NEW OPTICAL TECHNOLOGIES IN INTA FOR PLANETARY EXPLORATION

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Abstract

Recent advances in microfluidics systems have allowed the inclusion of complex biological and chemical analysis techniques in small physical dimensions, which has been called "lab-on-a-chip". These highly miniaturized systems must be able to incorporate sophisticated and very diverse optical techniques for the analysis of organic substances that allow the detection and identification of microorganisms and biochemical compounds through the “in situ” analysis of solid residues presents in soils, ice or fluids of liquid samples compatible with the lifetime. Raman spectroscopy, fluorescence spectroscopy, fiber optic sensors or holographic digital microscopy (DHMI) are techniques that seem very appropriate for this type of devices but that must be conceived in a very compact and versatile way for that they can be used in future planetary exploration missions.

In this sense, INTA is exploring and developing, at the laboratory level, novel optical systems that will allow their future inclusion as active sensors in the new range of optical instrumentation for planetary exploration of high performance and small size.

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1. Introduction

INTA is the Public Research Organization (OPI) specialized in aerospace research and technology development since 1942, among its main functions are the acquisition, maintenance and continuous improvement of all those technologies that can be applied to the aerospace field. INTA participates in nano-satellite and mini-satellite programs and in R & D activities in the field of small satellites from 20 kg to 150 kg or in scientific payloads of interest in national space missions. One of the most important fields in which INTA works is the development of new optical instrumentation compatible with the harsh conditions that are required to address future missions related to planetary exploration. The instrumentation that must be incorporated into these systems must allow to detect the biochemical structures that are related to evidence of life on extra-terrestrial planets (life detection). For this purpose, a set of complementary analytical techniques must be integrated in a unique instrument. In order to perform that best strategy is to detect the geo-biochemical parameters in liquid solutions or suspensions.

Building a prototype to test and verify the functionality required for a compact and versatile instrument for planetary exploration will allow INTA to lead the next ESA missions in this field. To achieve this, it is necessary to increase the TRL level of mainly: some of the critical optical elements or those analytical techniques necessary for planetary exploration. To mitigate the risk of its use in space, INTA has decided to promote some of the most critical optical elements with the development of several concrete initiatives, as will be shown in the following paragraphs.

2. The new concept Lab-on a Chip

A lab-on-a-chip (LOC) is a device that integrates one or more laboratory functions in a single integrated circuit (commonly called a "chip") from only millimetres to a few square centimetres to achieve high performance detection and automation, this LOCs can handle extremely small fluid volumes that should be analysed by using a new generation of optical instrumentation.

LOC [1] can provide several advantages, which are specified in their applications. Some typical advantages are: consumption of small quantities of fluids (less expense, lower cost of materials and less volume per sample for diagnosis). They can produce very fast analysis and response times due to short diffusion distances, rapid heating, greater surface area compared to volume, small heating capacities. The LOC, in general, produce compact systems, due to the integration of several functionalities in small volumes. One of the most important advantages for creating new space devices are the compact size, which allows high performance analysis and lower manufacturing costs.

3. Raman Laser Spectroscopy for optical sensing.

This method is a non-contact and non-destructive spectrometric technique that apart from its powerful analytical capacity to detect biomarkers allows easy integration into optical systems. Recent advances in microfluidic systems promise efficient approaches to miniaturize and integrate various chemical processes involved in biological analysis and chemical engineering. These advances have led to the development of new systems or laboratory devices in a LOC to analyze traces of organic substances. In such miniaturized systems, the interfacial phenomena have a remarkable effect on the liquid flow structure and on the chemical properties due to the large surface / volume ratio considered. Using the Raman scattering of the molecules inside the microchannel pathways, it is possible to analyze the chemical content of different substances. INTA and UVa have jointly developed the ESA's Raman laser spectrometer (RLS) for the ExoMars 2020 [1], which has already been validated for space applications (TRL7). This laser, which produces a monochromatic beam of exciting photons with an irradiance of approximately 0.6-1.2 kW / cm2 in the sample, is ideal for microfluid applications (see "Fig. 1"). INTA has been leading the instrumentation required for this development.

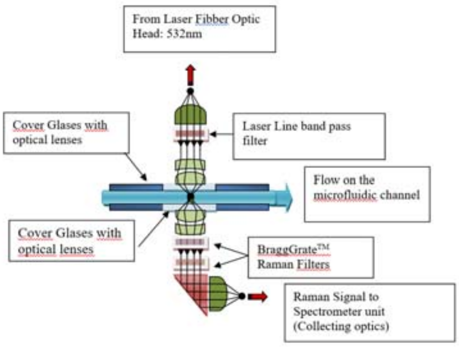

Figure 1. *Concept of a compact optical head for Raman spectroscopy on LOC.*

4. Digital holography microscopy as a new instrumentation for search of evidences of life.

Digital holography (DH) is an emerging technology for imaging applications. Although many of the remarkable properties of holography have been known for decades, their practical applications have been constrained because of the cumbersome procedures and stringent requirements on equipment. In digital holography, the holographic interference pattern is optically generated by superposition of object and reference beams, which is digitally sampled by a charge-coupled device (CCD) camera and transferred to a computer as an array of numbers.

Digital holography offers a number of significant advantages, such as the ability to acquire holograms rapidly, that can be used to elucidate the presence of microorganisms or bacteria. INTA has developed a digital microscope to explore the possibility of manufacturing a very compact systems that can be incorporated in a LOC, (see “Fig. 2”).

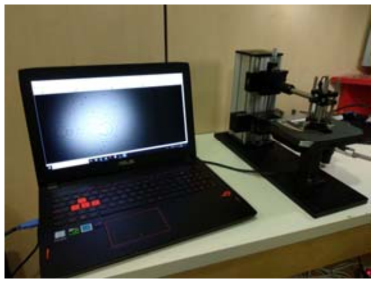

Figure 2. *Digital Holographic microscope developed at INTA*

5. Freeform optics for compact optical instrumentation

Freeform optics is a technique that is used in the development of high-quality optical systems. Conventional lenses and mirrors have a simple shape, either convex or concave, and they have their limitations. They cannot produce certain light-beam paths, so lenses and mirrors with a more complex aspherical or freeform surface are needed (see “Fig. 3”). The use of Freeform optics can reduce the size, the number of surfaces and, consequentially, the weight of payloads devoted to planetary exploration. In this sense, INTA is developing a spectrometer, based on Freeform optics, that can be easily adapted to future planetary exploration missions, (see “Fig. 3).

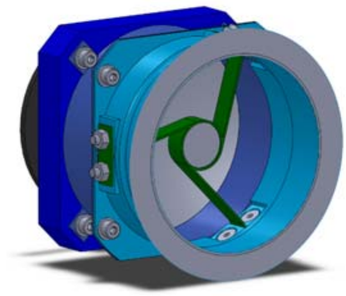

Figure 3. *Freeform optical telescope developed by INTA*

6. References

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