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Chirped optical Gausson perturbation with quadratic–cubic nonlinearity by collective variables

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Abstract
Here, collective variables approach is applied to obtain optical solitons in the presence of perturbation terms. Gaussian solitons are selected to retain the pulse to establish soliton setting. The numerical simulations of soliton parameters are performed for specific values of the Gaussian pulse parameters.

Keywords Quadratic–cubic nonlinearity · Collective variables · Solitons

1 Introduction

Optical solitons form the basic fabric in the field of telecommunication industry. They are the carriers for the transfer of information through optical fibers. These information transmission carriers serve the modern-day telecommunication system through Internet. These include electronic mail transmission, social media activities. It is established that solitons are caused due to its delicate balance that sustains between nonlinear and dispersive effects. These soliton refers to special form of wave packets that can travel undistorted over a long distances. The nonlinear Schrödinger equation (NLSE) is the fundamental model that governs this transmission dynamics for trans-continental and trans-oceanic distances.

These solitons are revolutionizing the telecommunication industry in leaps and bounds. Therefore it is imperative to address this NLSE model from a different perspective. This manuscript is therefore going to study the governing model with deterministic perturbation terms. While several journal papers are flooded with the integrability aspects of models having a plethora of nonlinear optical fiber forms, the purpose of the current work is to establish a dynamical system of six soliton parameters, in presence of such deterministic perturbations. These parameters are soliton amplitude, width, chirp, center position,

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speed and phase variation. The mathematical methodology adopted in this paper is known as "collective variables" (CV). The focus is also on a particular form of nonlinearity. It is quadratic–cubic (QC) type that first appeared during 1996 (Ablowitz et al. 2002). This was followed by a series of results that were sequentially reported.

The dynamical system thus developed will serve as a good alternative, with a flavor of numerical analysis, to write down the adiabatic dynamics of these soliton parameters. This dynamics serve as an essential commodity to proceed further with the study of solitons in optical fibers. A few such avenues are the establishment of quasi-particle theory to suppress intra-channel collision of solitons in optical fibers with QC nonlinearity. In the past, this theory was developed successfully only with Kerr law, power law, parabolic law, dual-power law (Biswas et al. 2011). Another avenue is to formulate the quasi-stationary solitons with QC nonlinearity. These parameter dynamics is an essential commodity for such an application using multiple scales. The dynamical system developed with CV approach from this paper will additionally enable us to address collision-induced timing jitter and four-wave mixing aspects of solitons with QC nonlinearity. Finally, one important aspect that also needs to be addressed is the issue of stochastic perturbation. This can only be done with the parameter dynamics developed in this paper. The inclusion of stochastic perturbation terms, in addition to the pre-existing deterministic perturbations in this work, will lead to Langevin equation that will yield mean free velocity of the soliton. The results of this paper will therefore carry a lot of validity, importance with futuristic applications in the field of nonlinear optics keeping an eye on telecommunication industry (Ablowitz et al. 2002, 2003; Biswas et al. 2011, 2013, 2018; Biswas and Konar 2007; Dinda et al. 2001a, b; Fewo and Kofane 2008; Fujioka et al. 2011; Green et al. 2008; Hayata and Koshiba 1994; Khan et al. 2019a, b; Pal et al. 2017; Shwetanshumala 2009; Veljkovic et al. 2015, 2017).

2 Governing model

The NLSE along with perturbation terms in dimensionless form is

$$iq_z + aq_{tt} + \left(b_1|q| + b_2|q|^2\right)q = i\left\{\alpha q_t + \lambda\left(|q|^2 q\right)_t + \theta\left(|q|^2\right)_t q\right\} \tag{1}$$

where $i = \sqrt{-1}$, $q(z,t)$ represents the complex-valued wave profile with two independent variables z (spatial component) and t (temporal component). On the left side of Eq. (1), the 1 term is the linear temporal evolution, while in the 2 term, a is the coefficient of group velocity dispersion (GVD). b_1, b_2 the nonlinear terms are quadratic and cubic respectively. On right side of (1) are the perturbation terms. The coefficient of α is inter-modal dispersion, while the coefficients of λ and θ are self-steepening term and nonlinear dispersion respectively.

In this article, we are considering the coefficients a, b_1, b_2, λ, α, and θ all are taking to be constants. But if we have to change this will be a very different problem and of course the law of change must be specified to consider a particular problem, and this will lead to a different project with time or space dependent coefficients. In this article, the results are come out by CV method but in future we are planning to work on three different methods like soliton perturbation theory, moment method and variational principal Method. Here self steepening does produce soliton radiation but in this paper we are focusing on the core soliton region and thus neglecting radiation that gives an approximation rather than the exact dynamics. In order to capture the dynamics of soliton radiation due to self steepening, we need to use the technique of "beyond all order asymptotics" that is outside the scope of the current manuscript.

3 Collective variable approach algorithm

In this approach, NLSE solution can be divided into two parts, (1) the soliton solution and (2) the residual radiation which is named as small amplitude dispersive waves. Decomposition of the original soliton field $q(z,t)$ is made at position z in the fiber and the time t, as follows:

$$q(z,t) = f(z,t) + g(z,t) \tag{2}$$

f and g denotes the pulse configuration and residual field respectively. Collection of variables represents soliton amplitude, temporal position, pulse width, chirp frequency and phase of pulse. The soliton field f is chosen to be dependent on N variables. Introduction of N collective variable in the function f increases the degree of freedom resulting in the expansion of available phase space of the system which is undesirable. Introduction of CV in function f increases the degree of freedom resulting in the available phase space, so due to undesirable effect there are some constraints and residual free energy.

Here, residual free energy is

$$q(z,t) = f\left(X_1(z), X_2(z), \dots, X_N(z), t\right) + g(z,t) \tag{3}$$

$$E = \int_{-\infty}^{\infty} |g|^2 dt = \int_{-\infty}^{\infty} \left| q - f\left(X_1(z), X_2(z), \dots, X_N(z), t\right)\right|^2 dt \tag{4}$$

Let C_j denote the partial derivative of residual free energy w. r. t, X_j then

$$\begin{aligned} C_j &= \frac{\partial E}{\partial X_j} = \frac{\partial}{\partial X_j}\int_{-\infty}^{\infty} |g|^2 dt = \frac{\partial}{\partial X_j}\int_{-\infty}^{\infty} g g^* dt = \int_{-\infty}^{\infty} \frac{\partial}{\partial X_j} g g^* dt \\ &= \int_{-\infty}^{\infty} \left(\frac{\partial g}{\partial X_j} g^* + g \frac{\partial g^*}{\partial X_j}\right) dt \end{aligned} \tag{5}$$

If we define the inner product as

$$< \gamma_1, \gamma_2 > = \int_{-\infty}^{\infty} \gamma_1(t)\gamma_2(t) dt \tag{6}$$

then we can write (5) as

$$
\begin{aligned}
C_j &= \left\langle \frac{\partial g}{\partial X_j}, g^* \right\rangle + \left\langle g, \frac{\partial g^*}{\partial X_j} \right\rangle = \left\langle \frac{\partial g}{\partial X_j}, g^* \right\rangle + \left\langle \frac{\partial g}{\partial X_j}, g^* \right\rangle \\
&= \left\langle \frac{\partial g^*}{\partial X_j}, g \right\rangle + \left\langle \frac{\partial g^*}{\partial X_j}, g \right\rangle = 2Re\left(\left\langle \frac{\partial g^*}{\partial X_j}, g \right\rangle \right) \\
&= 2Re\left(\left\langle \frac{\partial (q(z,t) - f(X_1, X_2, \dots, X_n, t))^*}{\partial X_j}, g \right\rangle \right) \\
&= 2Re\left(\left\langle \frac{\partial q^*(z,t)}{\partial X_j} - \frac{\partial f^*(X_1, X_2, \dots, X_n, t))}{\partial X_j}, g \right\rangle \right) \\
&= -2Re\left(\left\langle \frac{\partial f^*}{\partial X_j}, g \right\rangle \right) = -2Re\left(\int_{-\infty}^{\infty} \frac{\partial f^*}{\partial X_j} g dt \right),
\end{aligned}
\tag{7}
$$

where $\frac{\partial q^*(z,t)}{\partial X_j} = 0$ and Re denotes the real part. The derivative of C_j with respect to z will be

$$
\begin{aligned}
\dot{C}_j &= \frac{dC_j}{dz} = -2Re\left(\frac{d}{dz} \int_{-\infty}^{\infty} \frac{\partial f^*}{\partial X_j} g dt \right) \\
\dot{C}_j &= -2Re\left(\int_{-\infty}^{\infty} \frac{\partial f^*}{\partial X_j} \frac{\partial g}{\partial z} + g \frac{\partial}{\partial z} \frac{\partial f^*}{\partial X_j} dt \right) \\
\dot{C}_j &= -2Re\left(\int_{-\infty}^{\infty} \left(\frac{\partial f^*}{\partial X_j} \frac{\partial g}{\partial z} + \sum_{k=1}^{N} \frac{\partial^2 f^*}{\partial X_k \partial X_j} \frac{dX_k}{dz} g \right) dt \right)
\end{aligned}
\tag{8}
$$

Using Dirac's principle (9, 11, 16, 18, 19), a function is nearly zero, unless we can't set its variations equal's zero for all parameters. Hence, C_j are minimum when

$$C_j \approx 0 \tag{9}$$

$$\dot{C}_j \approx 0. \tag{10}$$

From the governing model (1), we have

$$
\begin{aligned}
q_z &= \frac{\partial f\left(X_1(z), X_2(z), \dots, X_N(z), t\right)}{\partial z} + \frac{\partial g(z,t)}{\partial z} \\
q_z &= \sum_{j=1}^{N} \frac{\partial f}{\partial X_j} \frac{dX_j}{dz} + \frac{\partial g(z,t)}{\partial z}.
\end{aligned}
\tag{11}
$$

By combining (1) and (11), we get

$$\sum_{j=1}^{N} \frac{\partial f}{\partial X_j} \frac{dX_j}{dz} + \frac{\partial g(z,t)}{\partial z} = \boldsymbol{\Psi} \tag{12}$$

where $\Psi = ia(f+g)_{tt} + \imath(b_1|f+g| + b_2|f+g|^2)(f+g) + \left\{\alpha(f+g)_t + \lambda(|f+g|^2(f+g))_t + \theta(|f+g|^2)_t(f+g)\right\}$. From (12), we can write

$$\frac{\partial g}{\partial z} = -\sum_{j=1}^{N} \frac{\partial f}{\partial X_j}\frac{dX_j}{dz} + \Psi \tag{13}$$

By substituting above equation in (8), we get

$$\begin{aligned} \dot{C}_j &= -2Re\left(\sum_{k=1}^{N}\int_{-\infty}^{\infty}\left(-\frac{\partial f^*}{\partial X_j}\frac{\partial f}{\partial X_k} + \sum_{k=1}^{N}\frac{\partial^2 f^*}{\partial X_k \partial X_j}g\right)dt\frac{dX_k}{dz} + \int_{-\infty}^{\infty}\frac{\partial f^*}{\partial X_j}\Psi dt\right) \\ &= 2Re\sum_{k=1}^{N}\int_{-\infty}^{\infty}\left(\frac{\partial f^*}{\partial X_j}\frac{\partial f}{\partial X_k} - \frac{\partial^2 f^*}{\partial X_k \partial X_j}g\right)dt\frac{dX_k}{dz} - 2Re\int_{-\infty}^{\infty}\frac{\partial f^*}{\partial X_j}\Psi dt. \end{aligned} \tag{14}$$

Here $j \in \{1, 2, 3, \ldots, N\}$.

Equation (15), in compact form becomes

$$\dot{\mathbf{C}} = \frac{\partial \mathbf{C}}{\partial \mathbf{X}}\dot{\mathbf{X}} + \mathbf{R}, \tag{15}$$

where $\dot{\mathbf{C}} = \left[\dot{C}_1, \dot{C}_2, \ldots, \dot{C}_N\right]^T$, $\dot{\mathbf{X}} = \left[\frac{dX_1}{dz}, \frac{dX_2}{dz}, \ldots, \frac{dX_N}{dz}\right]^T$, $\mathbb{R} = \left[R_1, R_2, \ldots, R_N\right]^T$, $R_j = -2Re\int_{-\infty}^{\infty}\frac{\partial f^*}{\partial X_j}\Psi dt$ and $\frac{\partial C_i}{\partial X_j} = 2Re\int_{-\infty}^{\infty}\left(\frac{\partial f^*}{\partial X_i}\frac{\partial f}{\partial X_j} - \frac{\partial^2 f^*}{\partial X_i \partial X_j}g\right)dt.$

4 Soliton parameter dynamics

In optical field the adiabatic parameter dynamics can be attained through CV approach. We assume the desired form of function. For optical soliton $N = 6$ will be interpreted. Gaussian soliton ansatz, chirped soliton pulse can take as $g = 0$

$$f = X_1\, \mathrm{e}^{-\frac{(t-X_2)^2}{X_3^2}}\, \mathrm{e}^{\frac{i}{2}X_4(t-X_2)^2 + iX_5(t-X_2) + iX_6}.$$

Here X_1, X_2, X_3, X_4, X_5 and X_6 denote soliton amplitude, soliton center position, pulse inverse width, soliton chirp, soliton frequency and soliton phase respectively. For, $N = 6$, the computation of R_j's is following. By substituting $g = 0$ in Ψ, we get

$$\Psi = iaf_{tt} + i(b_1|f| + b_2|f|^2)f + \left\{\alpha f_t + \lambda(|f|^2 f)_t + \theta(|f|^2)_t(f)\right\}.$$

After placing f in above expression, we obtain

$$\begin{aligned} \Psi = -i(&X_2^2X_3^4X_4^2a + X_3^4X_4^2at^2 - X_1^2X_3^4b_2\varphi_1^2 - X_1X_3^4b_1\varphi_1 + X_2X_3^4X_4\alpha - X_3^4X_4\alpha t - 4X_2^2a + 2X_3^2a \\ &- 4at^2 + 6iX_1^2X_2X_3^2\lambda\varphi_1^2 + 4iX_1^2X_2X_3^2\theta\varphi_1^2 - 6iX_1^2X_3^2\lambda t\varphi_1^2 - 4iX_1^2X_3^2t\theta\varphi_1^2 - 8iX_2X_3^2X_4at \\ &- iX_3^4X_4a + 2iX_2X_3^2\alpha - 2iX_3^2\alpha t + 2X_3^4X_4X_5at - X_1^2X_3^4X_5\lambda\varphi_1^2 - 2X_2X_3^4X_4^2at \\ &- 2X_2X_3^4X_4X_5a + X_3^4X_5^2a - X_3^4X_5\alpha + 8X_2at + X_1^2X_2X_3^4X_4\lambda\varphi_1^2 - X_1^2X_3^4X_4\lambda t\varphi_1^2 \\ &+ 4iX_3^2X_5at + 4iX_2^2X_3^2X_4a + 4iX_3^2X_4at^2 - 4iX_2X_3^2X_5a)\frac{X_1}{X_3^4}\varphi_1\varphi_2, \end{aligned} \tag{16}$$

where $\varphi_1 = \mathrm{e}^{-\frac{(t-X_2)^2}{X_3^2}}$ and $\varphi_2 = \mathrm{e}^{\frac{i}{2}(X_4\,(t-X_2)^2+iX_5\,(t-X_2)+iX_6)}$

The partial derivatives of f^* are

$$
\begin{aligned}
\frac{\partial f^*}{\partial X_1} &= \varphi_1\,\varphi_2^* \\
\frac{\partial f^*}{\partial X_2} &= 2\,\frac{X_1\,(t-X_2)\varphi_1\,\varphi_2^*}{X_3^2} + X_1\,\varphi_1\,\left(iX_4\,(t-X_2)+iX_5\right)\varphi_2^* \\
\frac{\partial f^*}{\partial X_3} &= 2\,\frac{X_1\,(t-X_2)^2\varphi_1\,\varphi_2^*}{X_3^3} \\
\frac{\partial f^*}{\partial X_4} &= -\frac{i}{2}X_1\,\varphi_1\,(t-X_2)^2\varphi_2^* \\
\frac{\partial f^*}{\partial X_5} &= -iX_1\,\varphi_1\,(t-X_2)\varphi_2^* \\
\frac{\partial f^*}{\partial X_6} &= -iX_1\,\varphi_1\,\varphi_2,
\end{aligned}
\tag{17}
$$

With help of (16) and (17), we get

$$
\begin{aligned}
R_1 &= 0 \\
R_2 &= -\tfrac{X_1^2\sqrt{\pi}}{12X_3}\begin{pmatrix} 9\sqrt{2}X_3^4X_4^2X_5a - \tfrac{3}{2}X_1^2X_3^4X_4^2\lambda - 3\sqrt{2}X_3^4X_4^2\alpha + 12\sqrt{2}X_3^2X_5^3a - 12X_1^2X_3^2X_5^2\lambda \\ -8\sqrt{3}X_1X_3^2X_5b_1 - 12\sqrt{2}X_3^2X_5^2\alpha - 36X_1^2X_3^2X_5b_2 + 12\sqrt{2}X_5a - 18X_1^2\lambda + 12X_1^2\theta - 12\sqrt{2}\alpha \end{pmatrix} \\
R_3 &= -\sqrt{2}\sqrt{\pi}X_1^2X_4a \\
R_4 &= \tfrac{\sqrt{\pi}X_1^2X_3}{288}\begin{pmatrix} 27\sqrt{2}X_3^4X_4^2a + 36\sqrt{2}X_3^2X_5^2a - 18X_1^2X_3^2X_5\lambda - \\ 16\sqrt{3}X_1X_3^2b_1 - 36\sqrt{2}X_3^2X_5\alpha - 18X_1^2X_3^2b_2 - 36\sqrt{2}a \end{pmatrix} \\
R_5 &= -\tfrac{1}{8}X_1^2X_3^3X_4\sqrt{\pi}\left(-4\sqrt{2}X_5a + X_1^2\lambda + 2\sqrt{2}\alpha\right) \\
R_6 &= \tfrac{X_1^2\sqrt{\pi}}{12X_3}\begin{pmatrix} 3\sqrt{2}X_3^4X_4^2a + 12\sqrt{2}X_3^2X_5^2a - 12X_1^2X_3^2X_5\lambda - \\ 8\sqrt{3}X_1X_3^2b_1 - 12\sqrt{2}X_3^2X_5\alpha - 12X_1^2X_3^2b_2 + 12\sqrt{2}a \end{pmatrix}
\end{aligned}
\tag{18}
$$

From (15) and inverting (18), we get

$$
\begin{aligned}
\dot{\mathbf{X}}_1 &= -X_1\,X_4\,a \\
\dot{\mathbf{X}}_2 &= 2\,X_5\,a - \frac{3}{4}\,\sqrt{2}X_1^2\lambda - \frac{1}{2}\,\sqrt{2}X_1^2\theta - \alpha \\
\dot{\mathbf{X}}_3 &= 2\,X_3\,X_4\,a \\
\dot{\mathbf{X}}_4 &= -\frac{1}{9},\,\frac{\sqrt{2}\left(9\,a\,\sqrt{2}X_3^4X_4^2 + 9\,X_1^2X_3^2X_5\,\lambda + 4\,X_3^2X_1\,\sqrt{3}b_1 + 9\,X_1^2X_3^2b_2 - 36\,a\,\sqrt{2}\right)}{X_3^4} \\
\dot{\mathbf{X}}_5 &= -\frac{1}{2},\,\sqrt{2}X_1^2X_4\,\lambda - 1/2\,\sqrt{2}X_1^2X_4\,\theta \\
\dot{\mathbf{X}}_6 &= \frac{\sqrt{2}\left(36\,a\,\sqrt{2}X_3^2X_5^2 - 9\,X_1^2X_3^2X_5\,\lambda - 36\,X_1^2X_3^2X_5\,\theta + 28\,X_3^2X_1\,\sqrt{3}b_1 + 45\,X_1^2X_3^2b_2 - 72\,a\,\sqrt{2}\right)}{72\,X_3^2}
\end{aligned}
\tag{19}
$$

5 Numerical simulations

Finally (19), is the model of nonlinear dynamics. In fact, we have a system of ODEs and it requires set of initial conditions. We assume the initial conditions $X_1(0) = 1$, $X_2(0) = 0$, $X_3(0) = 5$, $X_4(0) = 2$, $X_5(0) = 5$ and $X_6(0) = 0$. We use Runge–Kutta method order 4 and 5 for the integration. The model (1) are $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$. Figure 1 depicts amplitude variation X_1 versus time and it has periodic behavior. In Fig. 2, the central position X_2 of the soliton is plotted. Soliton inverse width is given in Fig. 3. Soliton chirp variation is shown in Fig. 4. Soliton frequency and phase variation are presented in Figs. 5 and 6. In the following figures, dotted lines represent the numerical results and solid lines represent the theocratical results.

$$\frac{\partial \mathbf{C}}{\partial \mathbf{X}} = \begin{bmatrix} X_3\sqrt{2}\sqrt{\pi} & 0 & \frac{1}{2}X_1\sqrt{2}\sqrt{\pi} & 0 & 0 & 0 \\ 0 & \frac{1}{4}\frac{X_1^2\sqrt{2}\sqrt{\pi}(X_3^4X_4^2+4X_3^2X_5^2+4)}{X_3} & 0 & -\frac{1}{8}X_3^3X_5X_1^2\sqrt{2}\sqrt{\pi} & -\frac{1}{4}X_1^2X_3^3X_4\sqrt{2}\sqrt{\pi} & -X_3X_5X_1^2\sqrt{2}\sqrt{\pi} \\ \frac{1}{2}X_1\sqrt{2}\sqrt{\pi} & 0 & \frac{3}{4}\frac{X_1^2\sqrt{2}\sqrt{\pi}}{X_3} & 0 & 0 & 0 \\ 0 & -\frac{1}{8}X_3^3X_5X_1^2\sqrt{2}\sqrt{\pi} & 0 & \frac{3X_3^5X_1^2\sqrt{2}\sqrt{\pi}}{64} & 0 & \frac{1}{8}X_1^2X_3^3\sqrt{2}\sqrt{\pi} \\ 0 & -\frac{1}{4}X_1^2X_3^3X_4\sqrt{2}\sqrt{\pi} & 0 & 0 & \frac{1}{4}X_1^2X_3^3\sqrt{2}\sqrt{\pi} & 0 \\ 0 & -X_3X_5X_1^2\sqrt{2}\sqrt{\pi} & 0 & \frac{1}{8}X_1^2X_3^3\sqrt{2}\sqrt{\pi} & 0 & X_1^2X_3\sqrt{2}\sqrt{\pi} \end{bmatrix} \tag{20}$$

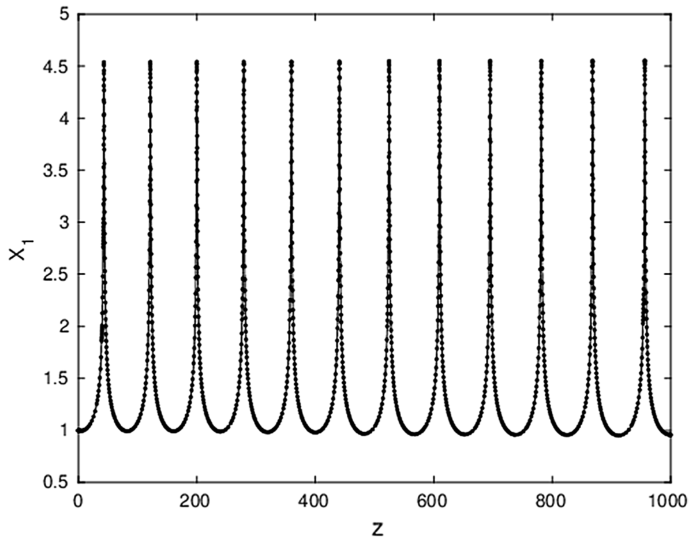

Fig. 1 Gaussian: X_1 versus z, $X_1(0) = 1$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

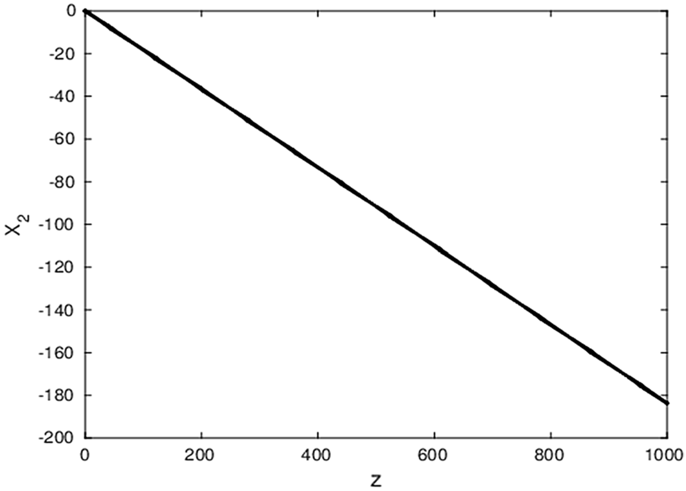

Fig. 2 Gaussian: X_2 versus z, $X_2(0) = 0$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

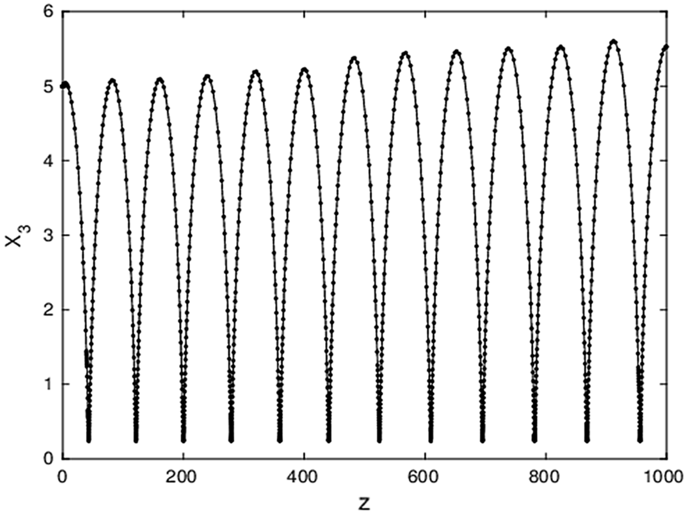

Fig. 3 Gaussian: X_3 versuss z, $X_3(0) = 5$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

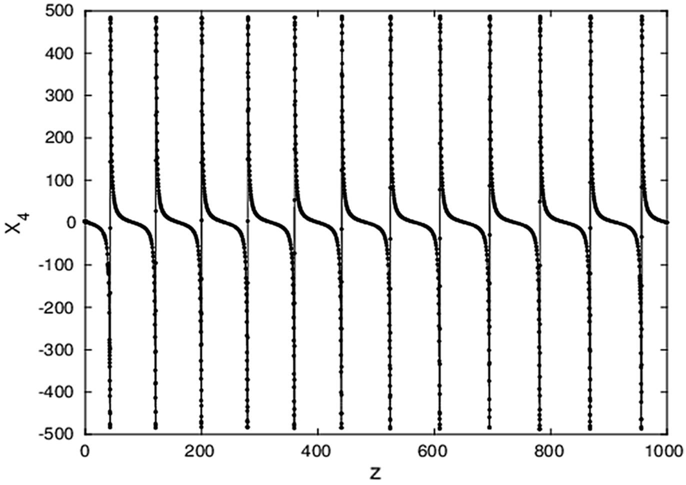

Fig. 4 Gaussian: X_4 versus z, $X_4(0) = 2$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

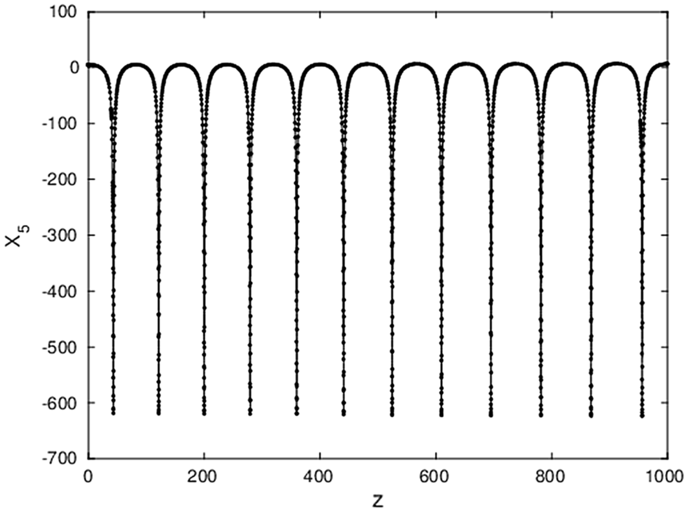

Fig. 5 Gaussian: X_5 versus z, $X_5(0) = 5$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

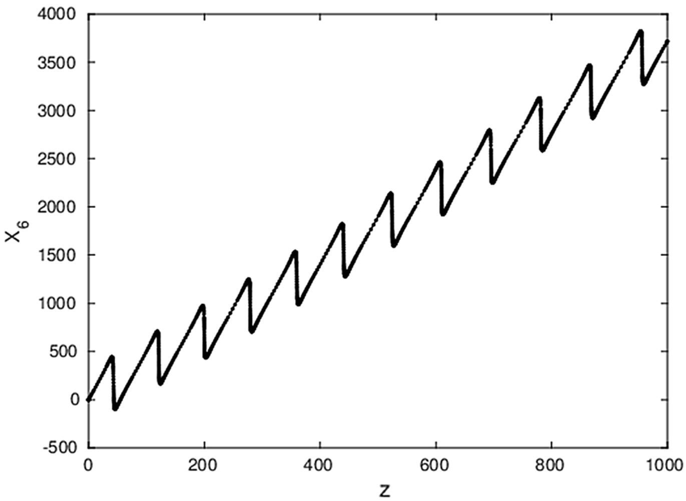

Fig. 6 Gaussian: X_6 versus z, $X_6(0) = 0$, $a = 0.001$, $b_1 = 11$, $b_2 = 0.01$, $\alpha = 0.25$, $\lambda = 0.01$, $\theta = -0.1$

6 Conclusion

Collective variables approach was applied to obtain the evolution equation that governs the dynamics of the soliton and its propagation through optical solitons. A technique for integrating the residual field has been manifested in collective variable treatment of optical Gaussons. This allows the soliton and also the selection of solitons ansatz function. Present approach has advantage to describe the soliton of the perturbed NLSE.

Using the approximation approach of Gaussian ansatz, we have derived the equations for the evolution of collective variables of the soliton. Finally, we have used suitable initial condition for the evolution of the system. For the set of model parameters, we computed the results that are depicted in figures. This paper could be used for further investigations of the soliton dynamics and the impact of nonlinear parameters on solitons amplitude, temporal evolution of pulse, frequency, phase and chirp.

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