A Compact Bathyphotometer

Paul D. Fucile
Woods Hole Oceanographic Institution
phone (508) 289-2622 fax (508) 457-2165 email pfucile@whoi.edu

Dr. Edith Widder
Harbor Branch Oceanographic Institution
phone (561) 465-2400 x315 fax (561) 468-0757 email widder@hboi.edu

Dr. Kenneth Brink
Woods Hole Oceanographic Institution
phone (508) 289-2535 fax (508) 457-2181 email kbrink@whoi.edu

Award Number: N00014-99-1-0346
http://science.whoi.edu/users/seasoar/biolumhome.html
http://www.hboi.edu/marine/biolum1.html

LONG-TERM GOALS

To develop a compact and low cost Bioluminescence (BL) measuring Bathyphotometer. This real time system can be hull mounted, towed, moored, or used as an over the side instrument. The low cost design allows it to be used as an expendable for underway measurements. The economy and simplicity of this instrument will allow investigators to make bioluminescence an affordable measurement.

OBJECTIVES

The worldwide database of marine bioluminescence is not as extensive as CTD profiles. This small economical solid state sensor allows investigators to add BL measurements to their data collection programs. Our objective was to implement this instrument as an over the side expendable or in an air drop package so that rapid surveys could be performed. Since the design is solid state, tolerance to high vibration and shock allows this instrument to be adapted for harsh environments.

APPROACH

The technical approach addressed the requirements to develop a low power solid state sensor with a compact housing and provide communications over expendable wire. Previous bathyphotometer designs have used Photo Multiplier Tubes (PMT) as the optical sensing element. Their cost, size, low shock tolerance, and requirement for a high voltage supply prohibit them from being used in an expendable. While a photodiode is not as sensitive as a PMT, when incorporated with an optimized front end integrating amplifier and micro controller the weak signal can be converted into a digital data stream. Relatively high speed sampling in the digital domain yields a wide dynamic range. A high compliance data transmitter has been designed to drive the limited bandwidth XBT wire. When using expendable wire an electronically balanced receiver makes up the deck unit that connects to a notebook computer for display and data logging.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**
4. TITLE AND SUBTITLE **A Compact Bathyphotometer**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,86 Water St,,Woods Hole, , M,02543**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

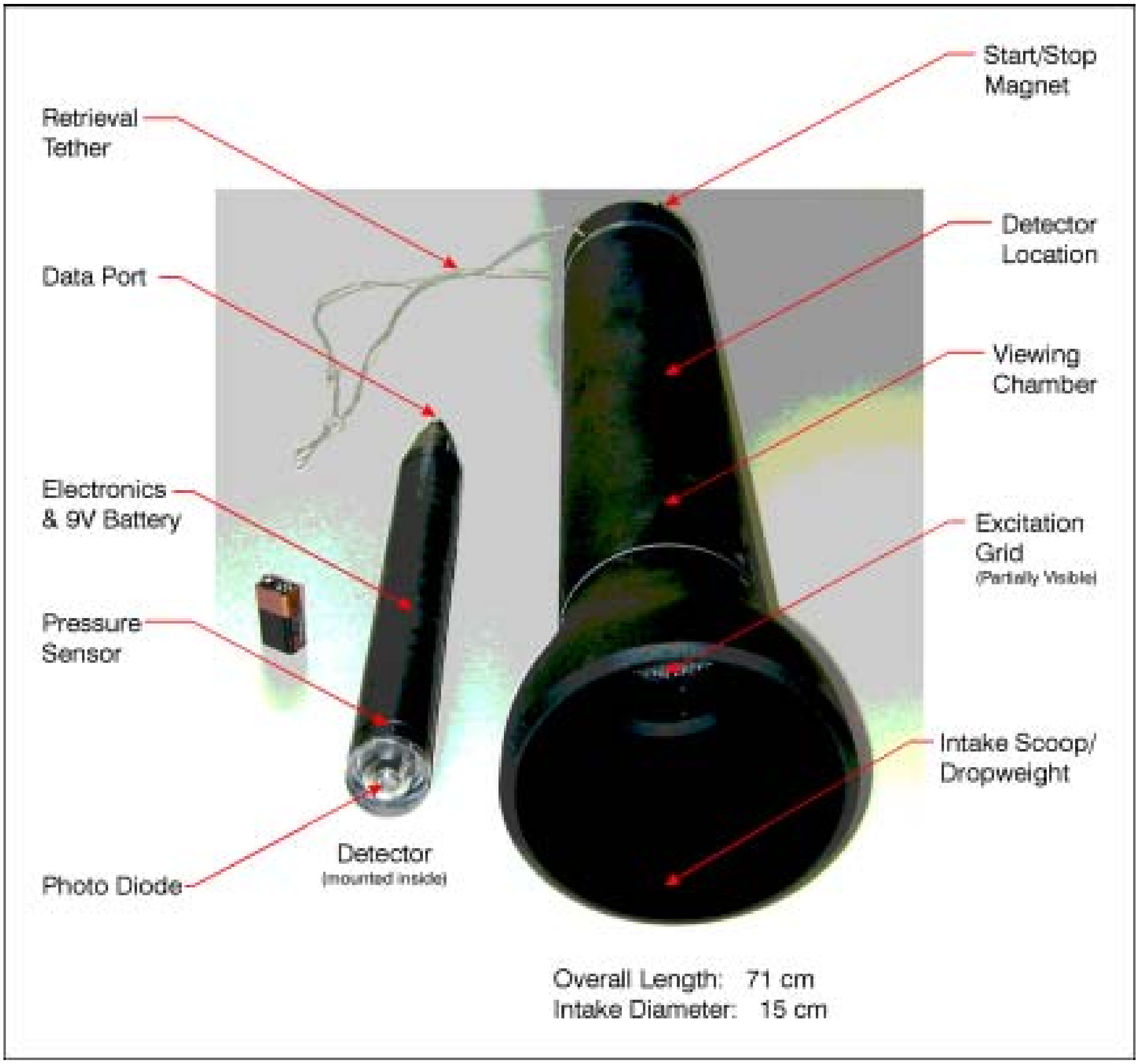

Figure 1. Solid State Bathyphotmeter showing the intake scoop, housing and detector.

To continue engineering and calibration tests, a retrievable version, the Solid State Bathyphotometer (SSBP) was constructed and is shown in Figure 1. This design employs an intake scoop to introduce organisms through an excitation grid and into a cylindrical chamber to view BL activity. The weight of the scoop causes the device to free fall causing organisms to strike the excitation grid and emit light. The solid state sensor measures the light and records the data internally. A pressure sensor provides a depth record. The current design drops at 2 meters per second and has a sampling rate to provide a one meter spatial resolution. The electronics contain drivers for expendable wire data transmission engineering tests. Chamber length is 25 cm and the diameter is 10 cm. The instrument is 71 cm long. The instrument weighs 4.1 Kg in air and 3.6 Kg in water. The present circuitry can measure two channels of light, pressure, and temperature. This version however only measures one channel of light and pressure. A 9V battery powers the circuit. Operating depth is typically to 125 meters.

WORK COMPLETED

A new version of the circuit board was constructed and interactive software for offloading data was written. A manually operated retrieval system was also made. Performance tests including radiometric and biological calibrations were carried out in the laboratory. Field tests were conducted for direct comparison of the SSBP with the Navy standard High Intake Defined Excitation Bioluminescence Profiler (HIDEX). The SSBP was deployed both on a towed vehicle and has been cast in a recoverable mode during three experiments.

RESULTS

Laboratory calibrations showed the sampling constraints of the design. The key improvement will be to design the lens to gather more light from the grid region. Imaging tests with biological samples showed the range of organism excitation times that the SSBP can capture. The light that bioluminescent organisms emit varies from species to species in both reaction time and intensity. This variability is the dominant limit in any bathyphotometer design. The SSBP geometry was shown to have a bias for the longer flashing organisms. This characteristic is understood and some possible solutions would be to make two optically opposing simultaneous measurements in the chamber or to locate the detector at the grid looking back into the chamber. The circuit supports an additional light measuring channel to help reduce this error. Further characterization may show that an improved lens design may allow a single light channel measurement. No significant re-excitation occurred at the dome of the detector. Spectral response tests showed the sensor to behave normally for silicon based detectors. Linearity tests showed the system to be linear over a 5 decade dynamic range.

A hand operated retrieval system allows two 100 meter casts to be performed in 5 minutes. The software allows the operator to prepare the SSBP for quick deployments. To start the instrument a magnet is removed. A beeper indicates if the probe is ready to go. The device is clipped to a light nylon cord and lowered overboard to the water line. It is then allowed to free fall at a nominal rate of 2 meters/sec. After the SSBP is brought on board it is connected to a PC by a simple serial cable. The data are offloaded, displayed, and stored. The SSBP memory is then erased, the magnet is replaced to power down the circuit, and a dummy plug is put on the data port. When the magnet is removed again the SSBP recognizes a clear memory and will auto start. The software in the SSBP detects a change in pressure and can be set to record data only during descent. This provides clean records showing the down cast. The battery voltage is displayed and gives the operator an indication of when the battery should be replaced. An alkaline 9V battery provides 12 hours of operating time.

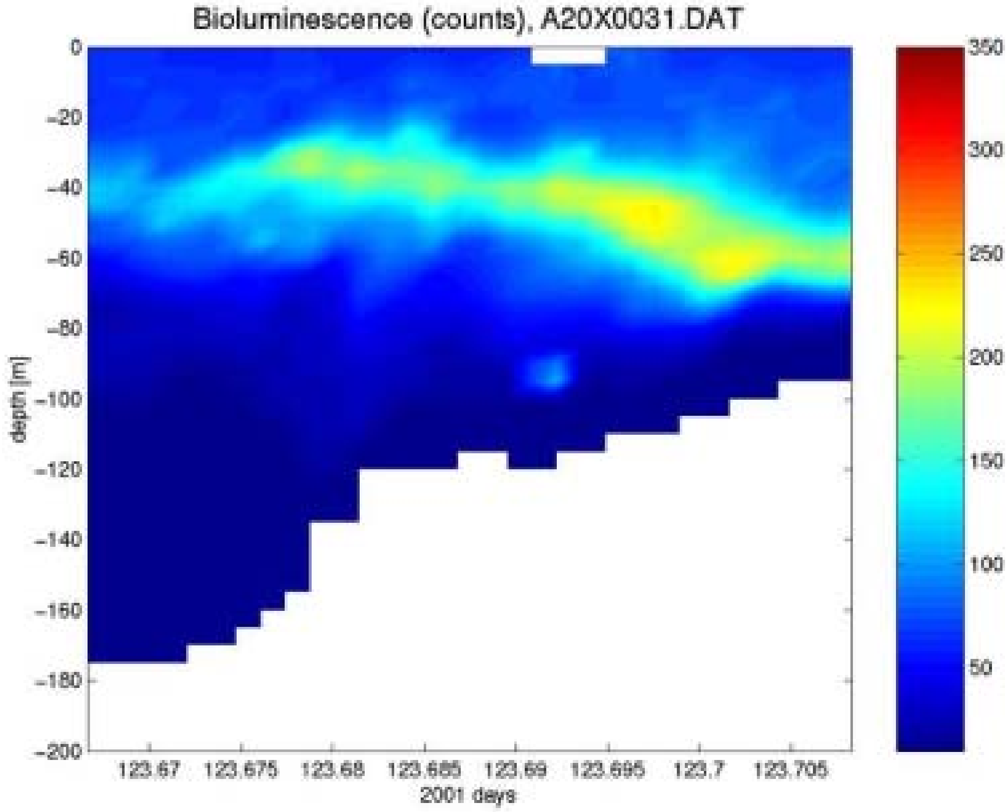

Figure 2. Bioluminescence profile from ASIAEX. The horizontal scale is 14 kilometers.

This instrument was deployed on the undulating towed vehicle SeaSoar as part of ASIAEX (South China Sea). An image showing a night time bioluminescence profile above the shelf break is shown in Figure 2. The SeaSoar typically flies from the surface to within a few meters of the bottom. The horizontal scale is 14 kilometers. The signal tracks extremely well with the fluorescence, temperature, and light attenuation signal. This signal was consistently measured over an 8 day period.

A rapid series of profiles were taken in the Tongue of the Ocean and are shown in Figure 3. The SSBP casts were taken at intervals of 15 minutes. The horizontal spacing is on the order of 1 kilometer. The bands shown are 1 meter bins.

The SSBP was used during the HYCODE experiment at LEO-15 along with HIDEX. During rough weather the SSBP was the only instrument used for bioluminescence measurements. The SSBP was used at 52 stations of which half were performed as comparative casts with HIDEX.

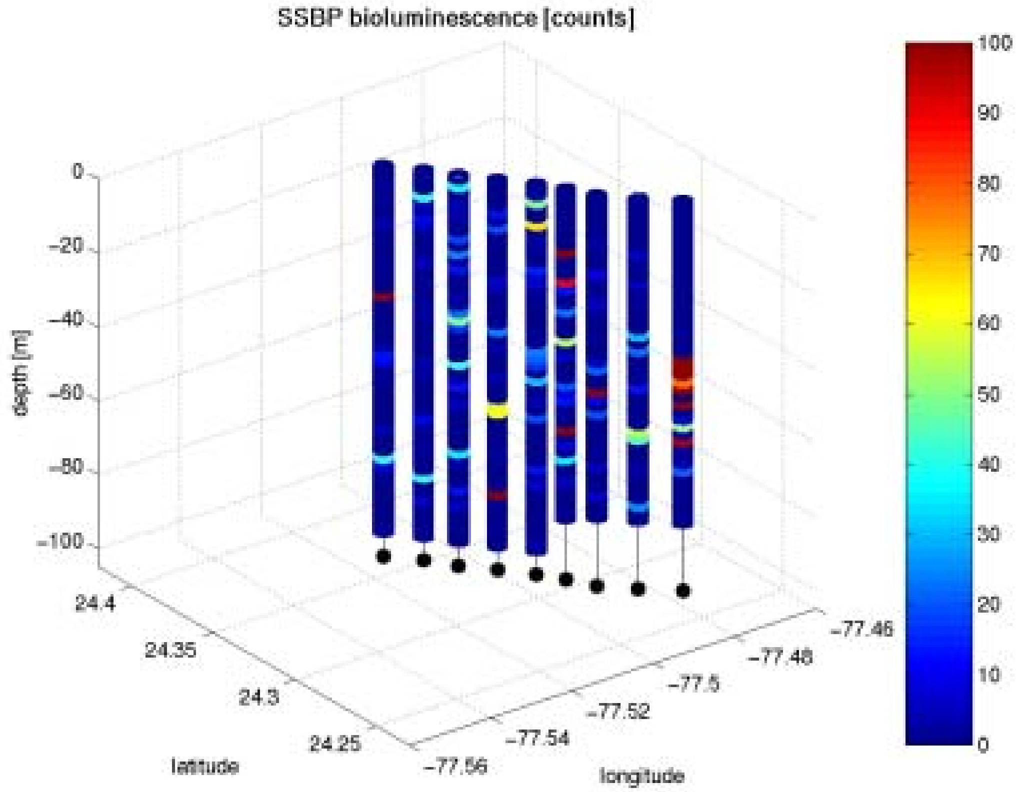

Figure 3. Bioluminescence profiles taken at the Tongue of the Ocean.

IMPACT/APPLICATIONS

The ability to have an economical Bathyphotometer for both vessel mounted and underway and over the side (expendable) measurements will improve the world wide data base. The expendable is similar to an XBT in terms of operation.

TRANSITIONS

This instrument has been provided to NAVOCEANO for performance comparison against HIDEX. This instrument was also used during HYCODE and was used at The Tongue of the Ocean. Comparisons with HIDEX have yielded encouraging results.

RELATED PROJECTS

The low power circuit can be easily modified to make other free fall optical sensors. For example a transmissometer and PAR sensor were made for the HYCODE experiment. The sensitive front end developed may also be used for laboratory experiments.

REFERENCES

Widder, E.A. (2001) Radiometric and biological calibration of photodiode-based bioluminescence detector. ONR Final Report, Grant number: N00014-99-1-0319.

Widder, E.A., S. Johnsen, S. A. Bernstein, J. F. Case, D. J. Neilson. (1999) Thin layers of bioluminescent copepods found at density discontinuities in the water column. Mar. Biol. 134: 429-437.

Widder, E.A and S. Johnsen (2000) 3D spatial point patterns of bioluminescent plankton: A map of the "minefield" J. Plank. Res. 22(3): 409-420.

Widder, E.A., J.F. Case, S.A. Bernstein, S. MacIntyre, M.R. Lowenstine, M.R. Bowlby, and D.P. Cook. (1993) A new large volume bioluminescence bathyphotometer with defined turbulence excitation. Deep Sea Res. 40(3): 607-627.

Widder, E.A. (1997) Bioluminescence - Shedding some light on plankton distribution patterns. Sea Technology March 1997:33-39.

Kocak, D.M., N.D.V. Lobo, and E.A. Widder. (1999) Computer vision techniques for quantifying, tracking and identifying Bioluminescent plankton. IEEE J. Oceanic Engineering 24(1):81-95.

Bivens, J., Geiger, M., Bird, J., Lapota, D., Fucile, P. Instrumental Evaluation Of Two Prototype Bioluminescence Sensors, *Proceedings of Ocean Optics 2000 Meeting*, abstract.

Fucile, P.D., Bahr, F, Brink, K, Neilson, D, Gawarkiewicz, G, Lee, C, Feb. 1998. Finely Resolved Physical and Bioluminescence Measurements Near Shelfbreak Fronts. *Proceedings of AGU Ocean Sciences Meeting*, abstract.

Fucile, P. D., Sept 1996. A Low Cost Bioluminescence Bathyphotometer. *Proceedings of the Gulf of Maine Ecosystems Dynamics Symposium*, abstract.