Single Photon Time Resolved Detection of Singlet Oxygen for In Vivo Monitoring of Photodynamic Therapy

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Detection of singlet oxygen ($^1O_2$) luminescence at 1270 nm provides a direct probe of the photochemical processes underlying photodynamic therapy (PDT). However, the extremely weak emission intensity and microsecond-scale lifetime of $^1O_2$ make its measurement in biological environments technically challenging, requiring advanced single-photon detection techniques. In this work, we present a portable time-resolved singlet oxygen luminescence detection (TSOLD) system based on single-photon counting for real-time monitoring of PDT [1-3]. The system combines a 690 nm nanosecond pulsed diode laser with a bifurcated fiber-optic probe that enables simultaneous optical excitation and near-infrared luminescence collection from the target tissue. The emitted signal is spectrally filtered around 1270 nm and detected using an InGaAs single-photon avalanche diode (SPAD), while photon arrival times are recorded through time-correlated single-photon counting electronics. The performance of the system was first validated in liquid phantoms containing benzoporphyrin derivative (BPD), where singlet oxygen luminescence and associated triplet-state dynamics were successfully resolved. The platform was subsequently applied to tumor-bearing mice to investigate BPD uptake and singlet oxygen generation in vivo. Time-resolved measurements revealed clear $^1O_2$ luminescence signals following BPD administration and enabled monitoring of changes before and after PDT illumination. These results demonstrate the practical realization of a compact single-photon detection system for real-time monitoring of photochemical processes in living tissue and highlight the relevance of this technology platform for improving PDT dosimetry and treatment monitoring.

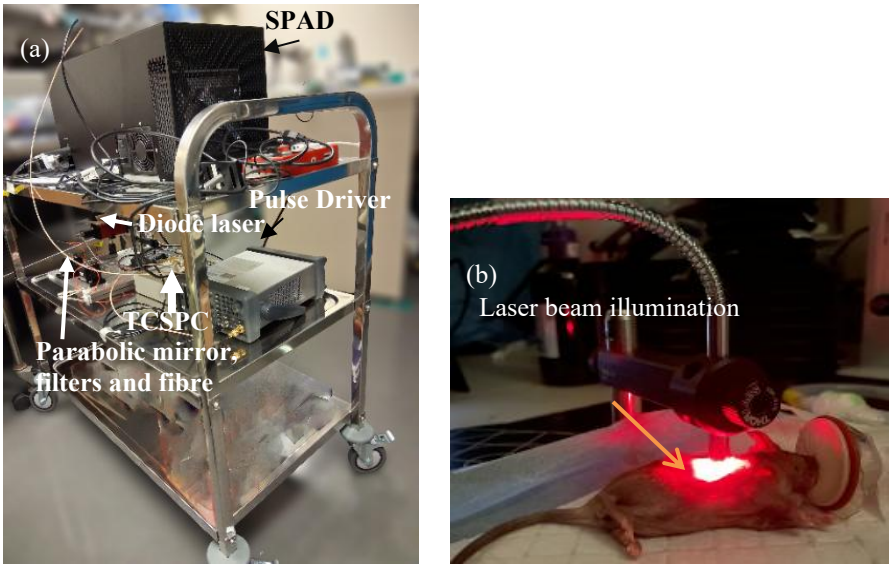

Fig. 1: ***(a)*** *Portable TSOLD instrument for in vivo $^1O_2$ detection and* ***(b)*** *690 nm laser illumination at the tumour site, during TSOLD measurement* [1].

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References
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[2] V. Vikas, et. al., *Antioxidant* (2025), 14(2): p. 176.

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