Low Reflection Loss Dispersion Compensation Scheme for Broadly Tunable sub-ps Solid State Lasers

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Abstract: Combination of high (R>99.9%) reflection from an ion-beam sputtered ultrabroadband chirped mirror and Fresnel reflection from a wedged fused silica substrate forming a Gires-Tournois interferometer provides a wavelength independent, adjustable dispersion compensation for broadly tunable sub-ps lasers such as Ti:sapphire.

1. Introduction

Operation of broadly tunable solid state sub-ps lasers and optical parametric oscillators relies on a net negative dispersion of the cavity due to solitary pulse formation [1]. Besides pulse energy, pulse duration of such lasers depends on the amount net negative dispersion in the laser cavity: in case of sub-10 fs, sub-100 fs and sub-ps Ti:sapphire lasers, the net dispersion is in the -100 fs^2, -1.000 fs^2 and -10.000 fs^2 range, respectively. Introduction of ultrabroadband chirped mirrors allowed constructing the first broadly tunable Ti:sapphire laser operating in the 80-150 fs regime [2], in which dispersion compensation was provided by a Brewster angled, SF10 prism pair. Dispersion of chirped mirrors is limited by their physical thickness [3], that is why they can provide less than -50 fs^2 dispersion over the whole tuning range Ti:sapphire (680 – 1040 nm). They cannot support sub-ps operation due to variation of dispersion as a function of wavelength and increased reflection losses, which are proportional to the overall group delay introduced by such mirrors [4]. Note that more than 100 reflections from chirped mirrors might be required for intra-cavity dispersion control of a tunable, sub-ps Ti:sapphire laser. Highly dispersive dielectric mirrors [5] exhibit ~1.000 fs^2 negative dispersion per reflection over a limited spectral bandwidth of ~50 nm, which limits their use in broadly tunable lasers. In a recent paper we reported on a ~20 MHz repetition rate, sub-ps Ti:sapphire laser, in which a piezo controlled Gires-Tournois interfermeter provided a proper amount of negative dispersion in the cavity for sub-ps operation at around 800 nm [6]. In that work a low dispersion, quarter-wave stack dielectric mirror and wedged fused silica substrate were used to build a Gires-Tournois interferometer (GTI) [7] with a mirror spacing varying from ~15 to ~30 micron to provide dispersion compensation at around 800 nm. Quarter-wave stack mirrors exhibit low reflection loss due to the low penetration depth of electric field in such structures at around the central wavelength, however, their high reflectivity range is limited.

Broadly tunable sub-ps lasers are of special interest, since their spectral bandwidth matches well with that of molecular vibrations [6], that is why they are well suited for stain free, *in vivo* CARS and SRS imaging of biological tissues. *In vivo* nonlinear microscope imaging also prefers fiber delivery of ultrafast laser pulses, which are used for multiphoton excitation [8]. Sub-ps lasers have considerable lower sensitivity for chromatic or angular dispersion owing to their reduced FWHM spectral bandwidth of ~1 nm [9], that is why they are well suited for fiber coupled, handheld scanning nonlinear microscopes [8] or for nonlinear microscopes using fast, acousto-optic scanners. Longer pulses of sub-ps lasers can be compensated by lower repetation rate of such ultrafast lasers resulting in peak intensities similar to ~100 fs lasers [6,8,9], that is why imaging quality is not compromised even in *in vivo* applications of these lasers.

In this paper we report on a low reflection loss dispersion compensation scheme developed for broadly tunable sub-ps pulse solid state lasers such as Ti:sapphire, in which combination of high (R>99.9%) reflection from an ion-beam sputtered (IBS) [10] ultrabroadband chirped mirror (UBCM) and Fresnel reflection from a wedged fused silica substrate forming a GTI provides a wavelength independent, adjustable dispersion compensation over the whole reflectivity range (680-1060 nm) of the ultrabroadband chirped mirror.