Dispersion management for a 100 PW level laser using mismatched-grating compressor

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Abstract: We report the dispersion management based on mismatched-grating compressor for a 100 PW level laser, which utilizes optical parametric chirped pulse amplification and meanwhile features large chirped pulse duration and ultra-broadband spectrum. The numerical calculation indicates that the amplified pulses with 4 ns chirped pulse duration and 210 nm spectral bandwidth can be directly compressed to sub-13 fs, which is close to the Fourier-transform-limit (FTL). More importantly, the tolerances of mismatched-grating compressor to the misalignment of stretcher, the error of desired grating groove density, and the variation of material dispersion are comprehensively analyzed, which is crucial important for its practical application. The results demonstrate that good tolerances and near FTL compressed pulses can be achieved simultaneously, just by keeping a balance between the residual second-, third- and fourth-order dispersion in the laser system. This work can offer a meaningful guideline for the design and construction of 100 PW level lasers.

Key words: Dispersion management; mismatched-grating compressor; 100 PW level laser.

1. Introduction

The development of high peak power lasers is of great significance in modern physics, as they can create extreme conditions and offer unprecedented means for high field physical researches. Due to the inventions of chirped pulse amplification (CPA) and optical parametric chirped pulse amplification (OPCPA) technique [1-2], several PW and 10 PW level lasers have been built up worldwide, the corresponding focused intensity has reached $10^{22}$~$10^{23}$ W/cm$^2$ [3-10]. Moreover, some countries have also commissioned the construction of 100 PW level ultrahigh peak power lasers, to pursue higher laser focused intensity and sequentially to explore frontier sciences. For example, the OPAL-75 PW in USA, the XCELS-200 PW in Russia, the ELI-200 PW in Europe, and the SEL-100 PW in China [11-14]. Currently, the majority of PW and 10 PW level lasers are based on the CPA technique with Ti:sapphire crystals. Nevertheless, limited by the available size of gain media and the transverse parasitic lasing [15], the Ti:sapphire based CPA technique may not be a great choice for 100 PW level lasers. In contrast, benefiting from the achievable large size (>400 mm) and broad gain bandwidth (>200 nm) of DKDP crystals, the DKDP based OPCPA technique has been seriously considered as a promising approach for the development of 100 PW level lasers. Such ultrahigh peak power lasers are generally characterized by very large chirped pulse duration and ultra-broad spectral bandwidth, in order to avoid the nonlinear effect in amplification and support sub-15fs compressed pulses. Thus, one of the crucial tasks in such 100 PW level lasers is the dispersion control, which determines the temporal profile as well as the peak power of laser pulses.

The dispersion matching between stretcher, amplifiers and compressor in different orders is known as vital for minimizing the pulse duration. However, the two degrees of the freedoms in traditional Treacy compressors, i.e. the incident angle and the grating pair separation, can only control the second- and third-order dispersion (GDD, TOD). The residual high-order dispersion, especially the fourth-order dispersion (FOD), is still a bottleneck to achieve the near FTL pulses compression. In order to control the FOD, several dispersion compensation methods have been developed. For example, mechanically deformable mirror [16], liquid-crystal modulator [17], grism pair [18], acousto-optic programmable dispersive filter (AOPDF) [19], and negative and positive chirped pulse amplification (NPCPA) scheme [20]. Limited by the dynamic range and spectral resolution, deformable mirror and liquid-crystal modulator are seldom applied in high peak power lasers. AOPDF and grism pair have been successfully applied in several high peak power lasers [21-
23], but their low transmission efficiency will affect subsequent amplification and finally degrade the pulse temporal contrast [24] which is a fatal parameter for 100 PW level lasers. Besides, the angular dispersion introduced by AOPDF is also a problem that should be carefully treated. Though NPCPA scheme is potential to completely compensate FOD without using any additional dispersion compensation components, it is only numerically demonstrated up to multi-PW lasers. Recently, another dispersion control method based on the combination of double-grating Offner stretcher and Treacy compressor is proposed and demonstrated in PW level OPCPA systems [25]. But this method may be invalid for 100 PW level lasers because of the significant increase of the material dispersion.

Mismatched-grating compressor is first proposed in 1997 by Kane and Squier [26]. Different from conventional Treacy compressor, an extra variable parameter (the grating groove density) is introduced by mismatched-grating compressor. In this scheme, GDD and TOD can be exactly compensated by mismatching the grating pair separation and the incident angle in stretcher and compressor respectively. Simultaneously, FOD can be nearly cancelled out by mismatching the grating groove density in stretcher and compressor. In this scheme, the gratings in compressors generally possess a higher grating groove density than that in stretchers. Because GDD, TOD and FOD can be simultaneously compensated, near FTL compressed pulses should be available by using mismatched-grating compressor in theory. However, the previous experimental results in both two PW level femtosecond lasers based on mismatched-grating compressor were not favorable. The compressed pulse durations barely reached ~30 fs, which are far from the FTL value [27-28]. This is mainly due to the gratings adopted in above two lasers were not equipped with the optimal groove density, which is limited by the commercial available gratings of that time. Fortunately, with the development of gratings manufacturing technique, the gratings with arbitrary groove density are customizable nowadays [29-31], which makes mismatched-grating compressor possess the potential for good dispersion management. However, the feasibility of mismatched-grating compressor possess the potential for good dispersion management. As a kind of passive dispersion management method, the optimal grating groove density has to be predetermined according to the calculated dispersion in lasers. Once there is a dispersion deviation in stretcher or material, the validity of mismatched-grating compressor has to be reevaluated. On the other hand, the error of desired grating groove density should also be taken into consideration. That is to say, the tolerance analysis is crucial important for the practical application of mismatched-grating compressor. However, there are few reports on the tolerances of mismatched-grating compressor so far to the best of our knowledge.

In this work, we focus on the dispersion control in 100 PW level lasers based on mismatched-grating compressor. The numerical results show that near FTL compressed pulses with 12.8 fs duration can be realized in the mismatched-grating compressor based SEL-100PW laser facility, which has a chirped pulse duration of 4 ns and a spectral bandwidth of 210 nm. Furthermore, we also investigate the tolerances of mismatched-grating compressor scheme for the dispersion control in this 100 PW level laser. Including the tolerance to the incident angle and the grating pair separation in stretcher, the grating groove density in stretcher, and the material dispersion in laser system. And the numerical results effectively clarify that good tolerances and near FTL pulse duration can be achieved simultaneously by keeping a balance among the residual GDD, TOD and FOD in the laser system. The good tolerances of mismatched-grating compressor is very necessary and crucial important for its practical application. Hence, this work provides a meaningful guideline for the design and construction of 100 PW level lasers.

2. Design of SEL-100PW laser based on mismatched-grating compressor

The SEL-100 PW laser facility was started in 2018 [14], aiming at the investigations of strong field quantum electrodynamics, vacuum birefringence and the positron-electron pair generation from vacuum [32-34], based on the collisions with intense hard X-ray lasers. As shown in Fig.1, the SEL-100 PW laser facility is mainly consisted of a high-contrast laser seed source, a double-grating Offner stretcher, three LBO based OPCPA power amplifiers, two DKDP based OPCPA high-energy main amplifiers, and a Treacy compressor. The real aberration-free characteristic endows double-grating Offner stretcher with the advantages of good beam quality and perfect-dispersion-match with a conjugated Treacy compressor [25]. The OPCPA amplifiers above are featuring with very broad gain bandwidth, and the amplified output spectrum is able to support sub-15 fs pulse duration. In addition, to avoid the pulse front distortion caused by the chromatic aberration in lenses [35-37], all the telescopes are designed as reflective-type utilizing off-axis parabolic (OAP) mirrors, which also can decrease the lenses introduced material dispersion in this 100 PW level laser facility.
The seed laser source has been developed [38], it includes a commercial Ti:sapphire kHz femtosecond laser, an infrared OPA, a gas filled hollow core fiber, and a cascaded second harmonic generation module. The output spectral width is ~265 nm with a central wavelength of 925 nm, the pulse energy is ~100 μJ, the pulse duration is ~10 fs (very close to FTL value), and the temporal contrast is about 10^{-11} level. The seed pulses are firstly injected into a double-grating Offner stretcher for temporal broadening. After the stretcher, the pulse spectrum ranges from 820 nm to 1030 nm, with a width of 210 nm and a chirped duration of 4 ns. The chirped pulses are firstly amplified to 25 J by the three LBO based OPCPA power amplifiers, then further amplified to 2500 J by the two DKDP based OPCPA high-energy main amplifiers, and finally temporally compressed to sub-15 fs by the Treacy compressor. Consequently, the laser pulses with >1500 J energy and sub-15 fs duration are promising to be achieved, corresponds to a peak power exceeding 100 PW.

Based on a comprehensive consideration of beam size, spectral bandwidth, dispersion ability and diffraction efficiency, the Treacy compressor is designed based on four meter-scale golden gratings with a groove density of 1400 g/mm from Horiba Jobin Yvon [30]. The incident angle and the grating pair separation of this Treacy compressor are 61° and 1200 mm respectively, with a compression factor of -19.9 ps/nm. The material dispersion is introduced by the nonlinear crystals (LBO and DKDP), the fused silica used for dichroic mirrors and window plates in laser facility, with the total thickness of 72 mm (LBO), 79 mm (DKDP) and 1130 mm (Fused silica), respectively. In addition to material dispersion, the optical parameter phase (OPP) [39] in all OPCPA amplifiers are also considered. The double-grating Offner stretcher will also employ golden gratings, and finally be designed based on the dispersion parameters of above Treacy compressor, materials and OPP. In view of the required grating size in stretcher is generally much smaller than that in compressor, which makes the gratings in stretcher much cheaper and easier to handle.

In this work, the stretcher and compressor are analyzed by ray-tracing method [40], the material dispersion is calculated by Sellmeier formula [41], and the OPP is simulated by coupled-wave equation [39, 42]. This calculation model is based on MATLAB, and has been demonstrated in our previous works [25, 38]. The phases of a double-grating Offner stretcher and a Treacy compressor are shown as Eq.1 and Eq.2, respectively. Here, ω is the angular frequency of pulses, G is the perpendicular separation of the grating pair, d is the groove density of the grating, θ and β are the incident and diffraction angles of pulses respectively, while the second term 2πGd^4 (tan β) is the so-called phase correction term. The dispersion (GDD, TOD, FOD) is found by the according derivate of the phase with respect to ω.

\[
\phi_s(ω) = \frac{ωG_s}{c\cos β_s} \left[ \sin (θ_s - β_s) \tan β_s - 1 \right] + \frac{2πG_s}{d_s} \tan β_s \tag{1}
\]

\[
\phi_c(ω) = \frac{ωG_c}{c\cos β_c} \left[ \cos (θ_c - β_c) + 1 \right] - \frac{2πG_c}{d} \tan β_c. \tag{2}
\]

Normally, the stretcher will also be designed with 1400 g/mm gratings, which matches that in compressor. But the residual FOD in this case will reach up to ~5.5×10^5 fs^4, when the GDD and TOD are simultaneously cancelled out by optimizing the incident angle and the grating pair separation in compressor. Such a large amount of residual FOD is difficult to be compensated unless some extra dispersion compensation methods.
are adopted, and hence it will significantly lengthen the pulse duration and degrade the temporal profile of the compressed pulses.

Table 1. Dispersion at 925 nm central wavelength of SEL-100 PW laser facility.

<table>
<thead>
<tr>
<th>Material</th>
<th>GDD/ fs²</th>
<th>TOD/ fs³</th>
<th>FOD/ fs⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretcher</td>
<td>8756341</td>
<td>-21501508</td>
<td>85574250</td>
</tr>
<tr>
<td>OPP</td>
<td>32715</td>
<td>45541</td>
<td>-41130</td>
</tr>
<tr>
<td>Compressor</td>
<td>-8789481</td>
<td>21459660</td>
<td>-85515395</td>
</tr>
<tr>
<td>Residual</td>
<td>1</td>
<td>-5</td>
<td>-5895</td>
</tr>
</tbody>
</table>

In order to directly achieve the dispersion control over GDD, TOD and FOD simultaneously, mismatched-grating compressor scheme is implemented in this 100 PW laser facility. Based on the numerical analysis, the optimal grating groove density for the stretcher is 1364 g/mm, which is not matching that in the above compressor. In this stretcher, the incident angle and the grating pair separation are 56.04° and 618.1 mm respectively, the curvature radii of the concave and the convex mirrors are 2 m and 1 m respectively. As a result, the chirped factor of this stretcher is about 19.8 ps/nm, corresponding to a chirped pulse duration around 4 ns. Given the above, the residual dispersion of mismatched-grating compressor based SEL-100 PW laser facility is about 1 fs², -5 fs³ and -5895 fs⁴, respectively. The detailed dispersion parameters of the double-grating Offner stretcher, the amplifiers and the Treacy compressor are listed in Table 1.

A 10-order super-Gaussian laser spectrum ranging from 820 nm to 1030 nm is simulated and shown in Fig.2(a), which can support a FTL pulse duration of 12.6 fs. The temporal profile and the spectral phase of compressed pulses are also calculated based on the design above, as shown in Fig.2. The phase distortion occurs mainly at the edge of the whole spectrum, and the maximal distortion is better than -1 rad. In this situation, the phase distortion induced influence on pulses compression is slight and ignorable. The temporal duration of compressed pulses is about 12.8 fs, which is very close to the FTL. This pulse duration is shorter than the expected value of sub-15 fs, and hence a higher laser peak power is promising based on the design above.

The numerical results indicate that special mismatching between the grating groove density in stretcher and compressor is feasible to realize the dispersion management for a 100 PW level laser, featuring with ultra-broadband spectrum and large chirped pulse duration. In addition, it is notable that the mismatched-grating compressor scheme is realized by optimizing the grating groove density in the stretcher here, in consideration of the required grating size in stretcher is usually much smaller than that in compressor. And this scheme can also be achieved by directly optimizing the grating groove density in the compressor.

Fig.2 (a) Simulated pulse spectrum and calculated spectral phase (b) FTL and corresponding compressed pulses of SEL-100 PW laser facility.
3. Tolerance analysis

Though our simulated result shows that mismatched-grating compressor scheme can facilitate the static dispersion compensation as high as FOD in theory, the practical performance will be greatly limited by the application conditions. As this scheme is fully based on the estimation of the dispersion in laser system, and thereby the feasibility is still doubtful once there is an error between the estimated and the actually induced dispersion values. In other words, the tolerances of such a passive dispersion management scheme based on mismatched-grating compressor is crucial important and necessary. In order to further demonstrate the feasibility of mismatched-grating compressor for the dispersion control in SEL-100 PW laser, the numerical investigation of its tolerances will be implemented in the following chapters. Including the tolerance to the misalignment of stretcher, the error of the desired grating groove density in stretcher, and the variation of the material dispersion in laser system.

3.1 Tolerance to the misalignment of stretcher

In the design above, the incident angle and the grating pair separation in the 1364 g/mm grating based stretcher are 56.04° and 618.1 mm respectively. Assuming that the incident angle or the grating pair separation in stretcher deviates from the preset parameters due to the misalignment, then the feasibility of mismatched-grating compressor, i.e. its tolerance to the misalignment of stretcher, should be carefully investigated.

In order to investigate the tolerance of mismatched-grating compressor to the misalignment of stretcher, the residual FOD and the corresponding compressed pulse duration are calculated as there is a variation of the incident angle or the grating pair separation in the stretcher. In the calculations, the GDD and TOD are simultaneously cancelled out by adjusting the compressor. The numerical results show that, sub-15 fs compressed pulse duration is always available in the case of an incident angle deviation between -3.8° and 2.3° or a grating pair separation deviation from -20 mm to 17 mm, shown as the pink bars in Fig.3(a) and Fig.4(a).

As the deviation of incident angle continues to increase, such as to 4°, the residual FOD will reach -30917 fs⁴. Such a residual FOD can lengthen the compressed pulse duration to ~18.4 fs. But this result is obtained by simultaneous cancellation of GDD and TOD. If a balance among the residual GDD, TOD and FOD can be achieved, the pulse duration is potential to be further shortened [43] and hence the tolerance of mismatched-grating compressor will be better. For this purpose, the 1400 g/mm gratings based compressor is optimized with an incident angle of 65.75° and a grating pair separation of 1220.1 mm, corresponding to a residual dispersion of 120 fs², 665 fs³ and -36728 fs⁴. As a result, the pulse duration is reduced from ~18.4 fs to ~12.9 fs. The spectral phase and temporal profile of compressed pulses under this condition are shown in Fig.3(b). Similarly, the tolerance to the deviation of the grating pair separation in stretcher can also be improved by keeping a balance between the residual dispersion. For example, when the deviation of grating pair separation increases to 20 mm, the residual FOD will reach up to -23783 fs⁴ as the GDD and TOD are eliminated simultaneously, corresponding to a compressed pulse duration of ~15.8 fs, shown as the dashed
circle in Fig.4(a). For this condition, the incident angle and the grating pair separation in compressor can be optimized to 60.98° and 1238.4 mm, respectively. And then, the residual dispersion is about 110 fs², 568 fs³ and -29077 fs⁴, resulting a compressed pulse duration of ~12.7 fs. The spectral phase and temporal profile of compressed pulses in this case are shown in Fig.4 (b).

The numerical results above demonstrate a very high tolerance of mismatched-grating compressor to the misalignment (incident angle or grating pair separation) of stretcher. Especially, we can find that a better tolerance can be achieved by making a balance among the residual dispersion rather than eliminating the GDD and TOD simultaneously. Thereby, the tolerance of stretcher misalignment (incident angle and grating pair separation simultaneous) are not investigated in detail, but a bad alignment case is analyzed by example.

Assuming that the deviations of incident angle and grating pair separation in stretcher are 4° and 20mm simultaneous, which should be a very bad alignment situation. But the laser pulses still can be compressed to ~13.7fs in this case, by optimizing the compressor to an incident angle of 65.73° and a grating pair separation of 1259.2 mm. The residual dispersion is about 163 fs², 694 fs³ and -54300 fs⁴. In other words, mismatched-grating compressor scheme also owns a high tolerance to the simultaneous misalignments of incident angle and grating pair separation in stretcher.

3.2 Tolerance to the grating groove density in stretcher

Based on the analysis in Sect. 2, the optimal design of stretcher is based on 1364 g/mm gratings, which can cancel out the GDD and TOD, meanwhile keep a small amount of residual FOD. To investigate the tolerance of mismatched-grating compressor to desired grating groove density, the compressed pulse duration with the variation of the grating groove density in the stretcher is numerically analyzed by making a balance among the residual dispersion. As Fig.5(a) shows, the pulse duration below 13.9 fs (1.1 FTL) is always available with the grating groove density between 1361 g/mm and 1368 g/mm (as the pink bar), and the pulse duration below 15.1 fs (1.2 FTL) can be obtained within a larger range from 1360 g/mm to 1369 g/mm (as the purple bar).
To make a comparison, the numerical results based on the simultaneous cancellation of GDD and TOD are also presented, as shown in Fig.5(b). We can find that the amount of residual FOD and the corresponding pulse duration will increase significantly, just with a slight deviation of the grating groove density from the optimal value. And sub-15fs pulse duration can be achieved only in the cases of 1363g/mm, 1364g/mm and 1365g/mm. This result demonstrates once again, a better tolerance can be realized by keeping a balance among the residual dispersion compared with eliminating the GDD and TOD simultaneously. For simplicity, in the following numerical analysis, the dispersion management scheme is only investigated based on a balance among the residual GDD, TOD and FOD.

To reveal more details of the analysis above, two specific examples are presented below. In the first case, the stretcher is composed of two 1361 g/mm gratings, and the 1400 g/mm gratings based compressor is optimized with an incident angle of 61.41° and a grating pair separation of 1197.4 mm. As a result, the residual dispersion in laser system is about 190 fs², 1070 fs³ and -61317 fs⁴ respectively, corresponding to a compressed pulse duration of ~13.5 fs (< 1.1 FTL). The spectral phase and pulse duration of compressed pulses are shown in Fig.6(a). In the second case, the grating groove density in the stretcher is 1369 g/mm, the incident angle and the grating pair separation of compressor are optimized accordingly to 60.33° and 1204.0 mm, resulting a residual dispersion of -227 fs², -1011 fs³ and 81924 fs⁴, respectively. As a result, the compressed pulses with ~15.0 fs duration (<1.2 FTL) are obtained, as shown in Fig.6(b).

According to above numerical investigation, we can know that the available grating groove densities for the stretcher are between 1360 g/mm and 1369 g/mm. This result demonstrates a good tolerance of
mismatched-grating compressor to the grating groove density in stretcher, in terms of contemporary gratings manufacturing technology.

3.3 Tolerance to the material dispersion in laser system

Generally, there is always an error between the actually introduced and the estimated material dispersion in laser system. Thus, it should also be quite important and meaningful to investigate the tolerance of mismatched-grating compressor to the variation of material dispersion, for its practical application.

In the design of SEL-100 PW laser facility in Sect. 2, the material dispersion induced by the nonlinear crystals (LBO and DKDP) should be much lower than that introduced by the dichroic mirrors and window plates, which are all made of fused silica and have a total thickness around 1130 mm. Thus, we just consider the variation of fused silica induced material dispersion in the following numerical investigations. The compressed pulse duration variation versus fused silica thickness is numerically calculated and shown in Fig.7. The results show that the pulse duration below 13.9 fs (1.1 FTL) can be achieved when the fused silica thickness error is between -110 mm and 135 mm, shown as the pink bar in Fig.7. Besides, the pulse duration below 15.1 fs (1.2 FTL) is still available when the error varies from -150 mm to 180 mm, shown as the purple bar in Fig.7. As a result, it indicates a good tolerance to the material dispersion in laser system for mismatched-grating compressor. The good tolerance will make this scheme feasible in practical application.

![Fig.7 The calculated pulse durations with the variation of fused silica thickness in laser system, after balancing the residual GDD, TOD and FOD by optimizing the compressor.](image)

Two special examples are presented again to reveal more details of above numerical analysis. In the first example, the error of fused silica thickness is supposed to be -150 mm. Meanwhile, the incident angle and grating pair separation in the 1400 g/mm gratings based compressor are 60.93° and 1198.4 mm respectively, corresponding to a residual dispersion of 235 fs², 1004 fs³ and -84561 fs⁴. As a result, pulse duration around ~15.0 fs can be obtained. The spectral phase and temporal profile of the compressed pulse are shown in Fig.8(a). In the second example with a fused silica thickness error of 120 mm. When the incident angle and the grating pair separation in compressor are optimized to 61.05° and 1201.2 mm respectively, a residual dispersion about -180 fs², -1150 fs³ and 57114 fs⁴ is achieved. And then, the compressed pulse duration of ~13.3 fs can be realized, as shown in Fig.8(b).
3.4 Tolerance to the grating groove density and material dispersion simultaneously

Based on Sect. 3.2 and 3.3, the tolerance of mismatched-grating compressor to the simultaneous deviations of the grating groove density in stretcher and the material dispersion in laser is also investigated. Figure 9(a) shows the compressed pulse durations variation after balancing residual dispersion, the blue and pink shades correspond to the 1.1 and 1.2 FTL values respectively. We can see that the compressed pulses below 1.2 FTL can be achieved in a relatively large region.

To see the results more clearly, the projection of available region (<1.2 FTL) on the horizontal plane is shown as Fig.9(b). As the increase of grating groove density, the tolerable range of fused silica thickness error changes in one direction, and with a similar range length. For example, when the grating groove density in stretcher is 1361 g/mm, the tolerance range of fused silica thickness error is about (-40~270 mm). And when the grating groove density in stretcher increases to 1368 g/mm, the corresponding tolerance range of fused silica thickness error varies to be about (-260~50 mm). Their range lengths are around 310 mm. While viewed from another perspective, the tolerable range of grating groove density will decrease with the increase of fused silica thickness error. In the case of no material dispersion error, the available range of grating groove density is largest, from 1360 g/mm to 1369 g/mm. When the fused silica thickness error increases to ±140 mm, the tolerable ranges of grating groove density are changed to be (1359~1365 g/mm) and (1364~1370), respectively. Therefore, the grating groove density and material dispersion are mutually related and restricted.

After making a compromise between the deviations of grating groove density and material dispersion, a relatively proper tolerable range of them (1362 ~1367 g/mm and -70 ~70 mm) is achieved, shown as the red area in Fig.9 (b). Within this area, sub-15 fs compressed pulses always can be achieved. Hence, we can find that mismatched-grating compressor also owns enough tolerance even when the grating groove density in stretcher and the material dispersion in laser simultaneously change.
In short, the mismatched-grating compressor based dispersion management scheme is highly tolerant to the misalignment of stretcher, including its incident angle and grating pair separation. Moreover, this scheme is also tolerant enough to the grating groove density in stretcher as well as the material dispersion in laser system. Thus, the mismatched-grating compressor should be practical to the dispersion management in 100 PW level lasers.

4. Conclusion

In summary, the dispersion management for a 100 PW level laser by using mismatched-grating compressor is numerically demonstrated. This scheme can make it possible to simultaneously cancel out the GDD, TOD and FOD, while without utilizing any extra dispersion compensation methods. The numerical results show that near FTL pulses can be achieved in the mismatched-grating compressor based SEL-100 PW laser facility, featuring with 4 ns chirped pulse duration and 210 nm spectral bandwidth. More importantly, we also thoroughly investigate the tolerances of mismatched-grating compressor scheme. Including the tolerance to the misalignment of stretcher, the error of the desired grating groove density in stretcher, and the variation of the material dispersion in laser system. The results efficiently demonstrate that good tolerances and near FTL compressed pulses can be obtained simultaneously by keeping a balance among the residual dispersion, which is a further proof to the feasibility of the practical application of mismatched-grating compressor. Hence, mismatched-grating compressor should be a feasible and promising scheme for the dispersion management of 100 PW level lasers. And this scheme can also be backwards compatible to PW as well as 10 PW level lasers.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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