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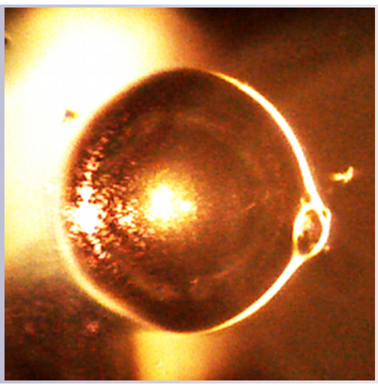
Biological Cell Resonators



by

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A thesis submitted to the degree of Doctor of Philosophy

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Faculty of Sciences
School of Physical Sciences

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Declaration of Authorship

I, Jonathan Michael MacGillivray Hall, certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

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Abstract

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Modern sensing technologies developed within the field of photonics incorporate a number of optical and acoustic phenomena. One such effect that has become a focal point in biosensing is *whispering gallery modes*. These modes occur within optical cavities that exhibit a degree of symmetry, and are thus able to support resonating waves. This thesis develops the theory of resonances, exploring under what conditions a micro or nanoscale device can sustain these resonances, and for which physical criteria the resonance conditions deteriorate. The study is then extended to consider the biological cell. The discovery of a biological cell resonator, in which modes are definitively sustained without artificial assistance, represents the culmination of this thesis.

The properties of resonators and their emitted energy spectra are studied within the general framework of the Finite Difference Time Domain method, requiring supercomputing resources to probe the transient behaviour and interactions among the electromagnetic fields. The formal theory of Mie scattering is extended to develop a cutting-edge, computationally efficient model for general, multilayer microspheres, which represents a valuable achievement for the scientific community in its own right. The model unifies the approaches in the field of mathematical modelling to express the energy spectrum in a single encompassing equation, which is then applied in a range of contexts.

The gulf between modelling and biological resonators is bridged by an in-depth study of the physical characteristics of a range of biological cells, and the selection criteria for viable resonator candidates are developed through a number of detailed feasibility studies. The bovine embryo is consequently selected as the optimal choice.

The scientific advancements contained within each chapter, including the improved models, the selection criteria and the experimental techniques developed, are integrated together to perform the principal measurements of the spectra within a biological cell. Evidence is established for the ability of a bovine embryo to sustain whispering gallery modes. This is a significant finding covering extensive research ground, since it is the first such measurement world-wide. The ability of a cell to sustain modes on its own represents a conceptually elegant paradigm for new technologies involving on-site cell interrogation and reporting of the status and health of a biological cell in the future. The methodological and technological developments contained within this interdisciplinary thesis thus become a vital asset for the future realisation of autonomous biological cell sensors.

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