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Material science and optics: applications from spectroscopy to metrology, from fundamental physics to space

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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 exhibitvery strong characteristic absorptions: simple molecules (CO_2, H_2O, H_2S, etc.), complex molecules (dioxins, explosives, organic fluids, etc.). Key light sources for mid infrared sensing and spectroscopy are coming from Material Science Research:Interbandand 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 referencesusing 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 opticalfibers). 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 researchactivity 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 ason 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, Chemistryand Fundamental Physics.

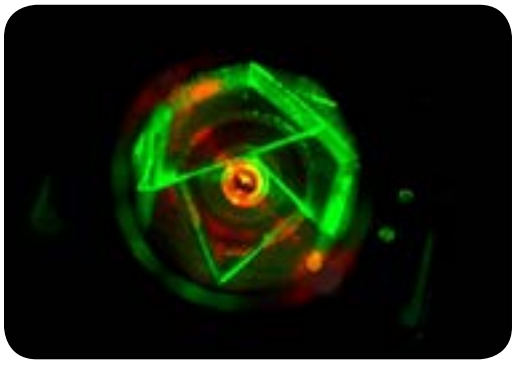

Figure 1: High-Q crystalline Whispering Gallery Mode Resonators have undergone an impressive development in the last years, demonstrating ultimate performance in laser stabilization from UV to MIR spectral range.

Recent Publications

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4. G. Gagliardi, M. Salza, S. Avino, P. Ferraro, P. De Natale, "Probing the Ultimate Limit of Fiber-opticStrainSensing", Science 330, 1081 (2010)
5. A. Giorgini, S. Avino, P. Malara, P. De Natale, G. Gagliardi, "Fundamentallimits in high-Q dropletmicroresonators", Sci. Rep. 7, 41997 (2017)
6. Consolino, A. Taschin, P. Bartolini, S. Bartalini, P. Cancio, A. Tredicucci, H.E. Beere, D.A. Ritchie, R. Torre, M.S.Vitiello, and P. De Natale, "Phase-locking to a free-space terahertz comb for metrological-grade terahertz lasers", Nature Communications 3, 1040 (2012).

Biography

Simone Borri has completed his PhD in 2007 from University of Firenze, Italy. He is researcher at CNR-National Institute of Optics since 2010. He worked as researcher for LENS, the European Laboratory for Nonlinear Spectroscopy, and IFN, the italian Institute for Photonics and Nanotechnologies. His main expertise is development of coherent sources and techniques for high-sensitivity and high-resolution molecular spectroscopy in the mid infrared. During his scientific activity he developed mid-IR and THz sources based on nonlinear frequency generation, and worked on trace-gas sensors based on cavity-enhanced absorption spectroscopy, photoacoustic sensing, Doppler-free spectroscopy, high-precision spectroscopy on molecular beams. He studied the noise properties of quantum cascade lasers, and developed locking techniques for linewidth narrowing, using also novel optical devices like crystalline whispering gallery mode resonators.

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