## 岡研究室 Oka Group

## 研究テーマ Research Subjects

- 1 量子物質のフロッケ・エンジニアリング Floquet engineering of quantum materials
- 2 量子多体系の非平衡状態 Nonequilibrium states in quantum many-body systems
- 生体現象、情報物理への場の理論の応用 Application of field theory to biology and information physics







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専攻 Course 理学系物理学 Phys., Sci.

量子物質の非平衡状態に潜む未知の自然法則を発見すると ともに、その理解をもとに物質相を自在に制御し機能発現さ せる方法を理論的に研究する。中でもフロッケ・エンジニア リングに代表される新しい理論体系が近年注目を集めており、 非平衡現象を平衡系に近い深さで理解することが可能になり つつある。さらに乱流、ニューラルネットワークといった古 典物理や、生命現象、日常的に非平衡現象が利用されてきた 半導体物理などの分野で蓄積されてきた知見を参考にしつつ、 場の理論や数値計算などの基礎的な手法を利用することで相 関電子系、トポロジカル物質、スピン系などの重要な量子物 質の非平衡現象の研究をおこなっていくとともに、化学反応 ネットワークや生物系における情報理論など、伝統的な凝縮 系物理学の範疇外の問題にも興味を持っている。

Our primary research focus around studying quantum materials driven far from equilibrium by external fields. Our objective is to discover new fundamental laws of physics that govern these exotic states and explore methods to control their collective dynamics. To achieve this, we employ innovative theoretical frameworks like Floquet engineering, which allows us to comprehend nonequilibrium physics at a similar depth as equilibrium systems. Additionally, we draw valuable insights from other research fields such as turbulence, neural networks, and nonlinear semiconductor optics, and apply them to investigate new exotic quantum materials. Our target materials encompass a wide range, including topological systems and strongly correlated systems. We will also investigate novel nonlinear response phenomena, such as the heterodyne Hall effect, wherein the quantum Hall effect is induced by oscillating magnetic fields. Furthermore, we have a keen interest in exploring problems beyond traditional condensed matter physics, such as chemical reaction networks in biological systems and information theory.

Floquet engineering of band topology oquet engineering in ultrafast spintro  $(E_{sp}\sim\Omega \leq E_{rh})$  $(E_{ig} - \Omega < E_{cb})$  Control of magnetization, spin current, topological order Inverse Faraday effect Renormalized exchange coupling Induced scalar chirality quet Kubo and TKNN formulae quet Keldysh greens function Correlated electrons driven by electric fields Switching (optical memory & Mott RRAM) New states, new functions Carrier generation
Breakdown and field induced states
Heating and thermalization
Higher harmonics generation Frequency conversion, heter Usage of metamaterial Higher harmonics generation Frequency conversion, heterodyne Usage of metamaterial -and near field techniques Floquet many-body methods (e.g. DMFT) Quantum field theory

(b) Hypergraph of the reaction (a) Optogenetic control of two GPCRs light 1 light 2 ≠ (V<sub>4</sub>) (G) GPCR 2 GPCR 1

量子物質のフロッケ・エンジニアリングの広がり。バンドトポロジー、スピン 秩序、相関電子系などの相制御や新原理に基づくデバイスの提案につながって

Floquet engineering in quantum materials. T. Oka, S. Kitamura, Annu. Rev. Condens. Matter Phys. 10, 387-408 (2019).

フロッケ・エンジニアリングの光遺伝学への応用と生体内情報伝達ネットワー ク制御

Application of Floquet engineering to optogenetics and control of cell signalling.

