Title of Project：Physical Properties of Quantum Liquid Crystals

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【Purpose of the Research Project】

In rod- or disk-shaped molecular systems, a state called "liquid crystal" appears in addition to the three states of matter; gas, liquid, and solid. Recently, electronic states that have similarities to liquid crystals have been observed in a variety of solid materials. These electronic states have been studied independently in the fields of quantum spins, strongly-correlated metals, and superconductivity, but here we define these states respectively as "spin liquid crystals", "charge liquid crystals" and "pair liquid crystals". In this innovative area research, we introduce a new concept "quantum liquid crystals" (QLCs) to unify these novel electronic states.

Within this, we will promote new collaborations between researchers from different fields, to clarify and control the physical properties of QLCs. We aim to understand the ground states of different QLCs; to establish the universal features common to all QLCs; and to understand the diversity of phenomena seen in experiment. In addition, by using state-of-the-art technologies, we will elucidate and control the elementary excitations of QLCs. This will lay the foundation for future QLC-based technologies exploiting the flexible characteristics of liquid crystals, and the large and fast responses of quantum systems.

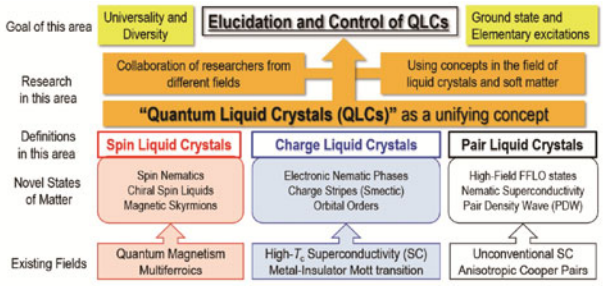

Figure1. Outline of the research project

【Content of the Research Project】

Within this innovative research area, we have identified four different themes, based on methodology, which will be used to promote new collaborations.

-A01: Development of QLC materials

To develop and characterize new materials in which novel QLC states emerge, using a broad range of established and original synthesis techniques.

-B01: Advanced measurements of QLCs

To elucidate QLC electronic states in experiment, by using a combination of established high-precision measurement techniques and through the development of new techniques, in combination with different technologies.

-C01: Theory of QLCs

To describe the order parameters of QLCs and effects of their quantum fluctuations, as well as to design QLC materials and their functionality.

-D01: Control and functionality of QLCs

To control QLC states and search for useful QLC functions, by utilizing micromachining-based nanoscience and ultrafast optics.

Research in this area will be interdisciplinary, and aims to establish the basics of new quantum technologies.

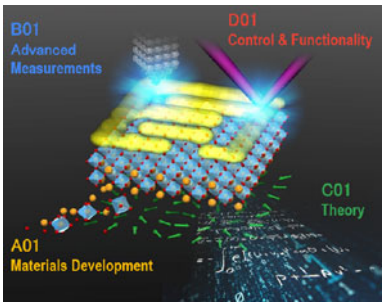

Figure2. Four themes to study QLCs

【Expected Research Achievements and Scientific Significance】

The advances in the field of "liquid crystals and soft matter" beyond the three states of matter have successfully led to many technological applications. Our QLC area can be considered as its quantum version, which can potentially generate novel phenomena and concepts. It will also pave a pathway to new QLC technology that has some useful functions in the quantum information.

【Key Words】

Quantum liquid crystals (QLCs): New electronic states similar to liquid crystals emerging from quantum effects. In liquid crystals molecules have anisotropy, but in QLCs quantum-mechanical degrees of freedom lead to anisotropic states with peculiar physical properties.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,134,000 Thousand Yen

【Homepage Address and Other Contact Information】

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