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DELIVERABLE

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Deliverable Name	**Sensing front-end sub-system implementation**
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Abstract (few lines):	This public report gives an overview on the work within task T5.2 up to month 16 of the PhasmaFOOD project. It is accompanied by a confidential Annex, which provides the details of the sensing modules, their setup, manufacture, assembly and test.

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Executive Summary

The PhasmaFOOD integration has been performed in terms of both software and hardware, including optomechanics, electronics and software. The integration of the hardware processing platform, storage and communication units are described in Deliverable Report D5.2. The implementation of the embedded software, mobile user interface and database platform for the PhasmaFOOD smart food analysis platform is described in Deliverable Report D5.3.

This Deliverable D5.1 relates to Task T5.2. It documents the physical realisation and implementation of all core sensing components as well as the optical and mechanical components required for the sensing sub-unit of the PhasmaFOOD device. The realisation and implementation is based on the previous design phase as described in detail in Deliverable Report D2.3 and on the specifications laid out in Deliverable Report D1.2. All single components have been manufactured, sourced and assembled together to realise the first integrated sensing front-end sub-system platform of the PhasmaFOOD device. This work is rounded off by a characterisation of the sub-assemblies in an optical laboratory.

For this, the project partners CNR and IPMS manufactured and sourced all necessary components to implement the optical design of task T2.1, accordingly with the required functions. Power consumption, spectral characteristics, hardware integration capabilities and communication interfaces were taken into account in close communication with partners WINGS, VLF and UTOV who are concerned with Task T5.1, the electronics implementation. CNR contributed to realise the VIS spectroscopy sensor with UV excitation and to integrate the VIS imaging system on the basis of the design made in T2.1. IPMS developed a dedicated MEMS-based NIR spectrometer including driving and read-out electronics to cover the restricted and tight space requirements of the PhasmaFOOD device. Furthermore, IPMS designed all mechanical hardware components to mount and house the optical and electronics components. Assembly of the optical and mechanical components were facilitated by IPMS. Here, the individual components were integrated, characterised and optimised for the PhasmaFOOD requirements.

With the finalisation of Deliverable D5.1, the key sensor elements are now available and the realisation of the sensing front-end sub-system lays the foundation for all future work towards the first PhasmaFOOD prototype and its validation and testing. The single sensor hardware units are now ready and tested to proceed to the final integration in terms of electronics and completion of the mechanical housing.

This Deliverable Report consists of a general, public document and a confidential Annex documenting the fabricated sensing sub-system prototype, including a matrix of sensing devices and test of the optical functions.

Document History			
Version	**Date**	**Contributor(s)**	**Description**
1.0	19/04/2018	IPMS	Summary of achievements in D5.1
1.1	25/04/2018	IPMS, CNR	Achievements in task T5.2
2	27/04/2018	IPMS, CNR	Completion

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Definitions, Acronyms and Abbreviations

Acronym	Title
CO	Confidential, only for members of the consortium (including Commission Services)
CR	Change Request
D	Demonstrator
DL	Deliverable Leader
DM	Dissemination Manager
DMS	Document Management System
DoA	Description of Action
Dx	Deliverable (where x defines the deliverable identification number e.g. D1.1.1)
EIM	Exploitation Innovation Manager
EU	European Union
FM	Financial Manager
MSx	project Milestone (where x defines a project milestone e.g. MS3)
Mx	Month (where x defines a project month e.g. M10)
O	Other
P	Prototype
PC	Project Coordinator
PM	partner Project Manager
PO	Project Officer
PP	Restricted to other programme participants (including the Commission Services)
PU	Public
QA	Quality Assurance
QAP	Quality Assurance Plan
QFD	Quality Function Deployment
QM	Quality Manager
R	Report
RE	Restricted to a group specified by the consortium (including Commission Services)
STM	Scientific and Technical Manager
TL	Task Leader
WP	Work Package
WPL	Work Package Leader
WPS	Work Package Structure

1 Overview

1.1 PhasmaFOOD sensing sub-system design

The PhasmaFOOD sensing device follows the modular concept presented in Deliverable Report D2.2 as shown in Figure 1.

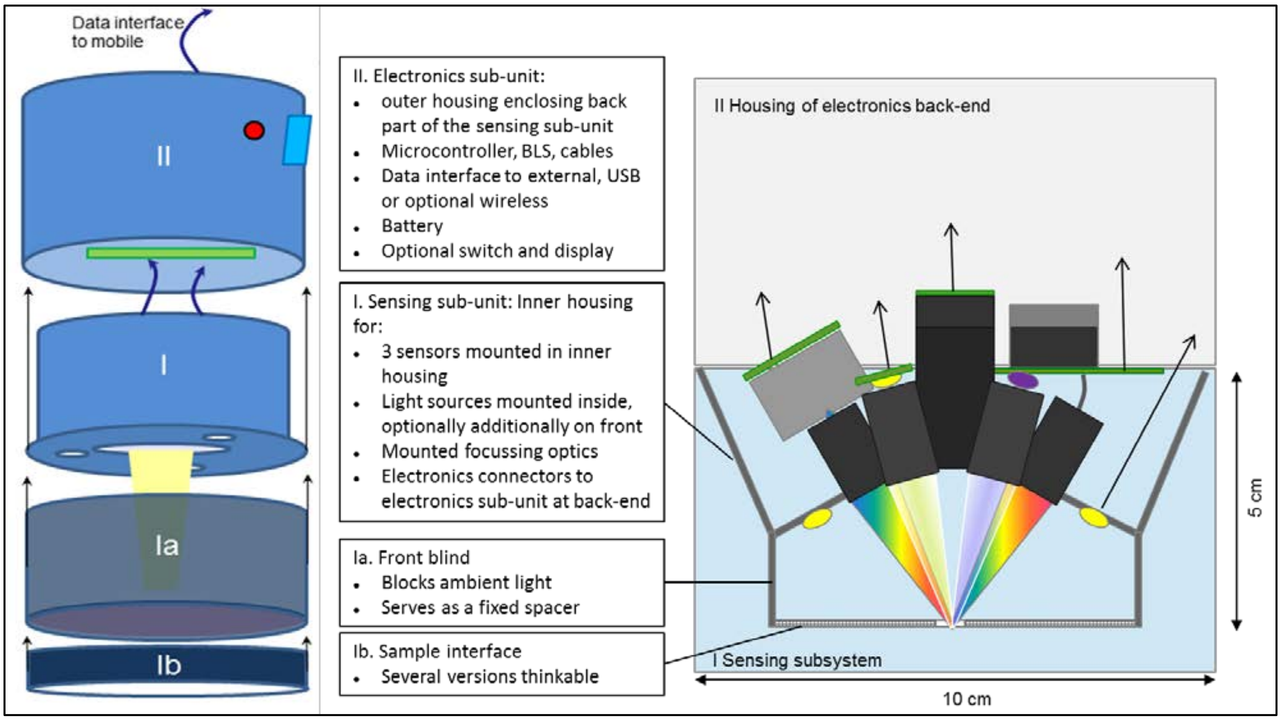

Figure 1 – Modular concept of the PhasmaFOOD sensing sub-unit and interfaces to the electronics sub-unit. Left: 3D schematic, as in Figure 1. Right: Schematic side view of the interior of the sensing sub-unit with approximate scale; Grey box – VIS spectrometer; Black box – camera; Black-grey box – NIR spectrometer; dark grey – module tubes; ellipses – light sources; green lines – driving boards; dark grey lines – housing; arrows – electrical connectors.

The device consists of two main building blocks:

I.) the **Sensing sub-unit** with all sensing components including a front blind (Ia) and a sample interface (Ib). This unit is described in the present Deliverable Report D5.1

and

II.) the **Electronics sub-unit** which is described in Deliverable Report D5.2.

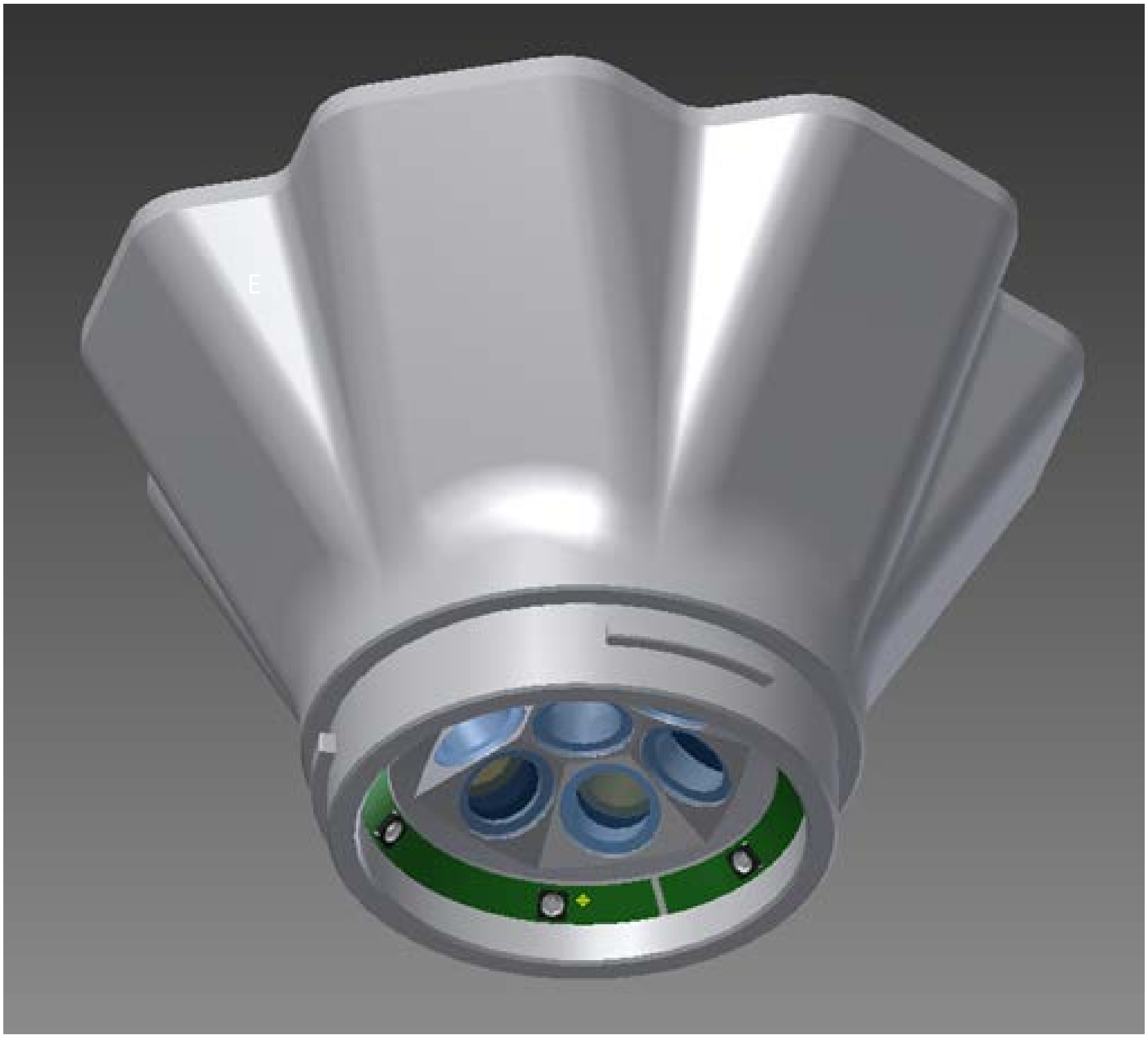

Figure 2 – Final design (first version) of the sensing front-end sub-unit. Tilted bottom view with VIS ring illumination and cylindrical ports. The sample interface can be attached to the bottom.

The **sensing sub-unit** with an inner housing includes the three sensor elements (VIS-spectrometer, NIR-spectrometer and camera), appropriate light sources for all sensor elements with mounting (for UV-excitation, VIS and NIR illumination), focussing optics with mounting and the necessary electronics connectors to the **electronics sub-unit**. In addition, the sensing sub-unit includes a front blind, which blocks ambient disturbing light from the sensors and serves as a fixed spacer between the individual sensors and the sample. This front blind is effectively used as a sample interface to ensure a proper contact of the PhasmaFOOD device with the sample. As there is a large variety of food to be investigated different sample interfaces have been taken into account.

The realised design of the sensing sub-unit is modular. It incorporates all sensors and the UV and NIR illumination as interchangeable modules into the housing of the sensing-sub-unit. Within these modules, each sensor and light source inside the housing is equipped with their input or output optics and electronical interface. The white LEDs for broadband VIS illumination are located on the sample-facing front of the housing with an electronical interface but no additional optical interface.

Within the sensing sub-unit, there are seven cylindrical ports available in total. Out of these ports, one is allocated to the Hamamatsu VIS spectrometer, another one to the IPMS NIR spectrometer and the remaining modules are dedicated to the camera and for sample illumination with UV or NIR illumination modules.

The optical design of the modules is documented in Deliverable Report D2.1 and the optomechanical design in Deliverable Report D2.3. This design of the housing enables a stable interrelation between the individual module tubes by fixing them into a single, conical mount. Thereby, the measuring spots of all sensors and the illumination spots of the light sources can be made to overlap at the sample interface in an optimal, stable and permanent way.

1.2 Interfaces to PhasmaFOOD electronic sub-system

The PhasmaFOOD sensing device is conceptualised as a single unit. The PhasmaFOOD electronic sub-unit is being developed in parallel to the sensing sub-unit. The interfaces between these sub-units are twofold: Firstly, electronical interfaces must be taken into account and, secondly, the mechanical interfaces must ensure the mechanical assembly.

Electronical interfaces concern:

1. The interface of the camera to the camera board.
2. The interface of the VIS spectrometer to the VIS spectrometer board.
3. The interface of the NIR spectrometer to the NIR spectrometer board.
4. The interface of all lighting components to the main electronics board.

Of these, the camera is commercially provided with a highly integrated board. In fact, provider Ximea is renowned for its smallest available industrial camera with a size of 15x15x9 mm including the board. The interface between camera and the main electronics board is a standardised USB connector documented in Deliverable Report D2.3.

The VIS spectrometer will be directly mounted onto a board specially developed by partner WINGS. As an interface, the Hamamatsu C12880MA spectrometer offers 10 pins, whose orientation, location and assignment was communicated to partner WINGS.

The NIR spectrometer received read-out and driver electronics from partner IPMS, who also fabricate the spectrometer itself. The interface from the read-out board to the active MEMS component of the spectrometer is achieved via micro-packaging techniques available to IPMS. The interface between the driver board and the main electronics board is again a USB connector, which uses a protocol specified in D2.3.

The NIR microlamps each require 5V DC input from the main electronics board for operation. This information was provided again in Deliverable Report D2.3.

The UV LEDs were specified in D2.3. They are purchased as SMD devices, i.e. they need to be contacted onto a small driver board prior to operation. These driver boards were designed and procured by partner IPMS and are described in the present Deliverable Report as they are part of the optomechanical implementation. Their interface to the main electronics board is a commercial socket of type Molex Part No. 53398-0271 (1.25mm Pitch PicoBlade Header, Surface Mount, Vertical, 2 Circuits).

The white LEDs were also specified in D2.3. They are also purchased as SMD devices. The driver board for the white LEDs was designed and procured by partner IPMS in adaptation to the mechanical design of the housing for the sensing sub-unit. It is documented in the present deliverable report and also connects to the electronics main board via the above Molex socket.

Mechanical interfaces are relevant for:

1. Fitting the VIS spectrometer board onto the VIS spectrometer module and into the sensing sub-unit housing. This was discussed between partners IPMS (optomechanical design) and WINGS (board design).
2. Fitting the NIR spectrometer boards onto the NIR spectrometer module and into the sensing sub-unit housing. This is internally covered by partner IPMS.
3. Designing the shape of the UV LED driver boards such as to fit onto the UV LED module. This is internally covered at IPMS.
4. Designing the white LED board such as to fit onto the front of the sensing sub-unit housing and designing a feed-through cavity inside the housing corpus for its connector. This is internally covered by IPMS.
5. Finding and detailing a concept to fit the main electronics board into a housing compatible with the sensing sub-unit. This was done in close communication between partners IPMS (mechanical design sensing sub-unit) and WINGS (board design).

1.3 Implementation procedure

This Deliverable Report describes the implementation of modules and housing of the sensing sub-unit including electronics interfaces as described above. The basis of this work (Task T5.2) was laid in the system specification (D1.2), the optical design documented in D2.1 and the optomechanical and electronics design of D2.3. From the latter, we directly proceeded to manufacture using:

- Purchase of commercial components (VIS spectrometer, VIS camera, UV LEDs, white LEDs, NIR microlamps, optical components like windows/lenses/filters/mirrors)
- Contract manufacture of board layouts and assembly (UV LED drivers, white LED driver)
- Manufacture of CAD-designed mechanical parts via CNC machines (module components such as sensor mounts, optics mounts and spacers) either by contract or at IPMS
- Contract manufacture of CAD-designed mechanical parts by 3D print (housing and sample interfaces of the sensing sub-unit)

These components were then assembled into modules and each module was tested individually in the optics laboratory at IPMS.

Furthermore, the NIR spectrometer contributed as a TRL6 component by IPMS was set up using micro-packaging techniques to assemble the MEMS components onto the read-out board, then adjusted and tested in the optics laboratory at IPMS.

2 Annex

In line with the DoA document, a confidential Annex is submitted as a separate, accompanying document. The Annex describes in detail which components were procured for which module, how they were assembled and tested.

3 Conclusion and next steps

Figure 3 – One sample holder of the sensing sub-unit with an apple.

The modules and housing of the PhasmaFOOD sensing sub-unit are assembled and successfully tested within T5.2. Within WP6 (validation), additional long-time stability tests of the modules will be carried out in order to help assess the stability and potential critical points of the PhasmaFOOD Use Case calibrations.

In parallel to T5.2, the electronics and software were developed in WP5, Tasks T5.1 and T5.3 in close communication between the partners involved. This communication will be intensified in the coming months, with partners visiting each other and carrying out joint laboratory tests. The upcoming work includes the assembly and test of these sub-assemblies: optomechanics, electronics and software, with the final goal of having the first working sensing system of the PhasmaFOOD project in in June 2018!

Partners involved in Work packages 3 and 6 eagerly await the sensing system with measurement already scheduled from July 2018.