Optik 160 (2018) 214–217

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Research on an imaging spectropolarimeter

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ARTICLE INFO

Article history:
Received 10 January 2018
Accepted 31 January 2018

Keywords:
Spectrometry
Polarization
Imaging
Remote sensing

ABSTRACT

Imaging spectropolarimetry has been explored as a technology which can meet our demand for more and more information in civilian and military applications. Spectrometry can distinguish target spectra from background spectra. The polarimetric has the ability to identify false targets and can improve the accuracy of detection for the objects. A experimental device has been developed which is operated in the visible wavelength to display the potential of this technique for future space-based systems. The experiment setup and some experimental results are presented in this paper.

1. Introduction

With the continuous increase of application requirement, it is very important for remote sensing technology to improve capabilities of objective analysis and expand the information dimensions. Imaging spectropolarimeter provide us with an effective means to respond to existing requirements [1]. In addition to the information obtained by hyperspectral imaging technology alone, polarization detection provide Stokes vector, degree of polarization and angle of polarization information, it can expand the information dimensions of the object, and has the potential for improving target contrast and providing orientation information of difference target [2–5].

In this paper, a method of hyperspectral polarization imaging technique is discussed, which is based on static intensity modulation and spatially spectral modulation. A experimental device has been developed which is operated in the visible wavelength to display the potential of this technique for future space-based systems. The experiment setup and some experimental results are presented in this paper.

2. Theoretical background

The schematic of the imaging spectropolarimeter can be seen in Fig. 1. The light radiating from the objects is collimated by the fore telescope optical system and then modulated by two retarders and one polarizer, the light is linearly polarized by the first polarizer and is then split by the Wollaston prism, which acts as a polarizing bearn splitter, producing two orthogonally polarized ray. Successively, the analyzer P2 is placed at the output of the Wollaston prism to convert the two component rays into a uniform state. Finally, imaging optical system images the interferogram onto a detector. The hypespectral and the polarization information of the object can be obtained by some data processing.

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https://doi.org/10.1016/j.ijleo.2018.01.130
0030-4026/

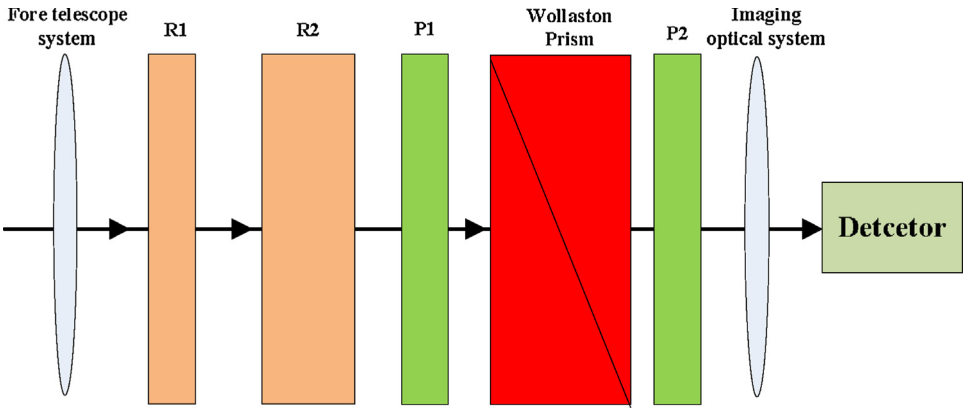

Fig. 1. Schematic of the imaging spectropolarimeter.

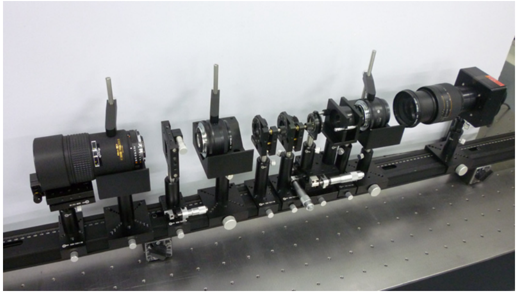

Fig. 2. Photo of the assembled breadboard spectropolarimetric system.

The spectral polarization state of the broadband light under measurement can be expressed in terms of the spectrally resolved Stokes parameters $S_0(\sigma)$,$S_1(\sigma)$,$S_2(\sigma)$,$S_3(\sigma)$, in which each of four elements depends on wavenumber σ, the reciprocal of wavelength λ. The phase retardations of R1 and R2 can be written as

$$\phi_1 = 2\pi B(\sigma) D_1 \sigma$$

$$\phi_2 = 2\pi B(\sigma) D_2 \sigma$$

where σ is the wavenumber, B(σ) is the birefringence of the retarder's medium, and D1 and D2 are the aforementioned retarder thicknesses.

Using the Mueller calculus to model the propagation of polarization states through the system,

The output stokes vector of the light is therefore given by [6–8]:

$$(S_{out}) = \frac{1}{2}\begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\phi_2(\sigma) & 0 & -\sin\phi_2(\sigma) \\ 0 & 0 & 1 & 0 \\ 0 & \sin\phi_2(\sigma) & 0 & \cos\phi_2(\sigma) \end{pmatrix}\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\phi_1(\sigma) & \sin\phi_1(\sigma) \\ 0 & 0 & -\sin\phi_1(\sigma) & \cos\phi_1(\sigma) \end{pmatrix}\begin{pmatrix} S_0(\sigma) \\ S_1(\sigma) \\ S_2(\sigma) \\ S_3(\sigma) \end{pmatrix}$$

$$= \frac{1}{2}\begin{pmatrix} s_0 + s_1\cos(\phi_1) + s_2\sin(\phi_1)\sin(\phi_2) - s_3\cos(\phi_1)\sin(\phi_2) \\ s_0 + s_1\cos(\phi_1) + s_2\sin(\phi_1)\sin(\phi_2) - s_3\cos(\phi_1)\sin(\phi_2) \\ 0 \\ 0 \end{pmatrix}$$

Because the sensor is only responds to S_0, which corresponds to the total intensity of the light. This recorded intensity is a function of wavenumber, this yields:

$$I(\sigma) = \frac{1}{2}s_0 + \frac{1}{2}s_1\cos(\phi_2) + \frac{1}{2}s_2\sin(\phi_1)\sin(\phi_2) - \frac{1}{2}s_3\cos(\phi_1)\sin(\phi_2)$$