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Study of upper atmospheric emissions using Mesosphere Lower Thermosphere Photometer (MLTP) designed at ARIES

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Mesosphere Lower Thermosphere Photometer (MLTP) has been designed at ARIES for studying mesosphere lower thermosphere coupling processes. MLTP utilizes f/2 optics with 4^{o} circular field of view. It has seven narrow bandwidth (FWHM ~ 4 Å) interference filters mounted on a geared filter plate housed in filter chamber under precise temperature controlled conditions. Out of these seven filters, filter at 630 nm is meant to monitor ionospheric F- region airglow emission due to atomic oxygen. MLTP has been successfully installed and made operational at Space Weather Laboratory of ARIES.

Keywords: Mesosphere Lower Thermosphere Photometer (MLTP), Space weather event, Upper atmospheric emission

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1 Introduction

Mesosphere Lower Thermosphere Photometer (MLTP) is designed with provision for seven filters on the filter plate having central wavelengths at 840 nm and 846 nm for OH(6-2) band emissions; 866 and 868 nm for O2(0-1) band; 557.7 and 630 nm for OI emissions; and 857 nm for background emission lines. Filter plate is rotated using a unipolar stepper motor to put filters over the detector for certain exposure time. Filter chamber is maintained at 23.5° C for best filter response by 16 peltier cooling units controlled by a thermo-electric temperature controller with accuracy better than 0.4° C. For having better temperature stability, MLTP has been kept in temperature controlled room with set temperature ~ 24° C.

MLTP uses a Photo multiplier tube (PMT) detector, which has 10x10 mm^2 photocathode made of GaAs (Model: R943-02) supplied by Hamamatsu Photonics, Japan. PMT output signal is fed to a computer through counting units C3866 and C8855 via USB interface. A computer controls operation of the instrument and data collection.

2 Scientific objectives

Solar flare, coronal mass ejection (CME), etc. alter Earth atmospheric conditions, particularly magnetosphere and ionosphere. Till now, several investigators[1-3] have reported geomagnetic storms and sub-storms and their subsequent effects on the earth atmosphere (magnetosphere, ionosphere). Due to these events, very highly energetic charge particles enter into Earth atmosphere, hence, ionospheric electron contents get changed significantly. Airglow (emission of electromagnetic radiation from upper atmospheric constituents due to various photochemical reactions) monitoring at 630 nm is an established method for the study of ionospheric electron content variability[4]. The extreme space weather events with significant geo-effectiveness can alter the electron density and variability. The intense energy precipitation over high latitudes is often percolated to the low and equatorial latitudes through disturbance dynamo actions[5]. The time constants for energy redistribution are not well understood till date. The MLTP operation at 630 nm over Nainital, which is a low latitude station, is therefore, well positioned to study the high and low latitude coupling during such space weather events. Therefore, one can trace solar activity indirectly by MLTP operations at 630 nm (peak emission altitude ~ 250 km). Under the IHY and CAWSES program, the MLTP is designed to study the energetic and dynamics of several atmospheric regions (lower thermosphere - mesosphere system) and ionosphere variability and space weather effects under varying solar geophysical conditions with the use of O (^{1}D) 630 nm emission.

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3 Mechanical designs

The mechanical design for the MLTP is done taking into account the location of various subsystems of airglow photometer and the amount of movement required in its components with desired accuracies. Guidelines for the design are: compactness, thermal stability, simplicity, ease and low cost of fabrication. Complete set up in operation after installation at Space Weather Laboratory of ARIES has been shown in Fig. 1. Mechanical design consists of the following main components:

3.1 Lens housings

Three threaded lens housings were designed for holding the three lens of diameter 50 mm and focal length 100 mm. The housings were manufactured from aluminium with provision for movement of ± 3 mm in axial direction for alignment. A locking arrangement was also provided in its housings so that there is no movement of the lens after achieving the desired alignment.

3.2 Apertures

Variable slide fit apertures of 0.5, 0.7, and 1.0 mm were fabricated from aluminium sheet for adjusting field of view. One of these apertures can be slided in the tube to the focus of first lens with a locking arrangement at its precise position.

Fig. 1 — MLTP system at Space Weather Lab

3.3 Filter chamber

A Filter chamber was designed to house the filter plate (Fig. 2) and mount 16 peltier elements, which are shown in Fig. 3. A 394 mm geared filter plate of 8.0 mm thickness having 392 spur teeth[6] on its periphery with provision for mounting seven filters and sixteen peltier elements was designed. The filter plate was made from aluminium with a rim of brass gear fastened on its periphery. A stepper motor that was coupled to its periphery rotated the filter plate. The filter plate rotates on shaft with a bearing arrangement and can be easily disassembled by removing a lock nut of M15 x 1 fixed at its top.

3.4 Thermoelectric cooler unit

The thermoelectric cooler was coupled through a flange at the end of the photometer tube. It also houses the photo multiplier tube R943-02 inside its

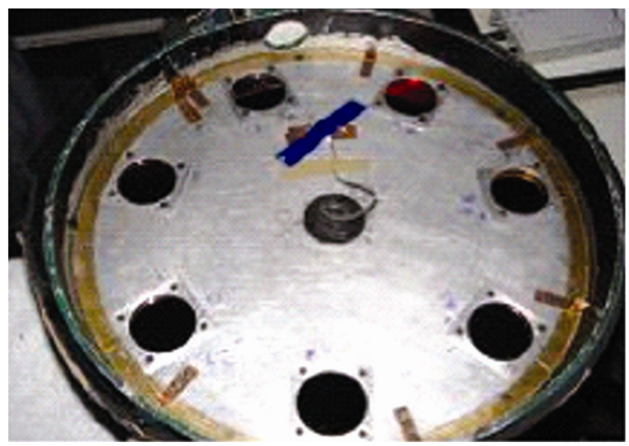

Fig. 2 — Geared filter plate

Fig. 3 — Peltier arrangement on filter chamber

housing. Water is circulated inside the housing to extract extra heat of the PMT.

3.5 Flexible stand

A light but rigid stand was required to support the airglow photomultiplier tube and its components at various positions. It was designed with aluminium channels with provisions for disassembly at several locations.

4 Fabrication, assembly and testing

Fabrication of MLTP components was mainly done on the milling and turning machines. Spur gear teeth were cut with high accuracy using gear hobbing machine. All the parts were inspected independently before assembly to achieve the desired assembly accuracies.

5 Electronics design

Controlling the temperature of filter chamber was most critical part of electronics design. Suitable software controlled stepper motor, controlling circuit and data acquisition software have been developed.

5.1 Temperature controlling unit

The interference filters have peak transmission 40-70% at 23.5° C, FWHM ~ 0.35-0.4 nm with low temperature coefficient 0.012 nm per °C. Due to this low temperature coefficient, the temperature of filter chamber is maintained with accuracy of 0.4° C or better with the help of an array of 16 air-cooled peltier elements (Fig. 3) equipped with a bipolar PID temperature controller. Peltier elements are selected over other conventional temperature controlling units due to some basic advantages, like compact size, lightweight and less maintenance with high efficiency. Bipolar temperature controller is used to achieve high temperature accuracy and stability around set temperature. The bi-polar temperature controller in closed loop condition is used to monitor the temperature of filter chamber and filter plate by a 100 ohm 3 wire RTD sensor (Fig. 2) and it controls the input power of the peltier array. To avoid any temperature fluctuations and to reduce the heat load of filter chamber, MLTP is placed inside an air-conditioned room.

5.2 Filter plate driving unit

One separate software controlled electronics card (Fig. 4) for controlling the rotation of filter wheel was designed, developed and fabricated. This card works as an interface between PC parallel port and unipolar stepper motor. A software program was written in C++ for generating 4-bit logic pattern for controlling the rotation of unipolar stepper motor (clockwise/anticlockwise). There is a zero positioning marker corresponding to background filter, which is sensed by optical sensor (H21A1 of Fairchild). At the beginning of each observation, the filter wheel is brought to this zero positioning sensor. A separate filter positioning optical sensor achieves the designated position of the filter wheel for any

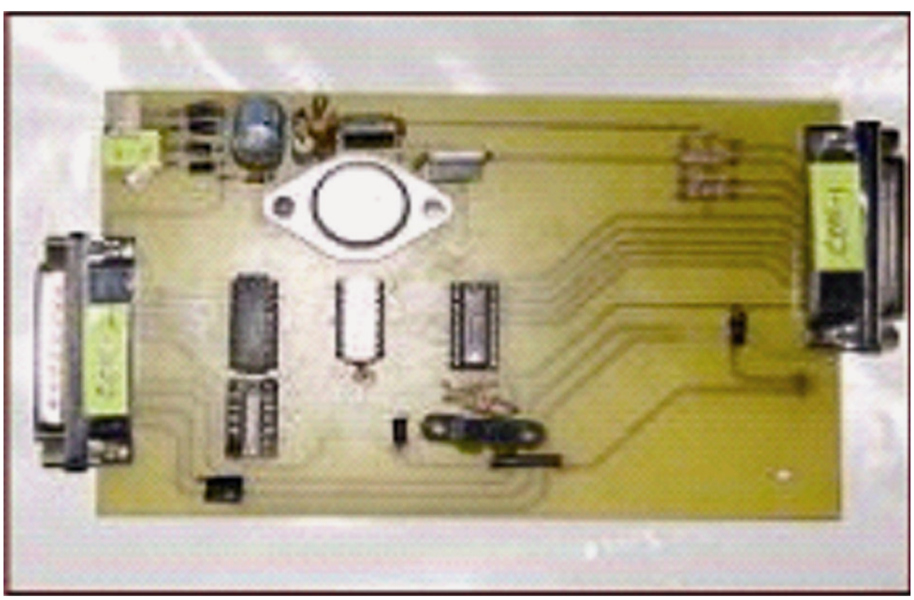

Fig 4 — Stepper motor controller card

specified observation. One optical sensor is placed on the card to monitor the power supply unit of the card. On failure of the power supply unit, control software stops the observation sequence and gives a notification. Exposure times for various filters can be adjusted to 1, 2, 5 and 10 seconds according to the observation.

5.3 Detector and data acquisition unit

R943-02 PMT is used as a detector for observations. The R943-02 is also equipped with standard pre-amplifier discriminator C3866 and a PC compatible counting unit C8855 that has a USB interface (supplied by Hamamatsu). The characterization of PMT was done and found ~ 1600 (-ve) V dc for the operating voltage of PMT for maximum S/N ratio. Software was developed using DLL and API file (supplied by Hamamatsu) for C8855. This software controls both motion of stepper motor and photon counter C8855. It monitors the status of control electronics card and generates a TTL pulse for external triggering of C8855.

6 Conclusions

MLTP has been designed and built in ARIES to study atmospheric dynamics in mesosphere-lower thermosphere region as well as Sun-Earth connection with help of various airglow emissions. This portable cost-effective instrument is suitable for carrying out observations at different locations. MLTP is capable of observing in a wide spectral region from ultraviolet (UV) to near infrared (NIR) region (160 to 900 nm) of the electromagnetic radiation. This worthy feature of MLTP has enabled it to get information of the several atmospheric regions simultaneously. High signal-to-noise-ratio, high sensitivity of the detector and low dark count have confirmed faithful signal reception. There had been several reports of 630 nm airglow monitoring being utilized to study the space weather and geomagnetic storms[7-8] (triggered through intense energy and momentum exchanges between IMF and geomagnetic fields). In the light of above, it will be very useful to study various solar activity triggered geomagnetic events and their effects on mesosphere-ionosphere-thermosphere systems with the help of MLTP. Though, no such event has been recorded through the MLTP since its operation, a sample plot showing nightly variation of 630 nm airglow emission is shown in Fig. 5 to complete the details of the instrument. The x-axis in the plot is local time in hrs from 0700 hrs LT on 14 January 2007 to 0500 hrs LT on 15 January 2007. The short period structures in the plot are representative of electron density variability at ionospheric heights. Such sensitive measurements during severe space weather conditions are expected to enhance the understanding of sun-earth systems and coupling processes under the IHY and CAWSES umbrella.

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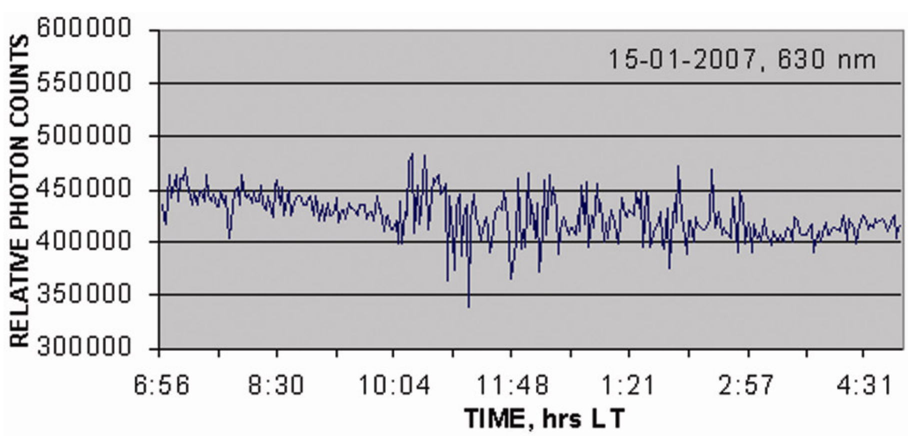

Fig. 5 — Sample plot showing night variation of 630 nm airglow emissions from 0700 hrs LT on 14 January 2007 to 0500 hrs LT on 15 January 2007

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