Adaptable Diffraction Gratings With Wavefront Transformation

Better resolution and aberration control are possible with a dynamic refractive grating.

Goddard Space Flight Center, Greenbelt, Maryland

Diffraction gratings are optical components with regular patterns of grooves, which angularly disperse incoming light by wavelength. Traditional diffraction gratings have static planar, concave, or convex surfaces. However, if they could be made so that they can change the surface curvature at will, then they would be able to focus on particular segments, self-calibrate, or perform fine adjustments.

This innovation creates a diffraction grating on a deformable surface. This surface could be bent at will, resulting in a dynamic wavefront transformation. This allows for self-calibration, compensation for aberrations, enhancing image resolution in a particular area, or performing multiple scans using different wavelengths. A dynamic grating gives scientists a new ability to explore wavefronts from a variety of viewpoints.

To create these gratings, surface relief diffraction grating grooves are formed on a flat substrate. Flat substrate is technologically the most convenient option for any type of gratings ruling and is especially essential for lithographically scribed gratings. Lithographic scribing is the newly developed method first commercially introduced by LightSmyth, which produces gratings with the highest performance and arbitrary groove shape/spacing for advanced aberration control. Next, an imprint of the grating is made on a deformable substrate, such as thin polymer film. The imprinted deformable substrate is then stretched over a circular, oval, or otherwise shaped opening, much like a membrane on a drumhead. The opening is connected with a chamber with the inside pressure that may be controlled by the user. The exact curvature of the substrate depends on the elasticity of the membrane, the difference between air or gas pressures on two sides of the substrate, and the shape of the opening. Very complex and challenging surface profiles may be obtained with relatively simple and inexpensive shaping of the opening. For example, oval opening produces generally toroidal grating surface.

Pressure is applied to one side of the substrate in order to change its curvature. As the curvature changes, so does the wavefront transformation of the diffracted (or reflected) light. Such wavefront transformations can be used to optimize imaging or spectra in a particular diffraction order, or imaging of reflected light. The ability to do so in a single unit is a major advance in the state of the art. Even without the dynamic aspect, this method provides a unique way of creating complex grating surface profiles for advanced optical designs using simple mechanical means.

This work was done by Dmitri Iazikov, Thomas W. Mossberg, and Christoph M. Greiner of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15679-1