Transparent quantum graphs

DAVRON MATRASULOV

Turin Polytechnic University in Tashkent
17 Niyazov Str., 100095, Tashkent. Uzbekistan
dmatrasulov@gmail.com •[0.5cm]

The problem of wave transport in branched structures and networks is of importance for many areas of contemporary physics, such as optics, fluid dynamics, condensed matter and polymers. Optical and quantum mechanical waves propagation in such systems appears e.g., in different branched waveguides [1-7]. Effective transfer of light, charge, heat, spin and signal in networks re-quires solving the problem of tunable wave dynamics. This can be achieved using the models, which provide realistic description of particle and wave transport in branched structures. An important feature of particle and wave dynamics in net-works is the transmission through the branching points, usually accompanied by the reflection (backscattering) of a wave at these points. Dominating of reflection compared to transmission implies large "resistivity" of a network with respect to the wave propagation. Hence it is important from the viewpoint of practical applications, to reduce such resistivity by providing a minimum of reflection, or by its absence. This task leads to the problem of tunable transport in branched structures, whose ideal result should be reflectionless transmission of the quasiparticles and waves through the branching points of the structure. In this work we propose models for quantum graphs and branched nanostructures with transparent branching points, where the quasiparticles can propagate without reflection at the branching points. To design such networks, the concept of transparent boundary conditions is applied to the derivation of the vertex boundary conditions for the Schrodinger and Dirac equations on metric graphs. This allows to derive simple constraints, which make usual Kirchhoff-type boundary conditions at the vertex equivalent to the transparent ones.

References

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