TALKS

1. Effective Medium Theory: Validity of Defining Constitutive Parameters for Photonics Crystals, Metamaterials and Periodic Composites

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The periodic artificial structures such as photonic crystals and metamaterials show unprecedented electromagnetic phenomena namely anomalous dispersion, bandgap for electromagnetic waves, self-collimation, negative refraction, super-prism, superlens, zero-refraction, near-unity absorption, cloaking/invisibility, optical activity and so on. However, defining the constitutive parameters such as dielectric permittivity, magnetic permeability, and refractive index for these periodic structures are valid only under linear, isotropic and homogeneous response. By highlighting the effective medium theory, I will show specific examples of defining constitutive parameters of periodic structures. I will also show how certain numerical calculations lacks meaning and absurd in defining the refractive index of the periodic structures. The importance of effective medium parameters in novel optics/photonics applications will also be demonstrated.

Keywords : Effective medium theory, Periodic Structures, Photonic Crystals and Metamaterials.

2. Beyond Hermiticity

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Quantum Mechanics (QM)- one of the most successful theory- works beautifully well across various domains of science. In conventional QM, the axiom of hermiticity of the Hamiltonian, describing any quantum system, ensures the real spectra and unitary time evolution. What if we relax this axiom? In this review talk, we shall dwell upon this aspect.

3. Effect of Confinement and Temperature on Polymer Dynamics

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Polymers are macromolecules composed of repeating monomer units. They exhibit unique properties under geometrical confinement, often deviating significantly from their bulk counterparts. We have investigated the structural relaxation dynamics of the biopolymer gelatin in bulk and under soft spatial confinement using dielectric relaxation spectroscopy. Gelatin is confined by the fluctuating surfactant monolayer of reverse microemulsions, with droplet sizes of 3 to 5 nm. Small-angle neutron scattering (SANS) confirms the stability of the microemulsion droplets after gelatin incorporation. Notably, the hydrated gelatin in soft confinement exhibits faster relaxation dynamics in comparison to its bulk counterpart, and it further gets accelerated with a reduction in the confining volume. Additionally, we have investigated the temperature- and pressure-dependent solubility, phase behavior, and self-assembly of the amphiphilic diblock copolymer PMMA-b-PNIPAM in aqueous solution using turbidimetry and SANS. Below the cloud point, it forms core-shell micelles in a clear solution, while heating induces large aggregates and turbidity. The temperature-pressure coexistence line forms an ellipse, highlighting the strong dependence of structure and phase behavior on both parameters.

1. P. M. Geethu, V. K. Aswal, and Dillip K. Satapathy, J. Appl. Phys. 127, 224701 (2020).
2. P. M. Geethu, Indresh Yadav, S. K. Deshpande, V. K. Aswal, and Dillip K. Satapathy, Macromolecules 50, 6518-6528 (2017).
3. Pablo A. Alvarez Herrera, Geethu P. Meledam, Bart-Jan Niebuur, Yamen Taji, Leonardo Chiappisi, Cristiane Henschel, André Laschewsky, Alfons Schulte, and Christine M. Papadakis, Macromolecules 57, 10263-10274 (2024).

4. Spintronic materials from Heusler Family

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Heusler alloys have been of great interest over the last decades due to their multifunctional novel properties. Heusler alloys as half-metallic ferromagnet, spin gapless semiconductor, and topological semimetals belong to the class of spintronics materials. This class of material offers an enormous variety of possibilities for material design since they are known to exhibit tunable electronic and magnetic properties. Heusler alloys exhibit rich and interesting ground-state properties such as magnetism, unconventional superconductivity, and heavy fermion behavior. The interplay between these properties and the topological order makes Heusler alloys ideal candidate for investigation of novel topological effects, new topological phases, and applications. The combination of band inversion and magnetism in these alloys provides a way to design the Weyl semimetals (WSMs). Many magnetic and nonmagnetic Heusler alloys have recently been reported to be WSMs candidates. Here, we present our theoretical investigation on the electronic, structural, and magnetic properties of CoMnVZ (Z = Al and Sb) Heusler alloy showing interesting topological properties.

5. Fizz the AI Buzz: Let's Understand How AI is Transforming Physics

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Artificial Intelligence (AI) revolutionizes physics, enabling scientists to in vent breakthroughs with advanced machine learning, neural networks, and data driven approaches. This Intelligence simulates quantum systems, predicts ma terial properties, analyses telescope data, and accelerates research with reduced costs while revealing hidden patterns. In the same line, AI rekindles astro physics, particle physics, and condensed matter physics, whereas in astrophysics, it aids gravitational wave detection, exoplanet discovery, and galaxy simulation. In particle physics, it aids LHC collision finding and Higgs boson discovery. Condensed matter physics drives material science breakthroughs, designing su perconductors, nanomaterials, and advanced materials with precision. However, integrating AI into physics poses its challenges as well. Issues like bias in AI models, the interpretability of AI-generated results, and the ethical implications of machine-driven discovery must be carefully addressed. And the success of AI in physics depends on collaboration between physicists, computer scientists, and data experts.

Through the talk ”Fizz the AI Buzz: Let’s Understand How AI is Transform ing Physics”, we will explore the incredible impact of AI on physics, highlighting recent breakthroughs, amazing applications, and exciting future possibilities. AI is not a mere tool for discovery, rather it’s changing the way we think about science. Join us as we dive into the exciting world of AI-driven physics, where algorithms and atoms support the new beginnings.

6. Analysing & Interpreting the 21 cm Cosmological Observation

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The redshifted 21-cm signal provides a unique window to explore the early universe, offering valuable insights into the Epoch of Reion ization and Cosmic Dawn. Observing and interpreting the 21 cm signal gives the opportunity to trace the evolution of neutral hydro gen in the universe, revealing details about the formation of the first stars, galaxies, and large-scale structures. However, the detection and interpretation of the 21 cm signal are hindered by bright astrophysi cal foregrounds, instrumental systematics, and observational noise. A key statistical tool for extracting cosmological information from 21 cm observations is the power spectrum, which quantifies the spatial fluctu ations of the signal across different scales and redshifts. This research emphasizes modeling the 21-cm signal and analyzing the data through statistical inference techniques, focusing on parameter estimation us ing Markov Chain Monte Carlo (MCMC) and Machine Learning (ML) methods.

7. FFBRST and the bridge between effective theories

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BRST symmetries are prominent to the quantization of gauge theories, which allows any gauge invariant theory to be formulated as a quantum theory. It employs an infinitesimal, constant Grassmann parameter to ensure gauge invariance at the quantum level. Finite field dependent BRST (FFBRST) transformations generalize this idea by allowing the transformation parameter to be both finite and explicitly dependent on the fields of the theory. This modification enables to interpolate between different gauge choices, all while preserving the invariance of the path integral measure. Here, we establish the FFBRST transformations to the BRST invariant effective action of the Christ-Lee model. Further, we interrelate the generating functional of different effective theories by means of FFBRST transformations.

8. Entanglement Entropy and Tensor Network Methods: Unveiling the Area Law

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Entanglement entropy provides a fundamental measure of quantum correlations in many-body systems. A key result is the area law, which states that for ground states of gapped local Hamiltonians, entanglement entropy scales with the boundary of the subsystem rather than its volume. This behavior contrasts with thermal states and generic excited states, which typically exhibit volume-law scaling. Tensor network methods, such as matrix product states (MPS) and projected entangled pair states (PEPS), naturally encode the area law and offer efficient numerical and analytical tools to study quantum many-body systems. This presentation will cover the basic formulation of the entanglement entropy area law, introduce tensor network approaches, and discuss their applications in proving and characterizing area-law behavior in various physical systems.

9. Realization of Negative Refractive Index for Circularly Polarized Light using Supramolecular Chiral Metamaterial

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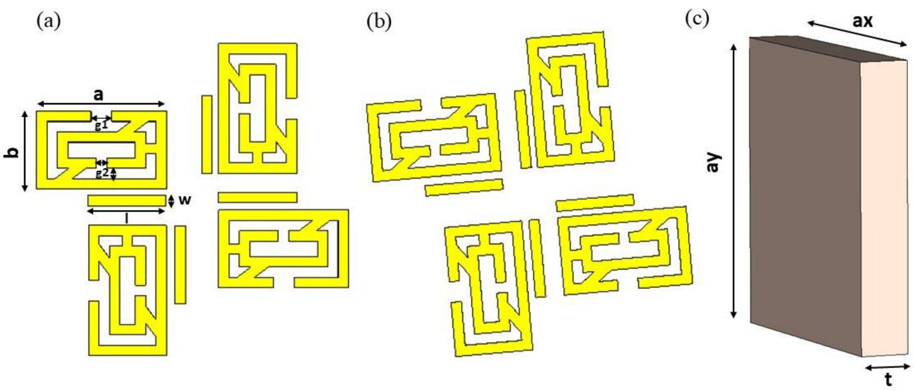
Metamaterials with negative refractive index have garnered significant attention due to their potential for seminal applications in optics and electromagnetics such as flat lens, super resolution and ultra-high confinement. John Pendry first proposed a novel way to get negative index through chirality. Chiral metamaterial structures can have giant optical activity and non zero negative real part of chirality leads to negative index of refraction for different polarized states. This work presents a novel approach to achieving negative index through chirality in metamaterials. We demonstrated a bi-layered metamaterial structure composed of mutually twisted planar metal (Silver) patterns in parallel planes which is shown in Fig.1(a) and (b) coated on a Si dielectric substrate, exhibiting strong optical activity. Unlike conventional negative-index materials that rely on simultaneous negative permittivity and permeability, our design leverages chirality to induce a negative refractive index. We are focusing on numerical results to confirm different refractive indices for right and left-circularly polarized waves, with at least one polarization experiencing a negative index in a specific frequency range especially in THz regime. This work not only validates theoretical predictions of chirality-induced negative refraction but also opens new avenues for manipulating electromagnetic waves in ways previously thought impossible.



10. Enhanced and Tunable Photoluminescence of Graphene Quantum Dots in a Tamm Plasmon Cavity

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Graphene Quantum Dots (GQDs) exhibit remarkable photoluminescence (PL) properties, making them highly attractive for applications in bioimaging, biosensing, and photonic devices. In this study, we present a facile synthesis method for GQDs via pulsed laser irradiation in chlorobenzene and investigate their PL characteristics. The integration of GQDs into a Tamm Plasmon Cavity (TPC) structure leads to a significant enhancement and tunability of their fluorescence emission. The strong light confinement within the TPC structure, combined with the Purcell effect, increases the spontaneous emission rate of GQDs, resulting in amplified and spectrally tunable fluorescence. This enhanced PL response holds great potential for high-sensitivity optical applications, including biosensing and single-molecule detection.

11. The Role of Magnetic Reconnection in Quasi-Periodic Pulsations of a Solar Eruption

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Quasi-Periodic Pulsations (QPP) are commonly observed in solar and stellar flares, providing insights into the underlying physical mechanisms governing energy release in the corona. In this study, we analyze a solar flare event on July 2, 2015, associated with a filament eruption that subsequently evolved into a coronal mass ejection (CME). Using observational data from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) and the Mauna Loa Solar Observatory (MLSO), we investigate the temporal and spatial characteristics of QPP during the eruption. Time-series analysis techniques, including Fourier and wavelet analysis, are employed to identify periodicities in the intensity variations. Our findings suggest that magnetic reconnection plays a crucial role in driving the observed QPP, as indicated by the dynamic evolution of the flare loops and associated plasma flows. This study contributes to understanding the relationship between QPP, filament eruptions, and magnetic reconnection, shedding light on the energy release processes in the solar corona.

12. Studying the Large Scale of the Universe

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The primary objective is to observe the distribution of matter on a grand scale throughout the universe. We employ the ΛCDM model to investigate the distribution of matter density (baryonic + cold dark matter) and dark energy density

throughout the universe. Here we have used 2df Galaxy redshift survey data and used different statistics methods like plotted comoving distance vs redshift and found that the experimental data is best matching with ΛCDM model curve. The current values of the Hubble parameter, matter density parameter, and dark energy density parameter are found to be $H_0 \approx 73.81 Kms^{-1}Mpc^{-1}, \Omega_{m0} \approx 0.279$ and $\Omega_{m\Lambda} \approx 0.721$ using χ^2 fitting which are matching with the observational data. Also, we have plotted two-point correlation function for different galaxy redshift surveys (2dfGRS, SDSS, DEEP2 and GAMA) and found the galaxy distribution in our universe through it.

13. Interfacing Method for Metal Oxide Gas Sensors Using Resistance to Time Period Conversion Circuit

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Metal oxide (MOX) gas sensors are highly valued for their high sensitivity and low fabrication cost. Traditional methods of interfacing these sensors with digital systems involve complex circuits comprising Analog-to-Digital Converters (ADC), signal conditioning circuits, and amplifiers. In contrast, this study presents an innovative "Direct Interfacing Method," which eliminates the need for such complex circuitry. By leveraging the inherent property of metal oxide gas sensors to change electrical conductivity in the presence of specific gases, this method converts variations in electrical resistance into time periods using an RC (resistor-capacitor) circuit. The time period of the resulting square wave is directly proportional to the sensor's resistance, which can be accurately measured using a microcontroller. The proposed direct interface circuit system is compact, portable, and demonstrates superior performance across a wide resistance range ($100k\Omega$ to $1G\Omega$). This method not only simplifies the interface design but also enhances the sensor's response time and reliability. The findings of this study suggest that the direct interfacing method is a promising alternative for efficient and effective gas sensing applications.

14. Studying the first stars of the Universe using 21-cm signal

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The recent findings from the James Webb Space Telescope (JWST) suggest a significant abundance of luminous galaxies in the early universe. These results of the observational study consistently point to efficient and rapid star formation occurring within the first few hundred million years after the Big Bang. These observations challenge our current theoretical understanding. To address this discrepancy between theoretical predictions and JWST observations of high-redshift galaxies, we modified our current models. In this study, we calculated the brightness temperature of the 21-cm signal with the help of the '21-cm semi-numerical predictions across cosmic epochs' code that includes radiative backgrounds and initial conditions from the CAMB code. We studied the variations of the 21-cm Global signal as well as the power spectrum across different redshifts. The global signal for the new model shows a significant deviation from the fiducial model. Also, the power spectra show interesting deviations. We are currently trying to quantify whether these deviations are detectable in observations or not.

15. Effective Parametric Retrieval of Metamaterial Enhanced Metal Halide Perovskite Absorbers in Terahertz Regime

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Metamaterials operating at terahertz (THz) region of the electromagnetic spectrum has remained a promising area of study. Metal halide perovskite materials are potential candidates for THz applications due to their excellent optoelectronic properties. In this work, we demonstrate metamaterial absorbers comprising concentric hexagonal gold rings with strip lines that is embedded on three different methyl ammonium lead halide ($MAPb(I/Br/Cl)_3$) perovskite substrates, for which the dielectric permittivity is defined by Gervais model. We have retrieved the electromagnetic parameters under transverse electric (TE) polarization in order to relate resonance properties and effective parameters, with the strong

absorption characteristics. The effect of field cancellation due to the back metal, which can lead to deceptive absorption measurements is also examined. The proposed design shows highest absorption of 99.67% at 0.59 THz for $MAPbCl_3$. The numerical results indicate that metamaterial implementation can significantly enhance the absorption of $MAPbI_3$ roughly by 13%. Thus, metamaterial-assisted metal halide perovskite serves as a promising candidate in thermal management systems, stealth technology and wireless communication in the THz regime.

16. Spatially-Modulated Metasurface Tiles for Dual-Band Electromagnetic Shielding at Terahertz Regime

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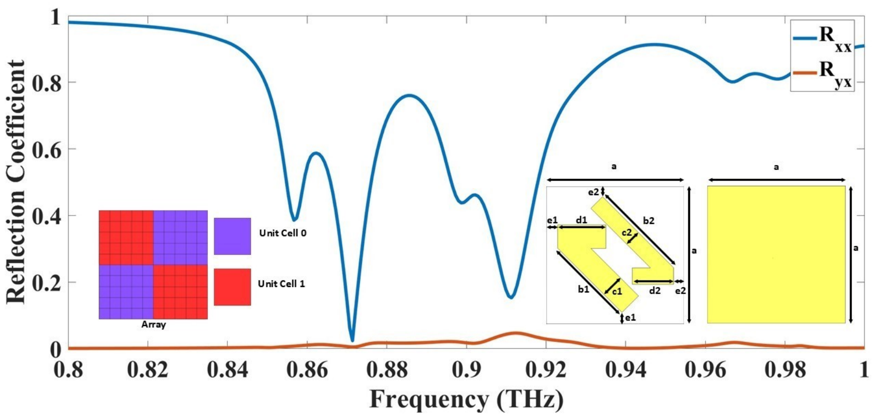
Metasurfaces (MSs) are the two-dimensional versions of metamaterials offering un-precedented control over amplitude, phase and polarization of electromagnetic radiation. In this work, we realize a spatially-modulated metasurface tile formed by the array of MS chiral unit cells. We consider two different basic metamaterial unit cells, where the unit cell-0 and the unit cell-1 (mirror image of unit cell-0) are chiral structures with ground plates that converts transverse electric (TE) polarization into transverse magnetic (TM) polarization at 0.95 THz and 1.03 THz but they have 180° phase response between them. We propose a checker board pattern of alternating 4x4 patches of unit cell-0 and unit cell-1 such that the proposed array eliminates the cross-polarization reflection (TM wave) as well as co-polarization reflection (TE) for a normal incident co-polarized incidence (TE wave) at both 0.871 THz and 0.911 THz simultaneously. This would be verification for the potential of this method to produce a broadband EMI shielding response. We implement the present design at THz frequency and the cross-polarization elimination is demonstrated using full-wave electromagnetic simulations. Our results pave the way for realizing ground planes for any polarization and hence broadband EMI shielding can be achieved in communication and space-component applications such as drones, satellites, and radars.



Reflection coefficient plot of the proposed array with checker board pattern. Array pattern is given in the left inset. Right inset shows the design of unit cell 0 with front and back views where, a = 100µm, b1 = 66µm, b2 = 73 µm, c1 = 17 µm, c2 = 12 µm, d1=35µm, d2 = 30 µm, substrate (fused quartz) thickness = 10µm, metal (gold) thickness = 1µm.

17. Exploring Generic Gravitational Wave Polarizations with a Null-Stream Based Bayesian Framework

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According to the predictions of General Relativity, Gravitational Waves(GWs) have only two polarisation modes, known as tensor polarisation. However, alternative theories of gravity predict that the GWs can have four more polarization modes: two vector polarization modes and two scalar polarisation modes. Generally, the strain measured by a GW interferometer is a linear combination of different polarization modes, and this linear combination depends on the interferometer's geometry and the source's location. In this work, we construct a Null-Stream-based Bayesian framework to analyze the strain data to detect and characterize the non-tensorial polarisation modes of GW, without requiring prior knowledge of the source's location. We then conduct a mock data study by injecting a set of reconstructed signal waveforms in the constructed framework to test the existence of the other polarisation modes.

POSTERS

1. The Weyl semimetallic behaviour of quaternary Heusler compound FeRhCrSi

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Theoretical prediction of half metallicity, ferromagnetism and spin gapless behaviour of Heusler compounds play a significant role in understanding and designing new materials for various spintronic applications. Heusler alloys show a stable half metallic state with a high Curie temperature and have compatible lattice structures with existing spintronic devices. These systems show variety of spintronic as well as topological properties with respect to different elemental composition and structure. We have performed spin polarized density functional theory calculations for the quaternary Heusler alloy FeRhCrSi. The density of states and band dispersion show a half metallic ferromagnetic state with a total magnetic moment of 3µB/formula unit. The band dispersion with and without spin-orbit coupling reveal spin semi metallic as well as a Weyl semi metallic behaviour in FeRhCrSi. The presence of Weyl nodes is further confirmed from the source and sink type of flux in normalized Berry curvature, from tight binding model studies. A finite Berry curvature is present in the system, which gives rise to a large anomalous hall conductivity of about 530 S/cm at the Fermi level. .

2. Aerosol optical properties retrieval using Cavity-enhanced Albedometer

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In this study, we present the development of a cavity-enhanced albedometer for the precise measurement of key aerosol optical parameters—absorption, scattering, extinction coefficients, and single scattering albedo (SSA)—across multiple wavelengths. The instrument was designed to address non-idealities typically encountered in traditional nephelometers, such as truncation error, sample losses,

and non-ideal wavelength responses. By optimizing its geometry and flow management, we minimized these errors, enabling accurate characterization of aerosol scattering and absorption properties. Experiments were conducted with NaCl. For the predominantly scattering NaCl, SSA values were close to 1, confirming negligible absorption. Cross-validation with a commercial aethalometer showed strong agreement in absorption measurements, confirming the albedometer's reliability. This work demonstrates the albedometer's effectiveness in capturing aerosol optical properties and identifies future improvements, including extending the spectral range and enhancing sensitivity for low-concentration aerosols.

Keywords : Cavity-enhanced Albedometer, Absorption Coefficient, Scattering and Extinction, Single Scattering Albedo (SSA)

3. Study of Light Localization in One Dimensional Random Media

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We explore the light localization in a one dimensional (1D) random layered medium in terms of its reflectivity. Introduction of randomness into a 1D photonic crystal (PC) degrades its photonic band gap and the band structure is completely destroyed when the randomness becomes very large. At different refractive index contrast between the layers of the PC, modifications of its first and second order photonic stop-bands are investigated with increasing strength of randomness. We observe that at a large strength of randomness, PC structures with and without a defect layer show similar reflection behaviour. Moreover, the band structure of PC with low index contrast is more sensitive to the randomness compared to that of the PC with the high index contrast due to poor light localization. Evaluation of photon decay length inside these structures with different strengths of randomness corroborates these results.

4. Effect of Dual Excitation on Tamm Plasmon Polariton Mode

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Plasmonics based nanophotonics is a fascinating area of research due to its potential to provide high-end future ready optoelectronic technologies. When the metal layer is coated on a distributed Bragg reflector (DBR), the localized mode excited at the metal-DBR interface, is known as Tamm plasmon polariton (TPP). In recent past, TPP has been studied extensively due to its wide range of applications in sensors, lasers, perfect absorbers and hot-electron photodetectors. However, a detailed investigation on different excitation schemes of TPP mode has not yet been explored. Here, we investigate the TPP in a silver-DBR structure for single side and both side excitations and compare the field confinement under these excitation schemes. The numerical simulation is performed using COMSOL Multiphysics software. The structure consists of a DBR and a 50 nm thick silver film on the top of it, where the number of DBR bi-layers is varied. The EM wave of power $P_{inc} = 1W$ in the optical frequency range is used for exciting the structure. The reflectivity of the structure is studied for different numbers of DBR bi-layers by exciting it from silver side and as well as DBR side. We observe that the metal side excitation is more efficient for better confinement of the TPP mode. Further investigation by splitting the same excitation intensity into two equal parts for both side excitation shows enhanced field confinement of the TPP mode compared to that of the single side excitation. This enhancement is achieved by controlling the respective phases of the excitation waves. These results would be useful for developing novel optoelectronic devices utilising different excitation schemes of the TPP modes.

Keywords : Tamm plasmon polariton, Distributed Bragg reflector, Dual excitation, Optoelectronic devices

5. An Observational Study of Solar Differential Rotation Using Sunspot Tracking

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Solar differential rotation, driven by convective plasma flows and magnetic field interactions, causes variations in angular velocity across different latitudes of the Sun. Although this phenomena has been extensively researched, our work focuses on using sunspot tracking tools to analyze differential rotation at the photospheric level.

Using data from the Michelson Doppler Imager (MDI) onboard NASA's Solar and Heliospheric Observatory (SOHO), we track sunspot positions over time to measure their movement across the solar surface. Advanced image processing techniques, implemented in Python with SunPy and Astropy, allow us to accurately extract sunspot positions and determine their rotational velocities.

Our findings confirm that the Sun rotates faster at the equator and gradually slows down toward the poles, consistent with the established studies on solar differential rotation. Additionally, a comparative analysis between theoretical predictions and observational data reveals important similarities and discrepancies, providing fresh perspectives on the intricate mechanics of solar rotation.

6. Investigating the Role of Dissipation and Collective Enhancement of Level Density in Neutron Emission from Compound Nuclei

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Nuclear fission is an obvious example of the collective rearrangement of nuclear matter. A fundamental feature of the fission process is the dissipation which is evident from the excess emission of measured pre-scission neutron multiplicity (ν_{pre}) than standard statistical model predictions. Apart from the effect of dissipation, collective enhancements of level density (CELD), where the large number of rotational and vibration levels at the fission saddle-point is also found to significantly influence the de-excitation of the CN. As very few efforts were made to explore the effect of CELD in fission, its effect in neutron emission probability is not clearly understood. In this context, we have systematically investigated the role of dissipation and the effect of CELD in neutron emission from CN over a wide range of masses. In this work, we have analyzed the reactions $^{18}O +^{150} Sm$, $^{19}F +^{169} Tm$, $^{16}O +^{194} Pt$ and $^{19}F +^{209} Bi$ leading to the formation of ^{168}Yb, ^{188}Pt, ^{210}Rn and ^{228}U compound nuclei, whose experimental data are available in the literature. These are analyzed within the framework of a statistical model incorporating dynamical hindrance in nuclear fission due to dissipation, shell corrections in the fission barrier and level density, and CELD. It is noticed that CELD plays crucial effect in neutron evaporation from an excited nuclei populated around 180 mass region. Detailed theoretical model and results from the analysis will be discussed during the presentation.

7. Periodic and Temporal Analysis of Solar and Geomagnetic Indices and their Associations Across Solar Cycles

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Solar transient phenomena, such as flares, coronal mass ejections (CMEs), and the solar wind, release vast amounts of energy and energetic particles that influence space weather and the Earth's magnetic environment. Understanding the impact of these solar activities on Earth is crucial for predicting space weather and its effects on terrestrial systems. We look at observational data from different observatories to study solar activity and how it affects things on Earth. We focus on solar magnetic and energetic activity as well as geomagnetic indices like the Ap and Kp indices. We begin by investigating the solar cycles from 1932 to 2024, identifying periodic patterns and trends in both solar and geomagnetic activity. We then narrow our analysis to each cycle to detect sub- cycle patterns. Additionally, we examine days with particularly high Ap index values, which indicate geomagnetic storm events, to compare their periodic behavior with normal days. To study the periodicities within each solar cycle, we apply Fourier transform and wavelet methods. We also explore the time lag response between solar and geomagnetic indices to better understand the delayed effects of solar activity on Earth's magnetic environment.

8. Systematic Analysis of Fission Fragment Charge Distribution in the Mass 190 Region Using General Description of Fission Observables (GEF) Mode

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Fission Fragment Distribution studies are an important probe in understanding the microscopic and structural properties of nuclei. The recent discovery of asymmetric fission in ^{180}Hg has reshaped the existing understanding of the fission mechanism in actinide nuclei. The asymmetric behaviour of several other isotopes in the actinide and pre-actinide region is found to persist up to excitation energy of 40 MeV. Microscopic properties such as shell effects and pairing energy

contribute significantly to this observed behaviour. The change from asymmetric to symmetric behaviour for higher excitation energies is attributed to the diminishing shell effect at the highest excitation energies. However, recent studies show the presence of asymmetric fission in transuranic nuclei even at higher excitation energies i.e. beyond 60 MeV. For higher excitation ener- gies, the particle evaporation from Compound Nuclei (CN) reduces its excitation energy, resulting in the persistence of shell effect. This contrary behaviour can only be under- stood through a systematic analysis of experimental data and by using computational tools across different mass regions. General Fission Code (GEF) is one such advanced tool that incorporates different pathways of fission process like the competition between particle emission, gamma emission and fission. This code utilizes available experimental data and improved theoretical models like Thomas-Fermi barriers of Myers and Swiatecki to estimate the fission barrier height. Another important parametrization adopted is the modelling of nuclear level density using constant temperature model at lower energies joined with modified Fermi-gas description at higher energies. In this work, we performed systematic analysis of four different reactions populating CN in the mass 190 region using GEF. For these reactions, asymmetric splitting is observed at lower excitation energies, while a symmetric distribution is observed at excitation energies beyond 40 MeV.

9. Simulating the Cosmos: Generating the Initial Conditions for Cosmological Simulations.

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The Cosmic Microwave Background (CMB) radiation provides a snapshot of the early universe, holding clues about its origin and evolution. This study utilizes data from the Planck satellite and theoretical models from CAMB software to investigate the primordial and matter power spectra, aiming to uncover the universe's initial conditions and refine our understanding of cosmic evolution. By comparing theoretical predictions with observational data, we test the validity of the ΛCDM model and explore the connection between primordial fluctuations and the current matter distribution. Our analysis reveals how quantum fluctuations from the early universe, magnified during inflation, shaped the large-scale structure of the cosmos. Additionally, we examine the roles of dark matter and baryons in structure formation, providing new insights into the universe's expansion and the nature of dark energy. These findings contribute to a deeper understanding of cosmic evolution and set the stage for future advancements in

cosmology.

10. Melamine Functionalized ZnO Cathode Buffer Layer for Improved Performance in Inverted Organic Solar Cells

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Due to its superior properties such as optical transparency, high electron mobility, low cost, and simple synthesis procedure, zinc oxide (ZnO) is widely used as cathode buffer layer (CBL) in inverted organic solar cells. However, the surface defects on ZnO act as recombination centres, thereby limiting the power conversion efficiency (PCE) and long-term stability. In this study, a nitrogen-rich organic molecule, 2,4,6-triamino-1,3,5-triazine (melamine) is used to passivate the surface defects on ZnO CBL. FTIR analysis confirmed the presence of melamine on ZnO surface after functionalization. The atomic force microscopy measurements revealed that there is no significant change in the surface morphology of ZnO after functionalization. Devices fabricated with the functionalized ZnO as CBL exhibited an average PCE of 6.22%, which is 7% higher compared to the reference device. The improvement in device performance was found to be due to reduction in series resistance and enhancement in both exciton dissociation and charge collection efficiencies.

Keywords : Organic solar cells, surface defects on ZnO, ZnO functionalization, power conversion efficiency, exciton dissociation efficiency, charge collection efficiency

11. Efficient Ternary Organic Solar Cells by Utilizing Energy Transfer Between Donor Materials

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Ternary organic solar cells (TOSC) are emerged as suitable contender for energy harvesting due to its superior properties such as cascade energy level alignment and complementary absorption spectra among the donors (D) and acceptors (A). Various active layer combinations in both D1: D2: A and D: A1:A2 were explored to achieve high efficiency in TOSCs. Here, we report the role of a donor material, PBDB-T in improving the PCE of PTB7-Th: COi8DFIC based binary device. The PBDB-T, PTB7-Th and COi8DFIC have complementary absorption spectra and form a cascade energy level alignment, which improves the light absorption and facilitates charge transfer in the active layer blend respectively. The photoluminescence spectra of the pristine PBDB-T, PTB7- Th and the PBDB-T: PTB7-Th blend at various weight ratios confirmed efficient energy transfer from PBDB-T to PTB7-Th. The devices fabricated with the ternary active layer blend provided a maximum efficiency of 9.71COi8DFIC based binary. After the initial analysis, the enhancement in PCE was attributed to the suitable morphology, cascade energy level alignment and energy transfer from PBDB-T to PTB7-Th.

12. Charge transport in self-assembled TS-CuPc in acidic PEDOT:PSS

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Organic p-type materials are extensively studied for their chemical, optical, and charge transport properties. Among these, solution-processable materials are particularly attractive due to their cost-effectiveness in the overall manufacturing of electronic devices. However, the electrical properties of these materials are highly dependent on processing conditions. This dependence calls for a deeper understanding of the charge transport mechanisms in these systems. One promising class of hole transport layer (HTL) materials is small molecules, with thermally evaporated crystalline Copper Phthalocyanine (CuPc) exhibiting excellent mobility. However, its water-soluble derivative, Copper Phthalocyanine-3,4,4,4- tetrasulfonic acid tetrasodium salt (TS-CuPc), has low film-forming ability and its amorphous nature makes it less effective when solution processed. It has been found that Phthalocyanines tend to form self-assembled structures in acidic medium, enabling ordered alignment of the molecules. Such a morphology is observed in its composite with acidic poly(3, 4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS), which has better solution processability than the pristine small molecule and a lower pH than PEDOT:PSS. In this study, we investigate the electrical transport properties of the PEDOT:PSS-TS-CuPc composite, where the TS-CuPc forms leaf-like self-assembled patterns. We report a comprehensive understanding of the transport mechanisms, detailing the temperature and electric field-dependent analysis of mobility in a diode architecture. A two-order increase in the mobility of the modified sample is observed. Additionally, we probe the anisotropy in transport by comparing in-plane and out-of-plane transport and its correlation to morphology and the nature of the self-assembled patterns.

13. Direct Deposition of PZT Thin Film on Single Crystal Diamond Substrate

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The integration of lead zirconate titanate (PZT) on a single crystal diamond enables the realization of multifunctional micromachined devices, such as high-frequency surface acoustic wave devices[1]. However, direct deposition of phase pure perovskite PZT thin film on a single crystal diamond substrate without a buffer layer has not been realized to date. Literature reports indicated that direct deposition of PZT films on a diamond substrate led to the formation of only a pyrochlore phase, which exhibits no ferroelectric or piezoelectric properties[2], [3]. Herein, we first report the deposition of perovskite PZT thin film on a single crystal diamond without any buffer layer using sol-gel synthesis method by optimizing the process parameters, particularly annealing temperature. Our results indicate that specific growth conditions are required for realizing the perovskite phase. The XRD pattern and Raman spectrum clearly confirmed the perovskite PZT phase.

1. S. Srinivasan, J. Hiller, B. Kabius, and O. Auciello, "Piezoelectric / ultrananocrystalline diamond heterostructures for high-performance multifunctional micro / nanoelectromechanical systems," *Applied Physics Letters*, vol. 90, no. 13, p. 134101, Mar. 2007, doi: 10.1063/1.2679209.

2. M. Chandran, B. Tiwari, C. R. Kumaran, S. K. Samji, S. S. Bhattacharya, and M. S. R. Rao, "Integration of perovskite PZT thin films on diamond substrate without buffer layer," *J. Phys. D: Appl. Phys.*, vol. 45, no. 20, p. 202001, May 2012, doi: 10.1088/0022-3727/45/20/202001.

3. M. Rath, D. Kumar, and M. S. R. Rao, "Integration of ferroelectric Pb(Zr0. 52Ti0.48)O3 thin films on conducting nanocrystalline diamond for high performance device applications," *Applied Physics Letters*, vol. 113, no. 3, p.

032904, Jul. 2018, doi: 10.1063/1.5035450.

14. Synthesis and Characterization of MnO_2 for High Performance Supercapacitor Electrode Application

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High-capacitance manganese dioxide (MnO_2) was synthesized via a co-precipitation method for supercapacitor electrode applications. The obtained MnO_2 was characterized using X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and Scanning electron Microscopy (SEM) to confirm its phase formation, purity, and morphology respectively. Electrochemical evaluations, including Cyclic Voltammetry, Galvanostatic Charge Discharge, and Electrochemical Impedance Spectroscopy were carried out to understand it's potential for electrochemical energy storage application. The fabricated electrode exhibited a specific capacitance of 220 Fg^{-1} at 1 Ag^{-1}. These findings underscore the potential of δ-MnO_2 as a highly efficient electrode material for supercapacitors

15. Direct Growth of Vanadium-Incorporated CoxSy Nanopyramids on Conducting Substrates: A Facile Approach for Enhanced Alkaline Hydrogen Evolution Reaction

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Developing efficient and cost-effective electrocatalysts for hydrogen evolution reaction (HER) in alkaline media is vital for large-scale hydrogen production. Cobalt sulfides (Co_xS_y) show promise as HER catalysts, but their activity remains still insufficient. Nanostructures with sharp edges are known to enhance H+ adsorption during HER, but the production of such morphologies and additional dopant incorporation require multi-step processes. Here, we developed a one-step hydrothermal method that simultaneously incorporates vanadium into cobalt sulfide nanopyramids (i.e., V:Co_xS_y), with pointed tip morphology,

which ensures synthesis scalability. Vanadium, with lower electronegativity and a smaller ionic radius than cobalt, modifies the catalyst's electronic and adsorption properties. The V:Co_xS_y nanopyramids grown on carbon cloth were used as binder-free electrodes for HER in 1 M KOH, demonstrating superior HER performance with an overpotential of 200 mV at 10 mA/cm^2 and a Tafel slope of 95 mV/dec, coming close to the Tafel slope of the benchmark Pt/C catalyst.

16. A comparative analysis of the electrochemical performance of δ-MnO_2 synthesised via coprecipitation and hydrothermal techniques.

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Supercapacitors have garnered substantial attention over recent decades due to their elevated power density, rapid charge-discharge capabilities, and excellent cyclic stability, positioning them as suitable candidates for use in electric vehicles, portable electronics, and renewable energy harvesting systems. Transition metal oxides particularly, MnO_2 are promising electrode materials due to their high theoretical capacitance, structural tunability, abundance, eco-friendliness, and affordability. In this study, δ-MnO_2 was synthesised via coprecipitation and hydrothermal reaction pathways. The structural, morphological, and electrochemical properties of the products were systematically compared to evaluate their supercapacitor performance. The X-ray diffraction studies and scanning electron microscopy (SEM) analysis of the products confirmed the phase purity and distinct morphological differences. Electrochemical characterisation such as cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), and electrochemical impedance spectroscopy (EIS) was performed to assess their specific capacitance, charge storage mechanism, and electrochemical impedance characteristics. The results revealed that the synthesis method plays a crucial role in tailoring the electrochemical behaviour of the material. The hydrothermally synthesised δ-MnO_2 demonstrates superior specific capacitance attributed to its enhanced crystallinity and its hierarchical morphology.

Keywords : Supercapacitor, MnO_2, Energy storage, Electrode materials

17. High-Q Dielectric Sensing with Fano Resonant Metasurface

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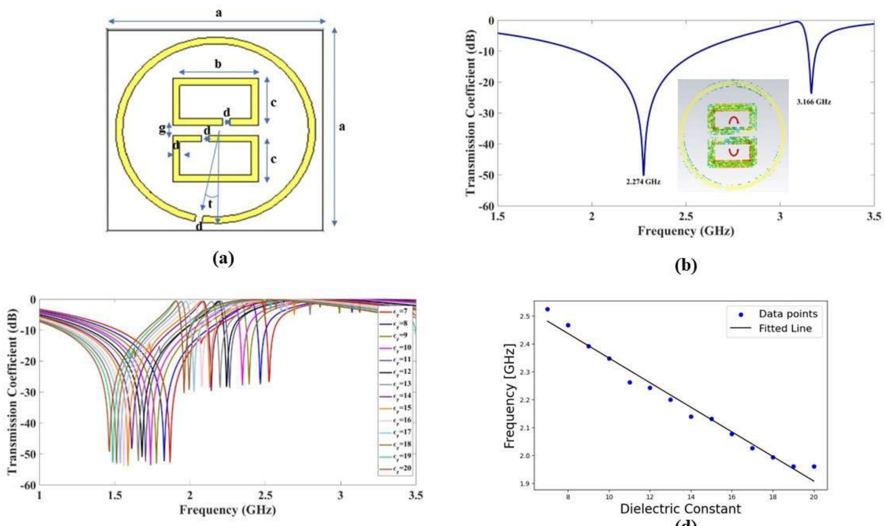
: In this work, we realise a microwave metasurface exhibiting Fano resonance which can be used for sensing the dielectric objects. The structure consists of an outer circular split ring resonator (SRR), which is responsible for the prominent dark mode at 2.274 GHz and two inner rectangular SRRs which produces the Fano mode at 3.166 GHz for normal incident transverse electric (TE) excitation. The inner SRRs also generates toroidal moments at 3.166 GHz which helps in minimizing radiative losses, making it ideal for dielectric sensing. Our results suggest that in the presence of a dielectric sample, Fano resonance curve redshifts significantly with an increase in dielectric constant of the sample, providing a reliable method for dielectric sensing. The proposed method is highly sensitive with a sensitivity of 0.0441 GHz per unit change in dielectric constant, so even a small change in dielectric constant can be detected with great accuracy. Moreover, the maximum Q factor of the Fano mode of the metasurface dipped in dielectric is found to be 3000. We attempt to use the proposed design to develop a sweat sensor at microwave frequencies. Similarly, the present design is also useful for molecular drug sensing, atmospheric pollutant sensing and gas sensing applications.



(a) (b) (c) (d)

18. MNZ metamaterial for broadband applications

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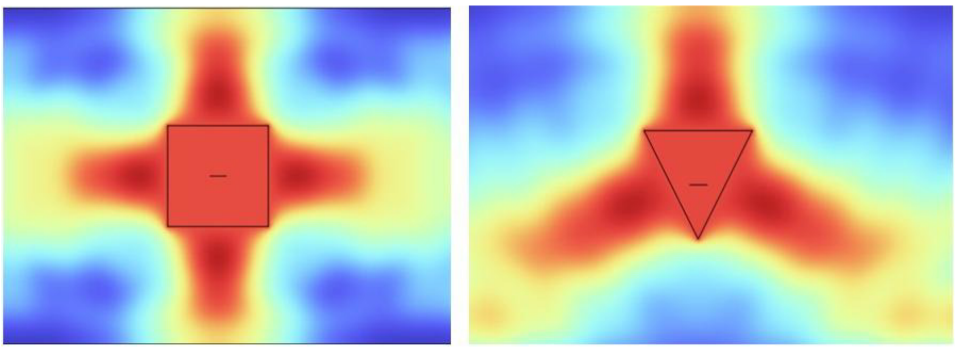
Mu-near-zero (MNZ) metamaterials, characterized by near-zero effective permeability ($\mu = 0$ approximately) at specific frequency ranges, have attracted significant interest due to their potential for electromagnetic wave manipulation, nontrivial field localization, and enhanced radiation control. These metamaterials offer unique functionalities such as impedance matching, wave tunnelling, and extraordinary transmission, making them highly promising for applications in antennas, sensors, waveguiding, and electromagnetic cloaking. In this work, we present the design and analysis of an MNZ metamaterial operating in the microwave regime. The metamaterial structure is engineered using a periodic arrangement of subwavelength resonators, tailored to achieve a near-zero permeability response within the desired frequency band. Simulations are conducted to investigate the dispersion characteristics, impedance properties, and field distributions using CST software. In figure (1) you can see how electric field from a line source behave inside a MNZ medium with different geometry. Furthermore, we explore potential applications of the designed MNZ metamaterial, particularly in improving antenna radiation efficiency, enhancing wavefront shaping, and enabling compact electromagnetic devices. The insights from this study contribute to the development of advanced metamaterial-based components for next-generation wireless communication, sensing, and stealth technology.



19. Exceptional Point of a Non-Hermitian Terahertz Metasurface for Controllable Polarization Transmission

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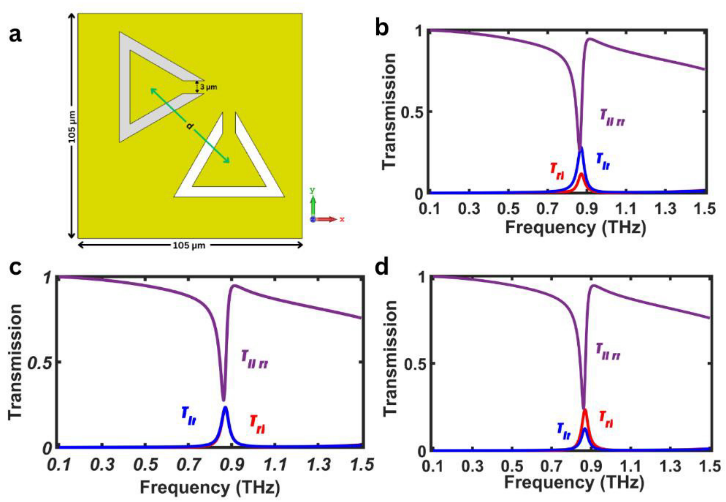
A non-Hermitian metasurface is a 2-D array of artificially engineered subwavelength structures that exhibit rich electromagnetic properties including the presence of exceptional points where parity-time (PT) symmetry breaks and eigenvalues and eigenvectors coalesce. In this study, we investigate a terahertz (THz) metasurface composed of a quartz substrate and two asymmetric triangular split ring resonators made of platinum and silver. Using the Drude model to account for metal dispersion, we computed the cross- and co-polarization circular transmission coefficients. By tuning the coupling strength between the rings through varying their separation, we could observe a merging of left-to-right circular polarization (T_{rl}) and right-to-left circular-polarization (T_{lr}) at a ring separation of $51.5 \mu m$, indicating the emergence of the exceptional point degeneracy. Beyond the exceptional point, the initially dominant transmission mode is suppressed whereas the previously suppressed mode gains dominance indicating the tunable control over polarization transmissions.



(a) The proposed PT-symmetric metasurface composed of platinum (blue) and silver (silver) triangular split ring resonators on the quartz substrate. (b)–(d) show the Circular transmission spectra for different coupling strength by varying the distance between the rings as (b) d = 48.1 μm (c) 51.5 μm and (d) 53.7 μm.

20. Modeling of Re-ionization Using Semi-analytical Galaxy Formation Techniqe

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The epoch of reionization (EoR) was an important phase in the early universe when the first galaxies formed and released radiation that ionized the surrounding hydrogen gas. Studying this period helps us understand how the universe evolved after the Big Bang. However, modeling reionization is challenging because it involves many complex physical processes. In this project, we use a semi-analytical galaxy formation model to study how galaxies grew and influenced their environment during reionization. This method is faster and more efficient than full hydrodynamical simulations while still capturing important astrophysical effects. Our model includes key processes such as gas accretion, star formation, energy feedback from stars, and radiation escaping into space. Using this approach, we aim to predict important observational features, such as how ionized regions expanded over time, the number and brightness of early galaxies, and the 21 cm radio signal from neutral hydrogen.

21. Non-Moire Tiles: A Novel Strategy for Polarization Engineering

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Non-Moiré (NM) tiles, formed by the contours of trigonometric functions, exhibit unique patterns and shapes, making them ideal for metasurfaces with robust electromagnetic functionalities. The NM designs reduce symmetry limitations and interference objects, allowing for precise wave control based on polarization and direction. This work uses a 2-D NM tile to realize a metasurface for broadband polarization conversion, tailored transmission, reflection, and beamforming characteristics. A 0.332 GHz bandwidth is observed between 3.948–4.28 GHz, with a maximum PCR of 93.62% at 3.851GHz. The results highlight the broadband capabilities and high PCR of the design, which could be extended to electromagnetic functionalities in microwave, THz, and optical frequencies.