Development of an Imaging Spectro-polarimeter

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ABSTRACT

Acousto-Optic Tunable Filter(AOTF) is a solid state electro-optical device which acts as an electronically tunable spectral filter. The specific point on the device is that we can get two diffracted beams perpendicularly polarized each other. So we developed an imaging spectro-polarimeter employing a visible AOTF and two CCD cameras each of which shows horizontally or vertically polarized spectral image of the object. Typical specifications of the visible AOTF imaging spectro-polarimeter completed are Spectral Range: 450-700nm, Spectral Resolution: 1.2-1.9nm, Spatial Resolution: 20 line pairs/mm(MTF: 0.3), Diffraction Efficiency: over 90%.

1. CONFIGURATION OF THE INSTRUMENT

The main components of the instrument is an object lens, a field stop, a collimate lens, an aperture stop, an AOTF with 7x7 mm aperture, an image lens and two CCD cameras. When we measure the power spectrum of the radiance, CCD cameras are replaced by two detectors of an optical power meter(Fig.1). The instrument is equipped with a finder which can help us to position the target. The finder mirror can be withdrawn from the light path during measurement.

2. TUNING PERFORMANCE

When white light beam enters Tellurium dioxide(TeO_2) noncollinear AOTF device, it separates zero-order (non-diffracted) beam and two diffracted beams; one is +1 order(extraordinary) and the other is -1 order (ordinary). The AOTF device installed in the instrument was specially manufactured by Brimrose Corporation of America so that we can optimize for both order (+1 and -1) light beams simultaneously.

2.1 DIFFRACTION EFFICIENCY AND SPECTRAL RESOLUTION

When 1.000mW Red He-Ne gas laser light (632.8nm wavelength) entered the AOTF, the diffracted light intensity was 0.438mW for both orders (+1 and -1) and the non-diffracted light (zero-order) was 0.072mW. Thus,

$$\text{Diffraction efficiency} = (0.438 + 0.438) / 1.000 = 0.876 = 87.6\%$$

Fig.2 shows the AOTF device spectral resolution (FWHM: Full Width Half Maximum) measured using Red He-Ne gas laser light(632.8nm). FWHM is 1.3nm and 1.5nm for -1 and +1 order respectively.

2.2 EXAMPLE OF SPECTRAL ANALYSIS

Fig.3 (-1 order) shows an example of spectral analysis for a helium electrodeless lamp light. Six peaks observed correspond to the each spectral wavelength in the spectrum table of helium at the wavelengths of 447.15, 471.31, 492.19, 504.77, 587.56, and 667.81 all in nm. Measurement of +1 order is not shown here, because it was almost identical to Fig.3.

Spectral measurement of such a lamp light as helium lamp light is used to calibrate the wavelength scale of the instrument, because of its well known spectrum.

3. SPATIAL RESOLUTION

Spatial resolution of the AOTF device was tested using USAF 1951 test pattern. As shown in the Fig.4, vertical (polar) spatial resolution is 114 line pairs/mm, while horizontal (azimuth) resolution is 102 line pairs/mm. Over all spatial resolution of the instrument was measured including from the object lens to CCD cameras. In the Fig. 5 , "GV -1" indicates -1 order, vertical pattern, green light (546.5nm) and "OH +1" indicates +1 order, horizontal pattern, orange light (577.0nm). The figure shows that MTF of every -1 order is larger than any of +1 order.

4. SENSITIVITY ADJUSTMENT OF THE OPTICAL POWER METER DETECTORS

In order to measure two diffracted beams; +1 order and -1 order at the same time, two detectors of the optical power meter were installed in the instrument instead of the two CCD cameras. In general, each detector has different sensitivity against wavelength. Fig.6 shows an example of Halogen lamp spectrum measured by the instrument. Halogen lamp light is confirmed non-polarized, so the two spectra curves should coincide each other. However the output of +1 order detector is higher than that of -1 order detector especially between 530nm and 630nm in wavelength. After eliminating the bias, +1 datum was divided by -1 datum in every wavelength. In Fig.7, the thin line shows the quotient in every wavelength and the thick line is the polynomial approximation(6th order) to the thin line. The polynomial equation is used to compensate the -1 order data. Both compensated sensitivity curve of the -1 order detector and non-compensated sensitivity curve of the +1 order detector are shown in Fig.8 together. Fig.9 shows compensated -1 order and non-compensated +1 order spectra of a Metal Halide lamp light.

5. CONCLUSION

An imaging spectro-polarimeter using an AOTF device is completed(Fig.10). Dimension of the instrument is 600mm long, 210mm wide, and 130mm high, except the object lens, the view finder and its lever. The total weight is 12.7 Kg. Most of the total weight depends on the rigid and heavy optical base of the instrument. The base should be replaced by a lighter one employing honey comb configuration in the future modification.

A traditional spectro-polarimeter employs a linear Polarizer disk rotating in the order of angle. This kind of instrument cannot obtain two polarized data at the same time. While the AOTF spectro-polarimeter can solve the problem and is expected to measure polarization of aerosol which changes with the time.

Spatial resolution of the instrument is found much lower than that of the AOTF device. The lower spatial resolution mainly depends on the collimate lens, the image lens and the CCD sensor. So we started to improve the over all spatial resolution of the instrument.

6. ACKNOWLEDGMENTS

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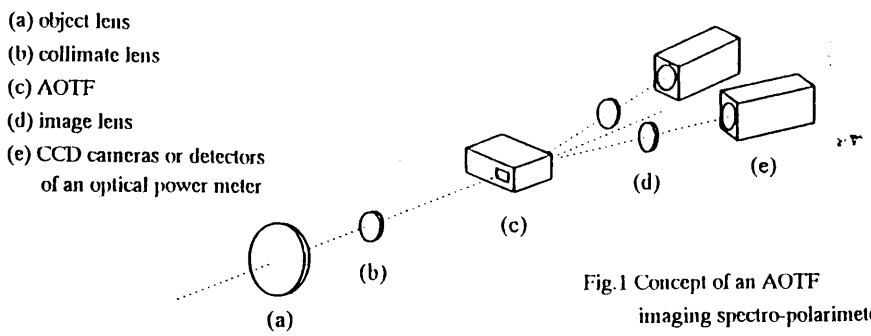

Fig.1 Concept of an AOTF imaging spectro-polarimeter

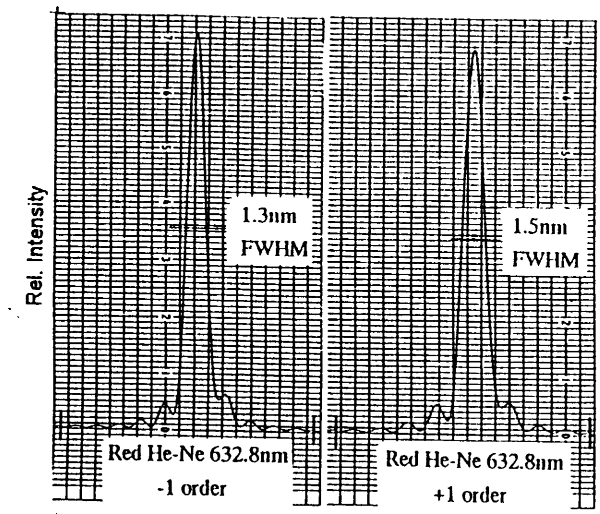

Fig.2 Spectral resolution (Bandpass shapes) FWHM of the AOTF device

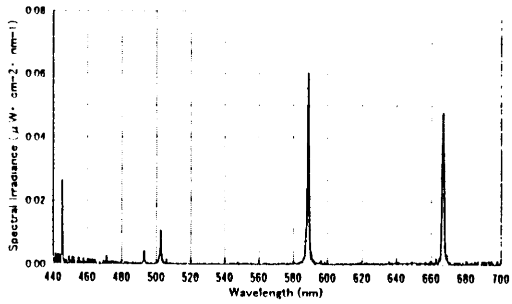

Fig.3 Spectral analysis for a helium lamp light

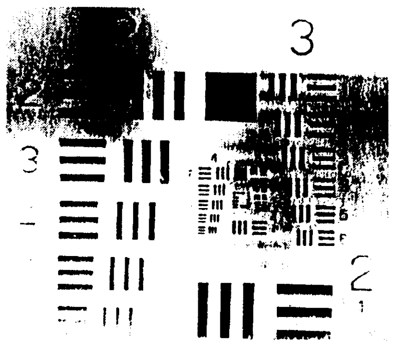

Fig.4 Spatial resolution of the AOTF device

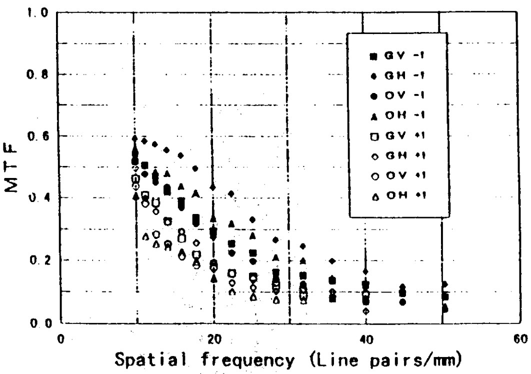

Fig.5 Spatial resolution of the instrument

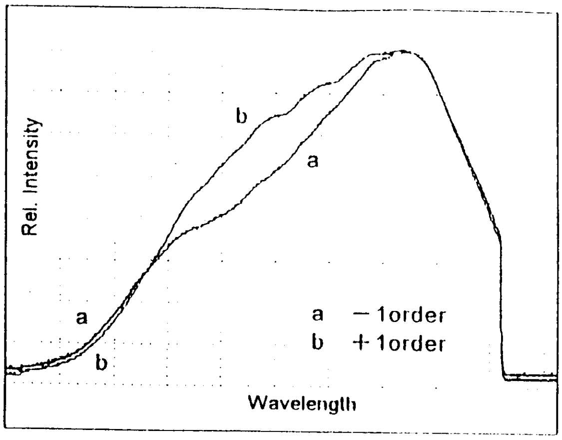

Fig.6 Spectra of a Halogen lamp

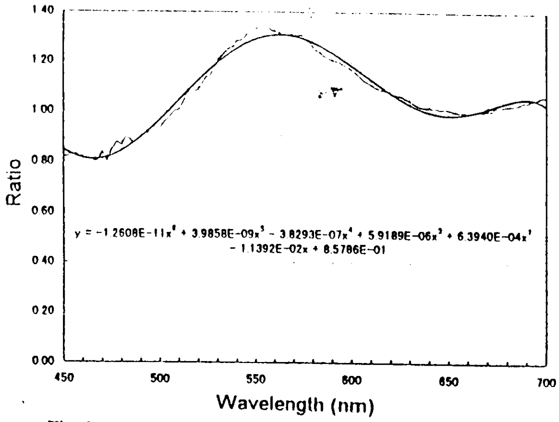

Fig.7 Polynomial equation to compensate -1 order data

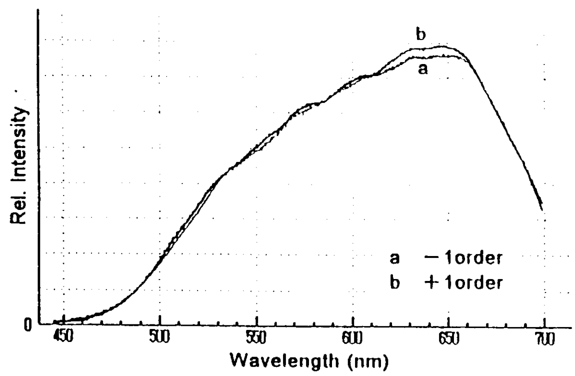

Fig.8 Compensated -1 order and non-compensated +1 order spectra of a Halogen Lamp

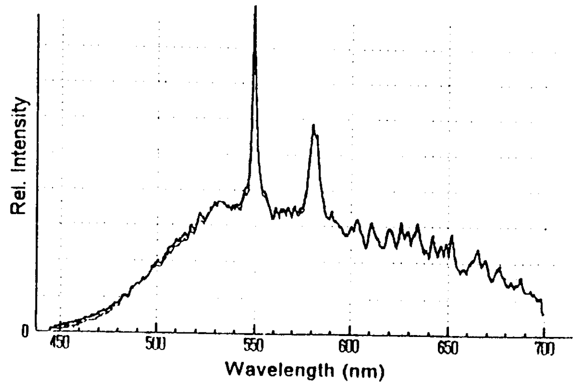

Fig.9 Compensated -1 order and non-compensated +1 order spectra of a Metal Halide lamp

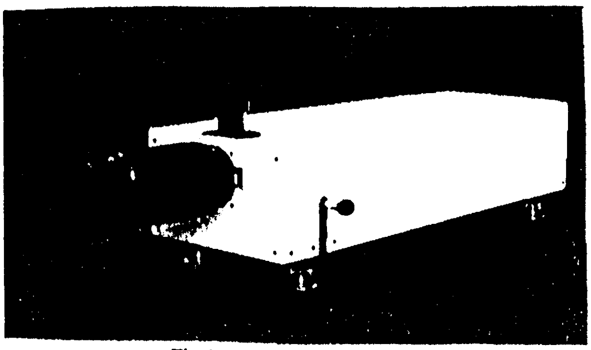

Fig.10 Appearance of the instrument