Innovations in Water Monitoring

Technology Backgrounder

In-Situ® Rugged Dissolved Oxygen (RDO®) Sensors Use the Latest Advancements in Optical Measurement Technology

RDO Sensors provide high-quality data and robust performance in many environments

Dissolved oxygen (DO) is one of the most important parameters monitored when evaluating water quality, aquatic biology, and other environmental and industrial processes. The In-Situ Rugged Dissolved Oxygen (RDO) Sensor measures DO using the latest advancements in optical measurement technology. Water quality professionals will benefit from In-Situ Inc.'s investment in new product development. By improving upon the breakthrough optical DO sensor technology that In-Situ Inc. first brought to the environmental market in early 2004, our latest generation of RDO Sensors provides higher quality data and more robust performance at a significantly lower cost than currently available optical DO probes.

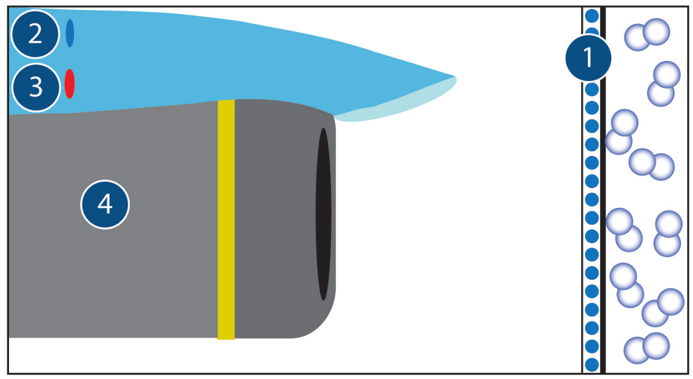

Figure 1. RDO Sensor includes lumiphore molecules (1) embedded in a sensing element, blue LED (2), red LED (3), and photodiode (4).

What methods are used to determine DO?

Traditional methods for DO determination include the Winkler titration method and electrochemical methods, such as polarographic (Clark cell) and galvanic probes. With electrochemical methods, molecular oxygen is consumed by an electrochemical process. Two dissimilar metal electrodes (anode and cathode) are in contact with an electrolyte solution. A semi-permeable membrane separates the electrodes from the sample. As oxygen molecules diffuse through the semi-permeable membrane, they are reduced at the cathode to form positively charged ions. The ions migrate to the anode where an oxidation reaction occurs. The oxidation/reduction reaction generates an electrical current that is directly proportional to the oxygen concentration.

Optical sensor technology takes a different approach to quantifying DO. Originally introduced in the 1970s, recent developments have allowed for the production of cost-effective probes that operate in demanding environments (Figure 1).

When the RDO Sensor initiates a reading, a blue LED emits blue light, which excites the lumiphore molecules. Excited lumiphore molecules emit red light, which is detected by a photodiode (Figure 2). Oxygen molecules quench the excited lumiphore molecules and prevent the emission of red light. This process is called "dynamic luminescence quenching."

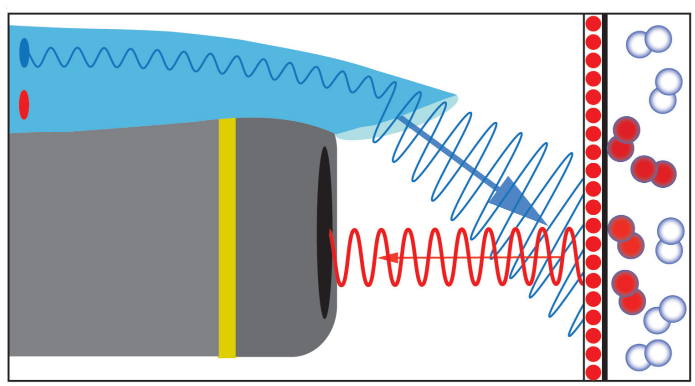

Figure 2. Lumiphore molecules are excited by blue light and emit red light, which is detected by a photodiode.

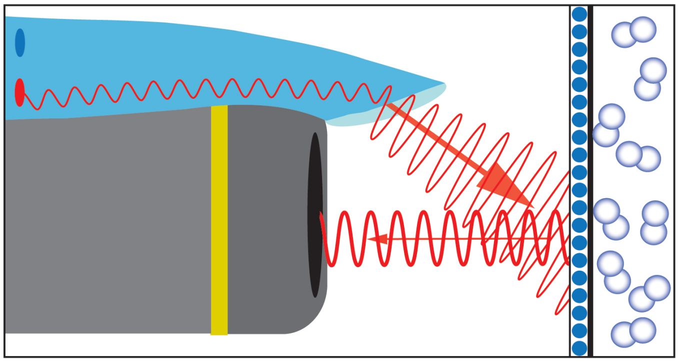

Figure 3. Optical electronics compute luminescence lifetime. The luminescence lifetime is based on the phase shift between the red returned light from the excited lumiphore molecules and the red reference light from the red LED.

The RDO® Sensor measures a phase shift between the red returned light and the red reference light (Figure 3). DO concentration and red returned light are inversely proportional. For example, high DO concentration reduces red returned light. Optical electronics calculate DO concentration and report results in mg/L (Figure 4). DO determination by luminescence quenching has a linear response over a broad range of concentrations and offers a high degree of accuracy and stability.

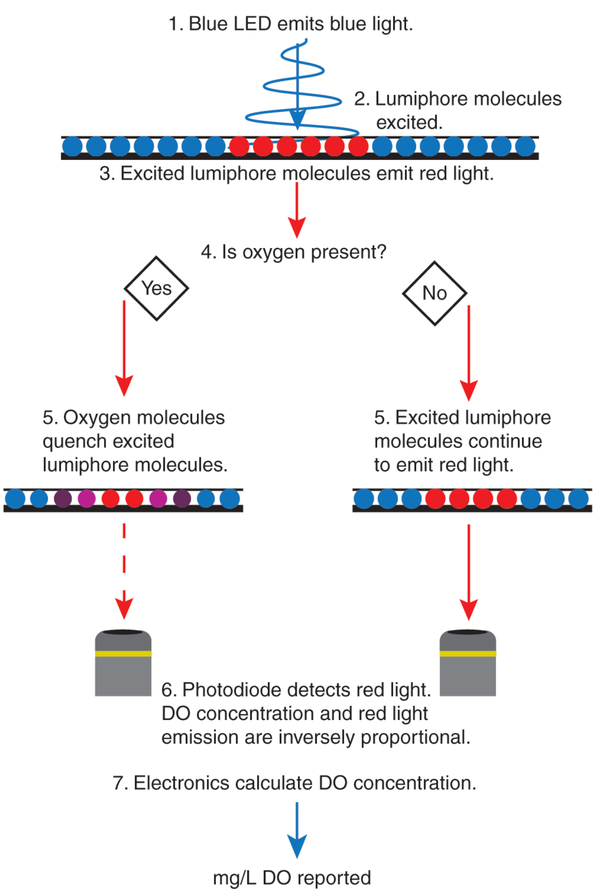

Figure 4. Summary of optical measurement process

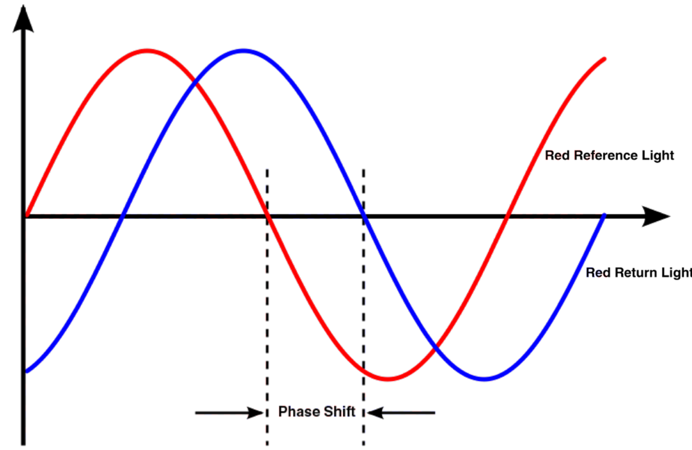

Figure 5. The luminescence lifetime is based on the phase shift between the red returned light from the excited lumiphore molecules and the red reference light from the red LED.

How do optical technologies differ?

Luminescence intensity measurements are not stable. Typically, luminescence lifetime methods are used to determine DO concentration. Luminescence lifetime can be measured by using either a time domain method or a frequency domain method.

1. **Time Domain Method**—Uses a pulsed measurement method to measure a single or an average of a series of exponential decay events. This method is susceptible to drift and interference from stray light.
2. **Frequency Domain Method**—Measures the phase shift between the entire signal and references wave forms across a number of cycles (Figure 5). This method delivers the highest accuracy across the widest operating range. The RDO Sensor uses this method, which delivers accurate, stable results.

What problems are eliminated with optical technology?

Until the development of optical DO technology, the ability to accurately monitor DO levels over long periods of time was limited. Electrochemical methods require sample stirring or flow and are functionally limited by the durability of their membrane. In addition, galvanic diffusion methods typically have slow response.

Optical DO technology eliminates the need for:

- Complex sensor storage and conditioning
- Sample flow and stirring
- Frequent calibration
- Membrane and electrolyte solution replacement

Variable	Galvanic	Polarographic Steady State	Polarographic Pulsed	Optical Life*
Flow dependence	Low	High	Low	None
Response time (to 90%)**	Slow	Medium	Medium	Fast
Range (0-200%) **Low end (0-1 ppm)** **High end (20 ppm)**	Yes + ++	Yes + ++	Yes + ++	Yes ++ +
Long-term stability	+	+	+	++
Frequency of maintenance	High	High	High	Low
Calibration Zero point required Factory or lab Difficulty	 No F N/A	 No F/L Medium	 No F/L Medium	 No F N/A
Notes	* Optical life is synonymous with optical lifetime. ** Slow ≈ 7 minutes; Medium < 1 to 3 minutes; Fast < 1 minute ++ indicates better performance than +			

Table 1. The Alliance for Coastal Technologies (ACT) conducts field tests that compare different technologies. In 2004, ACT tested galvanic, polarographic, and optical probes in field conditions. The table above is a comparison of DO measurement technologies produced for the ACT Workshop Proceedings, January 2004. (State of Technology in the Development and Application of Dissolved Oxygen Sensors, University of Maryland Technical Report Series No. TS-444-04-CBL, p. 11.)

Electrochemical sensors, no matter the level of biofouling, require a site visit at a minimum of every two weeks for maintenance and recalibration. Environmental professionals can deploy the optical RDO Sensor for an entire monitoring season, spanning months, without calibration, and can obtain accurate results in high-fouling environments, without the need for stirring or sample flow. Though DO sensors are subject to interference from active fouling, the optical RDO Sensor can be cleaned and redeployed without recalibration. Electrochemical sensors require frequent recalibration and replacement of the membrane and electrolyte solution.

What are the advantages of RDO® technology?

- **EPA approved**—The U.S. Environmental Protection Agency (EPA) has granted nationwide approval to three RDO methods. These methods can be used to determine Biochemical Oxygen Demand (BOD), Carbonaceous Biochemical Oxygen Demand (CBOD), and Dissolved Oxygen (DO) under the Clean Water Act. For details, visit www.in-situ.com/RDO_EPA_Approval.
- **Accurate results**—The sensor operates with no drift over long-term deployments. And, unlike membrane-based sensors, the RDO Sensor excels in hypoxic conditions. No sample flow or stirring is required.
- **Minimal maintenance**—The sensor face requires periodic cleaning, and sensor caps are replaced annually. No hydration, conditioning, or special storage is required. Membranes and electrolyte/filling solution are eliminated.
- **Long-lasting calibration**—When biofouling is minimal, the factory-calibrated RDO Sensor does not require calibration for long periods of time because it is not susceptible to drift due to the use of a non-consumptive, non-reactive method. Membrane-based sensors typically require calibration every two weeks, depending on sample conditions.
- **Rugged performance**—The abrasion-resistant sensing element withstands fouling, high sediment loads, and rapid flow rates. The lumiphore is not affected by photobleaching or stray light. In addition, unlike membrane-based sensors, the RDO Sensor is unaffected by sulfides, sulfates, hydrogen sulfide, carbon dioxide, ammonia, pH, chloride, and other interferences.
- **Automatic setup**—The RDO Sensor Cap includes pre-loaded calibration coefficients, serial number, expiration clock, and manufacture date for traceability. These features eliminate programming errors and improve ease-of-use.
- **Patented signal processing**—Proprietary design allows for stable, fast response and has low power requirements. The RDO Sensor is ideal for long-term deployments, dynamically changing conditions, and vertical profiling.

What products are available with RDO® technology?

In-Situ® Inc. offers both field and process instruments with RDO technology. The Aqua TROLL 400 Multiparameter Instrument (Figure 8) includes a built-in RDO Sensor. The TROLL® 9500 Water Quality Instrument is also available with the RDO Sensor (Figures 6 and 7).

The RDO PRO Probe is available for process and aquaculture applications.

- The stand-alone RDO PRO Probe can be integrated directly into a SCADA/PLC system or can be used with a controller, such as the Con TROLL® PRO System (Figure 8). The probe includes open communication protocols, including Modbus/RS485, SDI-12, and 4-20 mA. This probe is used to monitor wastewater treatment processes and recirculating aquaculture systems.
- The In-Situ Aquaculture Buoy continuously monitors DO levels in fish ponds. The buoy transmits signals to a host computer. When DO levels fall below a set point, the host computer turns on aerators to increase DO levels (Figure 9).

The superior performance of RDO technology combined with the lower total cost of ownership will essentially render membrane-based probes obsolete. RDO technology maintains monitoring integrity, provides accurate data, and reduces data loss. Compared to membrane-based sensors, RDO technology is much less susceptible to sensor drift and failure. Start using breakthrough technology today. Visit www.in-situ.com.

Figure 8. Both the Aqua TROLL 400 Multiparameter Instrument and the RDO PRO Probe connect to the Con TROLL PRO System for use in wastewater treatment plants and in recirculating aquaculture systems.

Figure 9.In-Situ wireless Aquaculture Buoy for inland fish production includes the RDO PRO Probe

Figure 6. RDO Sensor for the TROLL 9500 Instrument

Figure 7. TROLL 9500 Water Quality Instrument for environmental monitoring of surface water and groundwater

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