

Loss induced multiple symmetry breakings in the Fermi Pasta Ulam recurrence process

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Fermi Pasta Ulam (FPU) recurrence process describes the ability of a nonlinear system to excite multiple modes and then to return to its initial state. In fiber optics, such process has been investigated within the framework of modulation instability (MI) [1], corresponding to growth of weak perturbations at the expense of a strong pump. Nonlinear stage of MI and FPU recurrences in optical fibers have been widely investigated and many results have been obtained with an efficient compensation of the losses [2]. Investigations on water waves [3] demonstrated that dissipation of their water tank forces the system to operate in a single regime. Here, we provide a deeper and complete study on the impact of dissipation of the FPU dynamics. Thanks to a fiber optics system, we have been able to control the loss coefficient, allowing us to trigger the different corresponding FPU regimes.

Using a setup similar to the one in [2] and based on a multiple HOTDR system, we managed to record FPU recurrences in power and phase along the fiber length as a function of the loss, Fig. 1. The dissipation is controlled thanks to a counter-propagating Raman pump whose power is tuned to get an effective loss coefficient. A direct relation between the Raman pump power and effective loss coefficient is obtained, allowing a direct comparison between experiments (left panel) and simulations (right panel). Three different regions are discernible. In the 3rd

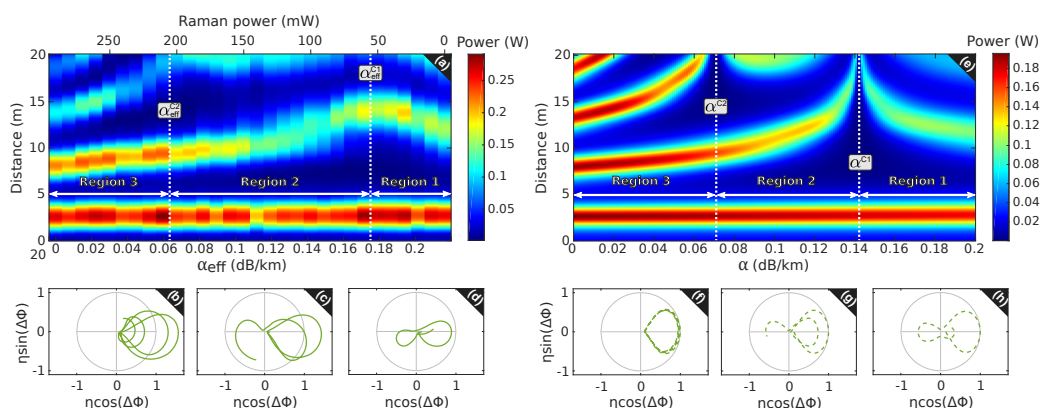


Figure 1: 2D-plot of the signal power evolution along the fiber length as a function of loss (a) in experiments and (e) in numerics. An example of phase-plane evolution is plotted for each region; (b)-(d) for experiments, and (f)-(h) for numerics. (b) and (f) $\alpha = 0.007$ dB/km, (c) and (g) $\alpha = 0.09$ dB/km, (d) and (h) $\alpha = 0.2$ dB/km.

one (quasi-perfect compensation of the losses), we observe 4 recurrences (Fig. 1. (a)), corresponding to 4 loops located in the right-half side of the phase plane (Fig. 1. (b)). This means that the maximum compression points remain at the same temporal location at each recurrence [2]. In the 2nd region (partial compensation), the first two recurrences are in phase and the 3rd one is shifted, as shown in the phase plane (Fig. 1. (c)), 2 loops in the semi-right side and one in the left one). In the 1st region (the loss is close to the fiber intrinsic value), there are 2 recurrences characterized by one loop in each semi-plane of the phase plane (Fig. 1. (d)). This means that these recurrences are phase-shifted [2]. Each region is separated by a critical value α^{CN} , determined from phase evolution (not shown here for clarity). Experiments are in good agreement with numerics (compare Fig. 1. (a)-(d) to (e)-(h)).

To conclude, we reported a complete study on dissipation impact on FPU dynamics in optical fibers thanks to the accurate control of the losses and to our non-destructive distributed measurement setup [2]. It reveals that dissipation strongly impacts the dynamics of FPU recurrence by forcing the system to evolve into several specific regimes.

References

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