STUDYING SENSOR CAPABILITIES OF ARCHIMEDEAN SPIRAL METAMATERIALS WITH C-SHAPED RESONATOR USING THIN DIELECTRIC FILMS IN THE TERAHERTZ FREQUENCY RANGE

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Archimedean spiral metamaterials are periodically repeated subwavelength gratings which were compressed and rolled into a closed surface described as a topologically closed flat 2D metasurfaces [1]. They support excitation of spoof-localized surface plasmon polariton resonances (LSPPR) at the terahertz and microwave frequencies, whose properties are similar to classical LSPPR. Spoof LSPPs have several advantages over familiar LSPPs for creating highly-performance sensors in the terahertz range. Spoof LSPPRs depend on the geometry of the metaparticle, which provides flexibility in designing the electromagnetic properties of structures. Spoof LSPP metasurfaces can support high order resonances, high field confinement and large field enhancement. Moreover, ohmic losses that limit the sensitivity of sensors in the visible range can be neglected at low frequencies [2]. As a result, it is possible to achieve a higher sensitivity in the THz frequency range than in the optical range and realize sensors that are valuable for solving the problems of investigations of thin layers as well as spectroscopy of tiny biological objects at the terahertz frequencies [3].

In this work, we compared the frequency amplitude and phase spectra of spiral metamaterials with C-shaped resonator coated thin dielectric films numerically and experimentally. The sensitivity and figure of merit (FOM) were calculated. It was shown that phase measurements enable to increase the FOM of this type of sensors.

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MUTUALLY CORRELATED OPTICAL AND TERAHERTZ PHOTONS: GENERATION AND APPLICATION

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Parametric generation of terahertz waves in nonlinear crystals has already been achieved by many groups aimed to construct the powerful sources of terahertz pulses at high gain [1]. But only few researches realize that the terahertz beam and the optical Stokes signal beam, if emitted at the same set-up in the absence of any external seeding, represent the so-called quantum "twin beams" and form together a kind of an entangled quantum state. The specific quantum properties of these beams are most clearly manifested in case of the low gain regime, when the unseeded parametric generation process transforms into spontaneous parametric down-conversion (SPDC) [2]. The pairs of mutually correlated photons ("biphotons") are generated under SPDC in a wide spectral range up to the pump frequency. The most famous are the all-optical biphotons emitted at comparable frequencies both in the optical range. Starting from pioneering works on SPDC-based spectroscopy and quantum photometry by D.N. Klyshko and A.N. Penin's group in Lomonosov MSU [3,4], now the optical biphotons are widely used in various quantum optical technologies, such as quantum communication, computing, metrology, imaging, and sensing [5]. The optical–terahertz biphotons, which consist from one optical photon, with close to laser pump frequency and one terahertz photon, with about two orders of magnitude lower frequency, also begin to attract a considerable interest. With the goal of expanding optical quantum technologies on the terahertz range, they have been tested in terahertz spectroscopy, sensing, and photometry [6].

We study optimal temperature, spectral and other experimental conditions for generation of optical–terahertz biphotons with the highest possible values of the correlation parameters, a second-order correlation function $g^{(2)}$ at low gain [7], and the photon noise reduction factor or covariance at high parametric gain [8]. The current absence of single-photon terahertz detectors makes it impossible to use typical quantum optical circuits for direct detection of the photon coincidences. The new approaches are developed for detection of the biphoton correlations, based on analysis of joint statistical distributions of analog readings of an optical detector in the signal channel and a terahertz detector in the idler channel of the SPDC set-up. Measurement of exact values of correlation parameters is of key importance in applications of the optical-terahertz biphotons in terahertz quantum ghost imaging with a single-pixel terahertz receiver, construction of single-photon terahertz sources, reference-free calibration of the spectral sensitivity of terahertz detectors, and other perspective tasks. Our current work is devoted to the study and absolute measurement of quantum efficiencies of the analog superconducting terahertz HEB bolometers. Experimental approaches based on the SPDC generation scheme with a nonlinear crystal placed in the He cryostat together with HEB and a single-photon detector in the optical detection channel are analyzed.

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ELECTRICALLY-TUNABLE REFLECTARRAYS FOR MILLIMETER WAVES BASED ON LIQUID-CRYSTAL-LOADED HIGH-IMPEDANCE SURFACES

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We present the results of experimental development of planar metamaterial structures operating in reflection in the range of 110-150 GHz and enabling spatially nonuniform electrical tuning of the reflection phase and amplitude. The devices have an optical diameter of 50-70 mm and are implemented as resonant high-impedance surfaces loaded with a thin liquid crystal (LC) layer. A unique nematic LC composition based on n-quaterphenyl and n-quinquiphenyl substances and distinguished by high optical anisotropy (0.39) and low dielectric losses (<0.002) at millimeter waves was developed for this work with the industrial implementation of the devices at the final stage. For 1D- and 2D-controlled meta-pixels of the reflectarrays we demonstrate two operation modes: 1) with phase tuning > 360 degrees, 2) with amplitude tuning > 30 dB. Possible applications of the developed devices as beam-steering/ beam-shaping antennas for 6G wireless communication systems, as well as spatial pattern generators in single-pixel subTHz imagers are discussed.

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EXCITATION OF FUNDAMENTAL PLASMON MODES IN GRAPHENE RECTANGLE DEPENDING ON FINITE WIDTH

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Two-dimensional (2D) plasmons can be used in terahertz (THz) devices for localization and gain of electromagnetic field [1]. One of the most useful materials for realization of 2D gas is graphene [2], which characterized by high mobility [3] and the relaxation time of the momentum of charge carriers, reaching 2 ps at room temperature [4].

We consider plasmon excitation in graphene rectangle separating two half-spaces with different dielectric constants. We solved the electrodynamic problem of incidence of electromagnetic wave polarized along the 0X