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Carlo Sirtori et al., J Material Sci Eng 2018, Volume 7
DOI: 10.4172/2169-0022-C8-113

19th World Congress on

Materials Science and Engineering

June 11-13, 2018 | Barcelona, Spain

High sensitivity metamaterial heterodyne detectors at $\lambda = 9\mu m$ operating room temperature

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Room temperature operation is mandatory for any optoelectronics technology which aims at low-cost and compact systems for widespread applications. In this work we present a 9µm photodetector and heterodyne receiver with enhanced performances up to room temperature, where we have estimate signal to noise ratio in the pW range. This has been realised by implementing a quantum well detector (QWIP) into a metamaterial made of subwavelength metallic resonators. Each resonator acts as an antenna and improves the photonic collection area, which is greatly increased with respect to the electrical area. Moreover the very short life-time of the excited carriers is a very important intrinsic property of QWIPs that have not been exploited for performances yet. Its typical value is in the order of a ps, which leads to two important consequences: the detector frequency response can be up to 100 GHz and its saturation intensity is extremely high in the in the order of 10^7 W/cm^2. These two figures are ideal for a heterodyne detection scheme, in which a powerful local oscillator (LO) can drive a strong photocurrent, higher than the detector dark current, that can coherently mix with a signal shifted in frequency with respect to the LO. Notably, these unique properties are unmatched in infrared interband detectors based on mercury-cadmium-telluride alloys, which have a much longer carrier lifetime and therefore intrinsic low-speed response. On the contrary the reduced physical area and the increased responsivity of our metamaterial devices allowed us to take full advantage of the intrinsic high frequency response of the quantum detector up to room temperature. By beating on it two quantum cascade lasers we have measured heterodyne signal at high frequencies up to 4.5GHz, with NEP in the pW range at 300K.

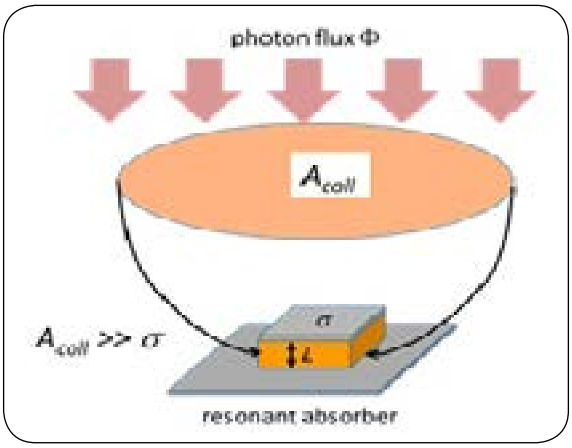

Figure 1:A general scheme of a detector which comprises a resonant absorber embedded in a metallic nanoresonator. Thanks to the antenna function of the resonator, photons are gathered on a collection area Acoll that can be much larger than the detector cross section σ

Recent Publications

1. Palaferri D, *et al.* (2016) Ultra-subwavelength resonators for high temperature high performance quantum detectors. New Journal of Physics. 18:113016.
2. Todorov Y, Desfond P, Belacel C, Becerra L, and Sirtori C (2015) Three-dimensional THz lumped-circuit resonators. Opt. Express 23:16838.
3. Palaferri D, *et al.* (2015) Patch antenna terahertz photodetectors. Appl. Phys. Lett. 106:161102.

4. Chen YN, *et al.* (2014) Antenna-Coupled Microcavities for Enhanced Infrared Photo-detection. Appl. Phys. Lett. 104:031113.
5. Todorov Y, *et al.* (2010) Optical properties of metal-dielectric-metal microcavities in the THz frequency range: Opt. Express 18:13886.

Biography

Carlo Sirtori received his PhD in physics from the University of Milan in 1990. The same year he joined Bell Labs where he started his research career on semiconductor quantum devices. In 1994 he was one of the co-inventor of the "Quantum Cascade Laser". In 1997, Carlo Sirtori joined the THALES Research & Technology (TRT) in France. Since 2002, he is Professor at the University Paris Diderot, and in 2010, he became Director of the MPQ laboratories of the University Paris Diderot. Carlo Sirtori is the author of more than 240 articles in peer reviewed journals and has given some 100 invited talks at international conferences. He has received several prestigious awards such as the Fresnel Prize (European Physical Society) and various prizes in the USA, such as the "quantum devices award". In 2010 he was awarded an ERC-advanced-grant for his pioneering research on quantum devices.

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