Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 54 (2014) 554–563

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Limb Viewing Hyper Spectral Imager (LiVHySI) for airglow measurements onboard YOUTHSAT-1

R.S. Bisht [a], A.K. Hait [a], P.N. Babu [a], S.S. Sarkar [a], A. Benerji [a], A. Biswas [a], A.K. Saji [a], D.R.M. Samudraiah [a], A.S. Kirankumar [a], T.K. Pant [b,*], T. Parimalarangan [c]

[a] *Space Applications Centre (SAC/ISRO), Jodhpur Tekra, Ahmedabad 380015, India*
[b] *Space Physics Laboratory, Vikram Sarabhai Space Centre, Tiruvananthapuram 695022, India*
[c] *ISRO Telemetry Tracking and Command Network (ISTRAC), Bengaluru 560058, India*

Available online 27 January 2014

Abstract

The Limb Viewing Hyper Spectral Imager (LiVHySI) is one of the Indian payloads onboard YOUTHSAT (inclination 98.73°, apogee 817 km) launched in April, 2011. The Hyper-spectral imager has been operated in Earth's limb viewing mode to measure airglow emissions in the spectral range 550–900 nm, from terrestrial upper atmosphere (i.e. 80 km altitude and above) with a line-of-sight range of about 3200 km. The altitude coverage is about 500 km with command selectable lowest altitude. This imaging spectrometer employs a Linearly Variable Filter (LVF) to generate the spectrum and an Active Pixel Sensor (APS) area array of 256 × 512 pixels, placed in close proximity of the LVF as detector. The spectral sampling is done at 1.06 nm interval. The optics used is an eight element f/2 telecentric lens system with 80 mm effective focal length. The detector is aligned with respect to the LVF such that its 512 pixel dimension covers the spectral range. The radiometric sensitivity of the imager is about 20 Rayleigh at noise floor through the signal integration for 10 s at wavelength 630 nm. The imager is being operated during the eclipsed portion of satellite orbits. The integration in the time/spatial domain could be chosen depending upon the season, solar and geomagnetic activity and/or specific target area. This paper primarily aims at describing LiVHySI, its in-orbit operations, quality, potential of the data and its first observations. The images reveal the thermospheric airglow at 630 nm to be the most prominent. These first LiVHySI observations carried out on the night of 21st April, 2011 are presented here, while the variability exhibited by the thermospheric nightglow at $O(^1D)$ 630 nm has been described in detail.

Keywords: Airglow; Ionosphere; Thermosphere; Electron density; Volume emission; Rayleigh

1. Introduction

The terrestrial upper atmosphere, altitude ⩾ 80 km, is a closely coupled two component system known as thermosphere-ionosphere system (TIS) where the neutrals (thermosphere) and plasma (ionosphere) coexist. Most of the present day technological systems in space like the satellites reside within this upper atmosphere. This part of the atmosphere responds to the incoming solar radiation through heating, photodissociation and photoionization of the neutral species, and to solar wind through ionosphere-magnetosphere interactions. Thus the thermosphere, being the dominant component, plays the primary role in the upper atmospheric energy balance. The lifetime of most of the thermospheric species, to a large extent, are controlled by photochemical processes, and consequently several species get excited and undergo specific spectral transitions leading to emissions that depend on the lifetime of the meta-stable state and the timescale of the ongoing quenching reactions. These non-thermal atmospheric emissions are known as the 'Airglow' (Chamberlain, 1961). Most of the prominent

* Corresponding author. Tel.: +91 471 2563563; fax: +91 471 2706535.
E-mail address: tarun@vssc.gov.in (T.K. Pant).

http://dx.doi.org/10.1016/j.asr.2014.01.016
0273-1177/

airglow emissions therefore emanate from various altitude regions in the TIS. Owing to the above and the fact that the airglow serves as the best tracer for the region from where it emanates, systematic monitoring of the airglow has emerged as one of the most preferred technique to look into the upper atmospheric energetics, dynamics and chemistry.

In the recent years the need for a comprehensive understanding of the complex processes of the ionosphere-thermosphere system, including its response to the various external forces such as the space weather forcing, so as to reach a level of predictive capability, has been felt. This realization has come in recent years as a consequence of the understanding of space weather effects in the terrestrial upper atmosphere (Rao et al., 2012 and references therein). The ionospheric variability can be studied through radio techniques like the radars, GPS, satellite based beacons, ionosonde, etc., while the thermosphere, as mentioned earlier, can be effectively investigated through measurements of the atmospheric airglow emissions. In fact, the airglow measurements from satellite platforms provide global coverage in extended time domains, covering different seasons and different epochs of the solar cycle. Such measurements from satellites in the past have generated the much needed thermospheric database that has eventually helped in developing upper atmospheric models with the predictive capability (Hedin et al., 1988; Hedin, 1991 and references therein). For instance, the airglow monitoring instrument called Wind Imaging Interferometer (WINDII) onboard NASA's Upper Atmosphere Research Satellite (UARS) provided the much needed wind and temperature data in the altitude range of 80–300 km using some specific airglow emissions in the visible range from the upper atmosphere (Thuillier et al., 2002). The optical spectrograph and infrared imager system (OSIRIS) on board the Odin spacecraft had been designed to retrieve altitude profiles of terrestrial atmospheric minor species. The spectrograph also detected the airglow by observing earth's limb, which had been used to study the mesosphere and lower thermosphere. The OSIRIS obtained spectra over the wavelength range 280–800 nm with a spectral resolution of approximately 1 nm (Llewellyn et al., 2004). Similarly, the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite has an airglow imager operating at the ultraviolet wavelengths which has provided information on the distribution of thermospheric density especially over low and equatorial latitudes (Emmert et al., 2006). Imager of Sprites and Upper Atmospheric Lightnings (ISUAL) (Chern et al., 2003) onboard FORMOSAT-2, launched in May, 2004, carried out airglow measurements in visible range by using a filter wheel controlled imager in the earth's limb view mode. These measurements in the Earth's limb view mode furnish excellent radiometric resolution and ease to generate vertical density profiles of the airglow emitting species.

Currently, LiVHySI aboard India's YOUTHSAT satellite is the only space borne hyper-spectral instrument operating in Earth's limb view mode and imaging simultaneously the airglow emission intensity in visible and near infrared wavelengths. In this context, the LiVHySI is a unique imager operating in Earth's limb viewing mode to measure airglow emissions in the spectral range 550–900 nm. Its performance has been satisfactory and it has generated the database that is being used for the upper atmospheric research.

The paper describes the salient features of this lightweight, low power consuming LVF (Linearly Variable Filter) based hyper-spectral imaging imager, its in-orbit operations and, quality and potential of observations carried out with it.

2. Payload configuration

LiVHySI is designed to cater to the requirement of very low mass, volume and power consumption so as to fit into the definition of a small or micro satellite payload. It employs a Linearly Variable Filter (LVF), popularly known as wedge filter, to generate the spectrum. The working principle of LVF is shown schematically in Fig. 1a. The LVF is placed in close proximity of an Active Pixel Sensor (APS) area array (512 × 256 pixel format with 50 μm pixel size). The optics used is an eight element f/2 telecentric lens system with 80 mm effective focal length. The overall schematic is shown Fig. 1b.

The LVF is aligned with respect to the detector such that detector's 512 pixel dimension covers the spectral range. The FOV (Field of View) of the imager is 18.2° × 9.2°. Detector is aligned with respect to optics such that its 512 pixel dimension is along 18.2° and 256 pixel dimension is along 9.2° field. Each pixel's field is 2.1 arc min. Operated from an altitude of 820 km, the pixel projection at a range of 3200 km is 2 km × 2 km. During the observations, the satellite is oriented such that the spectral dimension is in the latitude-longitude plane (aligned either along different latitudes or longitudes). Sensor's 256 pixel dimension is always aligned along the Earth's radial direction covering a range of altitudes. Thus, the horizontal swath coverage is

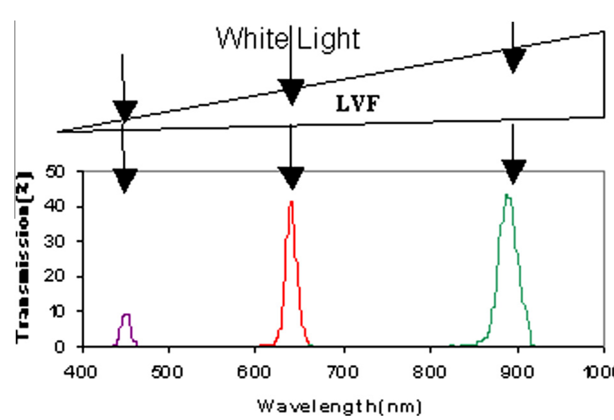

Fig. 1a. Schematic showing the working principle and transmission of LVF. Three emissions lines are also shown for illustration.