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SEMICONDUCTOR LASERS

Supersymmetric laser arrays

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Supersymmetry (SUSY) emerged within particle physics as a means to relate two fundamentally different classes of elementary particles: bosons (integer spin, Bose-Einstein statistics) and fermions (half integer spin, Fermi-Dirac statistics). Extensions to the Standard Model have also been proposed based on SUSY theory in order to resolve long-standing issues in quantum field theory, including the nature of vacuum energy, origin of mass scales and dark matter. Even though the experimental validation of SUSY is still an ongoing issue, supersymmetric/isospectral techniques have already found applications in low-energy physics, nonrelativistic quantum mechanics, and nonlinear dynamics, to name a few. On the other hand, waveguide laser arrays have been a subject of intense investigations for the purpose of building high-power phase-locked lasers, which are immune to the detrimental effects of nonlinearities or filamentation. Nevertheless, such systems suffer from multimode operation, which in turn leads to a chaotic emission.

Recently, a group led by Dr Mercedeh Khajavikhan in University of Central Florida proposed and demonstrated a scheme for filtering the undesired transverse supermodes of laser arrays by using the SUSY concept. In their proof of the concept experiment, the primary array is comprised of five identical coupled ridge-waveguide cavities. By applying appropriate SUSY transformations, a superpartner index profile can be synthesized with propagation eigenvalues that match the higher order modes of the main array (besides the fundamental in-phase mode). The arrangement was realized on an InP wafer with InGaAsP quantum wells as the gain material. Uniform pumping was applied to the main arrays, while loss was introduced in the superpartner array by blocking the pump beam using a knife edge. Under these pumping conditions, the system emits a diffraction-limited, narrow, and low-divergent beam, as opposed to conventional multi-transverse modes emission. The respective spectrum measurements indicate phase-locking in the fundamental in-phase mode. Their results may pave the way for the design of high-radiance single mode laser arrays, and provide a fertile ground in order to study the interplay between non-hermiticity, nonlinearity, and supersymmetry.

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OPTICAL PROPERTIES OF 2D MATERIALS

Signatures of moire excitons

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In van der Waals heterostructures of atomically thin 2D materials, the inevitable lattice mismatch and twisting between the building blocks always lead to the formation of Moire pattern, which is a periodic spatial pattern of varying atomic registries. Theory has predicted that such a nanoscale moire landscape can endow excitons highly intriguing properties (Science Advances 3, e1701696 (2017)), including their confinement in an array of quantum dot like potential traps with circularly polarized valley optical selection rules.

Now a team of researchers from University of Washington, Seattle, University of Hong Kong, Oak Ridge National Lab, and University of Tennessee have reported the first experimental signatures of such moire trapped excitons. In $MoSe_2/WSe_2$ heterobilayers, they discovered that at very low excitation power, the initially broad interlayer exciton peak in the photoluminesence becomes a series of ultrasharp narrow lines well seperated spectrally, the feature of zero-dimensionally confined excitons. The fact that all these emission lines exhibit strong circular polarization uniformly across the sample implies the confinements all have rotational symmetry, which defects or random traps cannot have in general in the moire background. Moreover, magneto-optical measurements show the emitter *g*-factors are also homogeneous across the same sample and take only two values in samples with twist angles near 60 degrees and 0 degree respectively. The *g*-factors match those of the free interlayer exciton, with values determined by the two possible valley-pairing configurations at these angles. These strong evidences consistently point to the moire excitons confined by the smooth moire potential where the traps always appear at the high-symmetry locals with intrinsic 3-fold rotational symmetry. This work points to new opportunities for exciton physics in 2D semiconductor heterostructures, including the possibility to have a new type of excitonic quantum emitters.

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PEROVSKITE SEMICONDUCTOR OPTOELECTRONIC DEVICES

Rational molecular passivation for high-performance perovskite light-emitting diodes

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Solution-processed metal halide perovskites (MHPs) have received significant interest for cost-effective, high-performance optoelectronic devices. In addition to the great successes in photovoltaics, their excellent luminescence and charge transport properties also make them promising for light emitting diodes (LEDs). To achieve high-efficiency perovskite LEDs (PeLEDs), extensive efforts have been carried out to enhance radiative recombination rates by confining the electrons and holes. In addition to enhancing radiative recombination rates, it is equally important to decrease the non-radiative recombination for improving the device performance. Passivation of the defects could be an efficient way for reducing

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the non-radiative recombination.

Recently, Feng Gao, Wei Huang, Limin Liu and their colleagues found that the candidate amino-functionalized passivation agent which form stronger hydrogen bonds with organic cations in perovskites are less effective in healing defect sites. Based on their findings, they designed new passivation molecules with decreased hydrogen-bonding ability, and hence improve their interaction with defects. In particular, they exploited O atoms within the passivation agent to polarize the passivating amino groups through the inductive effect, reducing their electron donating ability and hence relevant hydrogen-bonding ability. This results in enhanced coordination of the PA functional groups with the perovskite defect sites and hence much improved passivation efficiency. As a result, the trap mediated non-radiative recombination has been substantially decreased and a record value of 21.6% external quantum efficiency of PeLEDs has been obtained. The reports has showed us a guideline for designing molecular for surface passivation, which could be helpful for any type of perovskite optoelectronic devices.

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PEROVSKITE SEMICONDUCTOR OPTOELECTRONIC DEVICES

Surface passivation of perovskite film for efficient solar cells

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The power conversion efficiency (PCE) of perovskite solar cells (PSCs) swiftly increased from 3.8% to more than 20% during last 10 years, thanks to the advancement of perovskite film growth, device and interface engineering. However, solution-processed perovskites are usually polycrystalline, that is the photoactive films contain substantial structural disorders, such as grain boundaries, interfaces and crystallographic defects. These defects have detrimental impacts on the performance and stability of PSCs.

In this work, a surface passivation approach was invented and investigated by the research team led by Prof. Jingbi You from Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China, based on which a high open circuit voltage (V_{oc}) and a high PCE were realized. Prof. You's team developed an organic halide salt, phenethylammonium iodide (PEAI), for post-treatment of mixed perovskites $FA_{1-x}MA_xPbI_3$ ($FA{:}HC(NH_2)_2$; $MA{:}CH_3NH_3$) to suppress the surface defects of perovskite polycrystalline films. Surprisingly, the mere organic salt PEAI instead of the previously believed PEA_2PbI_4 2D perovskite was responsible for the significant surface passivation effect. They carefully controlled the conversion between PEAI to PEA_2PbI_4 in the actual devices and discovered the existence of an thin layer of PEAI on top of perovskite surface, instead of PEA_2PbI_4, is the key to increasing the V_{oc} to as high as 1.18 V, which is 94.4% of the Shockley-Queisser limit V_{oc} (1.25 V). As a result, a 23.32% certificated efficiency (the highest PCE of PSCs of the article that has been reported in so far) was obtained by adopting this low-temperature solution-processed planar structure. This method is obviously meaningful for manufacturing low-cost, efficient and highly flexible perovskite solar cells.

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