## Dynamics of photon fluid flows driven by optical pistons

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The piston problem, i.e. the dynamics of a uniform gas at rest under the action of a moving piston, is fundamental in shock wave physics [1,2]. In conservative systems, shock waves are regularized by the formation, owing to dispersion, of rapidly oscillating non-stationary structures, called dispersive shock waves (DSWs) [3-6].

In this work, we investigate the analogous problem for a photon fluid. To mimic gas compression, we study the propagation, along a highly normal dispersive optical fiber, of a chirped square pulse with an abrupt jump of instant frequency (velocity) at its center (Fig. 1(a)). During the propagation, the two parts of this dual-frequency pulse propagate at different velocities mimicking gas compression. The fast part plays the role of a moving piston while the slow part plays the role of the compressed gas. The internal collision and squeezing of these two parts lead to the generation of a pair of DSWs connected by an intermediate plateau of constant density (Fig. 1(b)).

We performed a series of experiments that demonstrate the generation of DSWs from a bi-frequency pulse. More details about the experimental setup and specially the method used to synthesize the suitable initial state shown in Fig. 1(a) will be given during the conference. Figures 1 (c) and (d) depict the temporal profile and chirp properties of the square shaped pulses injected into 15 km of dispersion compensating fiber (DCF) to generate DSWs. During the propagation, the square pulse undergoes nonlinear effect and we observed, at the DCF output, the generation of a short central plateau, with several fast and regular oscillations aside (Fig. 1(e)). These oscillations correspond to a regularization of the shock and the formation of a pair of DSWs [2]. In addition to these results, we also observed special cases that has no equivalent in gas dynamics (not shown here) [7].

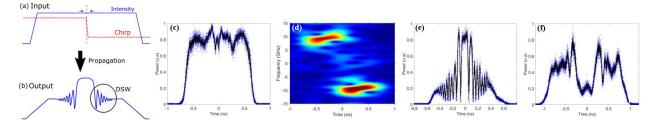


Fig. 1. (a,b) Illustration of the chirped square pulse and the generation of DSWs. (c) Intensity profile of the square pulse injected at DCF input. (d) Associated Spectrogram (frequency shift = 18.5 GHz). (e) Intensity profile recorded at the DCF output for an input peak power of 72 mW. (f) Intensity profile recorded at the DCF output for the anti-piston configuration. (initial frequency shift = 10.5 GHz, input peak power = 35 mW). DCF properties:  $\beta_2 = 1.7 \times 10^{-25} \text{ s}^2/\text{m}; \gamma = 3 \text{ W}^{-1} \text{ km}^{-1}$ .

In a second set of experiments, we reversed the sign of the chirp profile compared to the previous configuration. After propagation in the same fiber, we observed the formation of a rarefaction waves pair, connected by a small finite plateau (Fig. 1(f)). This process is analogous to the gas dynamics case when the piston decompresses and exhausts the gas, leading to a low pressure inside a reservoir.

In conclusion, we studied the optical analogy of a gas compressed/decompressed by a piston. We demonstrate the generation of dispersive shock waves and rarefaction waves. All the experimental results have been successfully reproduced by numerical simulations and show a good qualitative agreement. These results pave the way to study gas dynamics in relatively accessible optical fiber experiments.

## References

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