X-ray transmission gratings with enhanced second orders and deflected odd orders

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Transmission gratings with high line-densities and large thicknesses are usually preferred for X-ray applications. Fabrication of such high-aspect-ratio and dense structures is a challenge to the state-of-the-art technology. The dispersion of the second orders of a grating is twice as strong as that of the first orders. So if the second orders can be employed, the grating doesn't have to be so dense, making it easier to fabricate. However, there are two factors that limit the employment of second orders of an X-ray transmission grating. First, traditional X-ray transmission gratings have minimum efficiency in their second orders since the line-to-space ratio is usually around a unit. And second, the free spectral range is severely limited by overlap between the first orders and the second ones.

In this report, we provide a novel design of transmission gratings whose second-order efficiency is enhanced and whose odd orders are split and deflected away from its original diffraction plane. A typical diffraction pattern of a grating according to our design is shown in Fig 1. The pattern was captured using a CCD at a wavelength of 355 nm only for demonstration. The enhancement of the second orders is realized by adjusting the line-to-space ratio to 3:1, and the deflection of odd orders is realized by introducing a second periodicity vertical to the original one. (Fig. 2) Since the odd orders are deflected away, when scanning along the main diffraction direction by a detector narrow enough, only even orders are detected. Even when used for a wide spectral range, its first orders and second ones don't overlap anymore. Thus the second orders of the grating can be used without the aforementioned two troubles, improving its performance. This approach is especially useful when fabrication capability has limited the line density available.

An X-ray transmission grating according to this design has been fabricated (Fig. 3) using electron beam lithography and electroplating, and its performance is evaluated in comparison with a traditional grating with the same line density (Fig. 4). The period of both gratings is 160 nm. However, it can be seen that since only even orders of the new grating are detected, it could be used just like an 80-nm-period grating. The novel X-ray transmission grating can be used in place of traditional ones in many applications where stronger dispersion is needed and a certain level of sacrifice in diffraction efficiency is acceptable. The design principle can also be extended to utilize other high diffraction orders.

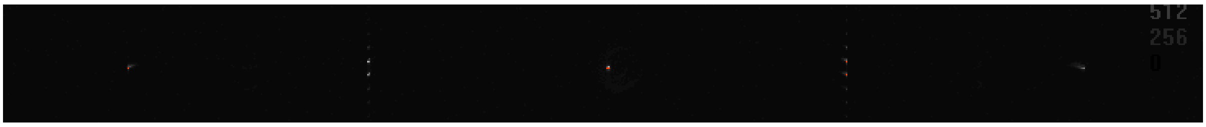

Fig. 1 Diffraction pattern of the novel grating. Each of the first orders is split and deflected away from its original position. Strong intensity can be detected in the second orders.

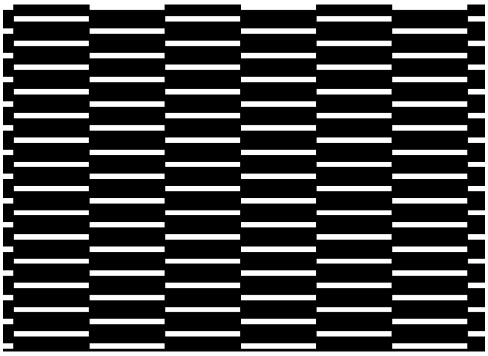

Fig. 2 The design of the novel grating. Black area is opaque. The line-to-space ratio is adjusted to 3:1, which can enhance the efficiency of second orders. And a second periodicity is introduced vertical to the original one. The 2-D arrangement causes the odd orders to split and to be deflected as shown in Fig.1.

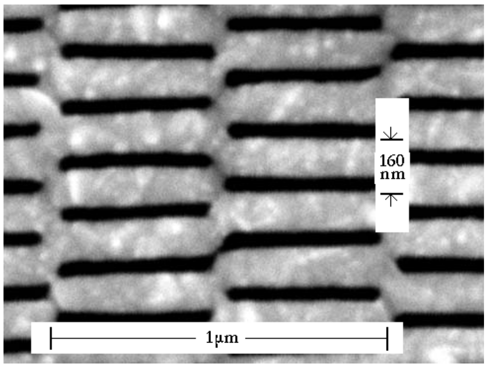

Fig. 3 SEM of an X-ray transmission grating designed according to our novel principle and fabricated by electron beam lithography and electroplating. The major period of the grating is 160 nm and the period along the second direction is 1 μm. The structure comprises gold bars supported

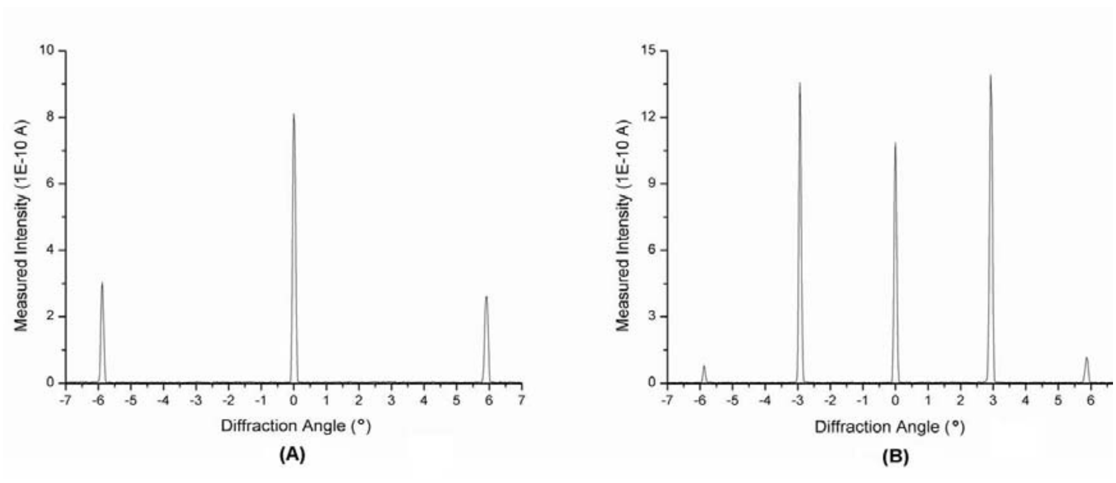

Fig. 4 Comparison between the diffraction performance of our novel grating (A) and that of a traditional one (B). The diffraction intensities were measured at the National Synchrotron Radiation Laboratory at Hefei with a wavelength of 8 nm. The two gratings are of the same size and are made of the same materials, the period of both gratings is 160 nm, and the two gratings are tested consecutively in a single session. For the novel grating, the detector is narrow enough to avoid the split first orders, so only its even orders are detected. The result shows that the novel grating can be used with its second orders with a moderate efficiency, and influence from the first orders can be completely excluded.