An achromatic eight-octant phase-mask coronagraph using photonic crystal

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For direct detection of faint exoplanets, high-contrast imagers would be indispensable for strongly suppressing central bright stars. In particular, extremely high contrast of 10^{-10} will be needed for detecting Earth-like planets. An eight-octant phase-mask (EOPM) coronagraph is one of promising concepts because of its high-contrast performance, small inner working angle, and simple optical configuration[1]. The EOPM divides a stellar image into eight-octant sectors and provides π-phase difference between adjacent sectors. Then a destructive interference occurs inside pupil area on a reimaged pupil plane, and the stellar light is totally diffracted outside the pupil area. The diffracted stellar light is blocked by a diaphragm called Lyot stop. On the other hand, a planetary image, formed at an off-axis position on the EOPM, will not be totally blocked by the Lyot stop and can be detected at a final focal plane. For detecting extremely faint planetary signal and carrying out spectroscopic characterizations, achromatic high-contrast imagers will be required.

We manufactured a coronagraphic mask based on photonic-crystal technology for realizing a fully achromatic EOPM[2]. The photonic crystal holds periodic nanostructure of refractive indices, and exhibits anisotropic properties of effective dielectric constants. The manufactured photonic-crystal mask consists of an eight-octant half-wave plates with fast axes of $\pm 45°$. As shown in figure 1, extremely small central defect, an order of submicron, was realized by the photonic-crystal technology. The photonic-crystal mask operates as an fully-achromatic EOPM when the mask is placed between two crossed polarizers with axes of 0° and 90°.

We carried out laboratory demonstration of the EOPM coronagraph using two laser light sources with different wavelengths as a simulated star (DPSS laser with λ = 532 nm, and He-Ne laser with λ = 633 nm). Figure 2 shows the experimental results. The light from the simulated star was strongly suppressed, and peak-to-peak contrasts of 7×10^{-6} and 3×10^{-6} were obtained for the DPSS and the He-Ne lasers, respectively. In a halo region, contrasts of about 10^{-6} and 10^{-7} were obtained for the both lasers at 3 and 13 λ/D, respectively. We expect improved coronagraphic performance with a use of extreme adaptive optics systems, because we assume that the residual speckle noise mainly comes from phase aberrations of the optical components.

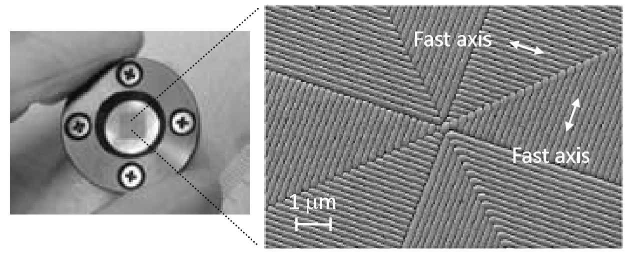

Figure 1: A picture and a scanning electron microscope image of a photonic-crystal coronagraphic mask. (manufactured by the Photonic Lattice, Inc.)

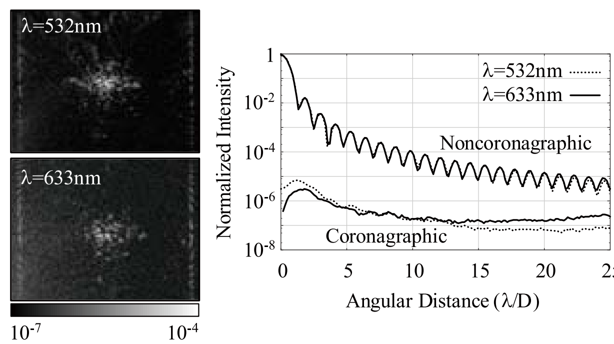

Figure 2: Experimental results of laboratory demonstration: (*left*) acquired coronagraphic images and (*right*) radial profiles of noncoronagraphic and coronagraphic images.

References

[1] Murakami, N., et al.: 2008, *PASP*, **120**, 1112.
[2] Murakami, N., et al.: 2010, *ApJ*, **714**, 772.