Changing the way to do Circular Dichroism…

All benefits from the coupling of chromatic light source and gratings monochromators over prisms

Principle of grating monochromators

MOS-500 is a circular dichroism spectrometer based on a double grating monochromator for the selection of the working wavelength.
In gratings the groove spacing and shape determine the distribution of energy of the diffracted light. Littrow configuration is used where the light is diffracted from the grating back toward the source (see figure 1). They have the advantage of maximum efficiency over a given range of specific wavelengths.

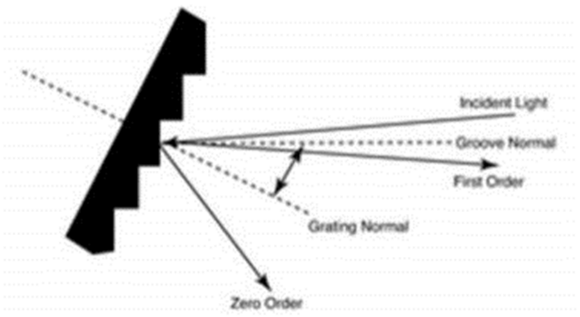

Figure 1: Grating in Littrow configuration

MOS-500 uses holographic reflection gratings which have a sinusoidal groove profile and are generated by the recording of an interference pattern onto a photoresist-coated substrate.
The gratings substrate is concave and the groove spacing is computer-optimized to produce high quality images of the diffracted light with a minimum of astigmatism and coma, even at large numerical aperture.

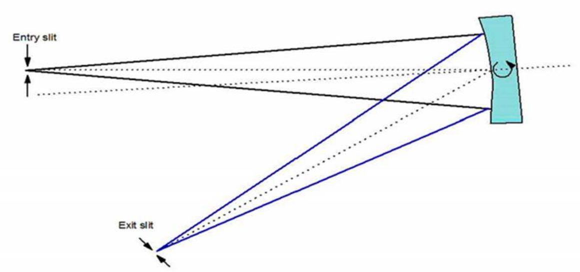

Figure 2: principle of a grating monochromator

This single component is used to disperse, to collimate and to refocus the light from the entrance slit onto the exit slit. Wavelength scanning is obtained through a simple rotation of the grating (figure 2).
Depending on the configuration, the grating monochromators can be used on a wide wavelength range from far UV to near IR (typically from 170 nm to 2000 nm). The MOS-500 monochromator has a wide aperture (f/3). The dispersion of the light on the exit slit is constant over the entire wavelength range (8 nm/mm for each grating, so 4 nm/mm for the double monochromator). It means wavelength accuracy is constant over the wavelength range of the MOS-500.

Comparison with prism monochromators

These devices are constructed around a synthetic silica crystal prism and use the variation of refraction index of silica with wavelength.

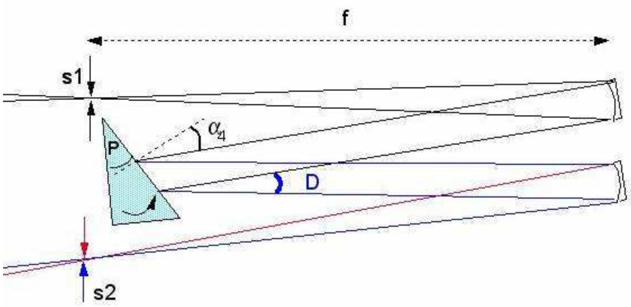

Figure 3: principle of a prism monochromator

As for the gratings the same Littrow configuration is used. However, because the prism operates with parallel light, two additional parabolic mirrors are necessary to illuminate the prism and refocus the light on the exit slit (see figure 3).

The dependence of the refraction index of silica with wavelength is not constant. It varies rapidly in the UV below 350 nm and tends to be more and more independent above (see figure 4).

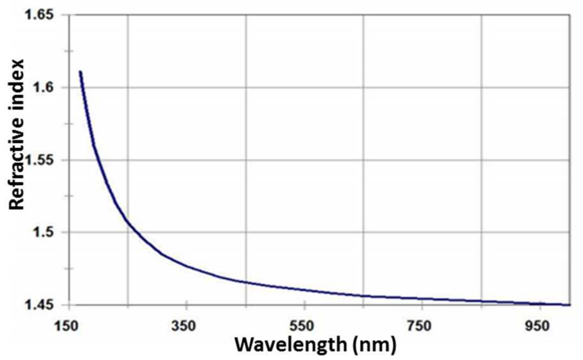

Figure 4: refraction index of silica

As a consequence, the dispersion of wavelength on the exit slit is not constant and the precision of wavelength adjustment degrades rapidly above 350 nm (red line in the figure 5). Accuracy can be 20 times better using gratings at 800 nm. Thus, because of this too low variation of the refraction index, prisms are definitively a bad choice on the visible and red side of the spectrum.

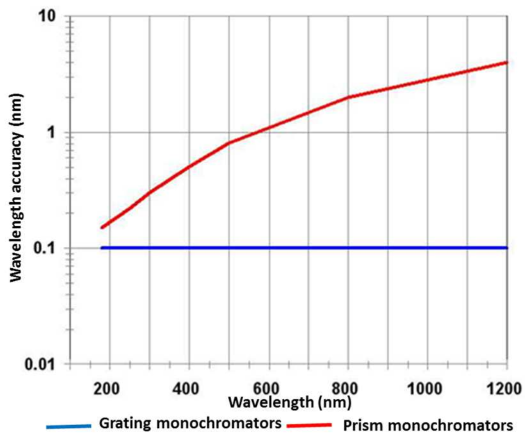

Figure 5: comparison of wavelength accuracy

Unsurprisingly all spectrometers of the market now use gratings. Only exceptions are CD spectrometers because of alleged higher performance in the UV below 300 nm.

It is also often read (or heard!) that gratings do not work in the far UV. This is clearly incorrect: holographic gratings can be constructed for wavelengths that range from 10 nm to more than 10000 nm. Interestingly, vacuum-UV synchrotron radiation experiments that work far below 170 nm, all use gratings. This is impossible with prism because of absorbance cut-off of silica below 170 nm. At the other end of the spectrum silica shows strong absorption lines above 2000 nm.

Light source and stray light

Circular Dichroism spectrometers all use Xenon arc lamp spectrum as light source. Xenon lamps emit most of their energy in the visible with only a small tail in the UV below 200 nm. It is this small tail that is used in the UV part of the CD spectra.

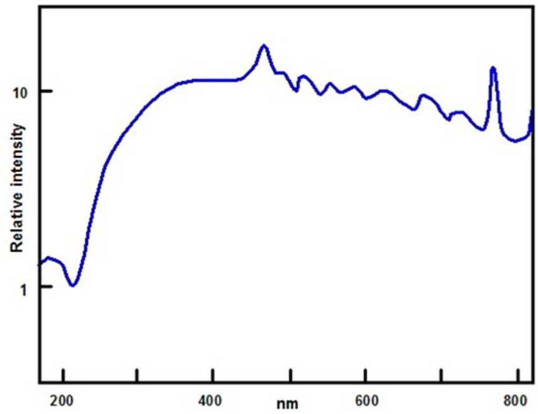

Figure 6 : xenon lamp light intensity

If the monochromator is illuminated with this entire spectrum it sees the intense white light above 300 nm. A small fraction of it will scatter in its structure and find its way to the sample at the same time as the working wavelength. If the sample has a high absorbance at this working wavelength this parasitic light that is not absorbed by the sample will create an error on the measurement.

Full spectrum illumination of the monochromator is used in all circular dichroism spectrometers except MOS-500. In these cases, the source is said to be achromatic.

To do this a parabolic mirror is used to focus the entire lamp spectrum on the entry slit of the monochromator (dashed red line in figure 7).

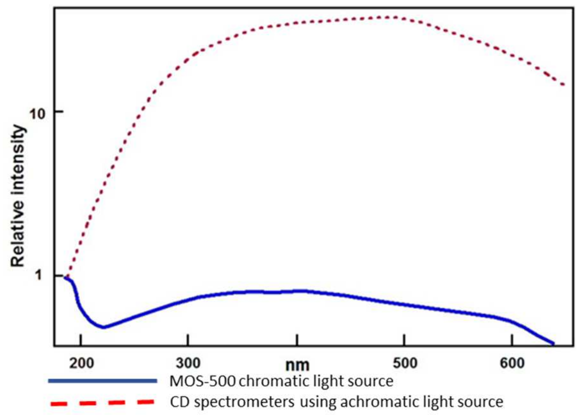

Figure 7: contribution of stray light at 190 nm (bandwidth 1 nm)

In MOS-500 we use a different and patented configuration that prevents this to happen. Contrary to other spectrometers the light source is chromatic. Using a combination of tunable lenses, only the selected wavelength is correctly focus on the entry slit of the monochromator. The other part of the spectrum is unfocused at the entry slit so that only a very small fraction of it illuminates the monochromator (blue spectrum in figure 7). It results in a very significant reduction of stray light.

It also prevents damage to the optics due to reduction of UV entering the monochromator when working at high wavelength, lifetime of optics is thus longer and operating cost reduced to their compare to classical achromatic light sources.

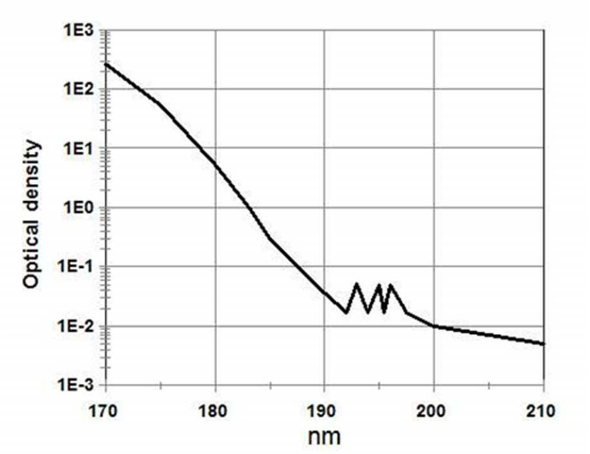

Figure 8: absorbance of air

Thanks to the design of the tunable chromatic light source the MOS-500 does not need any mirror in the light source housing. It means nitrogen flushing of optics is only necessary if user needs to go below 190 nm (figure 8 shows the absorbance of air along the entire light path of the spectrometer, it is clear that contribution of oxygen above 190 nm is negligible). All other circular dichroism instruments require permanent nitrogen flushing whatever the wavelength used, the only reason being to prevent corrosion of the light source mirror!

Conclusion

The combination of the best up-to-date double grating monochromator to the chromatic light source as proposed by the MOS-500 offer the highest perspective of evolution for circular dichroism spectroscopy. This technology offers the best precision and makes the MOS-500 an innovating and revolutionary spectropolarimeter which also cuts off most of running cost involved in competitive instruments.