# Design and Implementation of a Measurement System for Ultra-Weak Bioluminescence Detection From *E. coli* Cultures Applied to Sanitary Control

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*Abstract*— **Ultra-weak photon emission (UWPE) detection and measurement from biological samples is a promising tool with potential use in several fields such as agriculture, environmental science, food science and biomedicine. An instrumentation based on a photomultiplier module (PMT) is presented, and its performance in terms of dark-noise and bacteria detection was evaluated in order to assure that it is able to feasibly realize UWPE measurements applied to sanitary control. The UWPE counter relies on a dark-chamber and a PMT. The PMT window is placed in the center of the chamber, sight above a Petri's dish that contains the biological sample. under measurement rests. The PMT is cooled down to 10°C to minimize the dark-counts. At 10°C the dark-count is around 17 counts/s, which is feasible for *E. coli* detection.**

## I. Introduction

UWPE is a relevant research topic, since it can be applied in agriculture, environmental and food sciences. Also, it has a growing application in biomedicine [1].

UWPE is presented in all biological processes, and it only ceases after death. It has a spectrum ranging from 350 to 850 nm, and its intensities varies from tens to thousands photons.cm$^{-2}$.s$^{-1}$, or from $10^{-20}$ to $10^{-15}$ W.cm$^{-2}$ [1, 2].

The UWPE can be divided in spontaneous and stimulated emission or delayed luminescence (DL). DL is produced after stimulating a biological sample with some kind of physical or chemical stress, or even with a light source. Its response is quite distinct among biological samples and from living and non-living samples, as demonstrated by Zeiger in [3]. While spontaneous emission presents intensities from tens to hundreds photons.cm$^{-2}$.s$^{-1}$, or from $10^{-20}$ to $10^{-17}$ W.cm$^{-2}$, the stimulated emission ranges from hundreds to thousands photons.cm$^{-2}$.s$^{-1}$, or from $10^{-17}$ to $10^{-15}$ W.cm$^{-2}$.

The UWPE phenomenon was discovered by Alexander Gavrilovitch Gurwitsch in the years 20s [2], when he theorized the existence of a kind of radiation, which he called mitogenetic radiation. Only in 1951, Strehler and Arnold, using the recently invented photomultiplier tube (PMT), and using as biological samples a kind of algae [4] positively confirmed the existence of the mitogenetic radiation. Short after, in 1954, Colli and Facchini made the first UWPE measurements from seedlings using a PMT [5, 6].

Since then, many groups studied the UWPE correlation between the development capability and germination rate of different seeds: barley [7], rice [8], soya [9]. In addition, a general patent was registered in 2001 [10].

In the case of microorganisms, the UWPE from *Escherichia coli* [11, 12, 13, 14, 15], *Lactococcus lactis lactis* [14, 15], *Serratia mercescens, Enterococcus faecalis, Lactobacillus plantarum*, *Proteus vulgaris, Deinococcus radiodurans, Vibrio fisheri* [15], were also studied. Others studies are related to microorganism defense mechanisms, and the source of light emission [16].

The most accepted theory about biophotons origin points to the cellular structures and their metabolism, where oxidative stress with formation of reactive oxygen species (ROS) takes place [17].

The central component of a UWPE/DL counter is the PMT module, capable to operate in photon-counting mode, and must have a low dark-count noise [18].

UWPE experiments demand specific photon-counting systems, sometimes suitable for each specific application. For instance, Tudisco *et al* performed optical biopsy of human cells using DL with very short time from light excitation to starting photon counting. A specific electronic control that

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