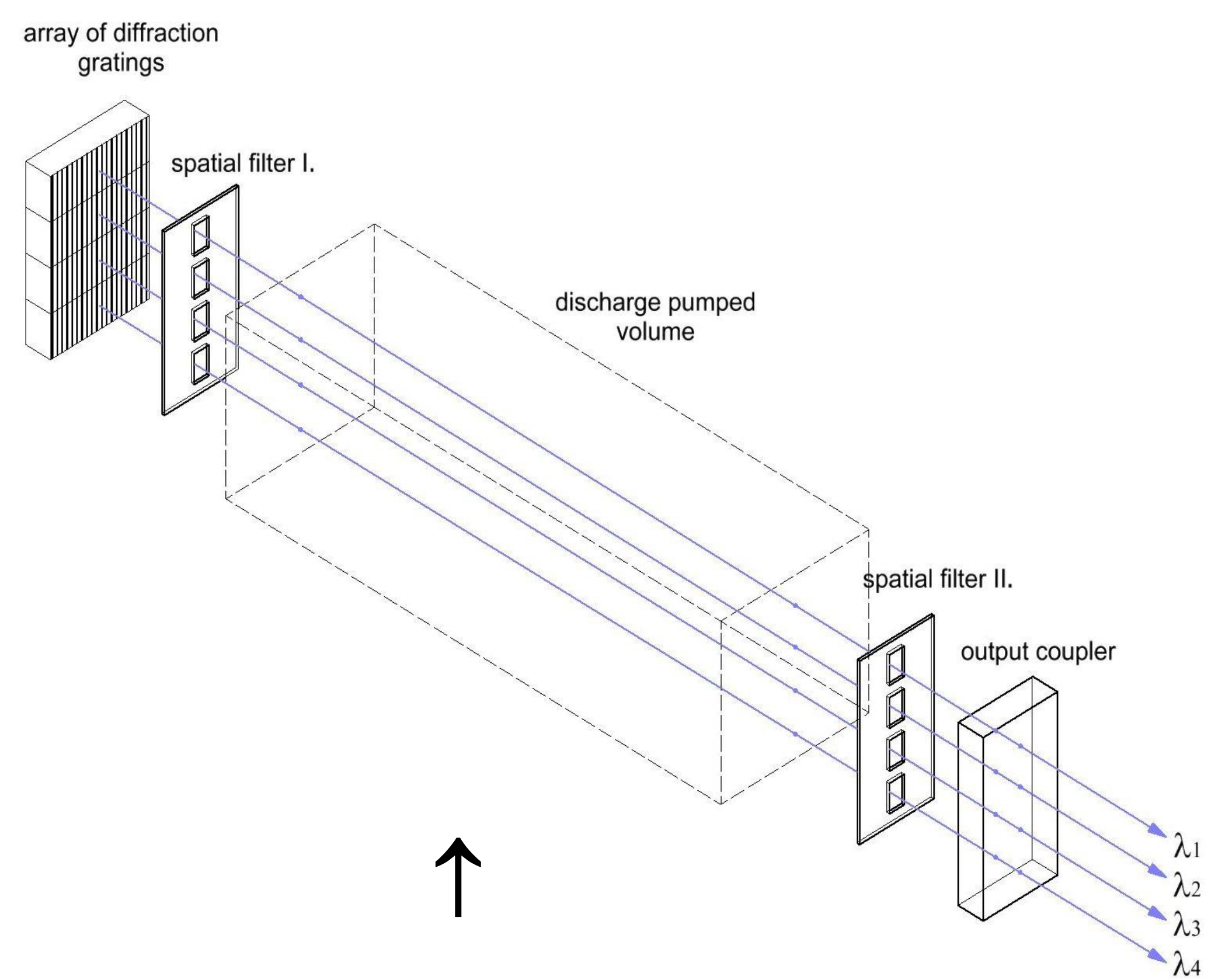
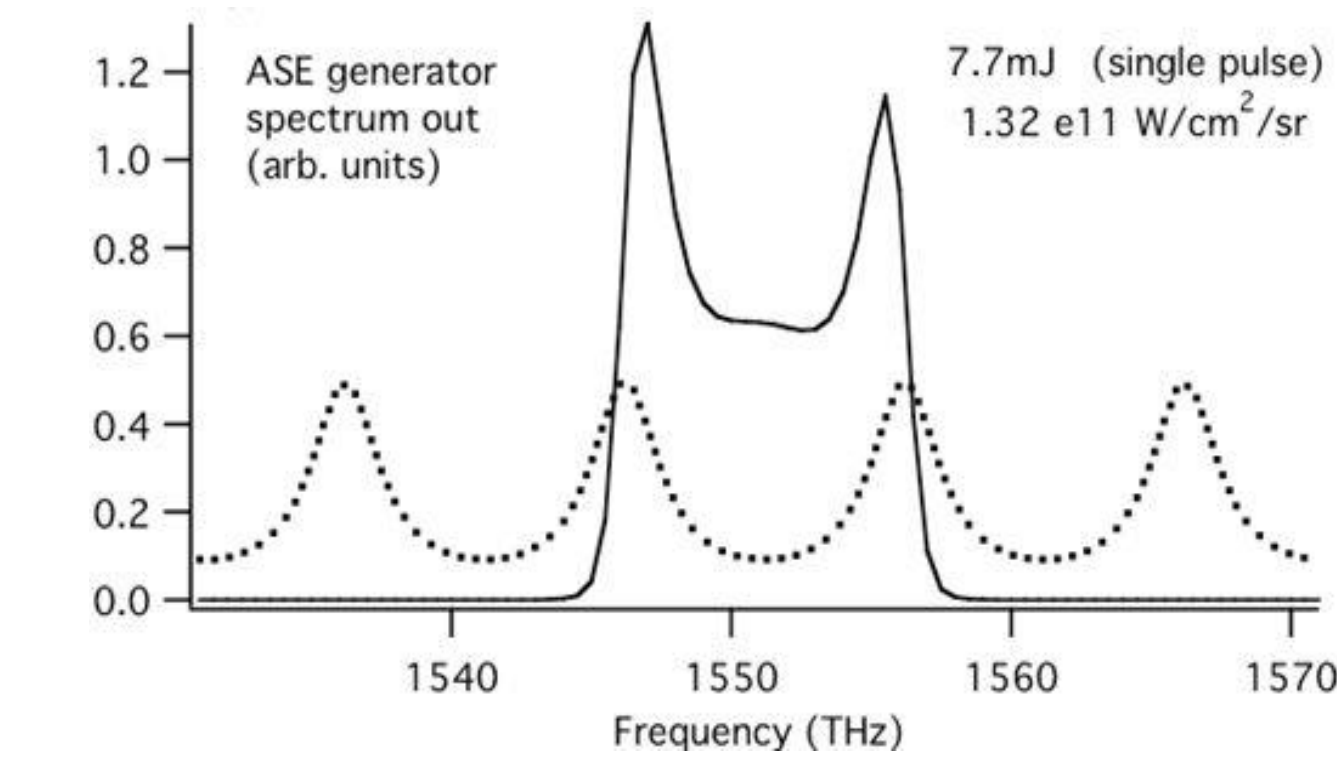
The KrF laser bandwidth has maximum 3 THz (0.62 nm) FWHM. High gain or passes in resonators reduce the laser bandwidth due to gain narrowing to ~0.1 nm after several roundtrips [3].



Based on the homogeneously broadened transition of KrF a flat-topped tuning curve of >1 nm bandwidth can be realized by gain-narrowed resonators and/or by amplification of narrowband pulses. A combination of such pulses could result in a large overall bandwidth comparable to that of spontaneous emission. The oscillators must have the same electrical pumping in order to obtain synchronized outputs.



The addition of 10 pulses with different narrow bandwidths gives a near flat top profile. As it was shown in [4], even if the seed pulses are not uniform, after the saturated amplification broad flat top spectra can be obtained either for KrF or for ArF. The Figure of McGeoch and Obenschain shows such a case.



A possible realization of a synchronously operated array of excimer oscillators is shown here by four independent resonators formed by spatial filtering using different parts of the common pumped volume. For this reason the individual oscillators are automatically synchronized temporally, but spatially fully incoherent. With the use of spectrally selective resonators – slightly detuned from each other – the output becomes temporally incoherent as well. Detuning of the resonators can be accomplished by an array of diffraction gratings stepwise slightly rotated with respect to the others.

Conclusions

We propose a new arrangement of excimer laser system for direct drive IFE systems, and especially for shock ignition. It consists of several synchronously pumped oscillators detuned from each other. After the amplifier stages the bandwidth will be extended to the full range of the available bandwidth. The single narrowband beamlets are not only detuned from each other but they are spatially incoherent as well. Therefore such a system is much more favorable than the imaging system of ISI detuning. A further advantage of the system that it can be applied for KrF and ArF systems as well, using the full 10 THz of the latter.

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References

- [1] S. Bodner; *J. Fusion Energy* **42**:33 (2023)
- [2] A.J. Schmitt, S.P. Obenschain., *Phys. Plasmas* **30**, 012701 (2023)
- [3] M.J Shaw et. al., *J. Chem. Phys.* **105**, 1805 (1996)
- [4] M.W. McGeoch, S.P. Obenschain; *Opt. Express* **33**, 48423 (2025)