

# PhD THESIS DEFENSE: Imaging Cytometry Technology for Environmental and Biomedical Applications

JUAN MIGUEL PEREZ ROSAS

July 28, 2020

11:00

ICFO Auditorium and Online (Teams)

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PhD Thesis Defense, July 28, 2020, 11:00. ICFO Auditorium - MsTeams

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Early detection of microorganisms in environmental and biomedical applications is critical for the effective response to potential pathogenic treats. Most traditional methods and instrumentation for the analysis of these samples are becoming obsolete due to the fact that they are time-consuming and have long response times. Modern solutions are limited to

high-end centralized facilities and specialized trained personnel, given their high-cost and complexity. There is thus a clear need to develop and introduce low-cost, easy to use, high-performance devices capable of rapidly identifying and quantifying pathogenic microorganisms in environmental and biomedical samples. The work behind this thesis was devoted to the design, development and validation in relevant industrial environments of two image cytometry devices capable of characterizing biological and industrial samples in terms of their microorganism content. Bringing a potentially high-impact solution to the current industry need.

The first technology, defined within the context of this thesis as Fourier image cytometry, is an optical device capable of increasing the sample volume tested when compared to traditional state-of-the-art counterparts. By evaluating the sample in the Fourier domain, the device is capable of measuring characteristics of particulate within a sample volume larger than other imaging systems. The result is an enhancement of both field of view (FOV) and depth of field (DOF) of the target sample. Furthermore, the implementation of the Fourier image cytometer in this thesis is a portable and compact device comprising of low-cost optics and electronics. The design of the entire device was performed with the objective to minimize the cost and maximize the capabilities. This was possible mainly due to the recent advances in image sensor technologies that simplify the device's optics. In our Fourier imaging cytometry, LED light sources and conventional achromatic optical lenses are at the basis of device's optics as opposed to high-end lasers or optical microscopes. For the detection scheme, a CMOS image sensor was used.

After optimizing the prototype and going through rigorous validation in a laboratory, the Fourier image cytometry introduced in this thesis was validated in two relevant industrial environments. The device was tested using real environmental samples. In the first industrial validation, it was used for the microorganism's identification and quantification in water coming from cooling towers. The second industrial validation used a further optimized implementation of the cytometer to analyze fresh and marine waters for their microorganism population, specifically phytoplankton within the context of ballast water and ballast water treatment systems.

The second image cytometry designed, developed and implemented within the scope of this thesis, focused on detection of microorganisms spread over surfaces. Following the motivation for low-cost compact devices, a Surface cytometer was designed. The Surface cytometer is an optical device capable of quantifying bacterial population over a surface of over 300 mm<sup>2</sup>. The device was completely autonomous thanks to the integration of a single-board computer within its design. The light source and detection scheme continued to be LED source and CMOS sensor detection. Similarly to the validation process of the Fourier

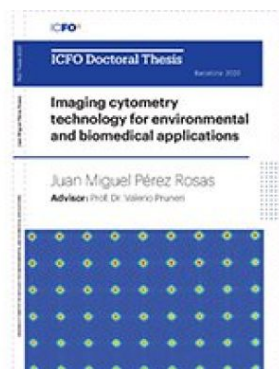
cytometer, the Surface cytometer was tested in controlled samples in a laboratory environment, before it was put to test on a biomedical application for bacterial growth monitoring and compared to standard devices of measurement of optical density, used today in the industry.

In summary, in this thesis we present two novel image cytometers and three clear industrial applications in which the devices were validated. This clearly indicates the potential of image cytometry as an effective low cost and portable tool for the analysis of microorganisms in the environmental and biomedical sector

**Tuesday, July 28, 2020, 11:00. ICFO Auditorium - MsTeams**

**Thesis Advisor: Prof Dr Valerio Pruneri**

**Hosted by: Valerio Pruneri**



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