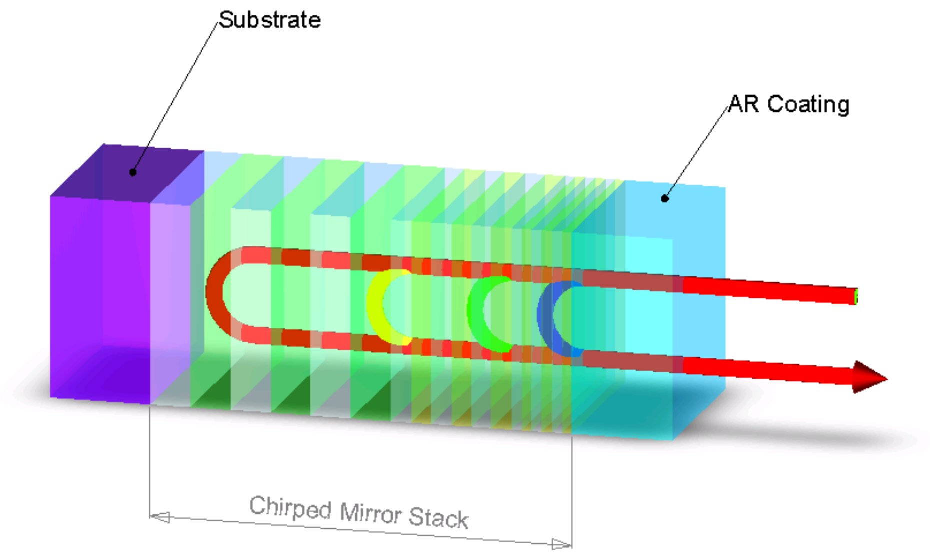
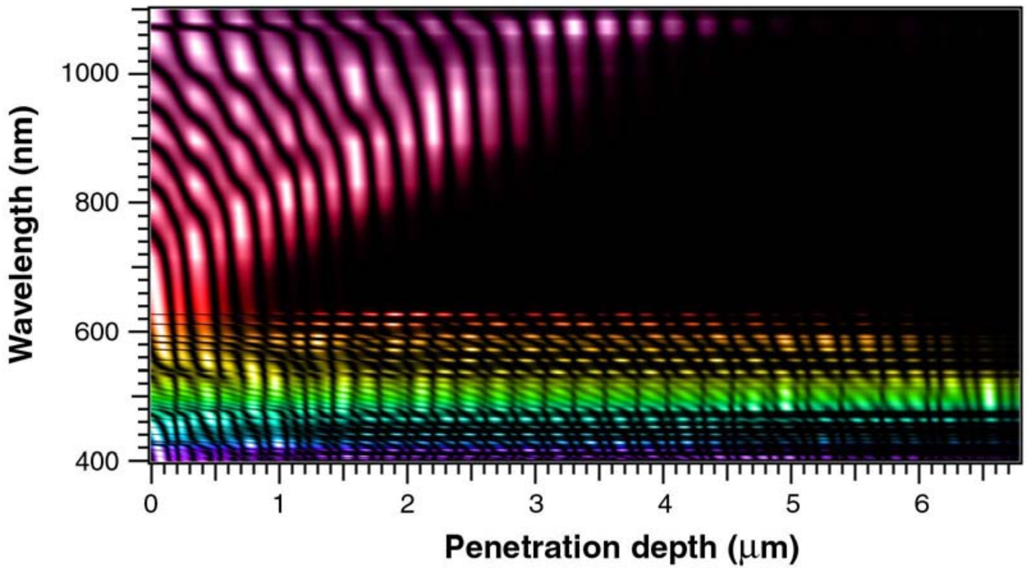
Deposition of Chirped Mirrors Using the Spector Ion Beam Deposition System

The advent of femtosecond laser technology has revolutionized research in areas of Biology and Chemistry while also finding niche applications in telecommunications and electronics. Using laser pulses, scientists can study the initial reactions in natural processes, motion of atoms and potentially electrons. Within the Telecommunications industry femtosecond laser pulses are being applied to both time-division and wavelength-division multiplexing. Enabling this technology are a combination of laser modulation advancements and the development of broadband dispersion compensating optical components.

Current laser technology characteristically has an inverse relationship between pulse duration and bandwidth, requiring any optical component used in short pulse applications to provide the desired response over a large bandwidth. Due to this increased bandwidth, the time domain shape of the pulse is adversely affected by material dispersion. In general, the longer wavelengths of light will travel faster than the shorter wavelengths resulting in an unusable signal. More specifically, the dispersion causes phase velocity of the pulse to increase in relation to the group velocity (hence the term Group-Delay-Dispersion GDD). The GDD of the laser amplifying medium, along with other components of the system, must be compensated for to achieve or maintain the desired pulse shape. Chirped mirrors, a rather recent development in the area of non-linear optics, have provided a solution for these phenomena.



Chirped mirrors use a multilayer periodic structure comprised of dielectric materials to compensate for dispersion. This is achieved by designing the mirror stack such that the thickness of the layers gradually decreases as you move away from the substrate. In effect, the longer wavelengths travel further into the stack than the shorter wavelengths thereby compensating for the normal affects of dispersion (refer to figure above). This affect can further be understood by observing the electric field patterns within an actual chirped mirror (below).



Electric field patterns versus wavelength in a double chirped mirror structure. (Image courtesy: Science 286 1511)

Although the theory of chirped mirrors is promising, to date manufacturing limitations hinder successful and consistent fabrication of extremely fast-chirped mirrors. These limitations manifest themselves primarily in layer thickness control and the lack of consistent dispersion characteristics for a given material. For a typical chirped mirror the majority of the layers (typical designs 50+ layers) are non-quarterwave which makes optical end point detection very difficult. By nature, these designs are extremely sensitive, requiring layer thickness error tolerances of less than 10 Angstroms. Additionally, the dispersion of the films must be consistent with varying degrees of layer thickness and substrate temperatures. Veeco's leadership in ion beam process technology has facilitated development of equipment and process solutions to meet these demanding requirements.

The SPECTOR® dual ion beam deposition system, utilizes the best RF ion source technology on the market, providing unmatched deposition rate, uniformity and film quality control. SPECTOR was recently combined with new process technology to deposit a chirped mirror using alternating layers of SiO_2 and TiO_2. These materials are favored because they give the largest index differential, which theoretically gives the highest bandwidth and reflectance. Layer thickness control was performed by time-power alone. This is feasible due to the exceptional beam current stability and energy control realized through the Veeco RF ion source package. In order to utilize the entire surface of the optic the index and thickness uniformities of the films were tuned to less than 0.02 % for both materials. The results, as illustrated below, stand for themselves. The mirrors possess the broadband reflectance required for pulsed laser applications, while the negative group delay dispersion remains consistent across the full bandwidth.

Inherently, ion beam deposition provides films with dense microstructure and excellent stoichiometry creating coatings with minimal scatter and absorption losses. SPECTOR's capabilities, coupled with our extensive process development experience provide you with an unbeatable solution to your optical coating needs.