Journal of Computational Electronics (2021) 20:2019
https://doi.org/10.1007/s10825-021-01814-4

Special issue on Wigner functions in computational electronics and photonics

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Accepted: 20 October 2021 / Published online: 23 November 2021

The Wigner Initiative[1] was founded in 2015 which led to a special issue on Wigner functions in the Journal of Computational Electronics[2] and in particular to the formation of the International Wigner Workshop series.[3] The Wigner community is highly active and inter-disciplinary with activities spanning from foundations of quantum mechanics and optics to nanoelectronics. This special issue contains 21 invited contributions and adds to the body of knowledge with presentations of findings across this diverse spectrum of activity.

The use of the Wigner function allows one to efficiently describe dynamic and dissipative quantum electron transport and to highlight quantum phenomena, respectively. Moreover, the Wigner approach is amenable to particle-based solution techniques, even in optics applications, that still preserve the quantum nature of the problem. Particles were suggested already in 1928 for solutions to the Schrödinger equation, and even Feynman talked about his paths being those of particles. So, particles are an inherent part of quantum mechanics and certainly become efficient in the Wigner approach, not the least because of the connection with classical mechanics.

The Wigner function approach already shows far-reaching success, but the continuous increase in complexity of modeled physical processes demands ongoing computational advancements to realize its potential. Therefore, this special issue highlights contributions with a focus on theoretical and computational advancements in the field of electronics, photonics, and related areas.

Several of the papers deal with the importance of getting proper boundary conditions for the evolution of the Wigner function, whether by semi-classical or fully quantum methodology (Dias et al., Eryilmaz et al., and Kosik et al.). Another group of papers deals with the mathematical approach to actually solving the Wigner equation of motion and the difficulty of handling the non-local integral over the potential (Muscato, Schulz et al., and Iwamoto et al.). A third group of papers discusses superposed states, cat models, and multimode coherent states (Cervenka et al., Rivera-Dean et al., and Truong et al.).

Further applications are varied and bring forth different views of the general use of the Wigner function. Camiola et al. discuss transport in graphene using the Wigner–Boltzmann equation. Amin et al. and Perepelkin et al. discuss the dynamics of the harmonic oscillator with insights gained from the Wigner function. Barletti studies particle localization from the phase-space perspective. Several papers study two-level models in optics (Ahn et al., Rundle et al., and Reis et al.). Weber et al. study electromagnetic waves in fluctuating media with the Wigner function, and te Vrugt et al. investigate four spontaneous collapse models which can describe the quantum-classical transition.

In basic applications, Villani et al. demonstrate the need for positivity and energy conservation in collision applications, while Singh et al. seek a form of the Wigner–Ville transform in signal processing that is cross-term free. Finally, Banerjee et al. explore the unification of the Wigner approach with the non-equilibrium Green's functions of Keldysh.

In all, these papers represent a broad brush overview of the strengths of the Wigner approach to quantum mechanics. We hope the readers enjoy these papers and find them useful.

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1 https://www.iue.tuwien.ac.at/wigner-wiki/.

2 https://doi.org/10.1007/s10825-015-0745-6.

3 https://www.iww-meeting.info.