Quiescent optical solitons with Kudryashov's generalized quintuple-power and nonlocal nonlinearity having nonlinear chromatic dispersion: generalized temporal evolution

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Abstract. We derive stationary optical solitons for the case when the nonlinear refractive index of Kudryashov's quintuple form is coupled with a nonlocal type of self-phase modulation in the presence of nonlinear chromatic dispersion. An enhanced Kudryashov's approach has made this derivation of soliton solutions possible for the case of generalized temporal evolution.

Keywords: solitons, Kudryashov's method, dispersion, temporal evolution

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1. Introduction

The theory of quiescent solitons is gradually gaining importance since it could be as a hindrance in the soliton propagation dynamics [1–10]. One of the main sources of such stationary solitons is a natural manifestation of chromatic dispersion, which is rendered nonlinear. This can lead to stalling of soliton propagation, an unwanted feature causing a disaster in telecommunication industry. In other words, the issue must be avoided at all costs. Below we will portray a mathematical picture of the quiescent solitons. It emerges from the governing nonlinear Schrödinger's equation with nonlinearity of a Kudryashov's quintuple-power law, which is coupled with a nonlinear refractive index of a nonlocal form. The current study is a sequel to the previous work on the same model which has been examined for the simpler case of a linear temporal evolution. Now we consider the same model with a generalized temporal evolution. The enhanced Kudryashov's integration algorithm will be implemented to recover stationary optical solitons in the model. The corresponding results will represent a generalized version of those reported previously in Ref. [1]. Accordingly, our present results collapse to the earlier ones whenever the generalized temporal evolution parameter relaxes to unity.

2. The enhanced Kudryashov's method

Our governing model is a nonlinear Schrödinger's equation where the source of self-phase modulation comes from a Kudryashov's quintuple-power law of nonlinearity, which is coupled with a nonlocal type of a nonlinear refractive index. In a dimensionless form, it can be structured as

$$\begin{aligned} & i(q^l)_t + a\left(|q|^r q^l\right)_{xx} \\ & +\left[b_1|q|^{2m} + b_2|q|^{2m+n} + b_3|q|^{2m+2n} + b_4|q|^{2m+n+p} + b_5|q|^{2m+2n+p} + \left(|q|^p\right)_{xx}\right]q^l = 0. \end{aligned} \tag{1}$$

In Eq. (1), the dependent variable $q(x,t)$ is a complex-valued function that represents a nonlinear wave profile. The independent variables x and t stand for the spatial and temporal coordinates, respectively. The first term in the l. h. s of Eq. (1) is associated with a generalized temporal evolution described by the evolution parameter l, while a denotes the coefficient of nonlinear chromatic dispersion. The b_j coefficients ($1 \le j \le 5$) entering in Eq. (1) form the self-phase modulation structure introduced earlier by N. A. Kudryashov [1]. Finally, the last term in the l. h. s. of Eq. (1) stands for the nonlocal nonlinearity.

We remind that the parameter l governs a generalized temporal evolution. The special case of $l = 1$ is reduced to the linear temporal evolution. The model given by Eq. (1) with the linear temporal evolution has been studied in 2022. Now we turn this page and study the same model with the generalized temporal evolution. As a consequence, our results would collapse to those obtained for the linear temporal evolution under the condition given by $l = 1$.

Let us consider the nonlinear evolution equation

$$F\left(u, u_x, u_t, u_{xt}, u_{xx}, \ldots\right) = 0, \tag{2}$$

where $u = u(x,t)$ is an unknown function and F a polynomial in u, with independent spatial and temporal variables.

The fundamental algorithmic procedures in the frame of the enhanced Kudryashov's method are as follows (see Ref. [1]).

Step 1. Use the following transformation:

$$u(x,t) = U(\xi), \quad \xi = k(x - vt), \tag{3}$$

where k and v are constants to be determined later. Then Eq. (2) is reduced to a nonlinear ordinary differential equation of the form

$$P\left(U, -kvU', kU', k^2U'', \ldots\right) = 0. \tag{4}$$

Step 2. Assume that the solution of Eq. (4) can be expressed in the form

$$U(\xi) = A_0 + \sum_{l=1}^{N} \sum_{i+j=l} A_{ij} Q^i(\xi) R^j(\xi), \tag{5}$$

where $A_0, A_{ij}\left(i, j = 0, 1, \ldots, N\right)$ are constants to be determined and the functions $R(\xi)$ and $Q(\xi)$ satisfy the ordinary differential equations

$$R'(\xi)^2 = R(\xi)^2(1-\chi R\left(\xi)^2\right) \tag{6}$$

and

$$Q'(\xi) = Q(\xi)\left(\eta Q(\xi)-1\right), \tag{7}$$

with a, b, η and χ being arbitrary constants. The solutions of Eqs. (6) and (7) are given respectively by

$$R(\xi) = \frac{4a}{4a^2 e^{\xi} + \chi e^{-\xi}} \tag{8}$$

and

$$Q(\xi) = \frac{1}{\eta + be^{\xi}}. \tag{9}$$

Step 3. Determine the positive integer number N in Eq. (5) by balancing the highest-order derivatives and the nonlinear term in Eq. (4).

Step 4. Substitute Eqs. (5)–(7) into Eq. (4). As a result, we get a polynomial of $Q(\xi), R(\xi)$ and $R'(\xi)$. In this polynomial, we gather all the terms of the same powers and equate them to zero. Then we get an over-determined system of algebraic equations which can be solved, e.g., with Maple or Mathematica, in order to obtain the unknown parameters k, v, a, b, η, χ, A_0 and A_{ij} $(i, j = 0,1,\cdots,N)$. In this manner one can obtain the exact solutions of Eq. (2).

3. Application to governing equation

In order to integrate the model equation, we set the wave transformation

$$q(x,t) = U(kx)e^{i(\omega t+\theta_0)}, \tag{10}$$

where ω represents the wave number and θ_0 stems from the phase constant. Inserting Eq. (10) into Eq. (1) gives

$$\begin{aligned} &ak^2(r+1)U^{r+1}U'' + ak^2\left(l^2+(r-1)r+l(2r-1)\right)U^rU'^2 \\ &+b_4U^{2m+n+p+2}+b_5U^{2m+2n+p+2}+b_3U^{2(m+n+1)}+b_2U^{2m+n+2} \\ &+b_1U^{2m+2}+k^2pU^{p+1}U''+k^2(p-1)pU^pU'^2-l\omega U^2=0. \end{aligned} \tag{11}$$

Let us assume the equality $r = 2m + p$. Then Eq. (1) becomes

$$\begin{aligned} &iq^l{}_t + a\left(|q|^{2m+p}\, q^l\right)_{xx} \\ &+\left[b_1\left|q\right|^{2m}+b_2\left|q\right|^{2m+n}+b_3\,|q|^{2m+2n}+b_4\left|q\right|^{2m+n+p}+b_5\left|q\right|^{2m+2n+p}+\left(|q|^p\right)_{xx}\right]q^l=0, \end{aligned} \tag{12}$$

while Eq. (12) changes to

$$\begin{aligned} &ak^2(2m+p+1)U''U^{2m+p+1} \\ &+ak^2\left[l^2+l\left(2(2m+p)-1\right)+(2m+p-1)(2m+p)\right]U'^2U^{2m+p} \\ &+b_4U^{2m+n+p+2}-l\omega U^2+b_5U^{2m+2n+p+2}+b_3U^{2(m+n+1)}+b_2U^{2m+n+2} \\ &+b_1U^{2m+2}+k^2pU^{p+1}U''+k^2(p-1)pU^pU'^2=0. \end{aligned} \tag{13}$$

Using the transformation

$$U = V^{\frac{1}{n}}, \tag{14}$$

one can transform Eq. (13) into

$$\begin{aligned} & n^2V^2\left(-l\omega + b_1V^{\frac{2m}{n}} + b_3V^{\frac{2m+2n}{n}} + b_2V^{\frac{2m+n}{n}} + b_4V^{\frac{2m+n+p}{n}} + b_5V^{\frac{2m+2n+p}{n}}\right) \\ & + k^2(p-1)pV'^2V^{\frac{p}{n}} + ak^2\left(l^2 + l\left(2(2m+p)-1\right) + (2m+p-1)(2m+p)\right)V'^2V^{\frac{2m+p}{n}} \\ & + k^2pV^{\frac{p}{n}}\left(nVV'' - (n-1)V'^2\right) + ak^2(2m+p+1)V^{\frac{2m+p}{n}}\left(nVV'' - (n-1)V'^2\right) = 0. \end{aligned} \tag{15}$$

Now let us put the conditions $p = n = 2m$. Then Eq. (12) becomes

$$\begin{aligned} & iq^l{}_t + a\left(|q|^{4m} q^l\right)_{xx} \\ & + \left[b_1|q|^{2m} + b_2|q|^{4m} + (b_3+b_4)|q|^{6m} + b_5|q|^{8m} + \left(|q|^{2m}\right)_{xx}\right]q^l = 0, \end{aligned} \tag{16}$$

while Eq. (16) transforms to

$$\begin{aligned} & 2V\left(2ak^2m(l+4m)V'' + 4b_1m^2\right) + V'^2\left(ak^2l^2 + 6ak^2lm + 8ak^2m^2\right) \\ & + 4b_5m^2V^4 + \left(4b_3m^2 + 4b_4m^2\right)V^3 + 4b_2m^2V^2 + 4k^2m^2V'' - 4lm^2\omega = 0. \end{aligned} \tag{17}$$

Balancing V'' with V^4 in Eq. (17) gives $N = 1$. Consequently, we obtain

$$V(\xi) = \lambda_0 + \lambda_{01}R(\xi) + \lambda_{10}Q(\xi). \tag{18}$$

Now we substitute Eq. (18) along with Eqs. (6) and (7) into Eq. (17). As a result, we get a polynomial of $Q(\xi), R(\xi)$ and $R'(\xi)$. After gathering all the terms of the same powers in this polynomial and equating them to zero, we obtain an over-determined system of algebraic equations. The latter can be solved by Maple or Mathematica. The following results have been derived in this way.

The ***Result 1*** is given by

$$\begin{aligned} & \lambda_0 = \frac{8b_5m^2 - a(b_3+b_4)(l+4m)(l+6m)}{4ab_5(l+4m)(l+5m)} - \frac{\lambda_{10}}{2\eta}, \\ & \lambda_{10} = -\frac{\eta\sqrt{\wp_1}}{2ab_5(l+4m)^2(l+5m)}, \quad \lambda_{01} = 0, \quad \omega = -\frac{\wp_3}{64lb_5^3a^4(4m+l)^6(5m+l)^4}, \\ & k = \sqrt{-\frac{m^2\wp_1}{a^3b_5(4m+l)^5(5m+l)(6m+l)}}, \; b_1 = -\frac{\wp_2}{8b_5^2a^3(4m+l)^4(5m+l)^3}, \end{aligned} \tag{19}$$

with

$$\begin{aligned} \wp_1 = {} & (l+6m)(l+4m)\Big\{3a^2(b_3+b_4)^2(l+4m)^3(l+6m) \\ & -8ab_5(l+4m)\left[ab_2(l+4m)(l+5m)^2 - 6(b_3+b_4)m^3\right] - 192b_5^2m^4\Big\}, \end{aligned} \tag{20}$$

$$\begin{aligned} \wp_2 = {} & a^3(b_3+b_4)^3(l+3m)(l+4m)^4(l+6m)^2 \\ & -4a^2(b_3+b_4)b_5(l+3m)(l+4m)^2(l+6m)\left(ab_2(l+4m)(l+5m)^2 - 6(b_3+b_4)m^3\right) \\ & -64ab_5^2m^3(l+4m)\Big\{ab_2(l+4m)(l+5m)^2 - 3(b_3+b_4)m^2(l+7m)\Big\} - 512b_5^3m^6(l+7m), \end{aligned} \tag{21}$$

$$\begin{aligned}\varrho_3 &= a^4\left(b_3+b_4\right)^4\left(l+2m\right)\left(l+4m\right)^6\left(l+6m\right)^3-8a^3\left(b_3+b_4\right)^2 b_5\left(l+4m\right)^4\left(l+6m\right)^2\\ &\times\left[ab_2\left(l+2m\right)\left(l+4m\right)\left(l+5m\right)^2+12\left(b_3+b_4\right)m^4\right]+16a^2b_5^2\left(l+4m\right)^2\left(l+6m\right)\\ &\times\left\{a^2b_2^2\left(l+2m\right)\left(l+4m\right)^2\left(l+5m\right)^4+24ab_2\left(b_3+b_4\right)m^4\left(l+4m\right)\left(l+5m\right)^2\right.\\ &\left.-12\left(b_3+b_4\right)^2 m^4\left(l+6m\right)\left(l^2+6lm+11m^2\right)\right\}+512ab_5^3m^4\left(l+4m\right)\\ &\times\left\{ab_2\left(l+4m\right)\left(l+5m\right)^2\left(l^2+6lm+2m^2\right)+2\left(b_3+b_4\right)m^2\left(l^3+16l^2m+95lm^2+206m^3\right)\right\}\\ &-12288b_5^4m^9\left(2l+11m\right).\end{aligned} \tag{22}$$

Substituting Eq. (19) and Eqs. (6) and (7) into Eq. (18) yields

$$q(x,t)=\left\{\frac{8b_5m^2-a\left(b_3+b_4\right)\left(l+4m\right)\left(l+6m\right)}{4ab_5\left(l+4m\right)\left(l+5m\right)}+\frac{\lambda_{10}}{b\exp\left[\sqrt{-\dfrac{m^2\varrho_1}{a^3b_5(4m+l)^5\left(5m+l\right)\left(6m+l\right)}}\,x\right]+\eta}-\frac{\lambda_{10}}{2\eta}\right\}^{\frac{1}{2m}} \times e^{i\left(\left\{-\frac{\varrho_3}{64lb_5^3a^4(4m+l)^6(5m+l)^4}\right\}t+\theta_0\right)}. \tag{23}$$

Setting $\eta=\pm b$ in the solution given by Eq. (23), we arrive at dark and singular solitons:

$$q(x,t)=\left\{\frac{8b_5m^2-a\left(b_3+b_4\right)\left(l+4m\right)\left(l+6m\right)}{4ab_5\left(l+4m\right)\left(l+5m\right)}+\frac{\sqrt{\varrho_1}}{4ab_5(l+4m)^2\left(l+5m\right)}\tanh\left[\sqrt{-\frac{m^2\varrho_1}{4a^3b_5(4m+l)^5\left(5m+l\right)\left(6m+l\right)}}\,x\right]\right\}^{\frac{1}{2m}} \times e^{i\left(\left\{-\frac{\varrho_3}{64lb_5^3a^4(4m+l)^6(5m+l)^4}\right\}t+\theta_0\right)} \tag{24}$$

and

$$q(x,t)=\left\{\frac{8b_5m^2-a\left(b_3+b_4\right)\left(l+4m\right)\left(l+6m\right)}{4ab_5\left(l+4m\right)\left(l+5m\right)}+\frac{\sqrt{\varrho_1}}{4ab_5(l+4m)^2\left(l+5m\right)}\coth\left[\sqrt{-\frac{m^2\varrho_1}{4a^3b_5(4m+l)^5\left(5m+l\right)\left(6m+l\right)}}\,x\right]\right\}^{\frac{1}{2m}} \times e^{i\left(\left\{-\frac{\varrho_3}{64lb_5^3a^4(4m+l)^6(5m+l)^4}\right\}t+\theta_0\right)}. \tag{25}$$

These soliton solutions are valid under the condition

$$ab_5\varrho_1<0.$$

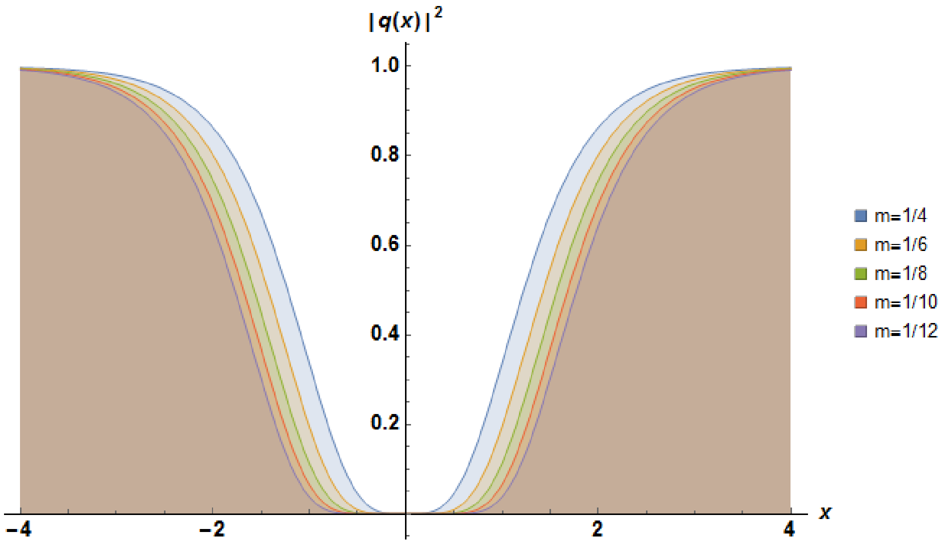

Fig. 1. Profiles of a dark quiescent 1-soliton given by Eq. (24).

Fig. 1 displays the profiles of a dark quiescent 1-soliton obtained at $l=1.5$. The other parameter values chosen by us are as follows: $b_5=1$, $a=-1$, $b_3=1$, $b_4=1$, and $b_2=1$.

The ***Result 2*** can be described as follows:

$$
\begin{aligned}
\lambda_0 &= \frac{8b_5m^2 - a\left(b_3+b_4\right)\left(l^2+10lm+24m^2\right)}{4ab_5\left(l^2+9lm+20m^2\right)},\\
\lambda_{01} &= \sqrt{\frac{\chi\varrho_1}{8a^2b_5^2(l+4m)^4(l+5m)^2}},\quad \lambda_{10}=0,\\
k &= \sqrt{\frac{m^2\varrho_1}{2a^3b_5(l+4m)^4(l+5m)^2\left(l+6m\right)}},\\
b_1 &= -\frac{\varrho_2}{8a^3b_5^2(l+4m)^4(l+5m)^3},\\
\omega &= \frac{\varrho_4}{256a^4b_5^3l(l+4m)^5(l+5m)^4},
\end{aligned}
\tag{26}
$$

where c_1 and c_2 are given by Eqs. (20) and (21), and

$$
\begin{aligned}
\varrho_4 = &\left(a\left(b_3+b_4\right)\left(l+4m\right)\left(l+6m\right)-8b_5m^2\right)\Big[5a^3\left(b_3+b_4\right)^3\left(l+2m\right)\left(l+4m\right)^4\left(l+6m\right)^2\\
&-8a^2\left(b_3+b_4\right)b_5\left(l+4m\right)^2\left(l+6m\right)\\
&\times\left\{2ab_2\left(l+2m\right)\left(l+4m\right)\left(l+5m\right)^2-\left(b_3+b_4\right)m^2\left(l+10m\right)\left(5l+16m\right)\right\}\\
&-64ab_5^2m^2\left(l+4m\right)\\
&\times\left\{2ab_2\left(l+4m\right)\left(l+5m\right)^2\left(l+8m\right)+\left(b_3+b_4\right)m^2\left(l^2-18lm-160m^2\right)\right\}\\
&-1536b_5^3m^6\left(3l+20m\right)\Big].
\end{aligned}
\tag{27}
$$

Substituting Eq. (26) and Eqs. (6) and (7) into Eq. (18) yields

$$q(x,t)=\left\{\frac{8b_5m^2-a(b_3+b_4)\left(l^2+10lm+24m^2\right)}{4ab_5\left(l^2+9lm+20m^2\right)}+\sqrt{\frac{\chi\varrho_1}{8a^2b_5^2(l+4m)^4(l+5m)^2}}\right.$$
$$\left.\times\left(\frac{4a}{4a^2\exp\left[\sqrt{\frac{m^2\varrho_1}{2a^3b_5(l+4m)^5(l+5m)^2(l+6m)}}\,x\right]-\chi\exp\left[-\sqrt{\frac{m^2\varrho_1}{2a^3b_5(l+4m)^5(l+5m)^2(l+6m)}}\,x\right]}\right)\right\}^{\frac{1}{2m}} \tag{28}$$
$$\times e^{i\left(\left\{\frac{\varrho_4}{256a^4b_5^3l(l+4m)^5(l+5m)^4}\right\}t+\theta_0\right)}.$$

Setting $\chi=\pm 4a^2$ in the solution given by Eq. (28), we arrive at bright and singular solitons:

$$q(x,t)=\left\{\frac{8b_5m^2-a(b_3+b_4)\left(l^2+10lm+24m^2\right)}{4ab_5\left(l^2+9lm+20m^2\right)}+\sqrt{\frac{\varrho_1}{8a^2b_5^2(l+4m)^4(l+5m)^2}}\right.$$
$$\left.\times sech\left[\sqrt{\frac{m^2\varrho_1}{2a^3b_5(l+4m)^5(l+5m)^2(l+6m)}}\,x\right]\right\}^{\frac{1}{2m}} e^{i\left(\left\{\frac{\varrho_4}{256a^4b_5^3l(l+4m)^5(l+5m)^4}\right\}t+\theta_0\right)} \tag{29}$$

and

$$q(x,t)=\left\{\frac{8b_5m^2-a(b_3+b_4)\left(l^2+10lm+24m^2\right)}{4ab_5\left(l^2+9lm+20m^2\right)}+\sqrt{-\frac{\varrho_1}{8a^2b_5^2(l+4m)^4(l+5m)^2}}\right.$$
$$\left.\times csch\left[\sqrt{\frac{m^2\varrho_1}{2a^3b_5(l+4m)^5(l+5m)^2(l+6m)}}\,x\right]\right\}^{\frac{1}{2m}} e^{i\left(\left\{\frac{\varrho_4}{256a^4b_5^3l(l+4m)^5(l+5m)^4}\right\}t+\theta_0\right)}. \tag{30}$$

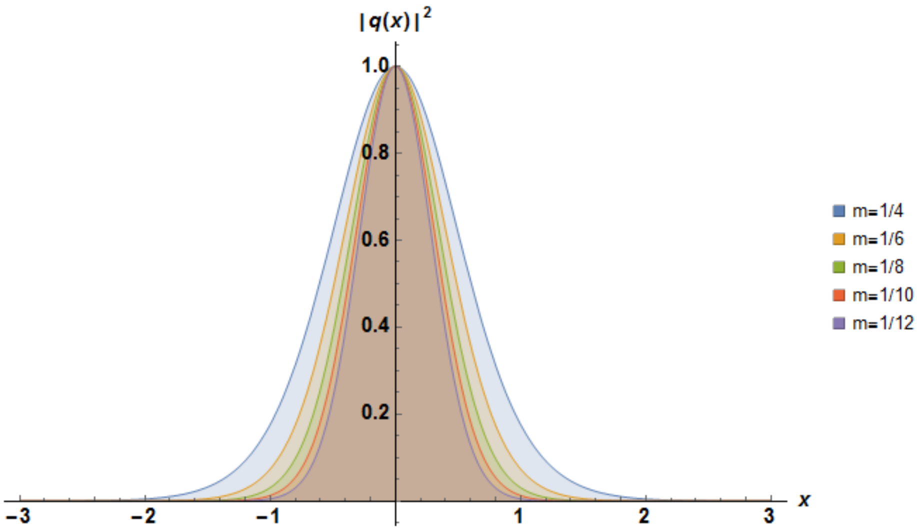

Fig. 2. Profiles of a bright quiescent 1-soliton given by Eq. (29).

These soliton solutions are valid at the condition

$$ab_5\varrho_1 > 0.$$

Fig. 2 shows the profile of a bright quiescent 1-soliton obtained at $l = 1.5$. The other parameters have been chosen as follows: $b_5 = 1$, $a = 1$, $b_3 = 1$, $b_4 = 1$, and $b_2 = 1$.

4. Conclusion

The present study is a sequel to the recent report [1] on the stationary optical solitons, which emerge from the governing nonlinear Schrödinger's equation with the Kudryashov's quintuple form of the nonlinearity coupled with the nonlocal structure of the nonlinear refractive index. This time the results concern the most general case of temporal evolution. Upon putting the generalized temporal evolution parameter to be unity, one arrives at the results reported in Ref. [1]. Therefore our present work portrays the generalized perspective of the stationary solitons arising from the nonlinear Schrödinger's equation with the novel form of the self-phase modulation suggested by N. A. Kudryashov.

The results of our work convey a very important practical message to the community dealing with the optical solitons. The ground engineers in the field of telecommunications must make absolutely sure that the chromatic dispersion is not rendered to be nonlinear all the time while the solitons are being transmitted across transcontinental and transoceanic distances through optical fibres. Such is the stark warning to the industry!

References

1. Arnous A H, Nofal T A, Biswas A, Khan S and Moraru L, 2022. Quiescent optical solitons with Kudryashov's generalized quintuple-power and nonlocal nonlinearity having nonlinear chromatic dispersion. Universe. **8**: 501.
2. Ekici M, 2022. Stationary optical solitons with complex Ginzburg–Landau equation having nonlinear chromatic dispersion and Kudryashov's refractive index structures. Phys. Lett. A. **440**: 128146.
3. Ekici M, 2023. Stationary optical solitons with Kudryashov's quintuple power law nonlinearity by extended Jacobi's elliptic function expansion. J. Nonl. Opt. Phys. Mater. **32**: 2350008.
4. Hong W-P, 2008. Existence conditions for stable stationary solitons of the cubic–quintic complex Ginzburg–Landau equation with a viscosity term. Zeitsc. Natur. **63a**: 757–762.
5. Kudryashov N A, 2022. Stationary solitons of the model with nonlinear chromatic dispersion and arbitrary refractive index. Optik. **259**: 168888.
6. Kydryashov N A, 2022. Stationary solitons of the generalized nonlinear Schrödinger equation with nonlinear dispersion and arbitrary refractive index. Appl. Math. Lett. **128**: 107888.
7. Sonmezoglu A, 2022. Stationary optical solitons having Kudryashov's quintuple power law nonlinearity by extended G/G'-expansion. Optik. **253**: 168521.
8. Yalci M and Ekici M, 2022. Stationary optical solitons with complex Ginzburg–Landau equation having nonlinear chromatic dispersion. Opt. Quant. Electr. **54**: 167.
9. Yan Z, 2006. Envelope compactons and solitary patterns. Phys. Lett. A. **355**: 212–215.
10. Yan Z, 2006. Envelope compact and solitary pattern structures for the GNLS(m,n,p,q) equations. Phys. Lett. A. 357: 196–203.

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generalized quintuple-power and nonlocal nonlinearity having nonlinear chromatic dispersion: generalized temporal evolution. Ukr.J.Phys.Opt. **24**: 105 – 113.
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Анотація. *Одержано стаціонарні оптичні солітони для випадку форми Кудряшова з п'ятим степенем для нелінійного показника заломлення, поєднаної з нелокальним типом самофазової модуляції за наявності нелінійної хроматичної дисперсії. Удосконалений підхід Кудряшова дав можливість одержати солітонні розв'язки для випадку узагальненої часової еволюції.*

Ключові слова*: солітони, метод Кудряшова, дисперсія, часова еволюція*