

Refraction of a soliton by a soliton gas in a recirculating fiber loop

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Soliton gases (SGs) represent large random soliton ensembles in physical systems that exhibit integrable dynamics at the leading order. SGs have been recently evidenced in optical and in water wave experiments [1,2]. Nowadays, the question of the collective dynamics and statistical properties of SGs is an active research topic in statistical mechanics [3], mathematical physics [4], nonlinear physics [5] and constitutes a chapter of turbulence theory termed integrable turbulence [6].

We present an optical experiment made in a recirculating fiber loop [7] where we observe that the nonlinear interaction between an individual (tracer) soliton and a dense SG results in a refraction phenomenon (see Fig. 1) similar at qualitative level to what is observed in ray optics at the interface between two media having different refractive indexes. Unlike the classical refraction of light rays, the observed phenomenon is of a nonlinear nature and finds its origin in the interactions between the tracer soliton and the SG.

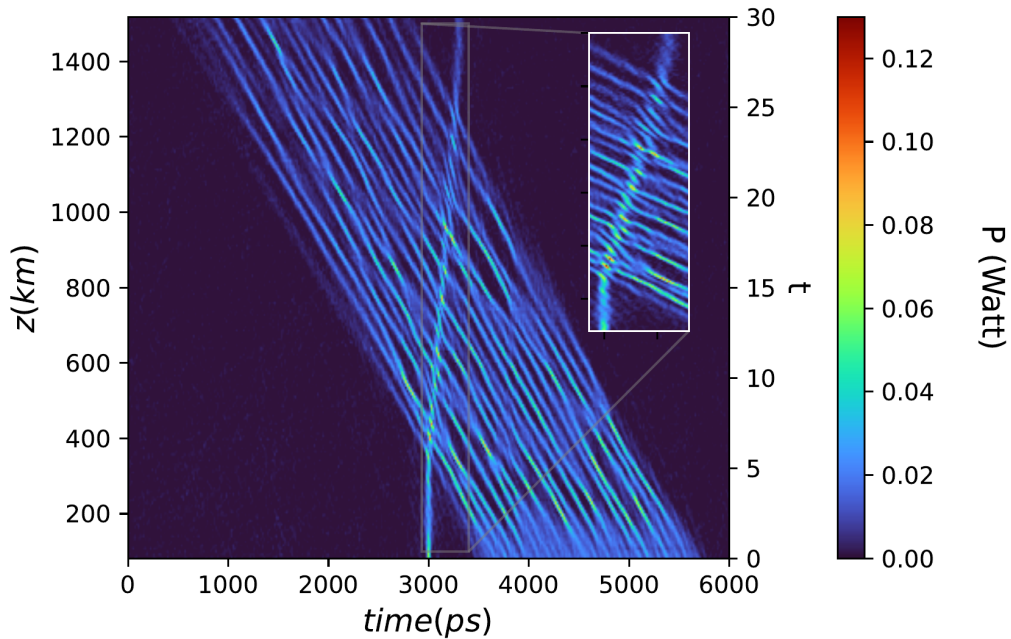


Fig. 1 Typical space-time diagram showing the refraction phenomenon observed in the interaction between a tracer soliton and an optical SG. The tracer soliton has a duration of ~ 58 ps. It is shifted by ~ 280 ps due to its interaction with the optical SG that has a duration of ~ 2 ns. The maximum propagation distance reached in the experiment is ~ 1500 km, which corresponds to a propagation over 60 nonlinear lengths (or to a normalized evolution time of 30, as indicated by the right vertical axis).

We measure the position shift associated with the solitonic refraction and we show that it is quantitatively well described by the inverse scattering transform (IST) theory [8] despite weak dissipation occurring in the experiment. The velocity change associated with the refraction phenomenon is found to be in good quantitative agreement with theoretical predictions from the kinetic theory of SGs [9]. Our results validate the collision rate ansatz that plays a fundamental role in the kinetic theory of SG and also is at heart of generalized hydrodynamics of many-body integrable systems.

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