Physical Sciences

Shaping Diffraction-Grating Grooves To Optimize Efficiency

Spectral response of a grating could be tailored to complement responses of other components.

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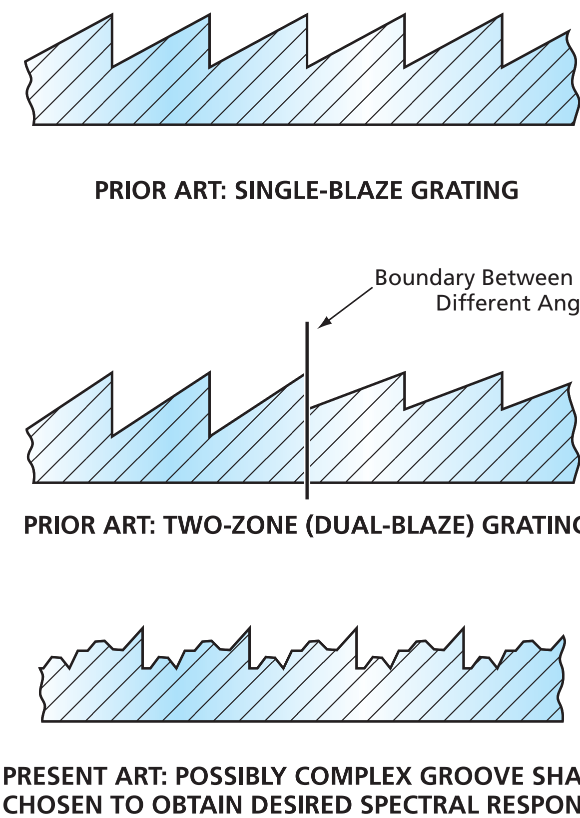
A method of shaping diffraction-grating grooves to optimize the spectral efficiency, spectral range, and image quality of a spectral imaging instrument is under development. The method is based on the use of an advanced design algorithm to determine the possibly complex shape of grooves needed to obtain a desired efficiency-versus-wavelength response (see figure). Then electron-beam fabrication techniques are used to realize the required groove shape. The method could be used, for example, to make the spectral efficiency of the grating in a given wavelength range proportional to the inverse of the spectral efficiency of a photodetector array so that the overall spectral efficiency of the combination of the grating and the photodetector array would be flat. The method has thus far been applied to one-dimensional gratings only, but in principle, it is also applicable to two-dimensional gratings.

The algorithm involves calculations in the spatial-frequency domain. The spatial-frequency spectrum of a grating is represented as a diffraction-order spectral-peak-width function multiplied by an efficiency function for a single grating groove. This representation affords computational efficiency and accuracy by making it possible to consider only the response from one grating groove (one period of the grating), instead of from the whole grating area, in determining the response from the entire grating. This combination of efficiency and accuracy is crucial for future extensions of the algorithm to two-dimensional designs and to designs in which polarization must also be taken into account.



All of the Grooves of a Grating are designed to have the same possibly complex shape, which is chosen in an iterative process to obtain a desired spectral response. This approach offers greater design flexibility than does a prior method of tailoring the spectral response of a grating by dividing the grating into two or more zones that contain conventional sawtooth grooves having different blaze angles.

The algorithm begins with the definition of target values of relative efficiency that represent the desired spectral response of the grating in certain spectral frequencies calculated from the diffraction order and wavelength. The grating period is divided into a number of cells — typically, 100. The phase contribution from each cell is determined from the phase of the incident electromagnetic wave and the height of the grating surface in the cell. The total contribution from all cells to each target value is then calculated. Then a method known to specialists as the optimum-rotation-angle method is used to adjust the height of each cell so that the total response from all cells is optimized. The computation is iterative and continues until the desired response is obtained. In the event that the desired response is unphysical, the algorithm nevertheless strives to generate a grating-grove profile for which the response approximates the desired one as closely as possible.

This work was done by John Backlund, Daniel Wilson, Pantazis Mouroulis, Paul Maker, and Richard Muller of NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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