Coherence Monitor - Searching for the Light of Life

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Abstract

A quasi real-time detection system to monitor biological samples or cells exposed to physico-chemical stressors has been designed and built in a first version. The detection principle is based on the release of electromagnetic emissions (photon flux) originating from live biotic structures that are below the threshold of human perception (Fig.1).

Methods

The detector essentially consists of a highly sensitive Photo Multiplier tube (PMT) that has been tied up with essential peripherals for applications in the bio-medical field (Fig.2). Doing so required the implementation of temperature and humidity sensors, a Peltier-operated sample holder, electro-mechanical shutters, broad- and narrow-band illumination sources and a band-pass filter for selecting specific wavelengths.[1] Six measurement modes are highlighted in Fig.3, whereby these are split into two major groups, which regard the detection of spontaneous (left column) and the delayed (centremost and right column) emission of a sample.

Results

In a first series of test trials it was possible to document responses of:
i) a terrestrial symbiont organism (lichen) to diesel exhaust particles (Fig.5),
ii) a marine inverterbrate undergoing temperature stress (Fig.7),
iii) emission patterns of selected oocytes (unfertilized chicken eggs, Fig. 4),
iv) various cell lines – A431 (epidermoid carcinoma-), A549 (human alveolar basal epithelial-), HaCat (human keratinocyte) and HeLa (cervical cancer-cells) – under-going medium change and TNF-α exposure in various concentrations. The results of A431 are shown in Fig.6 an example.[2]

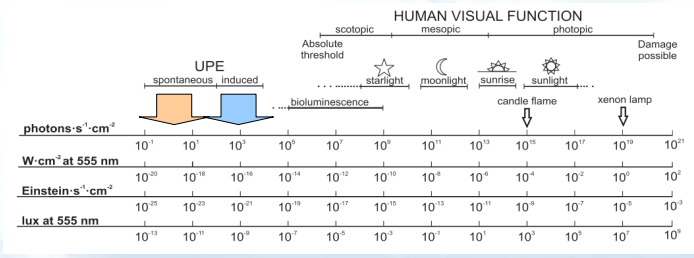


Fig. 1: Radiometric and photometric units comparing ultra-weak photon emission intensity with that of common light phenomena.

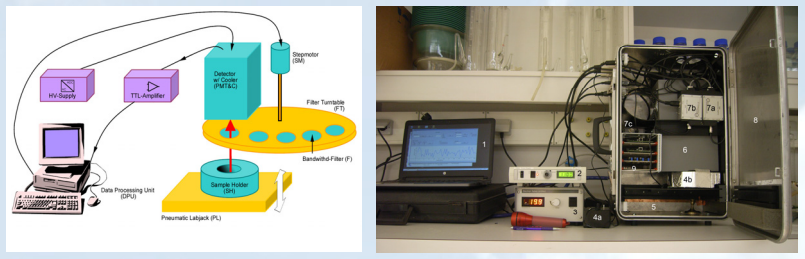


Fig. 2: Schematics (left) and actual pre-prototype of the CM (right). 1) data processing unit; 2) HV Power Supply; 3) PE-Power Supply; 4a) shutter control unit; 4b) high speed electromechanical shutter; 5) dark chamber compartment; 6) PMT-housing with detector and quartz window; 7a) signal amplifier; 7b) signal discriminator; 7c) TTL signal converter; 8) photon-proof aluminium lid cover; 9) electronics for induced illumination sources, thermostatisation via a PE unit in dark chamber & data interfaces to computer.

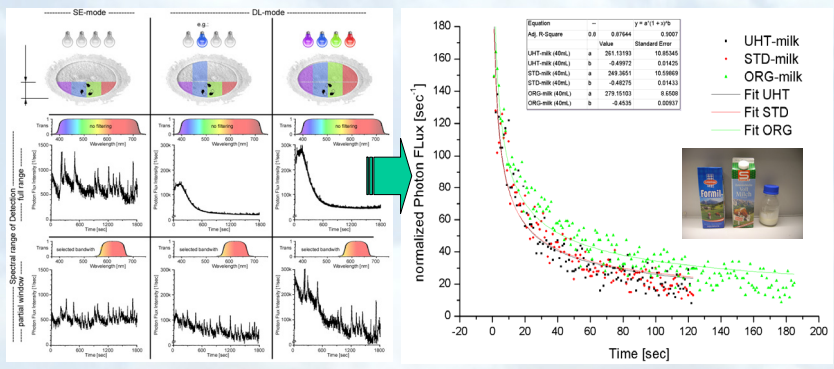


Fig. 3: Left pane - Measurement without prior stimulation enables recording of intrinsic = spontaneous emissions (SE-mode), whereas activation with a light source prior to measurement enables recording of photon charging properties = delayed luminescence (DL-mode) and can be done using mono- or polychromatic excitation sources.
Right pane – DL-modes of UHT, Standard (STD) & organic (ORG) milk samples; the organic sample strikes by an extended photon "storage" capacity.

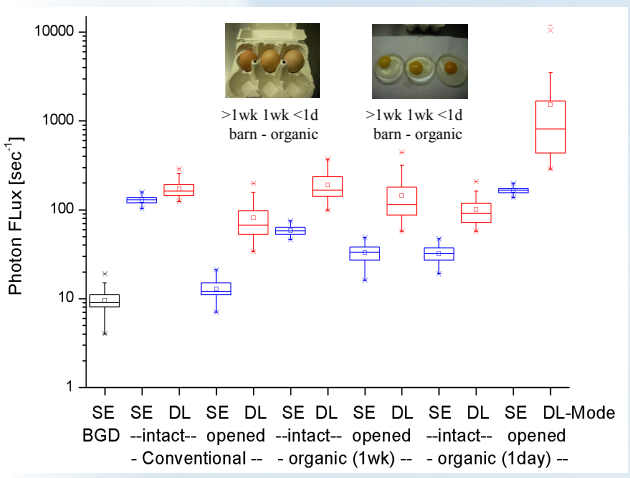


Fig. 4: - Inter-comparison of three kinds of **oocytes** - barn eggs (conventional), vs. free range husbandry (organic 1day old and 1 week old). Samples have been monitored with eggshells intact and eggshells removed. Extreme high photon flux yield was obtained from the organic 1 day old sample, indicating that this method can be used to indicate the level of freshness.

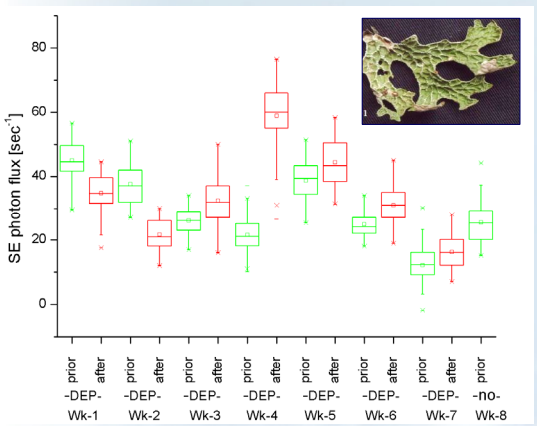


Fig. 5: SE-mode photon flux patterns of ***Lobaria*** exposed to diesel exhaust aerosol (DEP). Week 1&2 used 15L Tedlar bags filled with DEP, whereas Week 3-7 used 30LDEP-filled Tedlar bags.

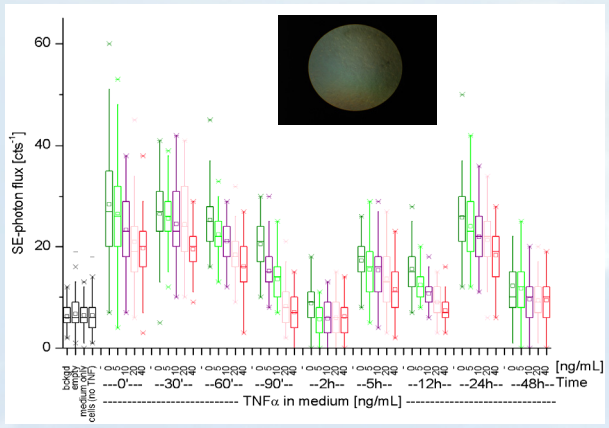


Fig. 6: SE-mode timeseries of photon flux densities obtained from A431 undergoing medium change and experiencing various concentrations of TNFα. While medium change induces the most intense photon flux a chronobiological pattern becomes evident over time

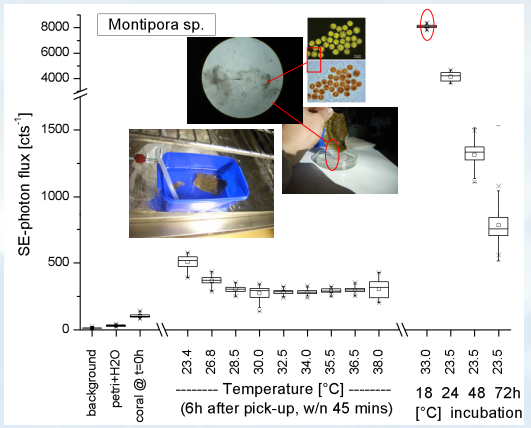
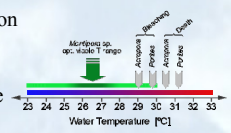


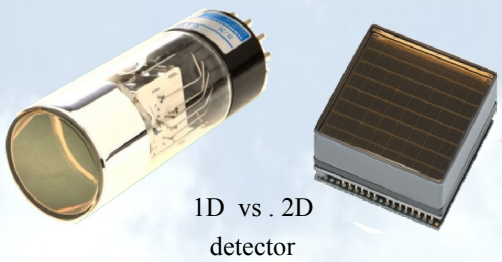
Fig. 7: Monitoring SE-mode photon flux of the coral ***Montipora*** sp. undergoing temperature stress. Excess flux below and above the optimal temperature range



Outlook

In order to provide the most flexibility of this tool, the current upgrading by implementing a tailor-made software-solution (LabView©) into the existing hardware, will further improve and enable operation of all six measurements= modes (as highlighted in Fig.3). In its final version it is intended to use this tool in the field of ontogenesis/morphogenesis (e.g. photon flux density in developmental biology), to study cell metabolism (photon flux variations in tumor vs. normal cells), to determine dose-effect relations in pharmacology as well as toxicology (photon spikes in response to chemical agents), investigate fractal properties in ecosystems (bio-communication) and eventually for the elaboration of novel parameters in food quality (organic vs. conventionally grown produce).

After completion of prototype-I a follow-up prototype-II is planned that extends the detector resolution from 1D to 2D. As the current photon-converting cathode acts as a 1-pixel detector with a circular aperture of 52 mm (1D), the 2D-model will feature a flat-panel type with an 8x8 detector matrix (64 pixel) measuring in total 52x52 mm. The shift from 1D to 2D will add spatial resolution to the existing time-serial recording. The 2D-detector will reveal photon flux-hotspots that are particularly useful in order to document i) events of bio-communication and ii) to identify sites that experience increased stress and how this stress-information propagates across cell cultures (in-vitro), or across modular organisms (lower invertebrates).



1D vs . 2D detector

Acknowledgements

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References

[1] Madl P. (2014) Detection and measurement of biogenic ultra-weak photon emission. in: Fels, D. Cifra M. Scholkmann F (eds) Field of the Cells (2015): 55-70.
[2] Madl P, Geppert M. Verwanger T (2016) Oscillations of ultra-weak photon emission from cancer and non-cancer cells stressed by culture medium change and TNF-α: dose and cell-type dependence – submitted to European Journal of Biophysics.