

Water waves crashing against a beach never have the same amplitude, some of them are small, some are considerably larger, and there are very large (and rare) extreme waves. Even if a sequence of identical waves is artificially generated in a water channel by a wave-maker, the certain wave-modes will quickly grow at the expense of the others. The same thing happens to electromagnetic waves in fibers, to Langmuir waves in plasmas, and to many, many others. Roughly speaking “half” of all wave-motions in Nature appears to be unstable with respect to modulations due to the ubiquitous modulation instability (MI).

Stable and unstable waves are distinguished by the classical Lighthill criterion. Many modern topics of nonlinear science, e.g., envelope solitons, breathers and rogue waves, turbulent wave systems and energy cascades, have their origins in the MI. Moreover, the fact that the same MI destroys uniformity of waves in different systems is of fundamental importance and to some extent allows studies of water waves in, e.g., optical fibers. And it was just fiber optic, where MI regimes that violate Lighthill’s criterion have recently been found.

The Project aims to investigate these exotic MI regimes first in fiber optic and then beyond optics. The proposed study will go in three different directions. First, we plan a detailed investigation of the wave turbulent states that result from the unusual MI regimes with the special accent on energy cascades and rogue events. Second, we are going to look for unusual MI regimes in other wave systems, such as surface water waves. Third, we will look for an extended Lighthill’s criterion to once again put all known MI regimes in the same context.

The proposed study is multidisciplinary, that is why the research team consists of one expert in MI and water waves and one expert in MI and fiber optics. Moreover, this kind of research requires (a) professional use of multiscale methods, kinetic equations, and asymptotic expansions, and (b) intense numerical simulations, contact with the experimentalists, and working knowledge of all nonlinear effects in fiber optics. Here we are going to profit from the collaboration of a mathematician (project leader) and physicist (employee). We believe that the proposed study will greatly contribute to both optics and hydrodynamics. Last but not least, the unusual MI regimes yield a new way to get optical supercontinua, which is important for applications to novel compact sources of highly coherent white light.