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Soliton fiber laser &Soliton wave in optical fiber: a literature review

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Soliton is the only stable shape of the pulsesatfiber withdispersionand nonlinearfeatures.Thisfeaturecause thatpulse width is between 1- 50 psand power(mw 10 ~ 1). Inthis article, acomplete overviewof thestudies which was done about solitonfiber lasers and thesolitonwavepropagationinan optical fiber was discussed.

1-Soliton FiberLaser.

In 2010 H. ZhangetalReview stable dark solitons[1] in an all normal dispersion fiber laser. They found experimentally that dark soliton formation is a generic feature of the fiber laser under strong continuous wave (CW) emission. However, only under appropriate pump strength and negative cavity feedback,stable single or multiple dark soliton could be achieved. Furthermore, they show that the features of the observed dark solitons could be well understood based on the nonlinear Schrödinger equation (NLSE). They proved experimentally that operating the laser in the negative cavity feedback regime, dark solitons could be automatically formed in the cavity, and under appropriate pump strength and negative cavity feedback, stable single or multiple dark soliton emission could also be obtained. Moreover, they found that the observed dark soliton features could be well understood based on the NLS.

Inthe sameyear,L.M. Zhao etal**,**reported on the experimental observation of dip-type spectral sidebands on the soliton spectra of a passively mode locked fiber laser[2]. We point out that the formation of the dip sidebands is due to a four-wave-mixing type of parametric process between the soliton and dispersive waves induced by the periodic soliton parameter variation in the laser cavity. Numerical simulations have well reproduced the experimental results

Also in 2012 SergeyK.Turitsyn etal[3],discussedinthe Nonlinear systems with periodic variations of nonlinearity and/or dispersion occur in a variety of physical problems and engineering applications. The mathematical concept of dispersion managed solitons already has made an impact on the development of fibre communications, optical signal processing and laser science. We overview here the field of the dispersion managed solitons starting from mathematical theories of Hamiltonian and dissipative systems and then discuss recent advances in practical implementation of this concept in fibre-optics and lasers.

In 2013JunsongPeng[4], etal inan article entitled High-energy all-fiber soliton laser employing a chirped fiber Bragg gratingStated that .They presented an all-fiber self-starting high-energy soliton laser based on a chirped fiber Bragg grating (CFBG). The oscillator is mode-locked by nonlinear polarization rotation (NPR). As the net dispersion is greatly increased by the CFBG, the pulse energy can be increased correspondingly. The single pulse energy is 4.8 nJ, and the pulse duration is 4.4 ps with a repetition rate of 16.6 MHz.

2-Soliton wave in optical fibers

Opticalsolitonsinfibersare goodexamplesofhowdeepanabsolutemathematical conceptintransferinformation technology. One of the most characteristic feature of the mentioned waves is the stability of them. The stability ofsolitons makethe longdistance transmission possiblewithout usingiterate waves . Today, oneof the most importantproblems inTelecommunication systems is achievement to opticalcompressionpulses. Oneof the main problemsinoptical systems is deformation and overspreadpulseduring thethepropagation path,Solitonpulseshave the capacityfor balance thedynamicbetweennonlinearityanddispersioneffectsin fiber and in this way they can pass lowdissipation and relatively longpathswithoutdeformation.

In 2008 Padma K. Shukla and MattiasMarklund[5]inan article entitled Statistical description of short pulses in long optical fibers:Effects of nonlocality, Stated that they present a statistical description of the propagation of short pulses in long optical fibers, taking into account the Kerr and nonlocal nonlinearities on an equal footing. They use the Wigner approach on the modified nonlinear Schr¨odinger equation to obtain a wave kinetic equation and a nonlinear dispersion relation. The latter exhibit that the optical pulse decoherencereducesthe growth rate of the modulational instability, and thereby contribute to the nonlinear stability of the pulses in long optical fibers. It is also found that the interaction between spectral broadening and nonlocality tends to extend the instability region.To summarize, they have presented an investigation of the modulational instability of incoherent optical pulses in a nonlinear optical medium that contains the Kerr and higher order nonlocal nonlinearities on an equal footing. By using the Wigner transform, they have derived a wave kinetic equation for incoherent pulses from the generalized nonlinear Schr¨odinger equation. The wave kinetic equation is further exploited to obtain a nonlinear dispersion relation, which exhibits new features of the modulational instability. They found that the decoherence of the optical pulses reduce the modulational instability growth rate due to a spatial damping caused by the broad optical pulse spectrum. However, the combined effect of a r-andom phase and a non-local nonlinearity is to extend the instability region as compared to the case of a monochromatic spectrum. Thus, the results thus contributes to the nonlinear stability of incoherent optical pulses in long optical fibers.

In 2009 LEI Da-Jun DONG Hui, et al [6]Studied the Generation of Efficient Dispersive Waves in Photonic Crystal Fibers.The studystates that Based on the generalized nonlinear Schr¨odinger equation, they investigate efficient dispersive wave (DW) generation in a photonic crystal fiber (PCF) by numerical simulation and discuss a way to control DW generation by using an initial input pulse chirp. It was shown that efficient red-shifted DW generation can be obtained in a PCF with negative dispersion slopes. The energy contained in the DWs was considerably decreased for both positively and negatively chirped pulses at the fiber output. This provides us with an opportunity to conveniently and efficiently manipulate the DW generation by controlling the pre-chirp of the soliton. Moreover, they also show that forthand.higher-order dispersion terms play little part in deciding the evolution of DWs.

In conclusion, they have numerically investigated the propagation of fundamental solitons in PCFs with a negative dispersion slope based on the GNSE. Simulation results show that the e_ciency of energy conversion from the soliton to the DW is very high. The initial chirp provides us with the opportunity to conveniently and e_ciently control the energy transfer process. The e_cient transfer of laser energy to new wavelengths therefore has high potential in many applications.

The survey of Dark solitons in optical fiber [7]with inhomogeneous effects in 2010 bye M. IdrishMiah was done.Thisreviewsummarizesthe workandresultsthatwill follow.

They study the nonlinear wave propagation in an inhomogeneous optical fiber core in the normal dispersive regime. In order to include the inhomogeneous physical effects, the nonlinear Schr ¨ odinger equation (NLSE), which governs the solitary pulse propagation in optical fiber, is modified by adding terms for phase modulation and power gain or loss. The modified NLSEs are bilinearized and exact dark soliton solutions are obtained.

Conclusions they have considered the more general case of inhomogeneities in fiber core medium .Theyhad modified the NLSE in order to include phase modulation and fiber gain and loss or damping effects.The modified NLSE governs the nonlinear pulse propagation in an inhomogeneous fibers sytem with fiber gain(loss) where the effects due to fiber gain(loss) and chirping of the pulse exactly balance each other.The complete integrability conditions have been derived for both gain and loss case sand the modified NLSEs in the anomalousdispersive regime have been exactly solved to construct dark soliton solutions . They found that the depth of the soliton is increased (decreased) for gain (loss)a sit propagates along the fiber.The pulse width was also found to be compressed (broadened)in propagation with fiber gain(loss) such that the area of the pulse envelope remains conserved,as found for bright solitons in the anomalous dispersive regime.

In the sameyear,Bright and dark solitonsstudied in the normal dispersion regime of inhomogeneous optical fibers: Soliton interaction and soliton control by Wen-Jun Liu et al[8].

Symbolically investigated in the paper was a nonlinear Schrödinger equation with the varying dispersion and nonlinearity for the propagation of optical pulses in the normal dispersion regime of inhomogeneous optical fibers. With the aid of the Hirota method, analytic one- and two-soliton solutions were obtained. Relevant properties of physical and optical interest were illustrated. Different from the previous results, both the bright and dark solitonswere hereby derived in the normal dispersion regime of the inhomogeneous optical fibers. Moreover, different dispersion profiles of the dispersion-decreasing fibers can be used to realize the soliton control. Finally, soliton interaction was discussed with the soliton control confirmed to have no influence on the interaction. The results might be of certain value for the study of the signal generator and soliton control.The dark soliton can be controlled by the DDF. Bright–dark and bright–bright solitons have been observed in the normal dispersion regime of the optical fibers, which might be of certain value to the studies on the signal generator. To test and verify the result,they had shown that the bright and dark solitons in the multi-soliton communication systems can also be controlled, and that the soliton control method have no influence on the mutual interaction. Their results indicate that a new soliton control technique might be developed

And also Qing-Chun Zhou, Xiao-XiangZeng[9] they investigate about Approximation theory for unequal amplitude soliton pairs in nonliear optical fibers.Inthis article The equivalent-particle approach was used to investigate the interaction of two unequal-amplitude solitons propagating in nonlinear fibers by regarding the interaction as a perturbation. The Newtonian equations for the motion of solitons are given. Results showed that the interaction of an unequal- amplitude soliton pair can be approximated as the product of a local interaction factor dependent on the propagation distance and a nonlocal interaction factor independent of the propagation distance. The local factor forces soliton interaction to alternate between the attractive and the repulsive, and, on a large scale, the average of this character markedly reduces the interaction of the unequal-amplitude solitons and the result of this study showed they had studied the inter action of two solitons propagating in a nonlinear optical fiber. The Newton equation for the first order of perturbation for the soliton is derived by regarding the soliton as an effective particle and using the perturbation method They compared the interaction of two equal amplitude solitons and that of two unequal amplitude solitons ,and found that the inter action contributions are composed of a local factor related to propagation distance and a global factor connected with soliton separation Compared with the equal amplitude case,two amplitude difference of a soliton pair can reduce or increase the nonlocal inter action factor,depending on the separation of the solitons.The well-known overall reduction effect of soliton interaction between two unequal amplitude results from the average of local phase related factor.

Among thearticles thatwere publishedin 2011inthecontext of Study of the gain saturation effect on the propagation of dark soliton in Er^{+3}-doped, $Ga_5Ge_{20}Sb_{10}S_{65}$chalcogenide fiber amplifier can benoted by Z. Tahma. M. Hatami[10] . In this article They study the effect of gain saturation on the propagation of fundamental dark soliton in a nonlinear, dispersive and amplifying medium. The Er^{+3}-doped, $Ga_5Ge_{20}Sb_{10}S_{65}$chalcogenide glass was used for dark and erbium doped silicon glass for bright solitons. The numerical simulations show that dark soliton doesn't split to subpulses unlike bright soliton and also the dark soliton is more stable in the presence of gain saturation and gain dispersion effects. So the chalcogenide glasses were suitable for designing all optical devices.

Amarendra K. Sarma[11]alsostudiedVector soliton switching in a fiber nonlinear directional couplerthis studied reports a detailed numerical study of soliton switching in a high as well as low birefringent nonlinear coupler. It wasshown that by controlling the polarization angle one can have nearly 100% transmission with excellent switching characteristics. It was shown that soliton remains stable during its propagation inside the coupler. However it was observed that high birefringent coupler exhibits relatively better soliton stability. They show that the coupler could be used as a soliton switch even at an input peak power less than the critical power, the power at which 50–50 power sharing takes place between the two cores, just by a judicious choice of the polarization angle.In 2012 Dowluru Ravi Kumar&B. PrabhakaraRao[12]Theresearch azSoliton interaction in birefringent optical fibers: Effects of nonlinear gain devicesstated thatthe presents the influences of polarization mode dispersion (PMD) on the performance of soliton transmission system in birefringent fibers. Dispersive waves generated in single mode fibers due to PMD degrade the soliton transmission system in two aspects. First, solitons continuously lose their energy, thus cause enhancement in pulse width. Second, the dispersive waves interact with neighboring pulses and cause distortion in a sequence of pulses. Both these effects reduce the effective bit-rate and degrade the performance of high-speed optical transmission systems. Optical fibers with large group velocity dispersion (GVD) have less dispersive waves and are relatively robust to pulse broadening, but it enhances the interaction between the adjacent pulses. They analyzed these effects of PMD on soliton propagation in birefringent fibers and introduced nonlinear gain devices with perturbation terms proportional to second and fourth power of amplitudes to reduce these effects. They proposed Symmetric Split-Step Fourier Method to solve the coupled nonlinear Schrödinger equations (CNLSE); which yields better results over the existing Split-Step Fourier Method.

Discussion

Optical solitonissetting the standardforadvancedtransmissions. Today, oneof the most importantproblems inTelecommunication systems, is to achieve optical pulsecompressionOneof the main problemsinoptical systems are deformation and wideningpulsealongthepropagation path,twoadjacentpulsesinapulsetrainmayinterferewith each other.Solitonpulsesare capable of, creatingadynamicbalancebetweennonlinearityanddispersioneffectsin fiber,and lowdissipationpathsare relatively longdistances withoutdeformation.Solitonpulsesinopticalpulsethat hasaspecificenvelopewhich obtained from nonlinearSchrödingerequations. Whereas,some factors such as loss fiber, nonlineareffects and so on can cause deformation femtosecondsolitonpulses.

More research work is needed to omit some adverse effects such as loss fiber, nonlineareffects and pulse width to promote transformation ofdata.

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