Fabrication of a UV Spectrometer For Use In *in situ* Mesospheric Analysis

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Abstract- The measurement of middle atmospheric temperatures has proven to be quite difficult. Factors such as solar intensity, wind speed and local pollution all have a direct effect upon mesospheric temperatures. A rocket designed to monitor many of these variables will be launched during the spring of 2000. The SUNY SPIRIT group has built a diode array spectrometer that will be incorporated on board this rocket.

Introduction

The hydroxyl radical (OH•) is an important intermediate involved the breakdown of numerous atmospheric pollutants. The radical is primarily created[1] according to the mechanism:♠

$$O_3 + h\nu \rightarrow O(^1D) + O_2$$
$$\underline{O(^1D) + H_2O \rightarrow 2OH}$$
$$O_3 + h\nu + H_2O \rightarrow 2OH + O_2$$

However, it is also can also be produced by reacting water vapor with various nitroxides or sulphoxides found in the atmosphere, but to a significantly smaller degree.

When it is hit by light from the near UV region, the radical promotes an electron to a higher molecular orbital ($2\sigma \rightarrow 2\pi_{(nb)}$). Electron promotion leads to the excited state noted as:

$$OH\bullet + h\nu \rightarrow OH^*$$

Upon relaxation, energy is released as a band of UV light (from 306nm to 309nm). By building a spectrometer tuned to this band, we can measure the presence of OH.

The SUNY SPIRIT team has incorporated this device into a larger group of *in situ* atmospheric experiments. This group of experiments will fly aboard a two stage Nike-Orion rocket in late spring, 2000.

Design & Fabrication

Many factors were considered in the design of the diode array. Care was taken to ensure a reliable and structurally sound payload. At the same time, the spectrometer was required to fit within constraints such as the mass, volume and power consumption of the device.

Foremost was the problem of environmental contamination. Concern was raised about the fact that the gases

♠ The background research is unclear as to whether an excited or ground state radical is produced. However, this distinction is unnecessary when the mechanism occurs in the upper atmosphere because the sun provides a consistent source of excitation energy. It is therefore assumed that every radical is involved in some stage of the fluorescence cycle. (See Poppe, et al) inside rocket could emulate the gases outside. Filling the chamber with N_2 (g), a reasonably inert gas, will eliminate the problem and show no interference with the OH* spectra.

The diode array consists of 21 EG & G Photodiodes. Contained within 18 of the photodiodes is an op-amp♣, required for amplifying the weak signal.

While ten of the 21 photodiodes are equipped with UV transmitting glass lenses for operation in the near UV the remaining lenses are quartz.

Two pairs of the diodes have been darkened, one pair is amplified and the other is not. All four serve as thermal and noise references.

These diodes used were selected because of their sensitivity to UV light. In order to make the diodes spectrally selective, the diodes were coated with a thin film containing 21 alternating layers of cryolite and lead fluoride.

In addition to the four darkened EG & G diodes, another unpowered diode has been positioned in the center of the array. The purpose of the extra diode is to help the team track the rotation of the rocket. Exposure to direct sunlight will cause the open diode to overload. During the post launch data analysis, signal overloads will be used to indicate direct solar exposure.

The frame of the diode array was machined from Delrin. The plastic is non-conductive and incredibly strong.

The diodes were arranged in two concentric circles on the Delrin frame. The holes for each diode were custom machined to increase stability. The four dark diodes were imbedded in the frame using only the Delrin as the light shield material. No opaque material was added to the windows of these four.

The backplate was designed to support the diodes and maintain a connection between the array and the telemetry package. The top of a peanut butter jar inspired the shape of the plate.

The backplate was machined from Delrin as well. The "peanut-butter jar" design was agreed upon because it allowed the connection to be sealed with a sizeable amount of RTV (an epoxy used to bond plastic).

A 21-channel interface board was designed for the array and included circuits to step the maximum signal voltage (Vsig) down from ±15V to ±5V as well as to provide power for the internal op-amps. The output of the processing board goes to an analog-to-digital converter and finally to the telemetry package.

The ten-pinned diodes were wired such that they could connect to the interface board (see **fig. 1**). Teflon shielded wires have been used to reduce signal interference. The unpowered diodes have only two pins, a signal and a ground.

♣ An operational amplifier is a device that boosts an incoming signal using an external power source; hereafter referred to as an op-amp.

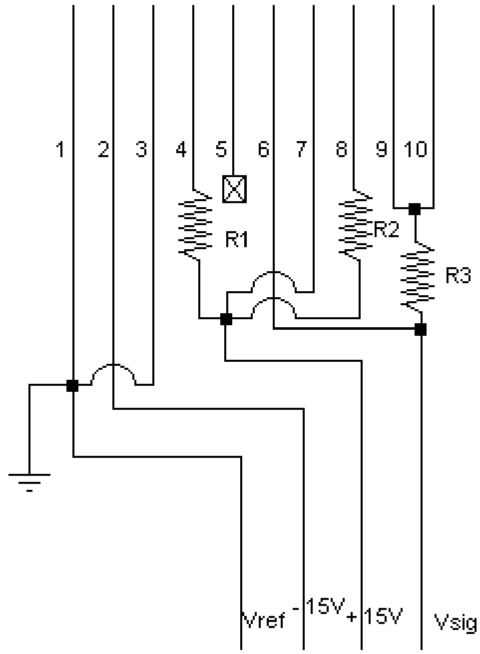

Fig. 1 – The ten-pinned diodes were wired so that they could connect directly to the interface board.

Finally, a layer of copper foil was affixed to the Delrin frame. The purpose of the foil is to keep the array grounded and reduce noise.

Calibration

The fully assembled spectrometer was subjected to a rigorous series of tests, designed to ascertain the limits of the device.

The first test was designed to measure the peak absorption of the diodes. A monochrometer was used to tune a beam of light spanning the IR-visible-UV spectrum (950nm to 200nm). Signal current across the diodes was measured using a Keithley 610 Electrometer set to ammeter mode. By measuring the sensitivity at 10nm intervals, the group was able to plot responsivity curves for each diode. Signal peaks for many of the diodes occurred in the mid-UV band (308nm to 320nm). Other peaks fell in the visible and near IR regions. This test demonstrated that selectivity in particular spectral regions could be achieved by taking signal differences between two diodes.

The second test was designed to measure the signal to noise ratio of the op-amp in each diode. Two common ground power supplies were adjusted to +/-15 volts to give a total peak-to-peak potential of 30V.

To make the measurement, the signal lead from each diode was attached to an oscilloscope. The reference lead was grounded. Measurements of the ratio varied from 3.57 to 2.64. All of the values were within the expected range and were determined suitable for reliable data measurement.

The shake test was intended to simulate the conditions that the payload would be subjected to during an actual launch. The diode array was jarred at forces in excess of 20g and survived unscathed.

Finally, the “pool test” was administered. The purpose of the pool test was to see if the fully assembled rocket would remain watertight upon submersion. This test was administered in the Olympic sized swimming pool at the Pennsylvania State University, State College PA. This test was also successful.

Conclusion

The SPIRIT Project has already accomplished its most difficult goal. The problems presented during the fabrication of the diode array were by far the most challenging. When the rocket is finally launched, it will mark the culmination of four years worth of work by the faculty and students on the team.

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Literature Cited

(1) Poppe, D.; Zimmerman, J.; and Dorn, H.P.; Field Data and Model Calculations for the Hydroxyl Radical. *J. Atmos. Sci.* **1995**, *Vol. 52 No. 19*, 3402-3407.