PULSATING AND ROTATING DISSIPATIVE LIGHT BULLETS IN (3+1)D CGLE THROUGH COLLECTIVE VARIABLE METHOD

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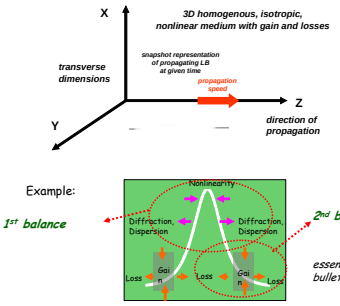
Dissipative Light Bullets

- *Dissipative Light Bullet (LB) : a (3+1)D spatio-temporal optical soliton which travels in a homogeneous nonlinear medium where dissipation and pumping are at play, such as in bulk optical amplifiers.*
- *Confinement in the three spatial dimensions and localization in the temporal domain are achieved by two balances. The first one is between focusing dispersive nonlinearities and defocusing due to chromatic dispersion and angular diffraction. The second balance is between nonlinear gain and loss terms, and is essential to provide stability. Both balances are coupled, so that dissipative LB can even be found in normally dispersive media, for instance [2].*
- *The existence of stable LB was demonstrated numerically [1,2] in a cubic-quintic Ginzburg-Landau (CGLE) propagation model. Using exact numerical calculation is a tedious procedure. Instead, we developed an efficient* ***semi-analytical method****, based on the "****Collective variable approach****"(CVA)[3] enabling* ***quick mapping of the domains of existence*** *for stable LB in the parameter space of the (3+1)D CGLE [4].*
- *Our method is also able to reveal domains where light bullets undergo* ***pulsations****. Knowing that stable pulsations manifest widely in dissipative nonlinear systems, we show in this work that for an appropriate choice of the trial function, we can obtain pulsating LB which rotates in space.*

[1] Ph. Grelu, J.M. Soto-Crespo, N. Akhmediev, Opt. Express **13**, 9353 (2005).
[2] N. Akhmediev, J.M. Soto-Crespo, Ph. Grelu, Chaos **17**, 037112 (2007).
[3] P. Tchofo-Dinda, A.B. Moubissi and N. Nakkeeran, Phys. Rev. E **63**, 016608 (2001)
[4] A. Kamagaté, Ph. Grelu, P. Tchofo-Dinda, J.M. Soto-Crespo, N. Akhmediev, Phys. Rev.E**79**, 026609 (2009).



Principle of the study

Cubic-quintic Complex Ginzburg-Landau equation (CGLE) extended to 3D

$$\psi_z - i\frac{D}{2}\psi_{tt} - i\frac{1}{2}\psi_{xx} - i\frac{1}{2}\psi_{yy} - i\gamma|\psi|^2\psi - i\nu|\psi^4|\psi = \delta\psi + \varepsilon|\psi|^2\psi + \beta\psi_{tt} + \mu|\psi|^4\psi$$

dispersion · diffraction · Kerr NL + sat. — Conservative terms

loss · NL gain · gain BW · sat. NL gain — Dissipative terms

Various trial functions can be tested. Example, *supergaussian* :

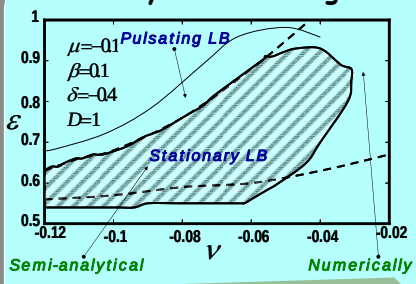
$$f_{SG} = X_1 \exp\left(-\frac{t^2}{X_2^2} - \frac{t^4}{X_2^4} - \frac{r^2}{X_3^2} - \frac{r^4}{X_3^4} + iX_4t^2 + iX_5r^2 + iX_6\right).$$

Xi collective variables : amplitude, pulse widths in t and r, temporal and spatial chirps, phase

-**Substitute** f **into CGLE**

-**Project onto the direction of** $\frac{\partial f^*}{\partial X_k}$ ⇨ **Equation of motion of collective variables**

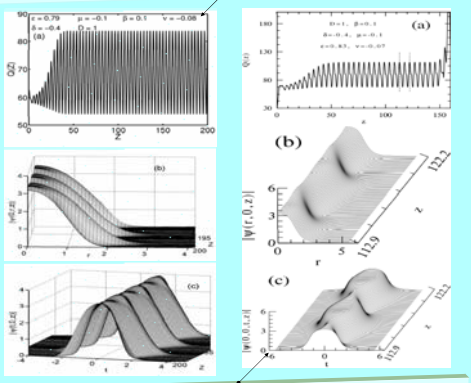
Stationary and Pulsating LBs



Map of stable light bullet in the (ν, ε) plane : comparison between semi-analytical results (super-Gaussian trial function) and direct simulation of CGLE

Phys. Rev.E**79**, 026609 (2009).

Pulsations of energy, temporal and transverse widths by CVA

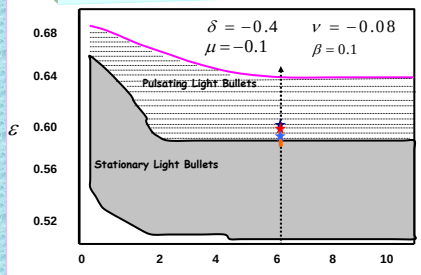


Similar "inflating-deflating" pulsations confirmed numerically

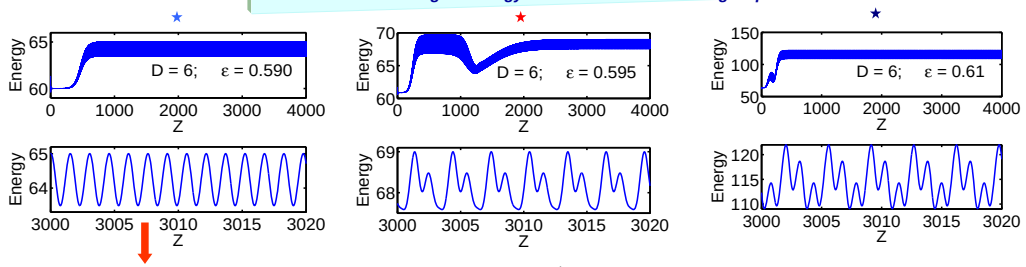
Pulsating and Rotating LBs

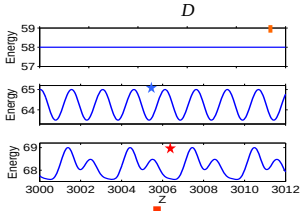
$$f = x_1 \exp\left(-\frac{t^2}{x_2^2} - \frac{X^2}{x_3^2} - \frac{Y^2}{x_4^2} - x_5XY + 0.5ix_6t^2 + 0.5ix_7X^2 + 0.5ix_8Y^2 + 0.5ix_9XY + ix_{10}\right)$$

Map of stable light bullet in the (D, ε) plane :

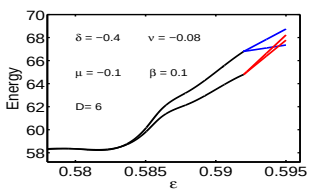


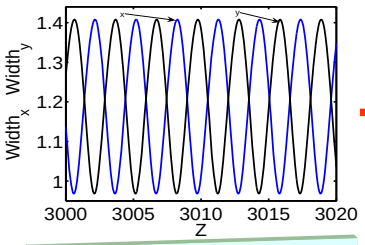
Evolution of Pulsating LB energy for various values of NL gain parameter ε



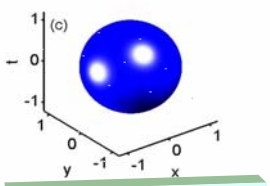


Cascade of bifurcation diagram





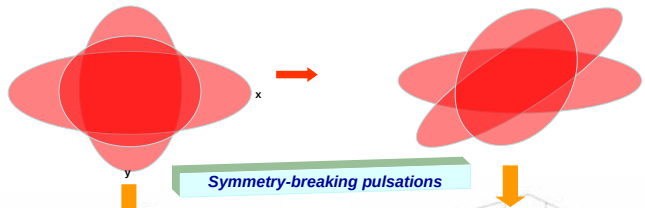
Evolution of LB spatial widths



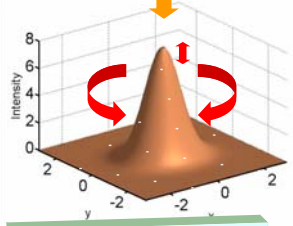
3D representation at given t

Antisymmetric mode inflation-deflation

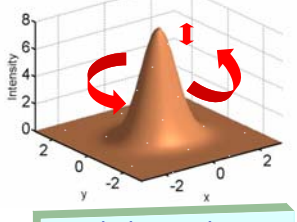
symmetry breaking and rotation



Symmetry-breaking pulsations



Pulsating - Semi - Rotating LB



Pulsating - Rotating LB

Conclusion and perspectives

- **Efficient and quick mapping of approximate solutions of (3+1)D CGLE. Great care should be taken in the appropriate choice of trial function. Comparison with limited number of direct calculations is required.**
- **Elementary types of Pulsating LBs readily found: Symmetric "inflation-deflation", asymmetric "inflation-deflation", Pulsation-Rotation**
- **LB needs to be confirmed experimentally (VCSEL?); application to parallel pre-processing and dynamical routing of optical data?**

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