Physics 198 Term Paper

Topological Order, Insulators, and Semiconductors

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1 Introduction

In every-day life, we often talk about different phases of matter such as "solids, liquids, and gases", but how do we actually classify different materials based on their phase?

One paradigm to classify them based on their ***symmetries***. Intuitively this makes sense. For instnce, a gas at equilibrium has translational symmetry because if we move from one point to any other the properties of the material (pressure, density, temperature, etc.) remain the same. In contrast to this, a crystal like $NaCl$ composed of a lattice of Na^+, Cl^- does not have translational symmetry because if we move from an Na^+ site to a Cl^- site, the electric charge of the site is different. This paradigm is called the Landau-Ginzburg theory of Symmetry-Breaking Phases.

Separate from this discussion, topological effects began showing up in tangible physics. In the 1980s, the Integer Quantum Hall Effect (IQHE) was discovered, and it was found that the origin for the amazing adherence to quantization of the hall conductance is topological in order. Soon after, the Fractional Quantum Hall Effect in which the hall conductance is quantized with fractional values rather than only integers, was discovered, and with it the first example of a phenomenon *beyond* the Landau-Ginzburg paradigm.

Fractional Quantum Hall Liquids cannot be understood solely based on their symmetries, but rather require a new ***topological order*** to be fully described. Quantum Hall Effect (QHE) states are an example of Thouless-type topological order, but another important one is Wen-type topological order.

Topological Insulators and Superconductors are [complete soon]

2 Symmetry-Breaking Phases and the Order Parameter

3 Beyond the Landau-Ginzburg Paradigm: Fractional Quantum Hall States and Topological Order

4 Topological Insulators

5 Topological Superconductors

References