

## Material Science and Optics: Applications from Spectroscopy to Metrology, from Fundamental Physics to Space

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### Abstract

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Material Science and Optics are intrinsically related from the earlier study on radiation-matter interaction. Over the last years, photonics has rapidly evolved towards more compact and sophisticated devices from the visible-near infrared (VIS-NIR) towards Mid and Far Infrared (MIR and THz). The challenge is the realization of integrated structures as a powerful technology for “packing” sources, detectors, electronics and optics into single and low costs platforms. In particular MIR and THz spectral region are very attractive for scientific and applicative reasons: this spectral zone is the “so-called” fingerprint region in which many substances exhibit very strong characteristic absorptions: simple molecules (CO<sub>2</sub>, H<sub>2</sub>O, H<sub>2</sub>S, etc.), complex molecules (dioxins, explosives, organic fluids, etc.). Key light sources for mid infrared sensing and spectroscopy are coming from Material Science Research: Interband and Quantum Cascade Lasers. For spectroscopic and metrology it is very important to have stable sources with narrow linewidth. In this view, a new class of materials (nonlinear crystals) and devices enable frequency conversion, in order to realize optical references using VIS-NIR sources or Laser Frequency Combs. A new Physics and new classes of devices are coming from research in crystalline Whispering Gallery Mode Resonators (WGMRs). These devices enable nonlinear generation of optical frequency combs, recently exploited in the Telecom region (making use of micro-resonators where light is coupled in and out by optical fibers). Such WGMRs are also providing outstanding performance in laser stabilization, even in the mid infrared-MIR spectral range. They can also be

used for direct sensing in gaseous or liquid compounds, with innovative applications in the field of medicine, human health and study of capillarity phenomena and viscous-elastic properties of fluids. Here, we report our recent research activity on crystalline and liquid WGMRs, used as powerful tool for nonlinear optics, bio-chemical sensing and mid-IR laser frequency stabilization, passive and active optical cavity-assisted surface-plasmon-resonance sensors as well as nonlinear crystals for generation of metrological mid-IR coherent light. These results open the way to new classes of compact MIR sources with a number of applications in Space missions, Metrology, Chemistry and Fundamental Physics.