Prismless passively mode-locked femtosecond Cr:LiSGaF laser

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A Kerr-lens mode-locked Cr:LiSrGaF laser containing no intracavity prisms has been demonstrated for the first time to the authors' knowledge. The laser produced stable near-transform-limited 44-fs pulses with an output power of 200 mW, tunable between 833 and 857 nm. Low-loss Gires–Tournois structured dielectric mirrors were used for dispersion control. The measured group-delay dispersion of the active medium as well as of the mirrors permitted to minimize the number of reflections, permitting higher output power.

Recent years have been marked by impressive developments in the field of ultrafast-pulse lasers: the discovery of Kerr-lens mode locking (KLM) in Ti:sapphire[1] and subsequent maturing of the Ti:sapphire-based ultrashort-pulsed technology down to sub-10-fs pulses.[2] Currently the KLM Ti:sapphire laser is a widely used commercially available tool. However, the bulky and expensive high-power cw lasers usually required for its pumping remain the major limitation to the development of large-scale real-world applications of ultrashort pulses. Therefore there is a strong impetus in femtosecond technology research toward developing compact, stable, and less expensive ultrafast sources. Especially attractive for this purpose are Cr^{3+}-doped $LiSrAlF_6$ (Cr:LiSAF; Refs. 3–5) and $LiSrGaF_6$ (Cr:LiSGaF; Refs. 6–8) which provide broadband gain over a spectral region similar to that of Ti:sapphire and suitable for AlGaInP laser diode pumping. A KLM Cr:LiSAF laser produced pulses as short at 18 fs,[9] whereas the Cr:LiSGaF laser has the advantage of substantially higher achievable output powers.[6,8] Recently a novel mirror dispersion control approach was suggested and successfully realized in a Ti:sapphire laser,[10,11] allowing stable, sub-10-fs pulses to be produced from a prismless Ar^+-pumped oscillator.[2] The first prismless diode-pumped Cr:LiSAF laser based on a semiconductor saturable-absorber mirror (no KLM action) with Gires–Tournois (GT) coating was realized last year by Kopf *et al.*[5] and yielded 160-fs pulses at 25-mW output power.

We report what is to our knowledge the first prismless Kr^+-pumped KLM Cr:LiSGaF laser, with low-loss GT structured dielectric mirrors replacing conventional cavity mirrors. The laser produced stable, reproducible, near-transform-limited 44-fs pulses at 200 mW of average output power.

The first suggestions for the compression of chirped optical pulses by means of interferometerlike structures go back to 1964.[12,13] Based on this idea, the technology of dispersive dielectrical mirrors was developed recently.

Currently there exist two types of dispersive mirror: GT interferometers,[14,15] which are essentially étalons, and chirped dielectric mirrors.[10] Chirped mirrors exhibit nearly constant group-delay dispersion (GDD) over a much larger bandwidth than can be obtained by GT interferometers for dispersion control. GT mirrors have the advantage of negligible transmission loss and relatively high and adjustable (by means of a change of the angle of incidence) GDD.

We performed lasing experiments with both chirped and GT mirrors. The results indicate that at the present state of research high losses in the chirped mirrors do not permit their use for dispersion control in Cr:LiSGaF- or Cr:LiSAF-based oscillators, unlike Ti:sapphire, which tolerates significantly higher intracavity losses.

The losses in dielectric mirrors originate from scattering and absorption inside the dielectric layers.[16] Dispersive mirrors, however, exhibit higher losses than conventional quarter-wave mirrors because of the higher field concentration within the layers (field trapping in interferometric GT structures and higher penetration depth in chirped mirrors).

Briefly, a GT dielectric mirror consists of a top reflector, a spacer region, and a practically 100% bottom reflector. In Fig. 1 we compare the group delay

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