TERADAYS

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Report of Contributions

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Contribution ID : **1** Type : **not specified**

Polarimetry of Terahertz Pulses from two-color plasma

Monday, 19 February 2024 12:40 (20)

Terahertz (THz) generation by two-color plasma has garnered attention for its capacity of providing intense and ultra-broadband THz pulses. Like any form of electromagnetic radiation, controlling wave polarization is crucial for a wide range of applications [1]. However, accurately characterizing and selectively controlling the polarization of broadband THz pulses remains challenging due to limitations in efficient optics. On the detection side, THz air-biased coherent detection has emerged as a promising solution, employing heterodyne detection and second-harmonic generation (SHG) induced by THz radiation [2]. Nevertheless, recent research has revealed that the laser-induced air plasma in this technique can exhibit birefringence, introducing systematic errors in polarization-state determination [3]. In a recent publication [4], we have proposed a simplified approach that uses a weak probe beam and avoids high-voltage DC bias fields. Unlike the terahertz air-biased coherent detection scheme, our approach provides a unipolar, intensity-proportional signal for SHG. Therefore, we have named this technique THz Unipolar Polarimetry (TUP). In Fig. 1a an example of TUP measurement is shown. In this presentation we will demonstrate the absence of induced birefringence in air in this experimental approach, ensuring accurate measurements of the polarization state of ultra-wideband THz pulses. Regarding the control, we act on the two-colors process by varying the fundamental wave (FW) chirp and the phase difference between the FW and the second-harmonic wave (SHW). These parameters are key factors in controlling different properties of the generated THz pulses: temporal shape, energy, and the polarization state. Specifically, our findings indicate that an elliptical THz polarization can be achieved under conditions where the chirp is optimized for maximum generation efficiency. Furthermore, under these optimized conditions, we observed that as the phase difference between the FW and SHW is increased, the polarization axis of the ellipse undergoes counterclockwise rotation. Nevertheless, measurements conducted with chirp values falling outside the optimal range result in the loss of ellipticity in THz radiation, revealing polarization structures reminiscent of a 'flower' shape. In Fig. 1b we display an example of these measurements.

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Session Classification : II session

Contribution ID : **2** Type : **not specified**

Terahertz Technologies as New Frontiers for Pathogenic microorganism Sensing: Drawbacks, Potentialities and Applications

Tuesday, 20 February 2024 10:20 (20)

The abstract is in attachment

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Session Classification : IV session

Contribution ID : **3** Type : **not specified**

Underway Projects for Innovative THz/IR Sources based on Particle Accelerators: SISSI 2.0 and SABINA

Tuesday, 20 February 2024 15:40 (20)

Terahertz/Infrared (THz/IR) radiation and technologies have found incredible development in the last few decades due to their applications in many different fields, ranging from indoor and outdoor communication, security, environmental monitoring, biological research, medical applications and finally as a spectroscopic investigation tool in condensed matter [1]. However, many of these applications requires increasingly high-power sources and demands for the possibility to manipulate radiation features such as pulse time duration, frequency spectrum and polarization. One of the most efficient ways of generating THz/IR radiation fulfilling these requirements is to use relativistic electrons accelerated in storage rings, where synchrotron radiation can be generated by means of bending magnets or specific Insertion Devices (IDs), or by accelerating electrons in LINACs, where the development of FEL technologies allows for coherent and monochromatic radiation to be produced.

Few projects are currently underway for the realization or the upgrade of innovative THz/IR sources based on particle acceleration, some of them involving two of the most important research facilities in Italy, i.e. the third-generation synchrotron Elettra in Trieste and the SPARC_LAB linear accelerator in Frascati.

Elettra 2.0 is a major upgrade of the Elettra facility towards what is called the 'ultimate' light source, which will allow both horizontal and vertical emittance to be greatly reduced in order to guarantee a substantial increase in brilliance and coherence for the emitted radiation. The main work on the structure consists in the upgrade of the magnetic optics without changing the basic features of the accelerator [2] and it will involve all the beamlines, including SISSI (Synchrotron Infrared Source for Spectroscopy and Imaging), which is the line dedicated to the collection of THz/IR radiation emitted by magnetic dipoles. The SISSI 2.0 Project is included in this major upgrade and aims to characterize the radiation produced by this beamline focusing on the interference effects and on the emergence of new edge radiation contributions caused by the complex magnetic structure of the new multi-bend achromats. In addition, the project involves the reorganization of the extraction beamline for the transport of radiation to an external user facility.

The same spirit of innovation is embodied by the SABINA project, which aims to make some major upgrades in the SPARC_LAB structure with the practical goal of realizing a FEL beamline operating as a user facility and producing quasi-monochromatic radiation over a wide spectral range from 3 THz up to 30 THz, with time duration pulses on the order of ps and energies in the mJ range. The core of the beamline consists of a series of three undulators based on the APPLE-X design that allows the emission of high intensity synchrotron radiation and the manipulation of high electric fields (~10 MV/cm) by controlling their polarizations (linear, circular and elliptical). The beamline also includes the transport of the produced radiation to an 'open to user' laboratory which will be equipped with the appropriate optical set-up necessary to perform a wide variety of scientific experiments concerning nonlinear and time-resolved optical spectroscopy.

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Session Classification : VI session

Contribution ID : **4** Type : **not specified**

Terahertz imaging for the detection of cimiciato-infected hazelnuts

Monday, 19 February 2024 17:20 (20)

In recent years, hazelnut cultivation is becoming increasingly important in terms of areas invested and crops expected. Among the various quality defects, one of the most detrimental alterations to hazelnut quality is "cimiciato" defect, which is caused by a group of insects belonging to the families of Coreidae and Pentatomidae. Nowadays no reliable automatic method to discriminate between healthy and cimiciato hazelnuts exists and the food industry still relies on manual visual inspection of shelled nuts.

The aim of this work was to validate a continuous-wave terahertz transmission imaging system to discriminate cimiciato-infected hazelnuts by a non-invasive method that can, potentially, be implemented in a realtime approach. Carrying low-energy photons, THz radiation is unable to induce ionization processes, which means that it is a perfectly safe radiation for biological tissues.

The trial was conducted on a sample of 150 hazelnuts. We set up a classification model and to assess its performance we used a validation sample of 50 hazelnuts. We plotted the distributions of the healthy and injured samples and fitted the two curves with a polynomial function. The data from each unknown nut was added as a new data point to each of the two distributions, and the minimum distance between this new point and the fitting function was calculated. The new data point was, then, assigned to the distribution with the lowe r distance and the correct/incorrect attribution was evaluated by visual inspection of the nuts. The procedure was able to correctly identify 100% of cimiciato hazelnuts in the mixed population with still a 25% false negative rate.

The developed method is simple, requires a low-cost apparatus and can potentially be implemented in real time, therefore, it can be of great interest for the food industry

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Session Classification : III session

Contribution ID : **5** Type : **not specified**

Terahertz saturable absorption from relativistic high-temperature thermodynamics in black phosphorus

Tuesday, 20 February 2024 15:00 (40)

Black phosphorus is a unique two-dimensional (2D) material (Figure 1) with a tunable infrared band gap and anisotropic conduction properties [1]. Black phosphorus also displays the occurrence of a pressure-induced topological Lifshitz transition turning the material from a narrow gap semiconductor to a massless Dirac metal due to a nonavoided band crossing [2]. We investigate the ambient pressure nonlinear terahertz (THz) electrodynamics of black phosphorus along the more conducting armchair direction and found that its THz saturable-absorption properties can be understood within a thermodynamic model by assuming a fast thermalization of the electron bath [3]. While black phosphorus does not display the presence of massless fermions at ambient pressure and temperature the material's anomalous THz nonlinear properties can be accounted for by a relativistic massive Dirac dispersion, provided that the Fermi temperature is low enough. This suggests that an optimal tuning of the Fermi level could be a strategy to engineer a strong THz nonlinear response in other massive Dirac materials, such as transition-metal dichalcogenides or high-temperature superconductors

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Presenter(s) : PERUCCHI, Andrea

Session Classification : VI session

Contribution ID : **6** Type : **not specified**

Terahertz electric-field driven dynamical multiferroicity in SrTiO3

Monday, 19 February 2024 15:40 (20)

The emergence of collective order in matter is among the most fundamental and intriguing phenomena in physics. In recent years, the ultrafast dynamical control and creation of novel ordered states of matter, not accessible in thermodynamic equilibrium, is receiving much attention. Among those, the theoretical concept of dynamical multiferroicity has been introduced to describe the emergence of magnetization by means of a time-dependent electric polarization in non-ferromagnetic materials [1,2]. In simple terms, a large amplitude coherent rotating motion of the ions in a crystal induces a magnetic moment along the axis of rotation, as schematically shown in Figure 1. However, the experimental verification of this effect is still lacking. With our work [3], we provide the first evidence of room temperature magnetization in the archetypal paraelectric perovskite $SrTiO_3$ due to dynamical multiferroicity. To achieve it, we resonantly drive the infrared-active soft phonon mode with intense circularly polarized terahertz electric field, and detect a large magneto-optical Kerr effect. A simple model, which includes two coupled nonlinear oscillators whose forces and couplings are derived from ab-initio calculations using self-consistent phonon theory at finite temperature [4], qualitatively reproduces our experimental observations in the time and frequency domains. A quantitatively correct magnitude of the effect is obtained when one also considers the phonon analogue of the reciprocal of the Einstein - de Haas effect, also called the Barnett effect, where the total angular momentum is transferred from the coherent phonon motion to the electrons. Our findings show a new path for designing ultrafast magnetic switches by means of coherent control of lattice vibrations with light.

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Session Classification : III session

Contribution ID : **7** Type : **not specified**

The LNF IR-THz beamline @ DA�NE: experimental set-ups and perspectives

Tuesday, 20 February 2024 16:00 (20)

The INFN-LNF DAϕNE storage ring produces a powerful source of Synchrotron Radiation in the THz range [1]. The brilliance of SR in the THz domain is up to three orders of magnitude with respect to conventional sources (i.e. mercury lamps), as shown in Figure 1, and the flux increases with the electron current stored. These aspects permit to perform experiments in several field from material science to biology and chemistry and offer the possibility to analyze samples in solid, liquid and gas phases [2-8]. Experimental set-ups available at SINBAD beamline and applications are presented. Moreover, prospectives of the Terahertz (THz) technology applied on cultural heritage field will be described [9,10].

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Session Classification : VI session

Contribution ID : **8** Type : **not specified**

Ultrafast THz spectroscopy of extended systems

Monday, 19 February 2024 15:00 (40)

In this presentation, I will discuss the use of THz ultrafast spectroscopy to investigate extended systems. Optical Pump – THz Probe spectroscopy (OPTPs) has been extensively used to investigate the carrier and lattice ultrafast dynamics in bulk and low-dimensional semiconductors and topological matter [1-5]. Free carriers, electron-phonon related phenomena, and low-energy collective oscillations of conduction charges show their fingerprint in the THz spectral range. Moreover, by lying close to the Fermi level, the charge carriers photoexcited by THz waves are closely connected to DC transport. Time domain detection allows the direct observation of the amplitude and phase of the THz pulse that has interacted with the material. From this information, the complex dielectric function of the material or its complex conductivity can be directly obtained, without the need for Kramers-Kronig relations. I will introduce different schemes for the generation and detection of THz pulses, the experimental configurations for measuring the charge-carriers dynamics, and the procedures routinely exploited to retrieve the pump-induced optical conductivity in the frequency domain from the THz fields acquired in the time domain. In this respect, I will go through some technical details that are usually barely mentioned in the literature. I will then give an overview of our recent results concerning the presence of large polaron and exciton in 3D and 2D perovskites, the coupling of native electron doping with far-infrared phonons in Sn-based perovskites and the ultrafast carrier dynamics in the $HgPSe_3$ layered semiconductor [6-9].

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Session Classification : III session

Contribution ID : **9** Type : **not specified**

High repetition rate THz generation by cavity enhanced optical rectification in GaP

Monday, 19 February 2024 10:00 (20)

Terahertz (THz) radiation exhibits properties of great interest and potential applications in several scientific fields. For example, THz waves (in the spectral range between 0.1 and 30 THz) find direct applications in spectroscopy of innovative materials, time-domain quantum optics, and biological sensing [1]. However, THz science remains challenging because of the lack of suitable sources and detectors. To fill this technological gap, various techniques have been explored over the years. For instance, quantum cascade lasers and photoconductive antennas are well-established methods to generate THz radiation [2]. Recently, frequency down-conversion of near-infrared light in nonlinear crystals emerged as a powerful alternative to more traditional methods. In particular, optical rectification schemes based on ytterbium (Yb) ultrafast lasers are now considered extremely promising [3]. Moreover, the use of an enhancement resonator able to store the infrared pulses from the Yb laser source boosts the power that can be used for optical rectification [4]. However, high-average power leads to a high thermal load for the nonlinear crystal. In addition, spatial deformation of the resonant mode can occur when the crystal is under stress inside the cavity, causing power losses and THz power drops. A crystal widely used is Gallium Phosphide (GaP) [5]. Recently, Hekmat et al. [6] published an extensive study on the behavior of this crystal when used for single pass optical rectification in the presence of high power. In this work, we propose a preliminary study in a slightly different regime of operation for GaP crystals, exploiting an enhancement resonator to achieve an average power > 300 W. This offers the chance to investigate the material properties at very high power together with the possibility of understanding the effect of GaP-induced mode deformation inside an enhancement cavity. We propose an experimental setup based on a amplified Yb fiber mode-locking laser (spectral width ˜ 7 nm around 1035 nm) with a repetition rate of nearly 100 MHz, with maximum power of 60 W, and a pulse length of 370 fs. The amplified pulses are boosted to nearly 300 W using an enhancement cavity inside which optical rectification in a GaP crystal takes place. This way, modal instabilities and high-power-induced effects on GaP are observable and characterizable together with the THz generation efficiency. Even if modal instabilities partially limit the maximum gain achievable with the enhancement cavity, the comprehension of the phenomenon will soon allow the implementation of mitigation strategies to fully exploit the advantage of optical rectification in an enhancement cavity for the high repetition rate and the milliwatt level average power THz generation, opening the way to promising applications in the THz region.

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Session Classification : I session

Contribution ID : **10** Type : **not specified**

Infrared Plasmons in Quantum Materials

Monday, 19 February 2024 10:40 (20)

Surface plasmons, the collective oscillations of electrons in metals and doped semiconductors, show outstanding electromagnetic (EM) properties spanning from a reduced wavelength in comparison to that of an exciting electromagnetic field, an extreme electric field enhancement several orders of magnitude larger than the incident field, to several nonlinear effects like harmonic generation and optical rectification. Although conventional metals, like gold and silver, are usually used in plasmonics, non-conventional and exotics materials now on the scientific edge, providing additional properties like plasmon tunability due to their extreme sensitivity to external parameters like doping, temperature, and electric and magnetic fields. In this work we present the generation of surface plasmon polariton in two quantum materials, patterned in the form of micro-ribbon arrays: the ultrahigh conductive PdCoO2 oxide and the Wey-II semimetal PtTe2. PdCoO2 layered delafossite is the most conductive compound among metallic-oxides, with a room-temperature resistivity of nearly 2 μΩcm, corresponding to a mean free path of about 600Å1. These values represent a record considering that the charge density of PdCoO2 is three times lower than copper [1]. PtTe2 is a Weyl semimetal, with topological nontrivial properties and the highest room-temperature electrical conductivity among metallic Transition Metal Dichalcogenides [2]. By changing the width W and period 2W of the ribbon arrays, we select suitable values of the plasmon wavevector q, experimentally sampling the surface plasmon dispersion (see Fig.1 for PdCoO2) in the mid-infrared electromagnetic region. Near the ribbon edge, we observe a strong field enhancement due to the plasmon confinement, indicating both materials as a promising infrared plasmonic candidates [3,4].

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Session Classification : I session

Contribution ID : **11** Type : **not specified**

Optical beatnote detection of a portable THz QCL comb by direct microwave mixing onto an Hot-electron bolometer

Monday, 19 February 2024 09:40 (20)

We present optical beatnote detection from a THz QCL comb operating at 80 K by direct free space mixing in a high-frequency Hot Electron Bolometer

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Session Classification : I session

Contribution ID : **12** Type : **not specified**

Terahertz imaging super-resolution

Monday, 19 February 2024 16:20 (20)

see attached file

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Session Classification : III session

Contribution ID : **13** Type : **not specified**

THz amplitude modulation by organic-based metadevices

Monday, 19 February 2024 10:20 (20)

THz radiation, in the region between 0.1 and 10 THz, has attracted a lot of interest in the last years due to its peculiar interaction properties with matter and the possibility of applying it both in telecommunications and sensing devices [1]. One of the current subjects of active investigation in this field is the enhancement and optimization of the interaction between THz radiation and materials for application in these fields.

In this framework, metasurfaces have been proposed for this purpose [2]. Metasurfaces are materials engineered in such a way as to express peculiar electromagnetic properties in a specific range of frequencies of the electromagnetic spectrum. In particular, it is possible to design metamaterials that can strongly interact with THz pulses to tune their frequency, amplitude, and phase.

We studied an innovative metadevice configuration that mixes the flexible properties of Split-Ring resonator-based metasurfaces with the dynamic tuning capabilities of organic semiconductors to achieve an electrically tunable metadevice [3]. This peculiar approach has been already demonstrated for microwaves [4] but there is yet no direct application in the THz spectral region. In particular, thanks to this device, we were able to obtain modulation depth of the THz amplitude in the order of 65% at a frequency of around 0.7 THz, as shown in Figure 1.

These performances are comparable to other state-of-the-art devices [5] but with the increased benefit of requiring a very low driving electric field, in the order of 1V. This capability comes from the use of so-called Organic Mixed Ion-Electron Conductors (OMIECs), a class of semiconductors whose permeability to charge carriers can be tuned by applying an external electric field, effectively changing the semiconductor conductivity.

Furthermore, we tested the effectiveness of applying different manufacturing methods to produce these metadevices, shifting towards a more scalable and cheaper approach exploiting ink-jet printing for both the metasurface and the organic semiconductor.

This work opens the way to the exploitation of OMIECs-based modulating devices for applications in telecommunications and sensing. Moreover, other fields like electronics or bioelectronics could benefit from the further development of the capabilities and properties of organic semiconductors.

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Session Classification : I session

Contribution ID : **14** Type : **not specified**

THz-photonics by all-dielectric phonon-polariton nonlinear nanoantennas

Tuesday, 20 February 2024 11:40 (40)

The THz spectrum offers the potential of a plethora of applications, ranging from the imaging through non transparent media to wireless-over-fiber communications and THz-photonics. The latter framework would greatly benefit from the development of optical-to-THz wavelength converters. Exploiting Difference Frequency Generation in a nonlinear all dielectric nanoantenna, we propose a compact solution to this problem. The approach is completely transparent with respect to the modulation format and can be easily integrated in a metasurface platform for simultaneous frequency and spatial moulding of THz beams.

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Session Classification : V session

Contribution ID : **15** Type : **not specified**

Micro-thermo-mechanical THz detectors

Tuesday, 20 February 2024 09:00 (40)

Thermomechanical bolometers based on high-quality mechanical resonators are a promising technology for broadband light detection. Further functionalities can be added by controlling the absorption spectrum of the devices. To this end, we embedded (almost-) 2D layers, minimally impacting the mechanical quality while, at the same time, offering strong absorbance. Further layer patterning could grant resonant absorption, for hyperspectral imaging or polarization sensitive detection. Transduction is usually performed through optical probing of the mechanical resonance, but direct electrical output can also be obtained through magnetic flux modulation, provided the mechanical object contains an inductive element. The concept is particularly useful in array readout, where many elements with different mechanical frequencies can be easily addressed in parallel.

Primary author(s) : TREDICUCCI, Alessandro

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Session Classification : IV session

Contribution ID : **16** Type : **not specified**

Chip-scale Terahertz quantum cascade lasers frequency combs: recent advances and applications in near-field nanoscopy

Monday, 19 February 2024 09:00 (40)

Optical frequency combs (FCs), that establish a rigid phase-coherent link between the microwave and optical domains of the electromagnetic spectrum, are emerging as a key high-precision tools for the development of quantum technology platforms. These include potential applications for communication, computation, information, sensing and metrology, and can extend from the near-infrared with micro-resonator combs, up to the technologically attractive terahertz (THz) frequency range, where powerful and miniaturized quantum cascade laser (QCL) can spontaneously generate stable FCs. In this talk I'll review our recent advances in the development of stable THz QCL FCs and harmonic frequency combs with record optical power/mode and record dynamic range and I'll discuss their application potential in the fascinating area of near-field nanoscopy.

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Session Classification : I session

Contribution ID : **17** Type : **not specified**

The THz Spectral Range: a Window of Opportunities

Tuesday, 20 February 2024 12:40 (20)

We are witnessing impressive progress in THz technologies, mostly driven by the promise of brand new application areas and different ways to interact with matter or to transmit information. Such progress is also related to the under-exploitation of a significant part of the electromagnetic spectrum represented by the far-infrared/THz region that borders with microwaves around 300 GHz and with mid-infrared, around 10 THz or even higher frequencies [1,2]. On the other hand, the potential role of novel photonics tools in the THz range is still to be unveiled but many important applications have already shown its importance. Indeed, material transparency/opacity to THz frequencies is different form nearby mid-IR and can provide better resolved information than lower frequency microwaves/RF [3]. Moreover, for transmission of information THz frequencies are the logical continuation of moving to higher and higher frequencies to get carriers able to carry more and more data [4]. In terms of interaction with matter, THz photons are the key to excite the rotational degrees of freedom of a large part of molecules, enabling metrological measurements to unveil new physics or also to control molecules in view of the most demanding applications on the horizon, like ultracold molecules for quantum simulation, sensing or computing [5,6].

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In these really exciting and thrilling times for THz science and technology, it is crucial to invent
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The Materials and Methods should be described with sufficient details. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

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Presenter(s) : CONSOLINO, Luigi (CNR-INO)

Session Classification : V session

Contribution ID : **18** Type : **not specified**

Terahertz Spectroscopy and Topological Quantum Materials

Monday, 19 February 2024 11:40 (40)

Quantum materials and terahertz radiation present a mutual interplay. On one hand, linear terahertz spectroscopy allows to study the unconventional excitations of quantum materials and nonlinear and time-resolved spectroscopy their temporal evolution. On the other hand, quantum materials can be used to produce and manipulate terahertz radiation, opening up the possibility of developing new devices and applications. In this talk, I will review our recent results on the investigation of topological quantum materials through linear and pump-probe terahertz spectroscopy and their use for generating terahertz radiation with unconventional properties.

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Session Classification : II session

Contribution ID : **19** Type : **not specified**

THz wave for Cultural Heritage @ IREA-CNR

Tuesday, 20 February 2024 10:00 (20)

Nowadays, Teraherz (THz) waves are receiving huge attention in the frame of cultural heritage [1], [2]. THz imaging and spectroscopy are, indeed, useful tools for gathering high-resolution (of the order of mm) information about construction modality, preparing drawings and author's repaintings, conservation state of artworks as well as to identify previous restoration actions, mainly of paintings and frescos. THz time-domain systems are part of the imaging/mapping technological tools of the Italian node of the European research infrastructure for heritage science (E-RIHS.it) [3]. Since 2014, research activities regarding the design of strategies for improving the imaging capabilities of THz waves and their application in artworks surveys are carried out at the Institute for Electromagnetic Sensing of the Environment, National Research Council of Italy (IREA-CNR) [4]. This communication aims at providing a critical overview of the THz potentialities and describing the main challenges for a reliable and accurate data interpretation; finally, some results mainly regarding majolica and ancient decorated mortar specimens will be presented, even with the aim to point out the developed strategies to solve issues in data acquisition and processing. [5], [6].

Acknowledge This study was partially funded by the European Research Infrastructure for Heritage Science (E-RIHS).

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Session Classification : IV session

Contribution ID : **20** Type : **not specified**

Exploiting THz imaging to map plastic foam density

Monday, 19 February 2024 17:00 (20)

Plastic foams are widely used materials made by mixing polymers with a gas [1]. Their mechanical and physical properties are governed mainly by the density, so it is important to assess this feature to check the accuracy of the production process. However, while simple in principle, density measurements are not straightforward in practice, especially when objects have a non-uniform density. Therefore, there is a huge interest towards the development of effective, possibly low-cost methodologies to accurately measure the foam density and its spatial distribution. Starting from the observation that the molecular mixture constituting the foam appears electrically homogeneous at THz wavelengths, this communication proposes an approach based on the use of time of flight (ToF) [2] to reconstruct the foam density spatial map. The approach is applicable to samples whose thickness and electromagnetic parameters are such that the impinging THz wave reaches a metal substrate behind the sample and neglects the possibly dispersive behavior of the material under test. It provides 2D maps that describe the spatial variability of the thickness and the effective refractive index of the sample under test, which embeds the changes of the material refractive index along the wave propagation path. The same idea was previously exploited for the characterization of magnetic scaffolds [3]. To enable the evaluation of the density, a set of uniform propylene foam samples having well-known density were first realized and characterized by means of the proposed approach to build a refractive index-density calibration curve. For a generic object under test, this curve is used to turn the estimated effective refractive index into a map of the density. The characterization of the sample depicted in Figure 1a is shown as an example of the proposed approach. According to the production process procedure, this sample is expected to be uniform, with density ρ = 214 kg/m3; determined by weighting the sample. Figure 1b shows the estimated thickness map, which is confirmed to be of about 8 mm, without relevant geometrical changes. Figure 1c reports the average sample refractive index map, which is then turned into the spatial density map in Figure 1d by using the calibration curve. As can be seen, the THz inspection reveals that, contrary to expectations, the actual density of the plastic foam sample is not uniform, due to some flaws occurring during the sample-production process. More examples and details will be given at the conference.

Figure 1. THz imaging of a PP foam: a) image of the sample; b) estimated thickness; c) estimated average refractive index; d) reconstructed foam density map. References 1. Landrock, A. H. Handbook of plastic foams: types, properties, manufacture and applications (Elsevier, 1995). 2. Jepsen, P. U., Cooke, D. G., & Koch, M. (2011). Terahertz spectroscopy and imaging–Modern techniques and applications. Laser & Photonics Reviews, 5(1), 124-166. 3. Zappia, S., Scapaticci, R., Lodi, M. B., Fanti, A., Ruello, G., Crocco, L., Catapano, I.. "Non-Destructive Characterization of Magnetic Polymeric Scaffolds using Terahertz Time-of-Flight Imaging". IEEE Transactions on Terahertz Science and Technology, 2023.

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Session Classification : III session

Contribution ID : **21** Type : **not specified**

THz Optics for Beam Tailoring by Form-Birefringence

Monday, 19 February 2024 16:00 (20)

Primary author(s) : KORAL, Can (Department of Science, University of Basilicata)

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Session Classification : III session

Contribution ID : **22** Type : **not specified**

THz dynamics of aqueous binary mixtures at a mesoscopic level

Tuesday, 20 February 2024 10:40 (20)

We report a study at a mesoscopic level on the THz dynamics of three aliphatic alcohols (2-propanol, methanol, and ethanol), one diol (ethylene glycol), and the corresponding water solutions at room temperature, using a time domain ellipsometer. The dielectric response of the pure liquids is nicely fitted using a generalized Debye-Lorentz model, which considers hydrogen-bond rupture and reformation dynamics, the motion of the alkyl chains and of the H-bonded OH groups, and the presence of molecular vibrations [1]. For the binary mixtures, we focus on the properties of the water-rich region, finding an anomalous behavior in the absorption properties at very low solute molar concentrations (XM). These results, first observed in the THz region, are in line with previous findings (mostly from thermodynamic measurements) and can be explained by considering the amphiphilic nature of the alcohol molecules. Figure 1 (i) presents the frequency dependent dielectric properties of (a) 2-propanol, (b) methanol, (c) ethanol, and (d) ethane-1,2-diol in the THz region achieved by a customized THz time-domain spectroscopic ellipsometer [2] and the corresponding fitting curves based on an effective Debye model [3], showing an excellent agreement. However, this model fails to reproduce the experimental results when an alcohol-water binary mixture is considered, especially for small (0-5 %) alcohol molar fraction XM. To better highlight the molecular dynamics of the solute at very low XM, we display in Fig.1 (ii) the deviation of the experimental results from the expected Debye behavior (Δk = kexp − kDebye). Results show that the mixtures behave completely out of the Debye prediction, which can be explained by the complex dynamics occurring in aqueous binary mixtures due to the competing, hydrophobic and hydrophilic, behavior of the alcohol. In the water-rich region (very scarce solute molecules), we measure a sudden drop in absorption properties of water, the dominant mechanism appearing to be the destruction of existing H-bonds between water molecules, since the hydrophobic behavior of the alcohol plays the main role. As the solute molar concentrations becomes higher, we first observe an increase in the absorption properties of the mixture, due to the formation of water clusters around alcohol molecules, followed by a Debye-like decay by increasing the alcohol concentration.

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Session Classification : IV session

Contribution ID : **23** Type : **not specified**

Material Characterizations in the Sub-THz Region for Particle Accelerators

Tuesday, 20 February 2024 16:20 (20)

Coatings play a crucial role for the functionality of vacuum chambers in particle accelerators, serving dual purposes by efficiently facilitating pumping and mitigating electron cloud effects. However, their impact on the surface resistance of chamber walls raises concerns, potentially influencing machine performances and imposing limitations on achievable energies and currents. Therefore, an electromagnetic characterization is essential for a comprehensive study of accelerator structures, particularly in the context of the next generation of particle accelerators where the demand for extremely short bunches accentuates the importance of assessing material responses in the sub-THz region.

In this presentation, we focus on the electromagnetic characterization of three different types of Non-Evaporable Getters (NEG) coatings. Specifically, we examine the CERN standard, a densified film using HiPIMS, and porous, high-pressure coated. NEG coatings are particularly utilized to achieve conditions of ultra-high vacuum. Additionally, we explore the characterization of Amorphous Carbon (a-C), necessitating a modification of the setup. a-C is primarily employed for mitigating the electron cloud effect.

Through this presentation, we will showcase the electromagnetic characterization of these coating materials using a time-domain method based on THz waveguide spectroscopy. This advanced methodology allows for a comprehensive exploration of the electromagnetic properties of coatings, providing valuable insights into their behavior within the sub-THz frequency range. The findings contribute to a deeper understanding of the intricate interactions between coatings and accelerator structures, with the aim of optimizing performance and efficiency in the evolving landscape of particle acceleration technologies.

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Presenter(s) : PASSARELLI, Andrea (INFN - Sezione di Napoli)

Session Classification : VI session

Contribution ID : **24** Type : **not specified**

Metamaterial quasi-optical components for astronomical instrumentation at millimetre and sub-millimetre wavelengths

Tuesday, 20 February 2024 09:40 (20)

We report on the development of novel optical components based on metamaterials, carried out in the last years, for mm and sub-mm astronomical instrumentation. Using the mesh-filter technology, we have realised transmissive and reflective half-wave plates, flat lenses, anti-reflection coatings, absorbers, etc. The metal-mesh technology, based on copper grids embedded within polypropylene layers, gives the possibility to accurately and arbitrarily manipulate the radiation across surfaces and allows in principle to replace any classical optical component with a mesh-equivalent one. The devices mentioned above can find applications in other fields such as telecommunications and security. The technology itself can be pushed further to realise novel/exotic metamaterials with properties of interest for theoretical studies. In addition, the realisation of these metamaterials can be extended into the Silicon technology, with all the advantages associated with it.

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Session Classification : IV session

Contribution ID : **25** Type : **not specified**

Optical Permittivity and Permeability in the THz Band from Independent Measurements of Normal Transmission and Reflection

Monday, 19 February 2024 12:20 (20)

An accurate retrieval procedure has been developed in order to extract both the dielectric and magnetic response of thin and thick samples in the THz band. Differently from a previous approach [1], the exact expressions of the complex reflection $\tilde{R}$ and transmission $\tilde{T}$ of the THz beam normally impinging on the sample surface are used. The core of the methodology consists in the independent employment of the experimental $\tilde{R}$ and $\tilde{T}$ values, processed by a total variation technique [2] to retrieve the complex impedance $\tilde{z}$ and refractive index $\tilde{n}$, namely $\tilde{z}_R$, $\tilde{z}_T$, $\tilde{n}_R$, $\tilde{n}_T$. From here the dielectric function $\tilde{\varepsilon}$ and permeability $\tilde{\mu}$ are obtained through $\tilde{\varepsilon}_i$=$\tilde{n}_i$ $\tilde{z}_i$ $\tilde{\mu}_i$=$\tilde{n}_i$/ $\tilde{z}_i$ to achieve $\tilde{\varepsilon}_R$, $\tilde{\varepsilon}_T$, $\tilde{\mu}_R$, $\tilde{\mu}_T$. The technique is applied to a thin film of BiFeO3 showing a small but finite magnetization and a phononic resonance at about 2 THz [3]. The BiFeO3 films have been grown on quartz, following a procedure similar to that previously optimized for the deposition on Si (100) substrate [4]. In particular, the films have been deposited in the temperature range 600−800 ℃ for 60 min using the Bi(phenyl)3 and Fe(tmhd)3 (phenyl = −C6H5, H-tmhd = 2,2,6,6-tetramethyl-3,5-heptandione), as precursors. The X-ray diffraction patterns, recorded in grazing incidence mode (0.8°), have confirmed the formation of pure, polycrystalline BiFeO3 films, while the field emission scanning electron microscopy image indicates the presence of grains of about 500-600 nm.

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Session Classification : II session

Contribution ID : **26** Type : **not specified**

The beam alignment problem in THz wireless networks

Tuesday, 20 February 2024 12:20 (20)

Terahertz (THz)-band communications are a key enabler for ultrahigh bandwidth and ultralow latency communication paradigms. When integrated with other THz-band applications, such as localization, sensing, and imaging, THz technologies may lead to the deployment of intelligent wireless communication systems. However, communications at THz are quite challenging due to the severe attenuation of signal power caused by high diffraction and penetration losses, as well as atmospheric absorption. To compensate for the severe path loss, high-directional beamforming with large antenna gains both at the transmitter and at the receiver is mandatory. Designing such a highly directional beamforming requires an initial beam alignment procedure prior to data transmission, in order to maintain a desired signal-to-noise ratio (SNR) level. However, fast and accurate acquisition of beam directions is quite challenging for THz-band communications due to the very low SNR available before properly aligning the beams with the dominant signal propagation paths. In this paper, we develop a receiver-assisted beam-alignment algorithm by which the receiver and the transmitter collaborate to identify the angle-of-arrivals and angle-of-departures associated with the strongest paths of the THz channel.

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Session Classification : V session