A RESEARCH STUDY ON 3-D SOLITON AND PHOTONIC CRYSTAL FIBRE

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ABSTRACT

We theoretically study broadband super continuum generation in photonic crystal fibers exhibiting two zero dispersion wavelengths and under continuous-wave pumping. We show that when the pump wavelength is located in between the zero-dispersion wavelengths, a wide and uniform spectral broadening is achieved through modulation instability, generation of both blue-shifted and red-shifted dispersive waves and subsequently through soliton self-frequency shift. This super continuum is therefore bounded by these two dispersive waves which allow the control of its bandwidth by a suitable tuning of the fiber dispersion. As a relevant example, we predict that broadband (1050–1600 nm) continuous-wave light can be generated in short lengths of micro structured fibers pumped by use of a 10-W Ytterbium fiber laser. Photonic crystal fibers with three and four zero-dispersion wavelengths are presented through special design of the structural parameters, in which the closing to zero and ultra-flattened dispersion can be obtained. The unique phase-matching properties of the fibers with three and four zero-dispersion wavelengths are analyzed. Variation of the phase-matching wavelengths with the pump wavelengths, pump powers, dispersion properties, and fiber structural parameters is analyzed. The presence of three and four zero-dispersion wavelengths can realize wavelength conversion of optical soliton between two anomalous dispersion regions, generate six phase-matching sidebands through four-wave mixing and create more new photon pairs, which can be used for the study of super continuum generation, optical switches and quantum optics.

The effect of initial frequency chirp is investigated numerically to obtain efficient super continuum radiation in photonic crystal fibers (PCFs) with two closely spaced zero-dispersion wavelengths. The positive chirps, instead of zero or negative chirps are recommended because self phase modulation and four-wave mixing can be facilitated by employing positive chirps. In contrast with the complicated and irregular spectrum generated by negative-chirped pulse, the spectrums generated by positive-chirped pulses are wider and much more regular. Moreover, the saturated length of the PCF, corresponding to the maximal spectrum width, can be shortened greatly and the efficiency of frequency conversion is also improved because of initial positive chirps. Nearly all the energy between the zero-dispersion wavelengths can be transferred to the normal dispersion region from the region withinthe two zero-dispersion wavelengths provided that the initial positive chirp is large enough.

Keyword: - *PCF, Fiber, Positive, Large, Crystal etc.*

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1. INTRODUCTION

We investigate the super continuum (SC) generation in an 1 cm long silica photonic crystal fiber (PCF) pumped by the pulse sources with single, dual, and triple wavelengths, respectively. The silica PCF has two zero-dispersion wavelengths at 900 and 2620 nm, respectively. When pumped by a single wavelength, the SC spectral range covers about 1000 nm. When pumped by dual and triple wavelengths, the SC spectral range covers wider than 2000 nm. Both the SC spectral range and the flatness are improved obviously when pumped by triple wavelengths. The maximum SC spectral range is obtained when the silica PCF is pumped by the triple wavelengths at 800, 1450, and 1785 nm. The SC spectral range covers 2810 nm from 350 to 3160 nm wider than three octaves. The 10 dB bandwidth covers 2280 nm from 450 to 2730 nm wider than two octaves. This is the first investigation on comparison of the SCs generated by different pump wavelengths up to three experimentally. The generated SC spectra have covered the full transmission window of silica fiber.

We demonstrate the super continuum (SC) generation in a suspended-core As2S3 chalcogenide micro structured optical fiber (MOF). The variation of SC is investigated by changing the fiber length, pump peak power and pump wavelength. In the case of long fibers (20 and 40 cm), the SC ranges are discontinuous and stop at the wavelengths shorter than 3500 nm, due to the absorption of fiber. In the case of short fibers (1.3 and 2.4 cm), the SC ranges are continuous and can extend to the wavelengths longer than 4 μm. The SC broadening is observed when the pump peak power increases from 0.24 to 1.32 kW at 2500 nm. The SC range increases with the pump wavelength changing from 2200 to 2600 nm, corresponding to the dispersion of As2S3 MOF from the normal to anomalous region. The SC generation is simulated by the generalized nonlinear Schrödinger equation. The simulation includes the SC difference between 1.3 and 2.4 cm long fiber by 2500 nm pumping, the variation of SC with pump peak power in 2.4 cm long fiber, and the variation of SC with pump wavelength in 1.3 cm long fiber. The simulation agrees well with the experiment.

In this paper is described 3D simulation for solutions used in optical fibers. In the scientific works is started from nonlinear propagation equation and the solutions represents its solutions. This paper presents the simulation of the fundamental soliton in 3D together with simulation of the second order soliton in 3D. These simulations help in the study of the optical fibers for long distances and in the interactions between the solutions. This study helps the understanding of the nonlinear propagation equation and for nonlinear waves. These 3D simulations are obtained using MATLAB programming language, and we can observe fundamental difference between the soliton and the second order/higher order soliton and in their evolution. (2016) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

We present the results of asymptotic and numerical analysis of dissipative Kerr solutions in whispering gallery mode micro resonators influenced by higher-order dispersive terms leading to the appearance of a dispersive wave (Cherenkov radiation). Combining direct perturbation method with the method of moments we find expressions for the frequency, strength, spectral width of the dispersive wave, and soliton velocity. Mutual influence of the soliton and dispersive wave was studied. The formation of the dispersive wave leads to a shift of the soliton spectrum maximum from the pump frequency (spectral recoil), while the soliton displaces the dispersive wave spectral peak from the zero dispersion point.

We provide an overview of recent experimental and theoretical developments in the area of optical discrete solutions. By nature, discrete solutions represent self-trapped wave packets in nonlinear periodic structures and result from the interplay between lattice diffraction (or dispersion) and material nonlinearity. In optics, this class of self-localized states has been successfully observed in both one- and two-dimensional nonlinear waveguide arrays. In recent years such photonic lattices have been implemented or induced in a variety of material systems, including those with cubic (Kerr), quadratic, photorefractive, and liquid-crystal nonlinearities. In all cases the underlying periodicity or discreteness leads to altogether new families of optical solutions that have no counterpart whatsoever in continuous systems. We first review the linear properties of photonic lattices that are key in the understanding of discrete solutions. The physics and dynamics of the fundamental discrete and gap solutions are then analyzed along with those of many other exotic classes — e.g. twisted, vector and multi-band, cavity, spatial-temporal, random-phase, vortex, and non-local lattice solutions, just to mention a few. The possibility of all-optically routing optical discrete solutions in 2D and 3D periodic environments using soliton collisions is also presented. Finally, soliton formation in optical quasi-crystals and at the boundaries of waveguide array structures is discussed.

2. THREE-DIMENSIONAL PHOTONIC CRYSTALS

There are several structure types that have been constructed:

- Spheres in a diamond lattice
- Yablonovite
- The woodpile structure – "rods" are repeatedly etched with beam lithography, filled in, and covered with a layer of new material. As the process repeats, the channels etched in each layer are perpendicular to the layer below and parallel to and out of phase with the channels two layers below. The process repeats until the structure is of the desired height. The fill-in material is then dissolved using an agent that dissolves the fill-in material but not the deposition material. It is generally hard to introduce defects into this structure.
- Inverse opals or Inverse Colloidal Crystals-Spheres (such as polystyrene or silicon dioxide) can be allowed to deposit into a cubic close packed lattice suspended in a solvent. Then a hardener is introduced that makes a transparent solid out of the volume occupied by the solvent. The spheres are then dissolved with an acid such as Hydrochloric acid. The colloids can be either spherical or no spherical.

- A stack of two-dimensional crystals – This is a more general class of photonic crystals than Yablonovite, but the original implementation of Yablonovite was created using this method.
- "The photonic crystal beam splitter that we made is a fundamental optical component used to control polarized light," explains Dr Mark Turner from Swinburne University. "Specifically what makes our device unique is its ability to directly work with circular polarization at a microscopic scale."
- Circular polarization uses 3D laser nanotechnology to exploit circular polarization to build a microscopic prism that contains in excess of 750,000 polymer nimrods. Light focused on this beam splitter penetrates or is reflected, depending on polarization.

3. FABRICATION CHALLENGES

Higher-dimensional photonic crystal fabrication faces two major challenges:

- Making them with enough precision to prevent scattering losses blurring the crystal properties
- Designing processes that can robustly mass-produce the crystals

One promising fabrication method for two-dimensionally periodic photonic crystals is a photonic-crystal fiber, such as a holey fiber. Using fiber draw techniques developed for communications fiber it meets these two requirements, and photonic crystal fibers are commercially available. Another promising method for developing two-dimensional photonic crystals is the so-called photonic crystal slab. These structures consist of a slab of material—such as silicon—that can be patterned using techniques from the semiconductor industry. Such chips offer the potential to combine photonic processing with electronic processing on a single chip.

For three dimensional photonic crystals, various techniques have been used—including photolithography and etching techniques similar to those used for integrated circuits. Some of these techniques are already commercially available. To avoid the complex machinery of nanotechnological methods, some alternate approaches involve growing photonic crystals from colloidal crystals as self-assembled structures.

Mass-scale 3D photonic crystal films and fibers can now be produced using a shear-assembly technique that stacks 200–300 nm colloidal polymer spheres into perfect films of FCC lattice. Because the particles have a softer transparent rubber coating, the films can be stretched and molded, tuning the photonic band gaps and producing striking structural color effects.

4. TECHOPEDIA EXPLAINS PHOTONIC CRYSTAL FIBER (PCF)

Fiber-optic cables are constructed with a core and a cladding of constant refractive index difference. Light travels through the core as a result of the refraction property of light, which occurs as a result of the difference between the refractive indexes of the core and cladding. This refracted light bears much higher loss during propagation over extended distances, and thus requires repeaters and amplifiers for extended distance communications.

In PCF, on the other hand, light is trapped in the core, providing a much better wave guide to photons than standard fiber optics. The polymers used instead of glass in PCF provide the advantage of a more flexible fiber, which allows for easier and less expensive installation. Various photonic crystals conforming to various photonic lattices are manufactured depending on the required properties of the propagated light.

Photonic crystal fibers are generally divided into two main categories:

- Index-Guiding Fibers: Have a solid core like conventional fibers. Light is confined in this core by exploiting the modified total internal reflection mechanism.
- Photonic Band gap (Air Guiding) Fibers: Have periodic micro structured elements and a core of low-index material (hollow core). The core region has a lower refractive index than the surrounding photonic crystal cladding. The light is guided by a mechanism that differs from total internal reflection in that it exploits the presence of the photonic band gap (PBG).

They can be made using a stack-and-draw fabrication process (see Figure 1), which is based on stacking glass capillaries and rods into a perform, allowing precise control of the core and cladding-index properties. Rare-earth and stress-element components are introduced simultaneously. Once the desired perform has been constructed, it is drawn into a fiber.

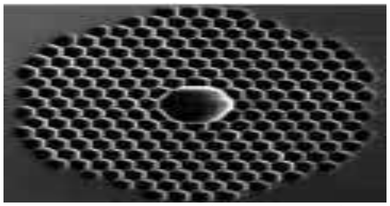

Fig-1: Stack-and-draw photonic-crystal-fiber (PCF) fabrication process.

4. DIFFERENT ANALYTICAL METHODS

Measuring fiber is highly complex. The fiber percentages provided in the our Purina Test Diet® specification sheets are all based on calculated values for crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Other common fiber determination methods include nonstarter polysaccharide (NSP) and total dietary fiber (TDF)

“Max Fiber” (Crude Fiber) is an average of crude fiber from all the ingredients in the formula. Briefly, the sample is first boiled in dilute acid and then in dilutes alkali. The acid hydrolysis removes free sugars and starch. The alkaline hydrolysis removes protein and some carbohydrates. This process also removes some hemi-cellulose and lignin nor will it measure soluble fiber; therefore, only partial recovery of fiber components is achieved. Crude fiber is only 1/7 to 1/2 of total dietary fiber.

Acid Detergent Fiber (ADF) refers to the insoluble fiber within a plant cell wall and is comprised of cellulose and lignin; whereas, **Neutral Detergent Fiber (NDF)** is a value comprised of ADF plus insoluble hemicelluloses. The ADF value can be subtracted from the NDF value to reach a figure close to CF; but, it will never be exact.

Total Dietary Fiber (TDF) allows for separate measurement of total fiber, insoluble fiber, and soluble fiber. This method still is unable to measure many oligosaccharides.

Nonstarter polysaccharide (NSP) methodology is most similar to the TDF method, but is unable to measure lignin.

Fiber in Purified Diets

Traditionally most, of not all, of the fiber in a purified diet has been supplied by cellulose, an insoluble fiber. At Purina Test Diet® we recognize the growing attention to the **function of fiber** in digestion and general lab animal health. Consequently, our new Purina Test Diet® DIO (diet-induced obesity) series provides equal parts of the **insoluble fiber** traditionally used in purified diets (cellulose) and **soluble fiber** (insulin), to more closely resemble a natural ingredient diet. Insulin is an oligosaccharide made from beets and artichoke and provides no measurable energy (kcal). At your request, we can modify any formula to substitute insulin, or another fiber source.

A new method to improve semiconductor fiber optics may lead to a material structure that might one day revolutionize the global transmission of data, according to an interdisciplinary team of researchers.

5. RESULT & FINDING

Physicists have discovered that dozens of 3-D knotted structures called "topological solitons," which have remained experimentally elusive for hundreds of years, can be created and frozen for long periods of time in liquid crystals like those used in electronic displays. Until now, topological solitons have been realized only in a few experiments, and for such a short time that it has been impossible to study them in any detail.

The new results may change all that, as they provide a way to produce a wide diversity of long-lasting topological solitons that can be studied with microscopes and, perhaps one day, play a role in novel optical and electrical applications.

The researchers, Paul J. Ackerman and Ivan I. Smalyukh at the University of Colorado, Boulder, have published a paper on the experimental realization of topological solitons in a recent issue of Physical Review X.

"Our work establishes experimental and numerical approaches for detailed studies of 3-D topological solitons, with the great advantage of enabling a direct comparison between experimental and theoretical results and with a potential impact on many branches of physics and the mathematical field of topology," Smalyukh told Phys.org. "Our work not only experimentally demonstrates 3-D topological solitons that mathematicians and theoretical physicists envisaged previously, but also reveals a series of solitonic structures that have not been anticipated." They are Statistical hypothesis testing, Variations and sub-classes, The testing process, Interpretation, Use and importance, Cautions, Radioactive suitcase, Statistical significance test, Conservative test, Exact test, Most powerful test, Common test statistics, Origins and early controversy, Criticism and 3D BEC Bright Solitons under Transverse Confinement: Analytical Results with the No polynomial Schrodinger Equation

6. CONCLUSIONS

In conclusions, based on collective variable approach, we have presented the cartography of stationary dissipative solitons modeled by the 3D complex cubic-quintic Ginzburg-Landau equation. We showed that the stationary soliton in this model can be regarded with asymmetric deformations of the pulse in the (x, y) plane. In particular, for a suitable choice of the ansatz function and the parameters, we have highlighted the evolution of physical parameters (amplitude, width…) of the soliton and analyzed their dynamics. Thus we investigated the influence of the dispersion parameter on the spatial and temporal profile of the 3D soliton.

We showed that the dynamics of soliton can be controlled by the choice of the system parameters. So according to the values of the nonlinear gain, the soliton energy becomes large leading in more complex dynamics. It appears quite clear that the collective variables approach is very efficient for approximating stable stationary solutions when a suitable trial function is chosen. And this technique is incomparably quicker than direct numerical computations.

Thus this present result can be deepened by implementing other dynamics (pulsating), or confirmed by purely numerical studies. Studies on this type of solitons are useful both from the fundamental point of view and for the development of corposants dedicated to the treatment with purely optical path of the guide optical pulses ultra high speed telecommunications.

One of the reasons why topological solitons are so difficult to experimentally realize is that they correspond to a physical system's lowest energy state in order to be stable. For this reason, they have been demonstrated only as transient structures in liquid crystals. It's also possible that topological solitons may exist in another medium, chiral ferromagnetism, but a lack of experimental imaging techniques prevents researchers from observing them

Freezing knots, Potential applications, Education.

7. REFERENCES

[1]. Y. W. Li, C. D. Hussey, and T. A. Birks, "Triple-clad single-mode fibers for dispersion shifting", J. Light wave Technol., 11 (11), 1812-1819 (1993).

[2]. M. Onishi, T. Okuno, T. Kashiwada, S. Ishikawa, N. Akasaka, and M.Nishimura, "Highly nonlinear dispersion-shifted fibers and their application to broadband wavelength converter", Optical Fiber Technology: Materials, Devices and Systems, 4 (2), 204-214 (1998).

[3]. Jonas Hansryd and Peter A. Andrekson, "Broad-band continuous-wave-pumped fiber optical parametric amplifier with 49-dB gain and wavelength-conversion efficiency", Photon. Technol. Lett., 13 (3), 194-196 (2001).

[4]. Jonas Hansryd, Peter A. Andrekson, P-O Hedekvist, Jie Li, and Mathias Westlund, "Optical parametric amplifiers and their applications" OFC, 123-125 (2002).

[5]. Jiro Hiroshi, Naomi Kumano, Kazunori Mukasa, Ryuichi Sugizaki, Ryo Miyabe, Shun-ichi Matsushita, Hideaki Tobioka, Shu Namiki, and Takeshi Yagi, "Dispersion slope controlled HNL-DSF with high gamma of 25 W$^{-1$km$^{-1$ and band conversion experiments using this fiber" ECOC 2002, (2002).

[6]. T.P.M. Man, T.A. Birks, W.J. Wadsworth, and P.St.J. Russel, "Fabrication of indefinitely long tapered fibres for supercontinuum generation", 438-440 (2001).

[7]. K. Tajima, "Compensation of soliton broadening in nonlinear optical fibers with loss", Opt. Lett., 12 (1), 54-56 (1987).

[8]. J.C. Knight, T.A. Birks, P.St.J. Russel, and D.M. Atkin, "All-silica single-mode optical fiber with photonic crystal claddding", Opt. Lett., 21 (19), 1547-1549 (1996).

[9]. Albert Ferrando, Enrique Silvestre, and Pedro Andres, "Designing the properties of dispersion-flattened photonic crystal fibers", Opt. Express, 9 (13), 687-697 (2001).

[10]. D. Mogilevtsev, T.A. Birks, and P.St.J. Russel, "Group-velocity dispersion in photonic crystal fibers", Opt. Lett., 23 (21), 1662-1664 (1998).

[11]. Kim P. Hansen, Jacob Riis Jensen, Christian Jacobsen, Harald R. Simonsen, Jes Broeng, Peter M.W. Skovgaard, Anders Petersson, and Anders Bjarklev, "Highly Nonlinear Photonic Crystal Fiber with Zero-Dispersion at 1.55 μm" Conference on Optical Fiber Communication--Post Deadline, (2002).

[12]. Kim P. Hansen, Jacob R. Folkenberg, Anders Petersson, and Anders Bjarklev, "Properties of Nonlinear Photonic Crystal Fibers for Telecommunication Applications", Conference on Optical Fiber Communication, 694-695 (2003).

[13]. Peter Andreas Andersen, Henrik Norgaard Paulsen, and Jakob Juul Larsen, "A photonic crystal fiber with zero dispersion at 1064 nm", ECOC, (2002).

[14]. B.T. Kuhlmey, "Modal cutoff in microstructured optical fibers" Opt. Lett., 27 (19), 1684-1686 (2002).

[15]. Jesper Lægsgaard and Anders Bjarklev, "Doped photonic band gap fibers for short-wavelength nonlinear devices", Opt. Lett., 28 (10), 783-785 (2002).

[16]. Jesper Lægsgaard, Niels Asger Mortensen, and Anders Bjarklev, "Mode areas and field-energy distribution in honeycomb photonic band gap fibers", J. Opt. Soc. Am. B, 20 (10), 2037-2045 (2003).

[17]. A. Boskovic, S.V. Chernikov, J.R. Taylor, Lars Gruner-Nielsen, and O.A. Levring, "Direct continuous-wave measurement of n^2 in various types of telecommunication fibers at 1.55 μm", Opt. Lett., 21 (24), 1966-1968 (1996).

[18]. Robert C. Eckardt and Robert L. Byer, "Measurement of nonlinear optical coefficient by phase-matched harmonic generation", SPIE, 1561, 119-127 (1991).