Solitons

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Solitons

Solitons are localized waves that propagate along one space direction only, with undeformed shape and some particle-like properties. They are structural basis for viewing and understanding nonlinear phenomena such as: tsunami, solitons in fibre-optic networks, modelling of elementary particles and high temperature superconductors, or martensitic transformations in shape-memory alloys. Thus solitons are one of the most important research fields in modern day physics.

Fig. 1. Kink (black arrow) and antikink (red arrow) solitons rotate the pendulums from 0 to 2π (kink) or from 0 to -2π (antikink).

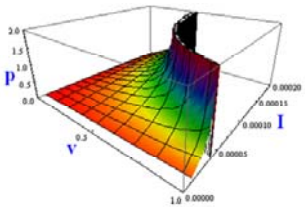
Kink solitons in transmission lines

The aim of my work was to investigate experimentally the behavior of kink and antikink solitons (Fig. 1) in mechanical transmission lines. Therefore, I have constructed and improved a linear transmission line (Fig. 2a) and a quite new circular transmission line (Fig. 2b).

Fig. 2. Solitons on mechanical transmission lines linear (left) and circular (right).

The obtained results I have compared with the solution of nonlinear Sine-Gordon equation describing rotation angle of a pendulum in the transmission line (1)

where is velocity of linear waves (- distance between two pendulums, - torque constant of a section of spring between two pendulums, - moment of inertia of a single pendulum of mass m and length L), is circular frequency (g - the gravitation), v is velocity, t is time. The (±) signs correspond to localized soliton solutions which travel with opposite screw senses, i.e., kink and an antikink solitons. I have analyzed experimentally as well as numerically (using program written by myself for modelling in „Mathematica 7") the influence of different parameters (v, , , , m and L) on kink and antikink solitons (Fig. 3). I observed the breather solitons as results of kink-antikink soliton collisions (annihilations).



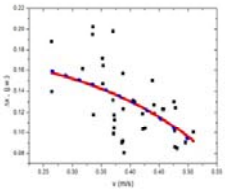


Fig. 3 (left). Theoretical soliton momentum vs. v an I.

Fig. 4 (right). Fitting the Lorentz contraction of soliton.

Contradictory to nontopological solitons, kink soliton may be entirely static. Soliton velocity is limited to the velocity of linear waves. Its amplitude is not related to its velocity. Sine-Gordona equation is Lorentz transformation invariant. Therefore, kink solitons satisfy features of relativistic particles. When soliton's speed is getting closer to this extreme velocity, kink is getting narrower it is a result of Lorentz contraction (Fig. 4). its momentum and energy are described by following formulas. (2)and (3) where soliton mass is equal to . Gravitation does not affect the mass of soliton.

Performed experiments

I have filmed experiments performed using the linear and circular transmission lines, e.g., the experiments showing corpuscular properties of soliton (during collisions of many types), the behaviour of soliton lattice, acceleration of solitons moving between two types of pendulums, balance of dissipative torque by gradient of pendulum moments of inertia, and the behavior of solitons in potential wells formed by pendulums that have different moments of inertia. Obtained data were analysed using "Tracker". I have fitted the experimental results with theoretical formulae.

1 Conclusions

Solitons are very interesting nonlinear phenomena. Using transmission line their properties may be studied very efficiently. Remarks of that investigation might be very useful considering understanding other nonlinear phenomena.