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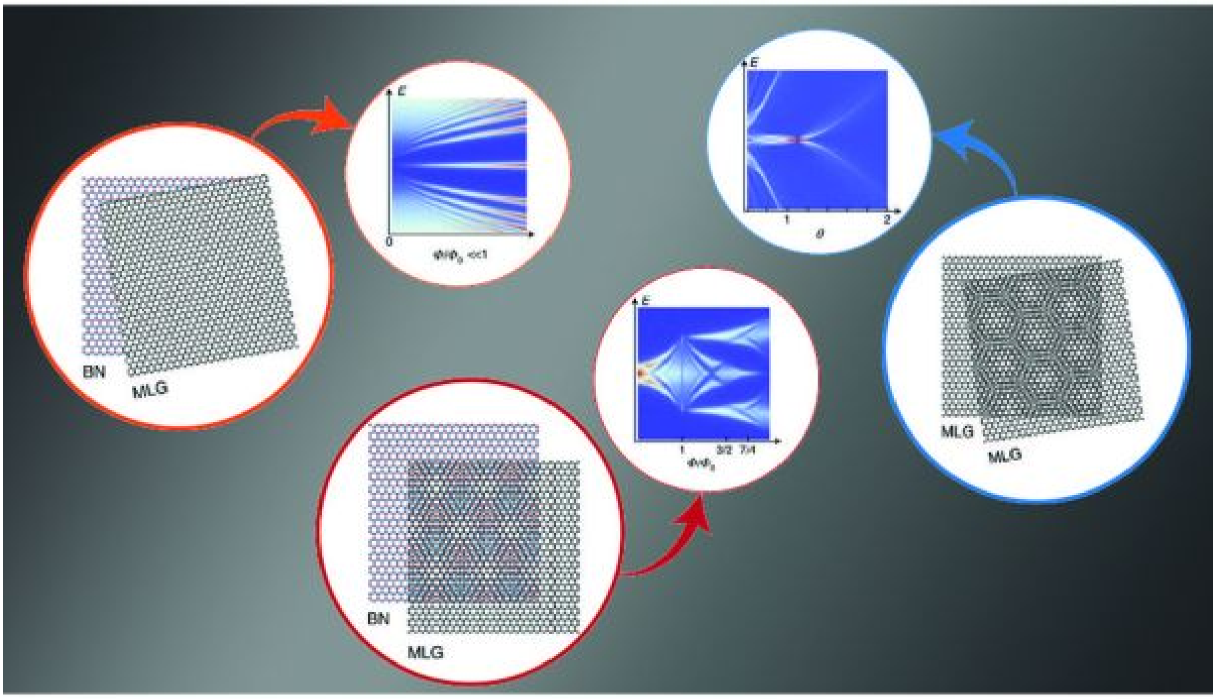

The Physics behind Twisted Bilayer Graphene

An international team of researchers, including ICFO Prof. Dmitri Efetov, give a thorough review in Nature Physics on the status and prospects of the physics behind stacked monolayers of 2D materials.

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Strongly correlated quantum materials are excellent testbeds for complex quantum phases of matter since they have shown to give rise to spectacular phenomenology, from high-temperature superconductivity to the emergence of states with long-range quantum entanglement. However, their complexity and the vast amount of system variables have so far hindered scientists to obtain a more complete, thorough understanding of its microscopic mechanisms.

Van der Waals heterostructures consist of individual layers of two-dimensional atomic materials such as graphene, hexagonal boron nitride, and transition metal chalcogenides, which are vertically stacked on top of each other. As the relative angle between the crystals can be freely chosen, this creates a new capability in physics - a concept which is called Twistronics. Scientists have recently found that by overlaying two individual layers of these 2D materials, complex heterostructures moire structures can be created, which host an amazing realm of unexplored and undiscovered physical phenomena.

Recently and considered one of major scientific achievements in these last two years, researchers found that, when tuning one of these systems, specifically in a twisted bi-layer graphene system, it was possible to drive the system from exhibiting strongly correlated states to presenting clear superconductivity features. That is, by changing the electrical charge carrier density within the device with a nearby capacitor, the material could be tuned from behaving as an insulator, to behaving as a superconductor, or even an exotic orbital magnet with non-trivial topological texture - a phase never observed before. Sor far, there is still no theoretical approach that can precisely explain such complex and exceptionally rich physics, and in particular, how these all these states may be linked or connected with each other and why they occur in such order.

In a recent study published in Nature Physics, researchers Leon Balents, Cory R. Dean, ICFO Prof. Dmitri K. Efetov and Andrea F. Young give a thorough report on the status and the prospects of these systems and the physics that arises from them. They focus on understanding the patterns that are created when two individual monolayers of these materials, called moire patterns, are stacked in a specific way, discuss the engineering in van der Waals heterostructures as well as explore how different phenomena emerge from the moire flat bands that are formed.

Flat bands are advantageous because they guarantee a large density of states, which amplifies the effects of interactions. Bearing this in mind, the researchers have focused their study on moire systems in Twisted Bi Layer Graphene (tBLG) in particular. They have studied various systems in which a small mismatch in periodicity of the pattern, introduced either by lattice mismatch or rotational misalignment, results in different physical scenarios, may it be correlating states, insulating states, superconductivity, etc. From these, they search, among other things, to understand and find answers to what may be the nature of the insulating states, what is the origin and nature of the observed superconductivity? How strong are analogies to other correlated electronic systems, such as high-temperature superconducting cuprates? This study is a step forward in understanding and setting the basis for the theory that may be capable of explaining in a future all the rich and very complex physics behind these novel materials and systems. Being able to control and manipulate such systems, and really understanding what is occurring inside them, will be a major advancement, if not a revolutionary shift, in the engineering of these materials and the development of applications for future innovative and disruptive technologies.