THE TEM: A VERSATILE TOOLKIT FOR EXPLORING QUANTUM MECHANICS

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Traditionally, the transmission electron microscope (TEM) is often considered as a sample characterization tool for tasks such as imaging the sample, measuring atomic positions and determining atom types. However, this application-centered approach neglects that, on a fundamental level, the TEM in fact realizes an experimental setup for a quantum-mechanical scattering experiment: the condenser lens system prepares the probe electron's state according to the experimenters' specifications, then the probe electron interacts with the specimen, and finally the outgoing probe electron's state is measured (e.g., its spatial, momentum, or energy distribution).

In this presentation, I will explore some of the quantum mechanical phenomena that can occur in the different parts of the TEM. Before and after the sample area, one is free to manipulate the quantum state of the probe itself, e.g. using beam shaping to create specific states such as vortex beams [2]. On the one hand, this allows to directly study and experiment with electron states, such as free-electron Landau states [4]. On the other hand, this paves the way of transforming one state into another to optimize measurements [2,3].

Regarding the sample, one usually has no means of determining its local quantum state on a nanometer scale before or after the interaction with the beam electron (after all, gaining information about the sample is the very point of investigating it in the TEM). In effect, this means that we are dealing with the interaction between a specifically prepared quantum system (of the beam electron) with a largely undetermined quantum system (of the sample). On a practical level, I will review ways of determining properties of the quantum system of the sample, such as the spatial distribution or spin information of individual states [4,5]. On a more fundamental level, I will discuss the fact that the interaction between quantum systems gives rise to entanglement, which has been largely neglected thus far [6].

Both the probe beam and the sample are inherently quantum mechanical objects. Fully embracing that fact may not only provide new insights into the underlying physics governing them as well as their interaction, it can also pave the way for new, optimized measurement schemes in the future.

References:

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