Omar A. Ashour

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Summary

I am a theoretical and computational physicist with a decade-long track record in research, marked by the authorship of 16+ papers in condensed matter physics, mathematical physics (nonlinear PDEs), and nonlinear optics and dynamics. I enjoy unraveling complex puzzles across diverse domains, often integrating techniques from other fields and thriving in collaborative work environments. My work seamlessly blends analytical and computational methods. I specialize in crafting solutions from the ground up, starting with simple yet insightful models solvable on a blackboard and progressively adding layers of complexity that demand the capabilities of supercomputers.

Education

PhD, Physics 2019 – May 2025
University of California, Berkeley *Advisor:* Sinéad M. Griffin
Research Area: Theoretical and Computational Condensed Matter Physics

MA, Physics 2019 – 2020
University of California, Berkeley

MS, Applied Physics (AS&T, College of Engineering) 2017 – 2019
University of California, Berkeley
Thesis: The Nonlinear Schrödinger Hierarchy: from Quasi Rogue Waves to Nonlinear Talbot Carpets GPA: 3.90

BS, Electrical Engineering (Optics) 2013 – 2017
Texas A&M University
Thesis: Maximal Intensity Higher-Order Breathers of the Nonlinear Schrödinger Equation GPA: 4.00

Selected Research Projects

Efficient Solvers for Nonlinear Schrödinger-type PDEs in Julia [arXiv] Independent Project

- Conceived and developed the Julia package `NonlinearSchrodinger.jl` from the ground up, specifically tailored for efficiently solving classically integrable nonlinear Schrödinger-type partial differential equations (PDEs).
- Implemented the Darboux transformation method to compute analytical solutions of PDEs with as many as 18 terms.
- Fine-tuned 32 numerical algorithms that optimize performance within this specialized problem domain, emphasizing an approach that enables rapid modeling on personal computers.
- Augmented the package with a user-friendly API and data visualization tools, enabling the computation and analysis of complex solutions with only a few lines of code.

Advancing Quantum Sensing: Quantum Materials for Dark Matter Detection PI: Sinéad Griffin

- Utilized analytical models and massively parallel numerical methods to propose innovative quantum sensors, specifically focusing on dark matter detection using topological insulating materials.
- Introduced a novel approach to dark matter detection, emphasizing a symmetry-breaking mechanism that complements traditional methods based on superconductors.
- Collaborated with high-energy theorists, condensed matter experimentalists, and materials scientists to assess the feasibility of proposed ideas given current and next-generation experimental capabilities.
- Implemented GPU-accelerated nonlinear coupled PDE solvers using Julia and `DifferentialEquations.jl` to explore pattern formation in multiferroic materials.
- Developed Python packages, soon to be open-sourced, and contributed to both open-source and proprietary Python and FORTRAN projects that were instrumental in streamlining the analysis of terabytes of calculated data.

Insights into the Nonlinear Schrödinger Hierarchy of PDEs PIs: Siu Chin, Milivoj Belić

- Published nine papers presenting and proving various mathematical results within the hierarchy, including the peak-height formula for computing the intensity of arbitrary solutions.
- Devised an experimentally feasible scheme for generating complex solutions in optical fibers.
- Utilized analytical methods like Darboux transformations, complemented with numerical approaches such as finite differences and symplectic integrators implemented in MATLAB and C/C++ with CUDA.

Skills and Tools

Programming	Python; Julia; MATLAB; FORTRAN; C/C++.
Numerical Modeling	Nonlinear, coupled, and diffusion PDEs; finite difference, spectral methods, and symplectic integrators; electronic structure methods (DFT, classical Monte Carlo, etc.).
High-Performance Computing	Nine years of experience with HPC clusters. Proficient in CPU (MPI, OpenMP) and GPU computing (OpenACC, CUDA-aware MPI) and massively parallel applications.
Dev Tools	Git; CI/CD; containerization (Docker, Singularity).
Web Development	Dash; Flask; Gunicorn; SQL (PostgreSQL) and NoSQL (MongoDB) databases; Kubernetes; CSS (Bootstrap); Javascript (jQuery). Independently developed the full stack for an upcoming web tool for sharing and analyzing electronic structure code input files.

Selected Fellowships and Awards

Ovshinsky Travel Award, American Physical Society, Division of Materials Physics 2024

Received a competitive travel award to present my research at the American Physical Society's March Meeting.

Berkeley Graduate Fellowship, University of California, Berkeley 2017 – 2019

A highly competitive fellowship that enabled me to dedicate two years during my MS degree to independent research in two subfields of physics, resulting in the publication of five research articles.

Miscellaneous

Certificates: Blockchain Fundamentals (BerkeleyX on edX)

Languages: English (bilingual), Arabic (bilingual), Spanish/French/German (elementary).

Erdös Number: 4

Addendum: Publications and Preprints

⋆ Equal Contribution † Corresponding Author

2024 **Omar A. Ashour** and Sinéad M. Griffin. Solid helium as a pressure tunable dark matter detector, *(in preparation)* (2024).

2024 **Omar A. Ashour** and Sinéad M. Griffin. Phonon-based topological quantum sensors for dark matter detection, *(in preparation)* (2024).

2023 Na Hyun Jo⋆, **Omar A. Ashour**⋆, Zhixue Shu, Chris Jozwiak, Aaron Bostwick, Sae Hee Ryu, Kai Sun, Tai Kong, Sinéad 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).