Biospherical Instruments Inc.

APPLICATION NOTE:

Measuring Light in Water in the Laboratory and Immersion Coefficients

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Measuring Light in Water in the Laboratory and Immersion Coefficients

1. INTRODUCTION

Biospherical Instruments' scalar irradiance sensors may be used in either water or air. Obtaining calibrated measurements requires adjusting the instrument's sensitivity to compensate for the "immersion effect," which is quantitatively expressed with the "immersion coefficient."

Figure 1 shows the signal of a scalar irradiance sensor that is illuminated from an overhead light source positioned at a fixed distance. The sensor is mounted in a tank that can be filled with water (Figure 2). The vessel is baffled to suppress reflections and other stray light. At the start of the experiment, the water surface is 200 mm above the collector. Water is slowly drained until the water level is below the collector (that is, the collector is dry). Figure 1 shows that the signal is much larger when the collector is dry than when it is wet—this difference is called the "immersion effect." In order to get the correct measurement result, it is imperative to specify the medium (air or water) in the instrument control software provided with the instrument. When "water" is specified, the software will apply the immersion coefficient.

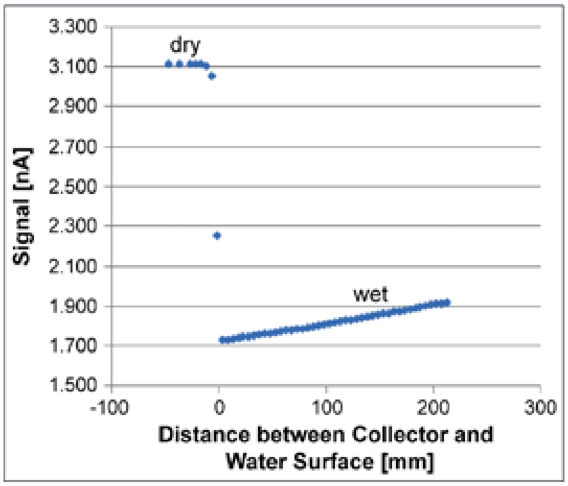

Figure 1. Signal of a scalar irradiance sensor that is illuminated from an overhead light source as a function of distance between the collector and water surface. The experiment starts with the collector fully submerged (distance at 200 mm). Because water reduces the optical path length, the signal is larger at 200 mm than at 20 mm, and because of the immersion effect, the signal is smaller when the sensor is wet than when it is dry.

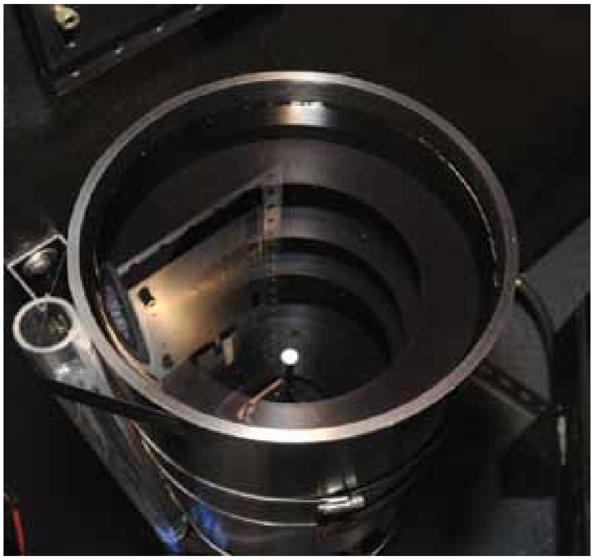

Figure 2. AMOUR scalar irradiance collector immersed in water inside a tank designed for accurate determinations of immersion coefficients. The small cylinder at the left is a sight glass to determine the water level. Internal baffles suppress stray light, and an aperture (not shown) is normally installed at the top of the container.

2. DETERMINING THE IMMERSION COEFFICIENT

The transmission of any collector depends on the refractive index of the medium in which it is used. Most radiometers—regardless whether they measure PAR, scalar or cosine irradiance, or radiance—are calibrated in air. In the aquatic or biological sciences, measurement of light sometimes needs to be conducted in another medium, with water being the most common.

Biospherical Instruments' scalar irradiance PAR sensors are supplied with the calibration factors needed for the applicable medium. In the case of AMOUR or QSL sensors, they are supplied with calibrations for both wet (in water) and dry (in air) measurements. Because these instruments are calibrated in air, an experiment such as the one described above is conducted to determine the change in instrument response caused by immersing the collector into water. The immersion coefficient is calculated from data such as those shown in Figure 1. Note that the immersion coefficient is not just the ratio of the instrument's signal when the collector is barely submerged and the signal when the collector is dry. Other factors have to be taken into account, such as the transmission of the air-water interface. Details of the calculation method are beyond the scope of this technical note but can be found in Hooker and Zibordi (2005).[1]

2.1 Practical Laboratory Examples of Measuring Light in the Laboratory and How the Immersion Coefficient Applies

At BSI, we sometimes get questions like “why does my PAR meter measure more [or less] light in my culture vessel than outside?” The answer is that “there is more [or less] light inside.” Below, we describe some controlled experiments that show the reasons for these observations.

The experimental setup included a 1,000 W tungsten halogen lamp that was mounted 86 cm from a stand where we could set different glass containers simulating culture vessels (Figure 3). The containers could be filled with water. The radiometer used for the experiment was an AMOUR sensor with a 1.3 cm wide scalar irradiance collector. The sensor was calibrated in the normal fashion on our calibration bench (not shown) and readings in water were corrected by applying the immersion coefficient using BSI’s µLoggerLight software.

Figure 3. Apparatus to demonstrate the immersion effect. A 1,000 W lamp is burning in the foreground. An AMOUR sensor measures the irradiance at the location where the vessels will be placed.

First, the sensor was dark corrected so that it would read zero when dark. Then, it was placed at 86 cm from the lamp without any container (Figure 4). The irradiance was 0.0062 µE cm^{-2} s^{-1} and is considered to be the “baseline” for this series of experiments.

Figure 4. AMOUR probe taking the baseline reading at the reference position in air.

Figure 5 demonstrates the readings taken with a spherical glass container both with and without water in the container. The container had a wall thickness of 0.32 cm, a width of 20.3 cm, and a height of 16.5 cm. The reading of the sensor with the collector placed in the center of the empty container was 0.0059 µE cm^{-2} s^{-1}, which is 95.2% of the baseline reading. The reading with water was considerably higher: 0.0105 µE cm^{-2} s^{-1}, or 169.4% of the baseline reading. When the sensor was moved to the left and right side of the container, the readings changed by about ±0.0002 µE cm^{-2} s^{-1}, which is a very small change.

Figure 6 demonstrates two additional effects that occur when using a spherical container. There is a gradient of light from the center and 1) moving closer to the light source decreases the signal from 0.0105 µE cm^{-2} s^{-1} to 0.0098 µE cm^{-2} s^{-1} (93.3% of the reading at the center of the container, and 158.1% of the baseline reading); and 2) moving away (toward the back of the chamber) increases the reading to 0.0145 µE cm^{-2} s^{-1} (138.1% of the reading from the center of the container, and 233.9% of the baseline reading). The most noticeable example of the chamber’s presence impacting the light levels are the values recorded

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[1] Hooker, S.B., and G. Zibordi, 2005: Platform perturbations in above-water radiometry, *Appl. Opt.,* **44,** 553–567.

behind the chamber, in air, at the focal point (caused by the lens) that the water-filled chamber created. This focal point was located 26 cm behind the center of the spherical container and gave a reading of 0.470 µE cm^{-2} s^{-1}, or 7580% of the baseline reading.

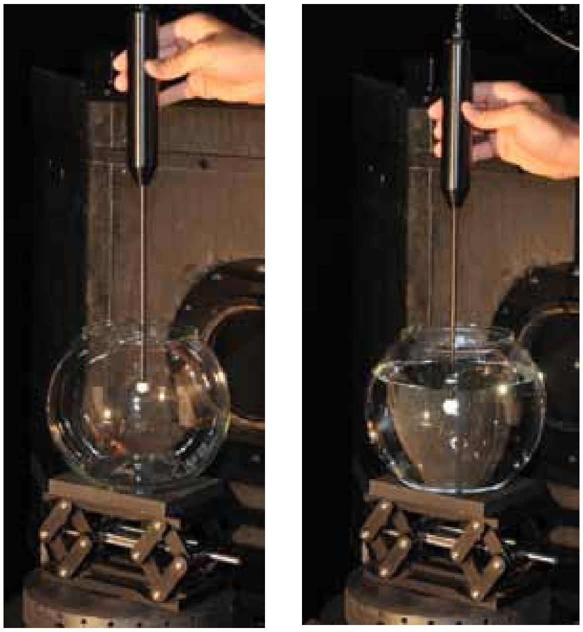

Figure 5. AMOUR probe located inside the spherical test chamber filled with (right) and without (left) water. With water, the irradiance was 69% higher than without. Also note that the collector sphere appears larger.

Figure 7 uses a cubical glass container made of molded glass (clear, but low quality glass) with a thickness of about 0.46 cm, a width of 15.2 cm and a height of 14.7 cm. The reading in air was 0.0063 µE cm^{-2} s^{-1} (101.6% of the baseline reading), and the reading in water (immersion corrected) was 0.0064 µE cm^{-2} s^{-1} (103.2% of the baseline reading). The effect of a container with flat walls is, therefore, rather small.

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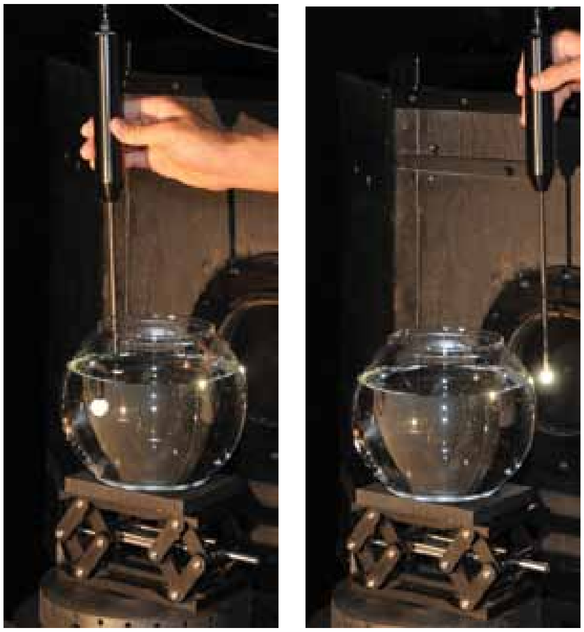

Figure 6. Spherical container, with the probe located off-center in the water-filled container (left) and behind the container at the focal point of the sphere (right). The maximum signal is observed at the focal point.

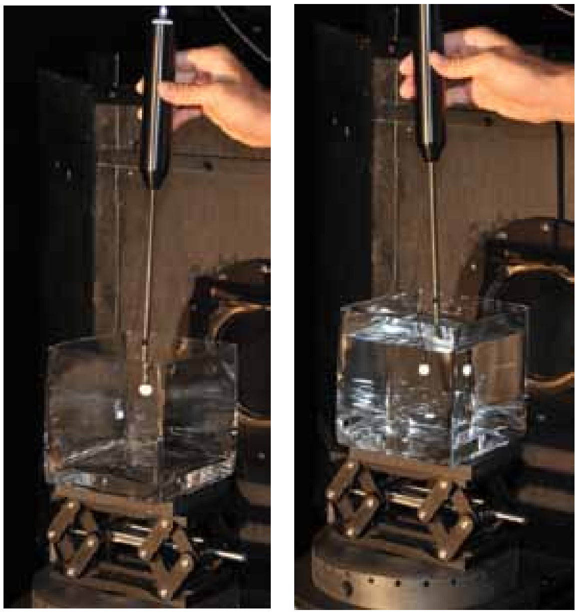

Figure 7. Cubical class container, empty (left) and filled with water (right). Little difference was observed with this container.