Broad tunability from a compact, low-threshold Cr:LiSAF laser incorporating an improved birefringent filter and multiple-cavity Gires–Tournois interferometer mirrors

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We demonstrate prismless tuning of a compact femtosecond Cr:LiSAF laser. The employed technique, which uses a specially designed birefringent filter in combination with dispersion compensation from a pair of multiple-cavity Gires–Tournois interferometer mirrors, provides tuning over 20 nm. We give the results of theoretical modeling of the tuning velocity and the spectral width of the central passband. We show, both experimentally and theoretically, that a single birefringent plate can be used to control the oscillating bandwidth of the laser. The effect this has on the output-pulse duration has also been investigated. © 2005 Optical Society of America

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1. INTRODUCTION

Cr:LiSAF is a versatile laser crystal having a high product of a stimulated-emission cross section and an upper-state lifetime that enables the construction of low-threshold and efficient laser systems.[1–3] Cr:LiSAF has a broadband emission bandwidth capable of supporting femtosecond pulses and an absorption band that is convenient for diode pumping. Thus compact femtosecond Cr:LiSAF lasers have been operated at gigahertz repetition rates[4] and have produced kilowatt peak-power levels as well as femtosecond pulses in the blue spectral region with single-pass extracavity frequency doubling.[5] Some of the laser configurations described in Refs. 1–5 suffer the common disadvantage of a fixed-center wavelength. For many applications, notably in pump-probe spectroscopy, the tuning of the center wavelength of the femtosecond pulses must be achieved over tens of nanometers. The most common approach to the tuning of a femtosecond laser involves the use of two prisms and a slit.[6,7] This technique has the inherent disadvantage that the typical prism separation increases the cavity footprint considerably. This separation also increases the amplitude noise and the jitter associated with the laser through air fluctuations shifting the beam relative to the slit. We describe here a technique for the tuning of the center wavelength of a femtosecond laser system that not only is conducive to low-threshold operation but also retains a degree of compactness that is not available with prism-based tuning techniques.

Recent years have seen considerable research into mirror-based dispersion-compensation schemes designed to provide broadband, engineerable control of dispersion in compact resonator configurations. Two design strategies that have been used with notable success are chirped mirrors[8] and multiple-cavity Gires–Tournois interferometer (GTI) (MCGTI) mirrors.[9] MCGTI mirrors consist of several GTI layers[9,10] at the front of the multilayer mirror structure. Unlike many chirped mirror designs,[11] no degradation exists in the reflectivity. This means that MCGTI mirrors are more applicable in low-threshold lasers, because they offer both attractively low-insertion losses and high per-bounce dispersion.

In this paper, a combination of MCGTI mirrors for dispersion compensation and a specially designed birefringent filter (BRF) is used to tune a femtosecond laser. Conventional birefringent filters[12] are excellent tuning elements for single-frequency lasers, but the task is rather different when one wishes to alter the center wavelength of the larger spectral width of a femtosecond laser. Naganuma *et al.*[13] have demonstrated that a birefringent plate whose optic axis is at a large angle to the surface of the plate is a suitable tuning element for a mode-locked color-center laser. We have adapted this design concept and have been able to demonstrate a filter with tuning properties more suited to a low-gain–low-threshold femtosecond Cr:LiSAF laser. We include the results of a Jones matrix analysis of the filter properties that yields such characteristics as tuning velocities and spectral passbands. An inherent property of the filter design proposed by Naganuma *et al.*,[13] and our subsequent adaptation, is that a number of passbands of varying width can be accessed by a simple azimuthal rotation of the filter. This

