Dear reader,

This thesis consists of two parts; an introductory part and a focused, scientific part. The scope of the described research is on methods and strategies which can be utilised for Raman spectroscopic detection of life signatures in planetary exploration. Measurements have been executed with large laser setups situated on heavy optical tables and with high power consumptions to develop a Raman based analytical method. Ongoing technological developments are continually reducing instrumental size and power consumption and we anticipate that continued developments will enable their use in planetary exploration.

Chapter 1 introduces the context of the research and the theory of Raman spectroscopy (RS). The interaction between light and matter is discussed with a focus on inelastic scattering of light by matter. The theory behind resonance RS (RRS) and the competing process of fluorescence are explained. Chapter 1 will also elaborate on Raman spectroscopy in planetary exploration to put this research in perspective. For this purpose an overview of Raman spectroscopic research of minerals, microorganisms and biomarkers for life is included.

The reason to focus on RS is that it can potentially be an important tool in planetary exploration since organic, biological and mineralogical features can be extracted from a Raman spectrum without destroying or pre-treating the sample. Chapter 2 describes various Raman spectroscopic modes with an emphasis on planetary sciences: ultra violet RS (UVRS) and time resolved RS (TRRS) with fast detectors like intensified charge-coupled device (ICCD) cameras for the suppression of the fluorescent background in Raman spectra. An explanation is given of how spatially offset RS (SORS) and TRRS can be used to distinguish different layers in translucent or transparent samples. The use of remote RS to record Raman spectra from distant samples up to tens to hundreds of metres is discussed. The second part of this chapter describes the technological possibilities of different RS configurations and the setups used in LaserLaB Amsterdam.

The next chapters form the focused part of this thesis. Each of the individual chapters are peer-reviewed articles, or comprise work that is still in preparation for publication.

Chapter 3 describes TRRS, SORS and conventional Raman microscopy for the depth analysis of multi-layered mineral samples. Various combinations of mineral samples were used to explore the possibilities and challenges to optimize detection of different mineral layers.
Chapter 4 explains RS to the non-expert in the field of planetary sciences. The appropriateness of gated detection in TRRS compared to non-gated detection in conventional RS is presented and the first step towards the quantification of a Raman signal from a carotenoid bearing microorganism is shown.

Chapter 5 elaborates on quantification of carotenoids in microorganisms and on more fundamental problems concerning the detection of carotenoids under resonance conditions: self-absorption and photodegradation.

Chapter 6 describes the final stage of the research: different Raman spectroscopic techniques for the detection of microorganisms behind mineral layers.

It will become clear from these chapters that Raman spectroscopy has a distinct potential for planetary exploration and one of the tools that can be used in the search for life on other bodies in our solar system. Ongoing miniaturization of electronic and optical compounds will help in the transition from equipment in the academic research environment to an instrument deployed on, for example, a Mars rover.

Take the following personal note into account when reading this thesis: My dissertation reflects my intrinsic fascination for science and technology. It is the grand finale of a four-year time period of academic research applied in the field of space exploration wherein I was able to push the boundaries of human knowledge just a little bit further, and I loved it!

Enjoy reading,

Jan-Hein