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Polarization Gratings: A Novel Polarimetric Component for Astronomical Instruments

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Polarization gratings (PGs) have been recently been developed for ultraefficient liquid crystal displays, nonmechanical optical beam steering, and telecommunication devices at optical and near-infrared wavelengths (0.4–2.0 μm). A PG simultaneously acts as both a spectroscopic and polarimetric disperser for circularly polarized light. With the use of a quarter-wave retarder (or analog) to convert linearly to circularly polarized light, these devices can be used as linear polarimetric analyzers. PGs offer high throughput and high levels of birefringence and can currently be constructed inexpensively to diameters of 150 mm, and development projects are in progress to double that size. In this article we report on the characterization of a PG sample at mid-infrared wavelengths (2–40 μm), including the birefringence, throughput, spectral response, and cold cycling survivability. We discuss these devices in the context of astronomical polarimetry, especially as the polarimetric components for a conceptual study of a SOFIA-based polarimeter.

Online material: color figures

1. INTRODUCTION

Polarimeters are deployed on several of the world's large telescopes, both at nighttime and solar observatories. Among the large nighttime telescopes, most have provision for polarimetry (currently or in the near future) in at least one component of their regularly available instrumentation suites. Demand for polarimeters on such telescopes remains a small but significant fraction of the total time requested; in the case of Michelle (the 7–25 μm imager, spectrometer, and polarimeter on the 8.1 m Gemini North (Glasse et al. 1997), immediately after commissioning of the polarimetry mode, demand for polarimetry peaked at 20% of the total Michelle time requested (taken from the Gemini World Wide Web pages[4]). Perhaps a more appropriate comparison (due to the longer baseline of usage statistics) is provided through comparison with the ISIS (Intermediate-dispersion Spectrograph and Imaging System) polarimetry mode on the 4.2 m William Herschel Telescope (WHT). ISIS is a dual-arm (blue and red) optical spectrograph, commissioned in 1989, and polarimetry was offered one year later. Demand for ISIS has remained consistently high since commissioning, and the instrument quickly became, and still is, the most requested instrument on the WHT. Between 2003 February and 2007 July, polarimetry on ISIS enjoyed an average demand of 9% of all awarded ISIS time, with a peak semester demand of 24% (I. Skillen 2008, private communication), representing a healthy demand for polarimetry. Astronomical applications of polarimetry are many and varied, including observations of debris disks around stars (Tamura et al. 2006), young stellar objects (Chrysostomou et al. 1996), ultracool dwarfs (Tata et al. 2009), and key optical observations in unified theories of active galactic nuclei (AGNs; Antonucci et al. 1985) and supported by Gemini polarimetry at 10 μm (Packham et al. 2007).

Advances in telescope design and instrumentation have greatly benefited users, but these advances can have detrimental effects on polarimetry. The development of adaptive optics (AO) on telescopes (e.g., WHT [Myers et al. 2003], VLT [Rousset et al. 2003], Keck [Wizinowich et al. 2000], and Gemini [Rigaut et al. (2000]) can increase the spatial resolution by over an order of magnitude through the reduction or elimination of the blurring effects of the Earth's atmosphere. This is accomplished through using typically complex and convoluted optical systems, including deformable mirrors, dichroic components, and oblique reflections. While an increase in spatial resolution often leads to a higher *measured* degree of polarization (otherwise reduced due to an averaging of the polarization in unresolved sources that do not have a single position angle of polarization), at optical wavelengths a freshly coated and dust-free aluminum 45° flat mirror introduces a polarization of ~10% (Leroy 2000) or ~0.8% at K (2.2 μm) (using data from Gray 1963, p. 6), and a succession of flat and dichroic components can introduce crosstalk between linear and circular

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Abstract

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