

PhD THESIS DEFENSE: Detection of particles, bacteria and viruses using consumer optoelectronic components

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The focus of this thesis is on the design, development and validation of two novel photonic sensors for the detection and characterisation of industrial and biological samples. The first one is a PSA in a collimated beam configuration using an innovative angular spatial filter, and a consumer electronic camera similar to that used in a smartphone. The small form factor angular spatial filter allows for the collection of diffused light from particles up to predefined discrete angles. By using angularly resolved scattering images acquired by the camera, a machine learning (ML) algorithm predicts the volume median diameter of the particles. Our system has achieved a mean absolute percentage error of only 0.72% for spherical particles in solution with sizes greater than 10 m and at concentrations up to 40 mg mL-1. Compare to traditional laser diffraction systems, the proposed PSA is an order of magnitude smaller i

size, weight and cost, and offers a promising approach to online industrial proces monitoring

As light scattering is influenced by factors other than particle size, including shape, refractiv index contrast and suspension concentration, the PSA can also be employed in biologica applications. To this end, the second part of the thesis aims to optimise the PSA for th measurement of small (< 10 m) particles such as microorganisms. The results demonstra e that the modified PSA in combination with ML is able to accurately classify different types f bacteria (Escherichia coli and Enterococcus sp.) and distinguish them from silica beads f comparable sizes, with an accuracy of 89%. Moreover, it can detect the concentration f bacteria in water with a limit of detection (LOD) of approximately 105 cells mL- . The final part of the thesis is dedicated to the development of a low-cost, portable optic l biosensor for the specific detection of particles smaller than bacteria, such as viruses (< 1 m). The proposed system, which we have called flow virometry reader (FVR), i a modification of a flow cytometer and relies on measuring light emissions from fluoresc nt antibodies that bind to specific viral particles. An LOD of 3,834 copies mL-1 for SARS-Co -2 in saliva can be achieved with the device. The FVR is clinically validated using 54 sal va samples in a blind test, with high sensitivity and specificity of 91.2% and 90%, respective y. These findings suggest that the FVR has the potential to be a highly viable alternative to current diagnostic methods for pandemic events, as it is faster (< 30 min) and less expens ve than PCR tests, while being more sensitive than today's COVID-19 rapid antigen tes s. The photonic sensing technologies developed in the thesis show significant potential for se in a wide range of applications, includi

particulate air pollution, causing cardiovascular and respiratory problems
particulate water pollution, which affects the ecosystems of rivers, lakes and oceans
total bacterial count in environmental or bathing water
viral pandemics

The technologies are particularly appealing in countries with limited resources due to their simple design, portability, short time-to-result and affordability, as well as the fact that the do not require a specialised laboratory or trained personnel to operate them.

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