Laser-induced photo emission detection: data acquisition based on light intensity counting

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Abstract. Laser Induced Breakdown Detection (LIBD) is one of the quantification techniques for colloids. There are two ways of detection in LIBD: optical detection and acoustic detection. LIBD is based on the detection of plasma emission due to the interaction between particle and laser beam. In this research, the changing of light intensity during plasma formations was detected by a photodiode sensor. A photo emission data acquisition system was built to collect and transform them into digital counts. The real-time system used data acquisition device National Instrument DAQ 6009 and LABVIEW software. The system has been tested on distilled water and tap water samples. The result showed 99.8% accuracy by using counting technique in comparison to the acoustic detection with sample rate of 10 Hz, thus the acquisition system can be applied as an alternative method to the existing LIBD acquisition system.

1. Introduction
Water is a very important element in all aspects of human life, such as for sanitation, drinking, animal husbandry, farming, industry and others. However, the growth of chemical industry has enhanced the water contamination possibility by chemical waste. Some technique has been developed to monitor the water quality by observing micro bacteria, contaminant, and dangerous particulates in water, such as the Photon Correlation Spectroscopy (PCS) technique. The methods could measure colloids whose sizes range between 0.001 and 3µm [1, 2] without requiring calibration. Nowadays, pollutants like pesticides, radioactive elements and viruses are present in groundwater as small colloids; thus need a more sensitive particle counter which can measure the size of particles in nanometer range to detect and prevent the possibility of poisoning [3].

In 2001, T. Bundschuh identified water content by Laser Induced Breakdown detection (LIBD) technique [4]. LIBD is a quantification technique for detecting aquatic colloids of very small sizes (10–1000 nm) at very low concentrations (in the range of 1 ng/L (ppt) to mg/L (ppm)) [4, 5]. The main principle of LIBD technique is the interaction between pulsed laser beam and colloids that causes the occurrence of Photo Acoustic Emission (PAE) from which the optical and acoustic effect in liquid can be measured [6]. Usually, LIBD technique uses CCD camera for image sensor [5, 8] or piezoelectric as a shockwave sensor [7] and they are supported by high speed data acquisition devices. In this paper, we offer a new alternative method for developing a real time data acquisition system to measure the change of the intensity which is caused by plasma formation in the water sample for LIBD application.
2. Methods
During LIBD experiment, the interaction between high energy pulsed laser and small-sized colloids can be analyzed to determine the size of colloids. Such interaction results in a breakdown phenomenon from which the transformation of plasma and shockwave can be observed to measure the size of the particle. When the laser energy interacts with the colloidal, first, one atom was ionized by Multiphoton Ionization (MPI). As the result, emerging electrons are subsequently accelerated due to inverse bremsstrahlung in the electric field of high power pulsed laser. When the energy is high enough, other atoms are ionized and the number of electrons release in double number or more. This phenomenon occurs repeatedly and increases the density of the free charge carriers; hence the plasma emission can be obtained. This plasma formation is called breakdown event [8, 9]. Detail experiment set up can be seen in figure 1.

![Figure 1. Schematic experimental characterization of nanomaterials in solution using LIBD techniques.](image)

The experiment was conducted by using high energy pulsed Nd:YAG (Neodymium-doped Yttrium Aluminum Garnet) laser with wavelength of 532 nm and pulse frequency of 10 Hz as shown in figure 1. The laser beam was focused into a cuvette, with sample inside, for 10 seconds (1000 pulses). Interaction between laser beam and nanoparticles in the water generated breakdown events in the form of plasma emissions. Enhancement of light intensity was also noticed. The Breakdown Probability (BDP) in this experiment corresponded to the probability of finding plasma within certain laser energy. BDP corresponded to the concentrations of colloids and the size of nanoparticles [9, 10] and the formula was defined as follow:

$$ BDP = \frac{\text{Counting number of breakdown}}{\text{Total number of laser shots}} $$

(1)

![Figure 2. Schematic program photo-counting detection by LABVIEW.](image)
Photodetector captured the optical signal when breakdown event occurred. The light intensity was rising at the moment the plasma occurred and the data acquisition counted it as an analog signal. By using National Instrument device NI DAQ USB-6009 and LABVIEW software, the analog data was converted to a digital signal processed by PC. In this experiment, we built the digital counting program for data acquisition system. The schematic program can be seen in figure 2.

The conversion of analog signal into digital signal by LABVIEW software and NI DAQ 6009 proceeded as following. When voltage increased, which was caused by the change of intensity, the digital signal also increased and reached the peak signal. When the peak reached above the threshold voltage, the signal was counted and saved into PC for every 0.5 second as shown in figure 2. We assumed that each peak signal corresponded to the plasma emission when breakdown occurred.

3. Result and discussion

To check the reliability of the data acquisition system, first, an experiment has been set up to verify its accuracy and stability. The characterization was performed in the dark room and the condition was controlled to resemble LIBD system with 10 Hz light pulse.

![Figure 3. Data acquisition system accuracy for pulsed light with frequency of 1-250 Hz.](image1.png)

![Figure 4. Data acquisition system stability for pulsed light with frequency of 10 Hz.](image2.png)

The accuracy of data acquisition system and sensor has been tested by using pulsed light with frequency of 1-250 Hz. As shown in figure 3, the data slope of sensor and data acquisition accuracy is 0.86. The counting stability of data acquisition system using 10 Hz pulsed light was 9.88±0.1 Hz for one hour acquisition, as shown in figure 4. The accuracy and stability were good enough to apply this method into LIBD system. By using schematic in figure 1, we obtained the result application of data acquisition system as shown in figure 5 and figure 6. For the samples, tap water and polystyrene colloids (20 nm) were used as random samples to measure the size of nanoparticles and filtered water were used as control sample (table 1).

| Sample            | Threshold Energy (mJ) | Max. BDP at Energy 4.5 mJ |
|-------------------|-----------------------|----------------------------|
| Filtered water    | 1.5                   | 0.9                        |
| Tap water         | 0.5                   | 1.1                        |
| Polystyrene 20nm  | <0.5                  | 1.25                       |
Photodiode responded the increasing intensity when the breakdown occurred and sent the analog signal to ADC in DAQ. The increasing of light intensity as an analog signal was converted into digital signal and read as a peak signal when it was much higher than threshold signal. Then it would be measured as a digital counting as shown in figure 5 and 6. In the condition where there was no breakdown occurred, the peak was not higher than the threshold signal, so the digital count was zero. Voltage background corresponded to the condition of light environment. To ensure that the data acquisition system and sensor could perform well, the experiment of the LIBD data processing based on the light intensity was conducted. The laser frequency was 10 Hz, the number of laser pulses was set to 1000, and the duration of each measurement was 100 seconds. Hence, the range of the signal could be processed for the three samples: tap water, filtered water and 20 nm polystyrene. The final results of data processing in the form of breakdown probability for each variation of pulsed laser energy up to 4.5 mJ can be seen in figure 7.

**Figure 5.** (a) Breakdown occurred. (b) No breakdown occurred. **Figure 6.** Front panel of LABVIEW program for counting breakdown.

**Figure 7.** Validation of system data acquisition and sensor in LIBD application.
As seen in figure 7, filtered water had highest breakdown threshold value (when BDP was 0.01) among all samples, followed by colloids in tap water and 20 nm polystyrene, which agreed with the literature [4, 8]. It means that the greater the size of the colloid, the smaller the energy needed to generate breakdown. Colloids in tap water are natural colloids, which generally has average size below 100 nm [11]. As seen in table 1, by using data acquisition and sensor based on light intensity counting, the breakdown probability of 20 nm polystyrene nanoparticle at 4.5 mJ was higher than tap water or filtered water. Therefore, it can be deducted that the size of the tap water colloids are smaller than 20 nm. From table 1 and figure 7, we can also see that the BDP for polystyrene particles or colloids with greater size has BDP more than 1. It happened as the multiple breakdowns occurred or light decay took place in such a long time with intensity higher than the threshold voltage, therefore causing the photodiode to detect it as multiple counting.

4. Conclusion
The data acquisition based on light intensity counting has been built for LIBD application using LABVIEW, DAQ USB NI-6009 and photodiode as the sensor. The light intensity rose as the result of breakdown generation, and then it was counted by photodiode as a digital signal. The frequency characterization gave a slope of 0.86 and counting stability of data acquisition system by 10 Hz pulsed light returned a value of 9.88 ± 0.1 Hz. The counting of breakdown corresponded to the BDP from each sample. From the experiment, it was proven that the size of 20 nm polystyrene colloids was larger than colloids in filtered water. The data acquisition system and the sensor for LIBD application based on light intensity counting can be applied as an alternative technique to the existing LIBD acquisition system.

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