FRIAS RESEARCH FOCUS OF THE ACADEMIC YEAR 2014/2015

DESIGNED QUANTUM TRANSPORT IN COMPLEX MATERIALS

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Abstract:

The proposed Research Focus will foster interdisciplinary research on the quantum design principles for efficient, scalable, affordable and sustainable light-energy conversion. We will gather leading expertise on quantum transport processes which determine light-energy conversion efficiencies in nature- and man-made, highly structured materials - from photosynthetic complexes to photovoltaic and lighting technologies. We will induce strong synergies between quantum research in physics, chemistry, material sciences at ALU, and technology-driven research at our Fraunhofer Institutes. On the educational side, this will be complemented by the development of an innovative, M.Sc.-level Interdisciplinary Quantum Science curriculum accessible for students of all here involved academic disciplines.

Sketch of Research Topic:

Given the anticipated increase of global energy demand in the 21st century, sustainable and affordable energy production as well as consumption count within the century's key challenges for modern societies. Bio-inspired energy production and conversion – e.g., in artificial photosynthesis - offer potentially highly rewarding perspectives, since, once achieved and scaled up, they could be significantly more efficient than other strategies such as, e.g., biofuel production. In particular, transforming biological design principles into technologies could dramatically reduce the required input of primary resources as arable land, energy, or water.

However, we lack scientific insights into many fundamental aspects of natural photosynthesis, which currently hamper the design of artificial photosynthetic devices with the required efficiency, scalability, and sustainability to be economically viable. Likewise, most of the microscopic quantum transport mechanisms which determine the efficiency of man-made light-energy conversion technologies (photovoltaics, LED) are only barely understood. Progress is driven by trial and error rather than by a systematic exploration of the quantum design principles that allow for optimal performance.

Recent research strongly suggests that microscopic transport processes in nature and in technology are fundamentally similar in many respects, such that results from either side await to be mutually communicated and explored. To make progress, a dedicated joint effort by physicists, chemists, material scientists and engineers is needed. This is the present Research Focus' very purpose.

To explore quantum mechanics for technological design, we need to guarantee the robust scalability of the relevant quantum phenomena, to identify possible physical carriers and implementations (in organic, anorganic or hybrid materials), and to account for relevant technological constraints in terms of affordability and sustainability. This will be reflected by the Research Focus' three Key Research Lines:

1) Controlled transport in engineered quantum systems: How can we implement specific quantum transport properties in engineered systems of increasing size, while maintaining robustness?

2) Optimal materials for optimal transport: Which materials can best accommodate and shield the transporting degrees of freedom?

3) Design principles for light-energy conversion technologies: Which are the structural elements to hardwire the quantum advantage in technological device engineering?

Each of these Key Research Lines will be coordinated by one of the proposal's PI's, and host Internal, External Senior and Junior Fellows. Affiliated Fellows attracted by the PI's through their respective scientific networks will join the group. At present, we anticipate strong input on the primary physical properties of photosynthesis, on macroscopic quantum electrodynamics, and on photovoltaic up-conversion.

Centered around the Research Focus' fellows' research, the scientific program will be complemented by a continuous lecture and seminar series, with the explicit purpose to offer advanced training on cutting-edge research for the proponents' institutions' B.Sc., M.Sc. and PhD students, to be condensed into an Interdisciplinary Quantum Science academic curriculum. The Research Focus will open with a one week International Workshop (approx 50 participants) in summer/fall 2014, and, if funding allows, run a one month International Summer School in August/September 2015.

Applicants for Junior Fellowships should have a strong interest in top-level interdisciplinary research as sketched above, and import relevant expertise, both experimental and/or theoretical, in quantum and classical transport phenomena in complex quantum systems, in controlled quantum dynamics of engineered multi-component systems (such as ion traps or hybrid quantum architectures), or in the fundamental working principles of light-energy conversion technologies. Furthermore, candidates are expected to engage in the Research Focus' educational and outreach activities.