An optical chip that spatially separates wavelengths

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Concave micro-gratings for optical communication applications can be fabricated using deep x-ray lithography.

A conventional planar grating spectrometer consists of a sophisticated arrangement of optical components and is rather large. To reduce the size, various micro-electro-mechanical system (MEMS) fabrication techniques have been proposed, yielding MEMS-based spectrometers that use moving parts for wavelength separation. Unfortunately, these moving parts are always associated with mechanical instability problems.

In our work, we use a concave micro-grating embedded inside a slab waveguide without any moving parts, allowing us to produce a real chip-based spectrometer. Our design has two advantages: first, the size of the spectrometer is dramatically reduced; and second, the mechanical instability resulting from moving parts is effectively removed.

The micro-grating has a circular cylindrical surface profile in a Rowland circle configuration that allows it to be used as a spectrometer or as a wavelength dispersion device. In the wavelength dispersion plane of such a grating, the divergent rays of different wavelengths coming from the entrance slit are spatially separated and focused on different locations of the Rowland circle. This is illustrated in Figure 1, which depicts the working principle of a reflective circular cylindrical grating.

For our design, a total of 2584 grating lines were generated. The grating height is 125 µm and the grating pitch is 3 µm. Figures 2 and 3 show scanning-electron-microscope images of the concave micro-grating fabricated using our DXL technology. The surface roughness of the side wall measured by atomic force microscopy is 5 nm, which far exceeds the standard for optical applications. We also measured the spectral resolution of the grating, which yielded a value of 1.1 nm, in very good agreement with the design value of 0.9 nm.

Our work demonstrates the successful implementation of a spectrometer-chip scheme based on a micro-grating embedded in a slab waveguide. It also shows that DXL technology...
is powerful enough to fabricate concave micro-gratings. Subsequent aberration calculations and ray tracing measurements have also confirmed that the chip-based spectrometer functions as designed. The incorporation of these advances in fabrication approaches will undoubtedly produce low cost polymer-based spectrometer chips with good spectral resolution.

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Cheng-Hao Ko received his PhD in Physics from the State University of New York at Stony Brook in 1995. He developed the world’s first multi-channel scanning photoemission microscope combining electron spectroscopy for chemical analysis (ESCA) and x-ray microscopy, which was set up at the National Synchrotron Light Source. He is currently a professor in the Department of Electrical Engineering at Yuan Ze University and is developing chip-based spectrometer technology for embedded spectral detection applications as well as MEMS/MOEMS-based biosensors.

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References