Omar A. Ashour

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Research Interests

Despite sustained efforts, direct detection of dark matter remains elusive. Propelled by cutting-edge advances in detector sensitivity and innovative proposals employing quantum materials, the search for dark matter has recently expanded to lower masses, encompassing well-motivated theories for light and ultralight candidates. However, detecting these low-mass candidates remains a formidable challenge, requiring target materials that exhibit measurable responses with just a few meV of energy deposition from dark matter scattering or absorption.

This burgeoning realm of quantum sensing exploits exotic phenomena in quantum materials, such as topological order, strong correlations, and magnetic spin textures as new pathways to low-threshold sensors. Such sensors go beyond next-generation dark matter detectors, with applications in quantum information science and future quantum technologies.

I am interested in harnessing the interplay between topological order and collective excitations, primarily phonons and magnons, to develop new quantum sensing schemes. Such excitations can break symmetries that protect the gapless boundary states in topological insulators, thus leading to a metal-insulator transition at the boundary, which could then be detected. My work employs various analytical and computational tools, such as density functional (perturbation) theory, many-body perturbation theory, and tight binding models, to elucidate the electronic, magnetic, and excited-state properties of various quantum materials. Additionally, I often utilize models from high-energy physics to study dark matter interaction with such materials.

Current and recent projects include:

- Studies of phonons in higher-order topological insulators and mirror Chern insulators.
- Confined magnons in antiferromagnetic topological insulators.
- Modeling the spin ice state in pyrochlores from first principles.

Education

2019 – 2025 **PhD, Physics**.
University of California, Berkeley, CA

Advisor Sinéad M. Griffin

2019 – 2020 **MA, Physics**.
University of California, Berkeley, CA

2017 – 2019 **MS, Applied Physics**, GPA: 3.90.
University of California, Berkeley, CA

Thesis The Nonlinear Schrödinger Hierarchy: from Quasi Rogue Waves to Nonlinear Talbot Carpets

2013 – 2017 **BS, Electrical Engineering (Optics)**, GPA: 4.0.
Texas A&M University, College Station, TX

Thesis Maximal Intensity Higher-Order Breathers of the Nonlinear Schrödinger Equation

Preprints and Publications

⋆ Equal Contribution

† Corresponding Author

2023 Na Hyun Jo⋆, **Omar A. Ashour**⋆, Zhixue Shu, Chris Jozwiak, Aaron Bostwick, Sae Hee Ryu, Kai Sun, Tai Kong, Sinead M. Griffin, and Eli Rotenberg. On the effects of strain, defects, and interactions on the topological properties of $HfTe_5$ (2023). [arXiv:2303.10836]

2023 Thomas F. Harrelson, Ibrahim Hajar, **Omar A. Ashour**, and Sinéad M. Griffin. Theoretical investigation of decoherence channels in athermal phonon sensors (2023). [arXiv:2109.10988]

2022 **Omar A. Ashour**†, Siu A. Chin, Stanko N. Nikolić, and Milivoj R. Belić. Higher-order breathers as quasi-rogue waves on a periodic background, *Nonlinear Dynamics*, **107**, 3819–3832 (2022).

2022 Stanko N. Nikolić, Sarah Alwashahi, **Omar A. Ashour**, Siu A. Chin, Najdan B. Aleksić, and Milivoj R. Belić. Multi-elliptic rogue wave clusters of the nonlinear Schrödinger equation on different backgrounds, *Nonlinear Dynamics*, **108**, 479–490 (2022).

2022 Thais Chagas⋆, **Omar A. Ashour**⋆, Guilherme Ribeiro, Wendell Silva, Zhenglu Li, Rogério Magalhães-Paniago, Yves Petroff, and Steven G. Louie. Multiple strong topological gaps and hexagonal warping in Bi_4Te_3, *Physical Review B*, **105**, L081409 (2022).

2022 Milivoj R. Belić, Stanko N. Nikolić, **Omar A. Ashour**, and Najdan B. Aleksić. On different aspects of the optical rogue waves nature, *Nonlinear Dynamics*, **108**, 1655–1670 (2022).

2021 **Omar A. Ashour**†. NonlinearSchrodinger: higher-order algorithms and Darboux transformations for nonlinear Schrödinger equations (2021). [arXiv:2103.14469]

2019 Stanko N. Nikolić, **Omar A. Ashour**, Najdan B. Aleksić, Yiqi Zhang, Milivoj R. Belić, and Siu A. Chin. Talbot carpets by rogue waves of extended nonlinear Schrödinger equations, *Nonlinear Dynamics*, **97**, 1215–1225 (2019).

2019 Stanko N. Nikolić, **Omar A. Ashour**, Najdan B. Aleksić, Milivoj R. Belić, and Siu A. Chin. Breathers, solitons and rogue waves of the quintic nonlinear Schrödinger equation on various backgrounds, *Nonlinear Dynamics*, **95**, 2855–2865 (2019).

2017 Stanko N. Nikolić, Najdan B. Aleksić, **Omar A. Ashour**, Milivoj R. Belić, and Siu A. Chin. Systematic generation of higher-order solitons and breathers of the Hirota equation on different backgrounds, *Nonlinear Dynamics*, **89**, 1637–1649 (2017).

2017 Runze Li, **Omar A. Ashour**, Jie Chen, H. E. Elsayed-Ali, and Peter M. Rentzepis. Femtosecond laser induced structural dynamics and melting of Cu (111) single crystal: an ultrafast time-resolved x-ray diffraction study, *Journal of Applied Physics*, **121**, 055102 (2017).

2017 Siu A. Chin, **Omar A. Ashour**, Stanko N. Nikolić, and Milivoj R. Belić. Peak-height formula for higher-order breathers of the nonlinear Schrödinger equation on non-uniform backgrounds, *Physical Review E*, **95**, 012211 (2017).

2016 Siu A. Chin, **Omar A. Ashour**, Stanko N. Nikolić, and Milivoj R. Belić. Maximal intensity higher-order Akhmediev breathers of the nonlinear Schrödinger equation and their systematic generation, *Physics Letters A*, **380**, 3625–3629 (2016).

2015 Siu A. Chin, **Omar A. Ashour**, and Milivoj R. Belić. Anatomy of the Akhmediev breather: cascading instability, first formation time, and Fermi-Pasta-Ulam recurrence, *Physical Review E*, **92**, 063202 (2015).

Research Experience

2021 – **Molecular Foundry, Lawrence Berkeley National Lab**, Berkeley, CA.
PI Sinéad M. Griffin
Topic Dark matter interaction with collective excitations in quantum materials

2019 – 2021 **Physics Department, UC Berkeley**, Berkeley, CA.
PI Steven G. Louie
Topic DFT and GW calculations of topological insulators

2017 – 2018 **NSF Nanoscale Science & Engineering Center, UC Berkeley**, Berkeley, CA.
PI Xiang Zhang
Topic Ultrafast spectroscopy of transition metal dichalcogenide monolayers

2014 – 2017 **Department of Physics and Astronomy, Texas A&M University**, College Station, TX.
PIs Siu A. Chin, Milivoj R. Belić
Topic Mathematical and computational studies of nonlinear Schrödinger equations

2016 – 2017 **Texas A&M Engineering Experiment Station (TEES)**, College Station, TX.
PI Peter Rentzepis
Topic Ultrafast X-ray studies of thin films, and ultrafast optical studies of bacteria

2015 **Institute of Electronic Structure and Laser (IESL-FORTH)**, Heraklion, Greece.
PI Stelios Tzortzakis
Topic Femotosecond laser machining of low-loss waveguides

Fellowships and Awards

2018 – 2019 **Anselmo J. Macchi Graduate Fellowship**, UC Berkeley

2017 – 2019 **Berkeley Graduate Fellowship**, UC Berkeley

2017 – 2018 **Cornell Graduate Fellowship** (declined), Cornell University

2016 **Richard E. Ewing Award** for excellence in student research, Texas A&M University

2014, ‘15, ‘17 **Gathright Scholar Award** for outstanding academic achievement, Texas A&M University

Mentoring and Community Service

2021 – **Undergraduate Mentoring**, I am involved in mentoring longer-term undergraduate students in the group, and have given talks to and mentored summer intern cohorts at LBL.

2020 **Scientist Ambassador**, I spent four weeks as an ambassador to a first-grade class, teaching them about the day-to-day life of a scientist.

2018 **Be A Scientist**, I worked with students at a local middle school for 6 weeks to design and conduct science experiments and foster critical thinking skills