Effect of Higher Order Dispersion on Optical Bistability in Presence of Cubic-Quintic Nonlinearity

Samudra Roy and Shyamal Bhadra
Fiber Optics Laboratory;Central Glass & Ceramic Research Institute
Jadavpur, Kolkata-700032, India
Email: skbhadra@cgcri.res.in

Abstract: Adopting variational approach the effect of defocusing quintic nonlinearity on pulse width is examined with numerical verification. Novel parametric effect of dispersion on minimum critical width of solitons and its bistable regime is predicted analytically

OCIS codes: (060.5530) Pulse propagation and solitons, (060.4370) fibers and nonlinear optics, (190.1450) bistability.

In double doped glass having non-Kerr type nonlinearity with refractive index profile $n = n_0 + n_2 I + n_4 I^2$ may support two states of soliton with same pulse width but at different energies provided the condition $n_2 n_4 < 0$ is satisfied [1]. The parametric effect of the effective dispersion on determining the regime of bistability and the minimum critical width of solitons is predicted. We initiate the problem with the dynamic NLCQSE considering the slow varying envelope approximation as shown below (γ and δ correspond to cubic and quintic nonlinearity) ,

$$\frac{\partial A}{\partial z} + \alpha A + \frac{i\beta_2}{2!}\frac{\partial^2 A}{\partial t^2} - \frac{\beta_3}{3!}\frac{\partial^3 A}{\partial t^3} = i\gamma |A|^2 A + i\delta |A|^4 A \ . \tag{1}$$

The reduced Lagrangian *L*, can be constructed with a suitable Gaussian ansatz as given by,

$$A(z,t) = a(z)\exp\left[i\phi(z) - i\Omega(z)(t - T(z)) - \frac{(1 + iC(z))(t - T(z))^2}{2\tau(z)^2}\right] \tag{2}$$

where $a(z), \phi(z), \Omega(z), T(z), C(z)$ and $\tau(z)$ correspond to the amplitude, phase, frequency shift from carrier frequency, temporal position, chirp and temporal width of the pulse respectively- as follows,

$$L = -iE\left[\frac{d\phi}{dz} + \Omega\frac{dT}{dz} - \frac{1}{4}\frac{dC}{dz} + \frac{C}{2\tau}\frac{d\tau}{dz}\right] + \frac{i\beta_2 E}{2!}\left[\Omega^2 + \frac{(1 + C^2)}{2\tau^2}\right] + \frac{i\beta_3 E}{3!}\left[\Omega^3 + \frac{\Omega}{\tau^2} + \frac{\Omega(1 + 3C^2)}{2\tau^2}\right] + \frac{i\gamma E^2}{2\tau\sqrt{2\pi}} + \frac{i\delta E^3}{3\pi\tau^2\sqrt{3\pi}} \ . \tag{3}$$

Euler-Lagrangian prescription can be utilized to predict the normalized pulse width (*y*) evolution as,

$$\frac{\partial^2 y(z)}{\partial z^2} = \frac{1}{y^3}\left[\frac{1}{\tau_0^4}(\beta_2 + \beta_3\Omega_0)^2 + (\beta_2 + \beta_3\Omega_0)\left(\frac{4\pi\delta a_0^4}{(3\pi)^{3/2}\tau_0^2}\right)\right] + \frac{1}{y^2}[\beta_2 + \beta_3\Omega_0]\left(\frac{\gamma a_0^2}{\sqrt{2}\tau_0^2}\right) \tag{4}$$

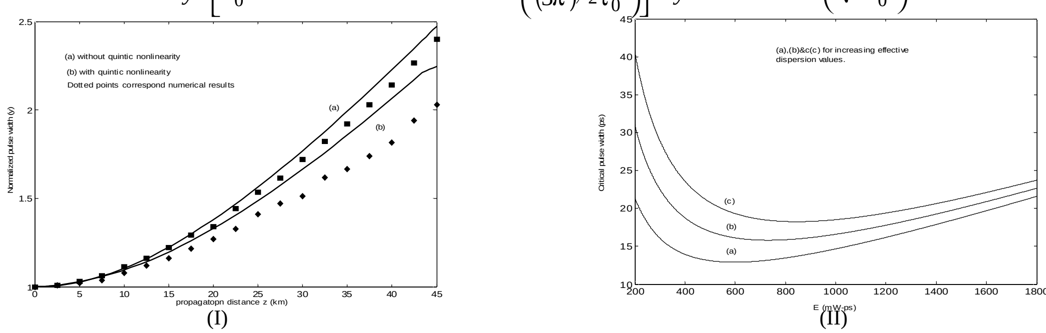

Fig 1: Plot (I) Effect of the defocusing nature of n_4 on pulse width. Plot (II) Parametric nature of effective dispersion on bistability.

Forming a potential function ϕ [2] according to the prescription $\frac{d^2 y}{dz^2} = -\frac{d\phi}{dy}$ a critical pulse width $(y_{critical})$ of bistable solitons may be obtained and it is predicted that the condition of stable solution can be achieved when $(\beta_2 + \beta_3\Omega_0)\gamma = \beta_{eff}\gamma > 0$ is satisfied in the anomalous dispersion domain .

References

[1] C.De. Angelis, 'Self-Trapped propagation in the nonlinear cubic-quintic Schrödinger equation: A variational approach.' J. Quantum Electron. **30** pp- 818-821. (1994).

[2] D. Anderson , 'Variational approach to nonlinear pulse propagation in optical fibers.' Phys.Rev. A **27**, pp-3135-3145, (1983)