Invited Paper

Measurement of dispersive properties of optical materials and mirrors using spectrally resolved white-light interferometry

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ABSTRACT

We present a simple, accurate and inexpensive interferometric technique based on the spectrally resolved white-light interferometry to determine the group-delay dispersion of optical elements, such as laser crystals and multilayer mirrors. Due to the different dispersion properties of these elements, different evaluation methods of the interference fringes are used for the mirrors and crystals. The reproducibility of our measurements is ±5 fs^2 and ±3 % for mirrors and crystals, respectively, with high spectral resolution over a broad spectral range (700-900 nm). These dispersion data are important for the construction of compact femtosecond solid-state lasers.

Keywords: group-delay dispersion, white-light interferometry, multilayer mirror, laser crystal

1. INTRODUCTION

Recently it has been demonstrated that the use of specially designed multilayer (chirped) mirrors[1] in the laser resonators allows to generate stable, sub-10 fs laser pulses[2]. In contrary to a pair of prisms the dispersion of these mirrors cannot be changed, hence it is essential to know precisely the dispersion of the multilayer mirrors and the laser crystals to produce low intracavity dispersion. In connection with femtosecond laser systems the higher derivatives of the phase shift $\varphi(\omega)$ of the optical elements are important: the group delay ($\tau=\partial\varphi/\partial\omega$), the group-delay dispersion ($GDD=\partial^2\varphi/\partial\omega^2$), and the third-order dispersion ($TOD=\partial^3\varphi/\partial\omega^3$). A number of papers have been devoted to the problem of the group-delay (GD) measurement in optical components[3-6]. These methods either have high precision with difficult apparatus or vica versa. When multilayer mirrors form part of a Fabry-Perot interferometer, the GD of the mirrors can be measured simply by determining the spectral position of transmission maxima, but this technique cannot be applied for measuring GD of other optical components[7].

The spectrally resolved white-light (SRWL) interferometry, which is a relatively simple and accurate method, has proved to be a useful technique to study the anomalous dispersion of vapours[8,9], to measure the refractive indices of dye solutions[10] and optical glasses[11]. In this paper we extend this technique showing how it is possible to determine the GDD of multilayer mirrors and laser crystals such as Ti:sapphire (Ti:S), Cr:LiCAF, Cr:LiSAF, and Cr:LiSGAF.

2. EXPERIMENTAL SETUP

Our experimental apparatus consists of a Michelson interferometer combined with a simple spectrograph, as shown in Fig. 1. The interferometer is illuminated by a white-light source (100 W tungsten halogen lamp). A horizontal slit is placed in front of the light source to increase its spatial coherence in the vertical direction. Both the beam splitter cube (Spindler & Hoyer No. 33520) and the reference mirror, which is a plane gold mirror, have negligible group-delay dispersion (GDD)[12]. A vertical slit placed to cut of a thin stripe from the white-light fringes appearing at the exit plane of the interferometer. This stripe is spectrally dispersed by a transmission grating (200 grooves/mm) and imaged onto a CCD chip (Electrim Corp.,EDC-1000, 165×196 pixels) by an achromatic lens (f=50 mm). When a multilayer mirror is tested, the reference mirror is tilted around a horizontal

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