Improvement of the intensity contrast of high-brightness CPA systems

Recent progress in the generation of intense electromagnetic fields is mainly driven by solid-state lasers using the Chirped Pulse Amplification (CPA) technique. The peak power of these laser systems surpasses the PW level and the focused intensities are up to the 10^{22}-10^{23} W/cm^2 range [1]. As **the maximum intensity** of laser systems **is continuously increasing** [2, 3] **an increasing interest is concentrated on the temporal and spatial quality** of the pulses (beams) [4]. The most critical figure of merit of high brightness laser systems is the intensity level of the temporal background prior to the main pulse. Prepulses of 10^7-10^8 W/cm^2 intensity are already detrimental for high intensity laser-matter interactions, as they can generate a preplasma [5, 6]. The already achieved and the planned intensities in the 10^{23}-10^{25} W/cm^2 range **set the necessary temporal contrast beyond 10^{13}-10^{18} !**

In s**hort-pulse excimer laser systems [7]** – due to the so-called direct amplification scheme – it is **only the** amplified spontaneous emission (**ASE**) **generated in the excimer amplifier chain** which **contributes to the background of the output,** having a "flat" temporal and spatial distribution.

In solid-state (e.g. in Ti:Sapphire) lasers it is not only the ASE, but **a coherent temporal noise** associated with the CPA scheme – superimposed on the flat, several nanosecond long, ASE-related background – **forms a ~100 ps triangular pedestal approaching the 10^{-4}-10^{-5} relative intensity** background **level** as shown in *Fig.1*.

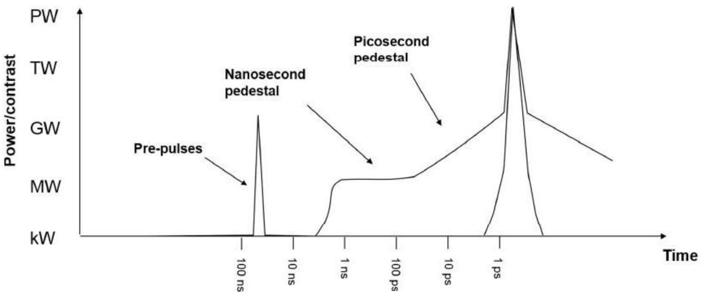

Figure 1

The **commonly used method** to improve the temporal contrast of short-pulse lasers **is based** on the use of **plasma mirrors** [8, 9, 10]. The limited ratio of the high and low intensity reflection limits **the maximum contrast improvement** to **~10^2** for a single stage, which is far below the necessary value to completely remove the coherent part of the noise.

The other candidate is **a high throughput, high-contrast pulse-cleaning technique, called as nonlinear Fourier filter (NFF)** [11, 12], where the nonlinear component is situated in the centre of a confocal telescope surrounded by a conjugated beam-block filter pair (**see** ***Fig.2***). As long as no modulation occurs in the focal plane – within the frames of geometrical optics – this arrangement has no transmission, allowing full exclusion of eventual prepulses. However, for an intense pulse, where controlled, selective phase modulation is introduced in the focal plane, finite transmission (up to 40%) is obtained. It is shown, that – due to the diffraction of light – **the achievable temporal contrast improvement** for input filters of "sharp" contours is relatively moderate ~10^3 [11, 12], but **can be raised to ~10^{10}** by the use of an apodized object as an input filter, whose spatial frequency components are properly matched to the capabilities of the main image system of NFF [13]. As a first experimental realization, an NFF arrangement completed by a low-NA preimaging system was integrated into the UV amplifier chain of our high-brightness KrF laser system [13], which **improved the temporal contrast** of its 100 mJ output **up to 10^{12}** [14]. Theoretical treatment of the optimum use of NFF in such systems is given in [15].

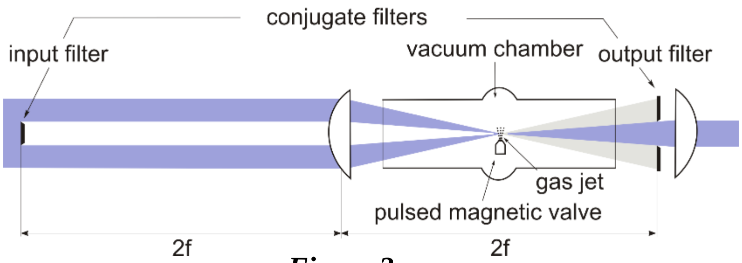

Figure 2

Beyond these superior parameters of NFF, a further practical advantages are its broad wavelength range, high-repetition rate capability and power scalability. For these reasons its **application to solid-state based CPA systems is** very promising, offering **a real breakthrough in the temporal contrast of such systems;** thus significantly improving the weakest parameter of these widely used lasers. Considering that **the required contrast improvement is generally more than 10^6** in CPA systems, **this** background **can not be removed by the commonly used techniques, except NFF**.

In the near past the basic process of NFF has been demonstrated; the controlled phase shift and the corresponding **dynamic directional modulation of a TW-class Ti:Sapphire laser pulse was realized**, similar to the UV excimer case. **In this approach** the NFF must be used after the temporal compression of the amplified pulses, moreover, the main part of the temporal noise (like the picosecond pedestal and eventual pre-pulse) is spatially coherent; therefore the construction of NFF must be somewhat different from that used in KrF systems; instead of the low-NA preimaging of a sharp object, **the use of a properly apodized object** – with well-defined spatial frequency components – **together with the use of a main image system of improved capabilities** in the NFF **is more advantageous/practical**.

Further optimization of the main image system together **with direct measurement of the intensity contrast is in progress**.

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