The focus of the interdisciplinary project QWCHAOSET is the experimental and theoretical study of properties of quantum systems using quantum graphs and microwave networks as model system. Quantum graphs, networks of bonds connected at vertices provide the most efficient model systems for the experimental and the theoretical study of closed and open quantum systems with chaotic classical dynamics. They can be considered as idealizations of physical networks in the limit where the lengths of the wires are much larger than their diameters. In the proposed project we will study experimentally and theoretically the most challenging problems on one-dimensional quantum systems: Fermi's golden rule for quantum graphs and networks, spectral statistics of nearly unidirectional quantum graphs and networks, the validity of a semiclassical trace formula and Wigner's reaction matrix for quantum graphs and networks belonging to the symplectic universality class. In quantum physics Fermi's golden rule refers to a relation providing the probability for decay of a bounded eigenstate to one embedded in the continuous spectrum, upon application of a perturbation. In unidirectional graphs, a particle launched in one direction cannot switch to the opposite one. We will investigate networks, where such a situation is possible but with small probability. The semiclassical trace formula gives the spectral density of a quantum system in terms of purely classical quantities, e.g., the lengths of periodic orbits. However, there are some limits of its applicability, which will be studied in this project. The symplectic universality class is used to describe statistical properties of spin ½ particles.

In the proposed investigations the main challenges in quantum systems will be pursuit by using microwave networks. The pioneering experiments with microwave networks were performed at the Institute of Physics PAS. They clearly demonstrated that quantum graphs with preserved or violated time invariance and non-negligible internal absorption may be experimentally simulated with microwave networks. Quantum graphs with broken time reversal symmetry will be simulated with the help of microwave circulators. These are three-port devices where waves entering one of the three ports are transmitted through exactly one other port each. A wave entering at port 1, 2 or 3 may, for example exit only at 2, 3 or 1, respectively. These unique properties of microwave circulators will be used in the construction of nearly unidirectional and symplectic networks. In the experiments microwave network analyzers and the flexible test port cables will be used to measure the scattering matrices of the networks. The experimental data will be analyzed and compared with the theoretical predictions.

The implementation of the joint project will significantly extend the knowledge on universal features of chaotic systems. Particularly, the results of the experimental and theoretical analysis will also deepen the knowledge about properties of low-dimensional systems, which become more and more important in future applications.

The partners of the joint project are leaders in their fields and have unique expertise that is appropriately complementary to make such an ambitious project successful. The Polish PI Leszek Sirko has the outstanding capability of performing experiments with microwave networks and the Chinese PI Barbara Dietz the vast knowledge in the fields of quantum chaos. The planned visits to the partner laboratories will allow for further strengthening of the collaboration. The results of the projects will be published as joint Polish-Chinese publications in leading scientific journals and will be presented at international conferences.