PHOTONICS21

Template

Photonics Impact Stories

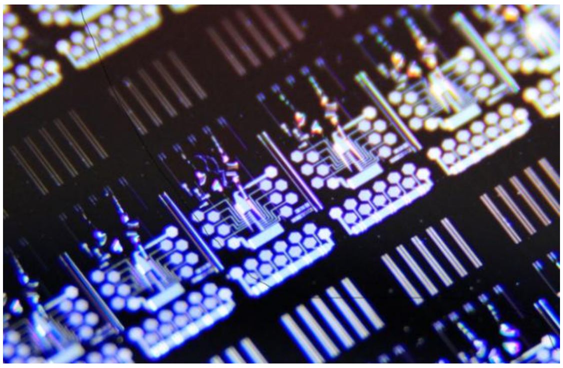
FOODSNIFFER: Light delving into our food and safeguarding our table

When the first seafarers and explorers introduced new plants from the New World into the Old Continent and when the trade of exotic spices forged the economies of empires, none could fathom that a few centuries later humankind would be able to massively transport food and produce all around the globe in a matter of hours. On the contrary, swept away by our modern trends of healthy eating, fusion cuisines that concoct culinary trends from different cultures and superfoods that can boost our performance, we almost forget that what we put daily onto our table may have originated in places located continents away. Adding to that that we also tend to forget that a large fraction of what we eat may have been produced miles away in large food processing industries using raw materials harvested miles away from these facilities. Thus, it becomes understandable why we tend to disregard the fact that foodborne diseases share the same means of transport as our food, and can reach large fractions of populations within hours several countries away from their point of origin. Shocking as they might be, food scandals, such as the *E. coli* outbreak in Europe or the aflatoxin-contaminated milk in China in 2011, are the direct result of the industrialization of agriculture and food distribution making Food Safety a major concern. The seriousness with which the Food Safety health issue is addressed in Europe is reflected in the stringent national legislations and EU directives that have been issued over recent years. At the same time, Food Safety has also become a core competency of the major market players in their competition for consumers. Still, only a one-digit percentage of our food is tested in EU, with the tests being performed by specialized public or private analytical laboratories relying on expensive equipment and highly-skilled personnel and with turn-around times that may range from a few days to a few weeks, a serious time limitation with ramifications both to public health and economic management of the European food industry. In addition, according to an alarming report of WHO/FAO report, "in most countries the surveillance infrastructure for foodborne diseases of both, microbiological or chemical etiology, is weak or non-existent".

Under this light, questions arise inevitably: ***Are we defenseless against foodborne threats and do we have to just suffer the consequences of globalized trade? Is there a way for us to obtain sufficient data, gain visibility and re-gain confidence in our food chains to reverse this trend***? With these questions in mind, FOODNSIFFER, a European FP7 project, coordinated by NCSR "Demokritos" (NCSR-D) in Athens, Greece, set out to develop and materialize a revolutionary photonics-based solution allowing to all participants in the food supply chain to **perform real-time, laboratory-quality molecular analyses targeting simultaneously several threatening food contaminants and to timely identify possible food-related threats at the source or along the distribution chain**.

FOODSNIFFER, exploiting the proprietary technological know-how of the two participating Institutes of NCSR-D (INN and INRASTES) and by merging the innovative capabilities of 10 European partners including 4 SMEs, designed a radical optoelectronic platform. The platform has at its core a 45mm^2 silicon chip containing a complete photonic circuit with multiplexed light-sources, ten interferometric sensors, a spectrum analyser and a photodetector array presenting this way the ultimate degree of integration. The chips, apart from the fact that they by-pass the inherent limitation of Silicon as an inefficient light-producing material restricted so far to electronic applications, are manufactured by mainstream processing technology that greatly reduces the fabrication costs and lab-to-market time. More importantly though, the complete photonic circuit-containing chips alleviate the need for external optical sources, freeing the final system from the extra cost and bulkiness of the sources and all optical

paraphernalia. The FOODNSIFFER solution is completed with a compact, cost-efficient reader controlled by a custom-produced smartphone, application that could also enable the real-time transfer of the results and meta-data (time, geolocation, producer, distributor etc) to the "cloud". The FOODSNIFFER solution was designed with a specific goal: to become an efficient tool capable of delving into our food searching for multiple potential threats with a single-shot analysis and safeguarding thus our family table.
Among the unique features of FOODSNIFFER -apart from the technological breakthroughs of its manufacturing from chip to systemic level- was the photonics principle of operation of its sensors. This principle, named Broad-band Mach-Zehnder Interferometry (BB-MZI), is a new twist on an old-time classic. MZI has been known for almost two centuries and has been routinely used in several optical sensing approaches. However, it has relied on the exclusive use of monochromatic sources, aka lasers. FOODSNIFFER has shown that MZI not only is possible with a broad-band source, but BB-MZI circumvents the limitations of "classical" MZI (known to the "connoisseurs" as phase ambiguity and signal fading) without any compromise on the sensitivities of the sensors.



Photograph of FOODNISFFER chips, each a complete photonic circuit containing 10 BB-MZI sensors with their optical sources, spectrum analyzers and arrays of photodetectors.

To demonstrate its versatility as a holistic solution for the entire food chain, FOODNSIFFER was put to the test for several food groups and substances yielding more than promising results. In the front of allergens and product adulteration, the system was proven capable of detecting within 5 min down to 0.06μg/ml of bovine milk in goat's milk and 0.04% of bovine milk in goat's milk, a concentration of one order of magnitude lower than the current state-of-the-art techniques. It also sequentially detected with a single chip bovine casein, peanut protein, soy protein and gluten. In more practical terms, FOODSNIFFER examined the rinsing water from a dairy company for allergens and the results obtained in 5min were confirmed by ELISA analysis in an international food analysis lab. Another targeted category of food contaminants were mycotoxins, and especially Aflatoxin B1, Fumonisin B1, Ochratoxin A and Deoxynivalenol, in beer and unprocessed cereals. The determination of these four compounds could be completed in 12 min and the detection limits achieved allowed their detection in beer and cereal samples at concentrations lower than the maximum allowable limits set by EU. The third category of contaminants used for the preliminary evaluation of the FOODSNIFFER system were pesticides. The panel included the pesticides chlorpyrifos, thiabendazole and imazalil and the determination was performed in white and red wines. The assay time was less than 15 min per sample whereas multiple assay cycles (at least 20) could be performed with a single chip through appropriate regeneration between runs. The pesticides determination was accompanied by simple dilution as sample preparation procedure greatly facilitating application for on-site determinations. As for the two other applications, the detection limits allowed the detection of the three pesticides at concentrations well below the Maximum Residue Limits (MRL) established by EU.
These achievements were just the beginning, and the researchers of NCSR "Demokritos" who conceived and initialized the FOODSNIFFER project are already visualizing the improvements required to render it a versatile analytical tool that will radically change the nature and the scope of Food Safety practice. Validation is the next necessary task that needs to be

undertaken and funding is sought out in order to transform the FOODSNIFFER vision to a real system that will radically change the way health risks are monitored, controlled, managed and verified in the global production, distribution and retailing of our food.

Photograph of the FOODSNIFFER system where one can appreciate its compact size compared to a smartphone. The yellow component is a cartridge with a mounted chip.

The FOODSNIFFER Consortium

The consortium consisted of the following partners: the Institute of Nanoscience and Nantoechnology (INN) and the Institute of Nuclear & Radiological Sciences and Technology, Energy & Safety (INRASTES) of NCSR "Demokritos" and ThetaMetrisis SA (Greece), VTT Technical Research Centre of Finland (Finland), TrustFood, LioniX BV and the Institute of Food Safety (RIKILT) (The Netherlands), Jobst Technologies GmbH (Germany), Eurofins Analytics France (France), the University of Almeria (Spain) and the Institute of Physics of Jagiellonian University (Poland).