Marco ABBATANGELO

IOT MOX SENSORS ARRAY FOR INDUSTRY 4.0 AND FOOD QUALITY CONTROL

The work developed in this Ph.D. thesis has been focused on the application of an array of metal oxide (MOX) gas sensors in the food field. The device with sensors is called Small Sensor Systems (S3) and it is designed and constructed at Sensor Laboratory (University of Brescia, Italy) in collaboration with Nasys S.r.l., a spin-off of the University of Brescia. It has been applied in the food field with different aims.

The first one was the development of an integrated device for Smart Home and Industry: the applications of this part are focused on works made in collaboration with Italian companies involved in production, processing, or storage of food. Applications in ovens (industrial and domestic) and fridges are enclosed to show the potentiality of this kind of device to follow cooking processes and to monitor the conservation of some types of food at low temperature. In addition, a case study in the context of the Industry 4.0 is reported: the use of an array of sensors for the identification of the aroma of the fruit jams to install the device directly on the production line of the company. Finally, the last application was related to the recognition of coffee blends and roaster in a coffee grinder that can easily be found in bars. In this presentation, the focus will be on the results obtained in ovens, both domestic and industrial, to highlight the potentiality and the performances of the sensors for automatic cooking.

The second aim was related to food quality control and the results obtained from different food matrices are presented. With Parmigiano Reggiano cheese, the aim was to train the array of sensors to distinguish between compliant and non-compliant grated cheese packs. With olive oil, the study aimed to recognize PDO oil from non-PDO oil and the geographical distinction between PDO olive oils from different regions. The last food matrix is beer, with which the behavior of not stabilized sensors and the recognition of not alcoholic and alcoholic beers were performed. Finally, the last application regards the detection and follow up of the development of Campylobacter jejuni in culture media and milk. For the presentation, Parmigiano Reggiano and olive oil has been chosen to show in detail the approaches that has been used.

To conclude, this PhD thesis work reflects not only the wide variety of uses and the flexibility of the application fields of the MOX gas sensors, but also the immense plasticity of this technology to be developed and tailored to the needs of the various application goals.

Mesay Addisu JIMA

NONLINEAR PROPAGATION IN MULTIMODE OPTICAL FIBER AMPLIFIERS

Single-mode Ytterbium-doped fibers can be used as an active medium to build lasers and amplifiers in the near infrared region where most lasers for cutting and drilling work. Currently, the maximum peak power of the emitted optical pulses is limited by the small cross section of those single-mode fibers and only by using large core multimode fibers peak powers greater than the state-of-the-art could be obtained. In this work, the numerical analysis of the beams amplified in multimode active fibers is presented and the results obtained by means of different mathematical models are compared. Particular attention is dedicated to the amplification of the modes carried by Ytterbium-doped graded-index fibers working at the wavelength of 1064 nm. A judicious choice of the doping profile can lead to a selective reshaping of the output beam and, at high peak powers (in the order of tens of kW), thanks to the nonlinear Kerr effect, most of the power is transferred to the lowest order modes leading to the formation of a bell-shaped output beam, which is very robust to any fiber perturbation (such as bending) and which is suitable for beam delivery over a distance of a few meters.

Andrea TOGNAZZI

TUNABLE OPTICAL DEVICES FOR LINEAR AND NONLINEAR LIGHT MANIPULATION AT THE NANOSCALE

One of the main breakthrough in material science of this century is the advent of meta-structures. They are based on the concept of meta- atoms, that is to say: properly engineered building blocks composed by one or more constituent materials. This idea was first employed in electromagnetism to achieve negative refraction, which cannot be observed in nature, and it has also been applied to tailor the thermal and mechanical properties of the so called meta-materials. Optical devices based on sub-wavelength resonators took great advantage of the modern nanofabrication techniques, allowing to mold the electromagnetic field distribution down to the nanoscale. The high field enhancement achievable in nanostructures has been employed for sensing, solar cells harvesting, spectroscopy and nonlinear applications.

Although versatile and compact, nanostructures are intrinsically difficult to dynamically tune, that is to say, it is challenging to switch or change the behaviour of a nano-sized object with an external stimulus on demand due to its small dimensions. An efficient way to tune the optical response of nano-objects is to change their refractive index by means of optical pumping, heating, external bias voltages or mechanical stress.

First, the fundamental mechanisms of ultrafast tuning in halide perovskites nanoparticles are discussed and the role of geometry is proved to be a key factor that determines the optical temporal dynamics. Then, a gold dipole nanoantenna with gap filled with vanadium dioxide is studied. The field enhancement inside the phase changing material has revealed to be the main parameter to take into account to achieve tunability, while the total phase changing volume is not relevant. This has direct impact also in sensing applications, since the sensitivity is not affected by the environment size but only from the local field enhancement.

At last, a silicon metasurface is employed to perform third harmonic generation and, for the first time, the corresponding diffraction orders polarization are studied. The experimental results are shown to be in agreement with full wave numerical simulations and also with a simple model based on multipolar decomposition. These results have direct implications in full wavefront control of nonlinear radiation in metasurfaces.