1 Science Performance Tests of AP
Science performance test of AP composed of following items have been carried out.
- AP Spatial Resolution Measurement
- AP FOV / Boresight Alignment Measurement
- AP Responsivity and S/N Measurement
- Imager Bright Flash Tolerance

2 AP Tests

2.1 AP Spatial Resolution Measurement

2.1.1 Designed Performance
AP consists of blue and red photometers; each of them has 16 channels. Each channel has a field of view (FOV) of 20 degree (horizontal direction) by 0.20 degree (vertical direction) and the vertical pitch between the channel centers is 0.23 degree. The FWHM of vertical FOV should be less than <0.25 degree and the vertical pitch 0.23-0.24 degree.

2.1.2 Test Setup and Procedure
1. In a dark room a point light source is mounted on an optical guide rail set in the right angle to the center of FOV direction at a distance of 4.3 m from the AP.
2. The light source is moved slowly along the guide rail and the outputs from the AP channels are monitored on PC screen. The light source locations where the outputs show half maximum (HM) values for each channel are marked on the guide rail.
3. The interval of the HM location for each channel (corresponding to FWHM of FOV) and the interval between the centers of HMs (corresponding to channel pitch) are measured with a ruler.
4. The angles of FWHMs of FOV and the channels pitch for the light source set at 3 m distance are calculated.
5. Image of the light source is out of focus at 4.3m distance, since the optical layout of AP is designed for subjects at infinity. Considering the focal length of the objective lenses used in AP, practical FOVs (HMs) are estimated.
2.1.3 Test Date and Place
20 February 2003 at NSPO, Taiwan

2.1.4 Results
The estimated FWHMs of vertical FOV are 0.24 (< 0.25) degree and the vertical pitches of channel centers 0.23-0.24 degree (average=0.235).

2.2 AP FOV / Boresight Alignment Measurement

2.2.1 Requirement
Whole FOV of AP composed of 16 channels for each color is 3.6 degree (vertical direction in observation) by 20 degree (horizontal direction in observation). The centers of two color photometers (A (blue) and B (red)) and the horizontal direction of FOVs should be coincident with those of Sprite Imager and Spectrophotometer. The error of FOV center location relative to FOV of the imager should be within 0.2 degree in vertical and 1.0 degree in horizontal, respectively.

2.2.2 Test Setup and Procedure
1. In a dark room a point light source is mounted on an optical guide rail set in the right angle to the center of FOV direction at a distance of 4.3 m from the AP. (Figures 2.2-1 and 2.2-2)
2. The light source is moved slowly along the guide rail and the outputs from the AP channels are monitored on PC screen. The light source locations where the outputs show half maximum (HM) values for channels of No. 1, 8(or 9) and 16 are marked on the guide rail. Such measurement is conducted for three guide rail positions: one at center and two at near both ends of in horizontal direction of FOV in actual observational attitude.
3. A fine wire, contacting with and being parallel to the side of AP, is stretched tightly between AP and the guide rail. The intersection point between the wire and the guide rail is marked on the guide rail.
4. Above 2 and 3 procedures are applied also for horizontal scans of light source.
5. The location of the vertical center of HMs on the guide rail in each channel is marked on the guide rail.
6. Based on the marks of center of FOV and the intersection point between the wire and the guide rail the alignment of FOV relative to the AP box is calculated. Horizontal and vertical coverage of FOV is also calculated.
7. A He-Ne laser at 4.3 m distance from AP (just above the optical guide rail) is set to irradiate one side of
the cube mirror on AP (Figure 2.2-3). The position and direction of the laser is adjusted precisely so that the reflected laser beam by the cube mirror returns to the laser output point.

8. By measuring the location of the laser output point relative to the intersection point between the wire and the guide rail determined in procedure 3, the normal vector of the cube mirror is calculated.

9. Procedures of 7 and 8 are conducted for three side of the cube mirror.

10. Based on the results of procedures 6 and 9 the alignment of FOV relative to three sides of the cube mirror is calculated.

Fig. 2.2-1 Schematic layout for calibration of FOV alignment

Fig. 2.2-2 Configuration of calibration of FOV alignment
2.2.3 Test Date and Place
20 February 2003 at NSPO, Taiwan

2.2.4 Results
The determined alignments of three mirrors projected on two planes are described in Figure 2.2-4
2.3 AP Responsivity and S/N Measurement

2.3.1 Requirement
AP shall detect typical sprites and elves with a sufficient S/N in the Sprites mode (Sampling rate = 20kHz and 2 kHz, Cutoff frequency of LPF = 10 kHz). On the other hand, AP shall detect blue jets and aurora/airglow with a sufficient S/N in the Aurora/airglow mode (Sampling rate = 200Hz, Cutoff frequency of LPF = 100Hz). The full range of A/D conversion input is 5.0 V.

2.3.2 Test Setup
To make the absolute sensitivity curve in the whole wavelength range of AP (340 – 850 nm) and estimate the outputs for typical optical phenomena, following two sensitivity measurements are carried out.

2.3.2.1 Measurement for Absolute Sensitivity
To measure the absolute sensitivity of AP a 2 m integrating sphere at National Institute of Polar Research (NIPR) is used. The distance from the objective lens of AP to the integrating sphere is 610 mm and FOV looks only the inside of the illuminated sphere (Figures 2.3-1 and 2.3-2).
2.3.2.2 Measurement for Wavelength Characteristics

To measure the relative sensitivity at wavelengths a monochrometer calibration system installed at NIPR is used. The layout of the measurement is shown in Figure 2.3-3 and 2.3-4. A diffuser is illuminated by a monochromatic light with a bandwidth of 0.5 nm. FOV of AP looks only the illuminated plate at a distance of 300 mm.
2.3.3 Procedure

1. AP output signals for the integrating sphere are recorded with PC at all channels at all high voltage levels, namely, 541 V (low), 670 V (medium) and 859 V (high).

2. AP output signals for the monochrometer calibration system are recorded at a high voltage level of 541 V (low) every 10 nm from 340 to 850 nm at all channels of both color photometers.

3. Considering the absolute intensity spectrum of light source of the integrating sphere, the absolute sensitivity curve in the wavelength range of 340-850 nm is derived based on the results of procedure 1 and 2.

4. Expected outputs for optical phenomena are calculated in the following conditions.
Sprites:

High voltage for PMT: middle (670 V)
Sampling rate: 20 kHz (sprites mode)
Range to the sprites: 3300 km
Horizontal width of sprites: 10 km
Luminosity (N2 1P and 2P): 15 MR
Electron temperature: 2 eV
Spectrum of sprites: see Figure 2.3-5

Fig. 2.3-5 Assumed sprites spectrum

Elves:

High voltage for PMT: middle (670 V)
Sampling rate: 20 kHz (sprites mode)
Luminosity (N2 1P and 2P): 1 MR
Electron temperature: 5 eV
Spectrum of sprites: see Figure 2.3-5
Channel 8 of Photometer-A and-B
relative outputs to other channels are analogous to the Figure 2.3-5

Airglow: (630 nm)

High voltage for PMT: high (895V)
Sampling rate: 20 0Hz (aurora/airglow mode)
Luminosity:  600 R in the line of sight  
Channel 8 of Photometer-B  

Airglow: (558 nm)  
High voltage for PMT: middle (670V)  
Sampling rate: 200Hz (aurora/airglow mode)  
Luminosity:  3 kR in the line of sight  
Channel 8 of Photometer-B  

Aurora: (558 nm)  
High voltage for PMT: low (541V)  
Sampling rate: 200Hz (aurora/airglow mode)  
Luminosity:  100 kR  
Channel 8 of Photometer-B  

Aurora: (428 nm)  
High voltage for PMT: middle (670V)  
Sampling rate: 200Hz (aurora/airglow mode)  
Luminosity:  100 kR in the line of sight  
Channel 8 of Photometer-B  

Blue Jets:  
Wavelength: 400 nm assumed  
High voltage for PMT: high (895V)  
Sampling rate: 200Hz (aurora/airglow mode)  
Luminosity:  300 kR  
Range to the blue jets: 3300 km  
Horizontal width of blue jets: 10 km  
Channel 8 of Photometer-A  

2.3.4 Test Date and Place  
24 July 2003 at NIPR, Tokyo, Japan
2.3.5 Results

Absolute sensitivity curve:

![Absolute sensitivity curves for Photometer-A (blue) and Photometer-B (red)](image)

Fig. 2.3-6 Absolute sensitivity curves for Photometer-A (blue) and Photometer-B (red)

Dark current noise:

- Photometer-A (blue): 1.5 mV at a high voltage level of 895 V(high)
- Photometer-B (red): 1.7 mV at a high voltage level of 895 V(high)

Circuit noise:

- Photometer-A and –B: < 20 mV

Expected output voltage:

Sprites:

1.8-2.8 V dependent on channel of Photometer-A (blue) (average~2.3 V)

~700 mV at all 16 channels of Photometer-B (red)

Detail output of each channel is described in Figure 2.3-7
Elves:

1.9V for Photometer-A (blue)
190 mV for Photometer-B (red)

Airglow (630 nm): 460 mV
Airglow (558 nm): 495 mV
Aurora: (558 nm): 2.75 V
Aurora: (428 nm): 3.0 V
Blue Jets: 800 mV

2.5 Imager Bright Flash Tolerance

2.5.1 Procedure
1. The FOV scans the sun at 10 degree/sec in the vertical direction at one time. This scan speed corresponds to satellite spin period of 36 sec with spin axis normal to AP base plate. The actual time the one channel of PMT was exposed to the focused sun image is 0.07 sec (FOV (~0.2 deg) + sun diameter (~0.5 deg)).
2. After 30 hours HV and electric circuit are turned on and the science data are checked using small light source moving along FOV of each channel.

2.5.2 Test Date and Place
16 June 2002 at Tohoku University, Sendai, Japan

2.5.3 Results
It is confirmed no damage on the PMT. It would be concluded that if the sunlight intrudes directly into AP's FOV in such a short period at one time, the PMT will suffer no serious damage.