One-way Particle Chains and Sector-way Meta-Weaves: New Paradigms for Nano-Scale Time Reversal Asymmetry

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With the ever increasing demand for nano-scale controlled electrodynamics, more flexible dispersion-engineering and nano-scale optical devices based on novel effects are under intensive quest. In this general endeavor, one way optical waveguides are key players that attract the attention of the scientific community. The breach of time-reversal symmetry, inherent in these structures, is of great scientific interest by itself, but they are appealing also from the practical point of view. They can be used as optical isolators and circulators, reduce unwanted structural disorder effects, and they can fundamentally alter waveguide-resonator or waveguide-nano-antenna interactions by offering new and better coupling/feeding schemes.

Nano-scale one-way guiding structures consisting of a flat linear chain of plasmonic nano-particles were recently suggested and studied by our group. The underlying physical mechanism is based on the recently-established two-type rotations principle, implying the simultaneous existence of geometric rotation (e.g. chirality), and electromagnetic rotation (e.g. Faraday). This principle allows for the ultimate miniaturization of one-way structures. An under-the-hood view of the physical processes is exposed by a rigorous Green's function theory developed for this new family of structures. It has been observed that the structure interaction with the spectral continuum plays a pivotal role in enabling the one-way behavior under the existence of two-type rotations. This is to contrast with one-way propagation in bulk crystals or crystal-crystal interfaces, where the spectral continuum is absence (as in e.g. Haldane's work), and the structure is large in terms of wavelengths.

The principles and results discussed above offer new landscapes for time-reversal asymmetry. Confluent with the single dimension of time, breach of time-reversal symmetry is traditionally perceived as one-dimensional concept. However, one-way nano-threads, such as our particle chains, can be used to weave meta-surfaces thus adding dimensions to this concept and generalizing it in a systematic manner. The resulting surfaces–the Meta-Weaves–possess generalized non-reciprocity such as "sector-way" propagation, and offer new possibilities for controlling the flow of electromagnetic signals in thin surfaces.

In this talk, the new family of non-reciprocal structures and their underlying theory will be presented and discussed, as well as potential applications in the field of nano-antennas.