Historical Overview

Diffraction gratings have a history of more than 200 years that dates back to their discovery in 1785 by the American astronomer David Rittenhouse. He noticed that light seeping through a silk handkerchief formed the same colors as a rainbow and made a grating by wrapping hair around two parallel clock screws. At that time, however, his discovery was not recognized in the world. This phenomenon was rediscovered by Fraunhofer in 1819. Fraunhofer’s first grating consisted of fine wire wrapped around two parallel screws. He also used a diamond tool to make a reflective grating with 9,600 grooves across a width of 12 mm and derived the grating equations.

In 1882 Rowland constructed a ruling engine for production of diffraction gratings which could make 14,000 grooves per inch. Most of the gratings around this time were made by ruling grooves directly into metallic mirrors.

In 1955, based on Harrison’s developments [1], improvements in ruling engines made it possible to control the shape of the grooves, and concentrate most of the energy in lower orders of diffracted light. This type of grating is called a “blazed grating” and today is one of the most commonly used types.

The last half-century saw many attempts to make gratings by recording interference patterns of coherent light onto light sensitive material and finally the production of this type of grating became possible with the appearance of the argon ion laser and the high-resolution photore sist. Since Rudolph and Schmahl’s creation of the first grating of this type in 1967, this field has seen remarkable progress. Because of similarities with holography, this type of grating is called a “holographic grating.”

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Finally in 1976, Aoyagi, Namba, et al succeeded in changing the profile of grooves from sinusoidal to sawtooth by etching diagonally with an ion beam [2]. This made it possible to create blazed holographic gratings with any blaze angle, and such gratings are now used extensively in spectrometers.

Technology

A grating produced by a holographic exposure method that adopted the two beams interference of laser beam is called a “holographic grating” (HG). With holographic gratings, there is very little stray light due to periodic errors, and concave holographic gratings (concave HG) have the highly useful property of being able to correct aberrations within the grating itself.

This unique grating manufacturing technology was patented in Japan as Japanese Patent No. 1046763 and was awarded the Okochi Memorial Prize. In order to facilitate more effective aberration correction for the wavelength region used in different types of gratings, Shimadzu developed an aspherical wave exposure method that uses aspherical waves for holographic exposure method (Japan Patent No. 1946518, U.S. Patent No. 5052766, U.K./French/German Patent No. 270700, Chinese Patent No. 23311, Singapore Patent No. 28110).

As a result, it is now possible to custom-design gratings of excellent performance to match the characteristics of different types of spectroscopic devices.

Shimadzu Corporation succeeded in producing this type of grating and the RIKEN Institute of Physical and Chemical Research, Shimadzu Corporation succeeded in blazing a holographic grating, something that had previously been thought impossible, using ion-beam etching technology. Based on this, Shimadzu was the first to develop the technology for manufacturing blazed holographic gratings (BHG), which, compared to conventional mechanically ruled gratings, ensure less stray light without any reduction in diffraction efficiency.

Figure 2: Manufacturing process for blazed holographic gratings

Unfortunately the ruling engines of that time made large mechanical errors, until 1915, when Michelson came up with the idea of using light interference to control the positioning of grating grooves. Based on this technology, gratings became commercially available.

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For the qualification of a grating, the intensity of the first-order light is plotted against delta (nm). From figure 4 it becomes evident that the LO-RAY-LIGH® grating produces first-order light much more sharply and with less stray light over the entire range. In the diagram, a grating with 1,200 grooves/mm was compared with a blaze wavelength of 250 nm.

Figure 4: Representation of the intensity of the first-order light as a function of the distance to the origin of the wavelengths in nm

New Holographic Exposure Method

Shimadzu has optimized the quality of the edges for the angle of reflection in the sawtooth pattern. This LO-RAY-LIGH® principle is a patented development that produces an outstanding grating quality. Until now, the generally accepted rule was: the more lines to a grating, the sharper the spectral image. With the LO-RAY-LIGH® grating technology, this rule has changed. The production process of the grating results in a high grating image precision which also yields a spectral resolution sharpness rendering better characteristics when compared to a conventional grating. The objective in the development of these gratings was a significant reduction in stray light.

References


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Measurement of High Density Samples Using Lo-Ray-Ligh® Diffraction Gratings in UV-VIS Spectroscopy

Figure 1: Standard plane blazed holographic gratings

Figure 2: Manufacturing process for blazed holographic gratings

Figure 3: Representation of stray light and comparison between a conventional grating, a LO-RAY-LIGH® grating and an aluminum reference mirror

Figure 4: Representation of the intensity of the first-order light as a function of the distance to the origin of the wavelengths in nm