Characterization of chirped mirrors

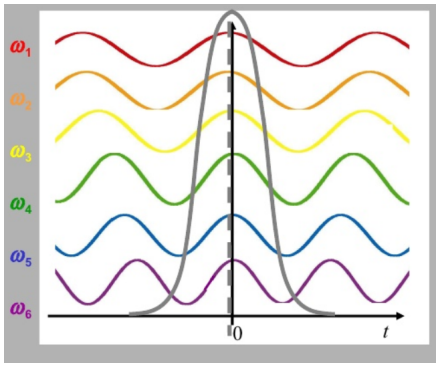

Figure 1: Constructive interferences

Femtosecond lasers are valuable tools used daily in basic research, whether in chemistry, physics or biology. These lasers delivers ultra-short optical pulses with (i) extreme peak power ranging from 10^6 to 10^{15} W - in comparison a nuclear plant produces about 10^8 W - which led to ground-breaking breakthroughs in nonlinear optics, light-matter interaction and strong field physics, (ii) extreme pulse duration and hence extreme temporal resolution for time-resolved spectroscopy and more generally for transient phenomena. The downside: ultrashort pulses tend to lengthen in media such as glass or air. This phenomenon, called "chromatic dispersion", can be understood by remembering than ultrashort pulses are nothing else than optical wave packets, i.e. a superposition (an "interference" in optical lingo) of a large number of monochromatic waves of different optical frequencies. In media characterized by frequency-dependent refractive index these frequency components propagate as different (group) velocities and the optical pulse acquires a chirp with propagation. One solution to counteract chromatic dispersion is to use "chirped mirrors", i.e. thick dielectric mirrors characterized by a frequency-dependent penetration depth. These chirp mirrors are genuine technological masterpieces and their characterization require advanced optical techniques such as broadband Fourier-transform spectral interferometry.

Chirped mirrors

by Nicolas Forget

A dielectric mirror, also known as a Bragg mirror (the Nobel Prize in Physics 1915 was awarded jointly to Sir William Henry Bragg and William Lawrence Bragg), is a type of mirror composed of multiple thin layers of dielectric material, typically deposited on a substrate of glass or some other optical material. By careful choice of the type and thickness of the dielectric layers, one can design an optical coating with specified reflectivity at different wavelengths of light. Dielectric mirrors are also used to produce ultra-high reflectivity mirrors: values of 99.999% or better over a narrow range of wavelengths can be produced. Alternatively, they can be made to reflect a broad spectrum of light, such as the entire visible range. A chirped mirror is a broadband Bragg reflector in which the period of the layers varies along the propagation direction. The basic idea behind the design of chirped mirror is to reflect different optical wavelengths as different depths in the mirror structure and thus to control, wavelength by wavelength, the optical group delay (see figure 2).

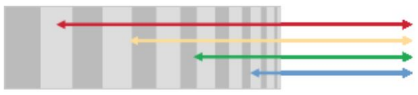

Figure 2: Principle of chirped mirrors

Metrology of chirped mirrors

by Nicolas Thire

As chirped mirrors are made on request and are relatively expensive, the characterization of the optical properties of these mirrors (reflectivity, group delay) is of paramount importance. This characterization is particularly challenging for broadband mirrors as the group delay to measure is small (typically a few femtoseconds). Fourier-transform spectral interferometry (FTSI) is of the most sensitive and precise technique for this purpose. Experimentally, FTSI is performed with a balanced Michelson interferometer in "equal thickness" configuration and a high-resolution spectrometer. A zero-dispersion mirror is placed in the reference arm and the chirped mirror to characterize in the other arm. The spectral interferences between the two arms are recorded by a spectrometer. For slightly different arm lengths, the interference pattern is essentially a fringe pattern caused by the chirped-mirrors. The students will first learn about FTSI, then assemble the optical setup and write a Python script to extract the chromatic dispersion of the chirped mirrors.

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