Dispersive Mirrors: Future and Past

V Pervak[1]

[1]*Department of Physics, Ludwig-Maximilians-Universität, München, Germany*
Contact Email: vladimir.pervak@lmu.de

Ever since lasers were invented, scientists have been trying to create short laser pulses that are as short as a single wave cycle of light. These pulses only have a few wave cycles, which makes them really good at using special optical effects. One of these effects is creating super-fast light pulses that are shorter than a femtosecond. To do this, scientists mix together different frequencies of light and control the phase of the light. This allows them to shape the way light waves change in laser pulses.

Dr. V Pervak will provide an overview of dispersive multilayer optics. Dispersive mirror (DM) offers high reflectivity and controlled group delay dispersion (GDD) over some 1.5 octaves spanning ultraviolet to near infrared frequencies. Nowadays, we cannot imagine ultrashort pulses being obtained without dispersive multilayer optics. A DM is a dispersive optical interference coating usually designed by optimizing the initial multilayer design. A DM is characterized by a certain value of the group delay (GD) or GDD. GD is the first derivative of the phase shift with respect to the angular frequency. GDD is the second derivative of the phase shift with respect to the angular frequency or is first derivative of the GD.

The short pulse penetrating through dispersive medium becomes longer due to the introduced GD. By introducing an inverse GD with a DM, the pulse can be compressed to its original pulse duration. In general, the GDD of mirror should compensate material dispersion (through which the initially short pulse passes) or the (nonlinear) chirp of the pulse so that the residual dispersion oscillations are acceptably small in all of the relevant spectral range.

The DM, crucial in ultrafast (femtosecond) lasers, offers unprecedented phase control over vast bandwidths and high efficiency. However, it suffers from unavoidable spectral oscillations due to interference between reflected waves from the top layer and those that penetrate and reflect from deeper layers. These oscillations can adversely affect the quality of controlled femtosecond laser pulses. During design optimization, residual fluctuations typically decrease to a low level. The GDD oscillations broaden the pulse and transfer energy from the initial single pulse to satellites. The period of the ripples determines the satellite's temporal position, while the amplitude determines the transferred energy.

Manufacturing DMs is challenging due to their sensitivity to layer thickness discrepancies. Magnetron-sputtering and ion-sputtering technologies provide sufficient precision, with modern sputtering achieving sub-nm precision. However, some applications require angstrom precision. A robust design algorithm addresses this sensitivity.

The 20-year evolution of dispersive multilayer design and fabrication enables the development of structures with low loss and high dispersion over a wide spectral range, compressing pulse durations to the theoretical limit.