Study of the partially-coherent light dynamics in optical fibre using Heterodyne Temporal Microscopy

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The Non-linear Schrödinger equation (NLSe) is one of the fundamental models of non-linear science describing dynamics of many physical systems like propagation of deep-water waves or light in the optical fiber. Despite its full integrability, study of problems including the stochastic initial conditions are considered as challenging for modern mathematics. Combination of a model described by an integrable non-linear equation together with stochastic initial conditions refers us to the fast-growing field of *integrable turbulence*, established by V.E. Zakharov [1]. Among outstanding results obtained in this field, there is well-studied conjecture : the Peregrine soliton (PS), a second-order solution of 1-D focusing NLSe on the finite background, can appear in the developed stage of integrable turbulence. Moreover, PS solution was widely considered as a prototype of so-called Rogue Waves (large amplitude water wave) [2]. From the first look on the problem this fact is counterintuitive : the PS is a very particular breather type solution which breezing period tends to infinity and the phase profile has a characteristic π-phase jump at the maximum compression point. However, recently it was directly observed that a coherent structure which intensity profile is locally similar to the PS can appear at the developed stage of 1-D NLSE integrable turbulence [3]. This experimental evidence together with a rigorous mathematical proof made by A.Tovbis and M.Bertola [4], and experimental confirmation [5] of the fact that the PS appears in the dispersionless limit of focusing 1-D NLS model as a regularisation of the gradient catastrophe, poses the problem of *direct single-shot observation of intensity and phase dynamics of partially-coherent initial conditions*.

This challenging task requires a tool which is able to provide measurements with a sub-picosecond resolution over a window of tens of ps and a wide dynamical range (along with the central peak, pedestal part also have to be measured accurately). Earlier, optical devices based on the principles of the temporal imaging demonstrated promising results. Temporal imaging is a technique built on the analogy between paraxial diffraction in space and dispersion in time [6]. However, this approach has to be adapted for the phase measurements.

Here we present here an extended version of the Time Microscope - *Heterodyne Time Microscope* (HTM) and Its modified version *Spatial Encoding Arrangement with Hologram Observation for Recording in Single shot the Electric field* (SEAHORSE). We report that the HTM provides direct simultaneous intensity and phase measurements over a window of 40 ps with ≈ 250 fs resolution and SEAHORSE provides temporal holograms allowing to get ≈ 70 fs resolution, keeping the window of measurements of HTM. During the experiments, we observed the PS on the different phases of its formation, its characteristic phase jump and zoology of coherent structures that appear at the developed stage of the integrable turbulence.

Références

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