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# International Journal of Future Generation Communication and Networking

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# International Journal of Future Generation Communication and Networking

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# International Journal of Future Generation Communication and Networking

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(Volume No. 16, Issue No. 1, January - April 2023)

## Contents

# Indian Banking: Digital Transformation of Automated Teller Machine Channel Over A Decade

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## ABSTRACT

*Banking and financial services have undergone massive transformation in digitization and digital payments over a decade. Indian banking is transforming from traditional banking to digital over the last ten years and this vital change makes the overall banking industry to get elevated to the next level in the global economy. The objective of this research paper is to study how digitization evolved in ATM cards and ATM Machines of Indian banking over a period of time. This study is based on secondary data which are mainly extracted from various data sources like research papers, articles published by corporates and Government of India, authentic websites of RBI, NPCI and bulletins published by them. From this research paper, knowledge gained about how digitization emerged in banks by introducing ATM cards and machines, transformation of technology into this platform over a decade. Scope for customer acquisition & accessibility through digitization, future milestone & trend to be set in this channel based on advancement in technology.*

***Keywords: ATM Cards, ATM Machines, Digitization, Transformation, Technology innovation.***

## INTRODUCTION:

Present banking demand and choice are for robust highly secured technology anywhere and anywhere, which meet the needs of tech-savvy customers. By knowing the habits, the customer's banks' tastes, requirements and aspirations have changed from product-centric to customer-centric. Digital transactions seem to be the new generation customer's most favoured option and Indian banks' ambition to introduce a world-class e-banking outreach is strong. Indian banking has undergone numerous innovations, and the way customers communicate with banks is most affected by technology among those innovations.

In addition to conventional branch networks, they provide electronic banking platforms and products such as ATMs, wallets, online banking and mobile banking. Evidences indicate a change from the conventional system to the online networks. This also offers a platform for digital innovation to leverage on a broad unbanked region, and ensures financial inclusion. Banks in India have begun competing with each other by upgrading their products digitally creative and user friendly by exploiting cost-effectively the use of the new technology. Banks have taken numerous measures over a decade to develop technology in this sense.

## OBJECTIVE OF THE STUDY:

The primary objective of the study is to find out how banks have introduced alternate banking channels that replaces physical human intervention like ATM cards, ATM machines, their development through

digital innovation and transformation over a decade, various level of milestones achieved by banks in India to facilitate user friendly ATM access and enhanced future development in this segment.

## RESEARCH METHODOLOGY

This research paper is framed primarily based on exploratory method. Secondary data collection from various sources have been adopted for the study. Data have been mainly extracted from various data sources like research papers, articles published by Government of India and corporates, authentic websites of RBI, NPCI and bulletins published by them.

## LITERATURE REVIEW

Aggarwal, Vani, Nidhi Ahuja, and Varsha Yadav [1] In their research paper they have mentioned that Digitization is not treated as an option in the Indian banking sector, rather it is unavoidable. Post demonetisation, Government has taken numerous digital initiatives to make India digitally engaged. It is the way to turn knowledge into advanced software, which has a significant hike in the operational cost of the banks. In India, banking has come up with technological advancements offered to their customers with high quality services at a competitive edge by making huge investments in various digital initiatives. Digital payments are the key to success for all banks in the digital economy

.

Cuesta, Carmen, et al. [2] have identified three phases, the first involves the introduction of new platforms and goods, while the second involves the transformation of technology infrastructure and the third includes significant organizational adjustments for strategic positioning in the digital world. Many organizations that have embarked on this transition earlier, and are now at a more advanced level, are better placed to satisfy emerging consumer expectations and be competitive relative to the latest digital financial service providers.

Dara, Sonia [3] in the paper discussed about Current cash payments are replaced with Digitization by "Instant Wallets." Many other facets of banks change or develop into something different. So the major question that needs to be addressed here is that "to what degree will banks be able to take advantage of the substantial opportunities emerging from digitization?" The effective use of digitization is of great importance in India.

Fathima, J. Shifa [4] discussed that, Banking and financial services have been very formal in nature, and given the current circumstances. Trends are, in any case, fast changing in the digital age. It is equally critical that the banks remain as honest as their customers remain authentic. The main goal behind the coordination of banking services with innovation is undoubtedly accommodation. Most people now consider creativity normal, to the degree that it impacts their way of life.

Goel, Manjusha [5] has discussed that, Technology has helped transform banking into paperless communication from bulk paper and waste and forms of moving funds. The technology established includes mobile banking (mobile technology), credit cards, debit cards (money transfer technology), electronic money, and automated teller machines. These technologies have created efficiencies and time-saving ways for people to do business. Importantly, technology has led to tighter protection and better business practices for everyone.

Gupta, Nishu [6] has mentioned that, by adopting business intelligence, the Indian Banking Sector is evolving and remaining in a competitive environment. Because of technology millions of people are

now accessible to financial services due to wider scope and low cost of delivery. For financial inclusion, the Indian Banking Sector is developing new banking and payment networks, digital platforms and as digital is improved there is a negative impact as well as account hacking etc. Indian banking has a paradigm change from paper to digital electronic payment system for payment.

Sharma, Priyanka [7] Digital transformation in transaction banking is capable of reducing operational costs and overheads leading to increased revenues, improved performance, stronger regulatory controls with lower risks and collaboration opportunities for emerging economy partners such as India to benefit from their tech talent to achieve desired results.

**Research Gap:**

Researchers have done a general study on transformation of digitization preferably in Indian banking but not discussed in detail about how digital products got introduced into Indian banking system and step by step process of transformation of digitization especially in ATM machines and card products over a decade. In this research paper, its clearly elaborated on how ATM and Card products transformed over a decade stage by stage according to the needs of the banking customers, considering safety and security aspects as well.

**Digital transformation of ATM Cards in Indian Banking system:**

Introduction of ATMs and card services in Indian banking created a big revolution in terms of cash transactions in banking operations and ease of customer operations. Originally when ATM cards were introduced in Indian banks it was a card made of close architecture only customers of the same bank are allowed use their own bank ATMs which was an intra bank operational architecture. Most of the banking customers were reluctant to utilize the services as they were scared and started ignoring the cards issued by the banks. Later banks decided to make ATM access as inter-operational with a limited open architecture. In this process banks enrolled themselves in National Financial switch formed by IDRBT – Institute for Development and Research in Banking Technology. Originally there were 37 member banks connecting 50000 ATMs and due to this development in ATM access all the member banks registered in NFS gave an inter-operable ATM access facility among those member bank ATMs. The ATM cards which was introduced earlier was only a platform with unique magnetic strip behind the card which can be used in Automated Teller machines and since cash transactions involved most of the customers were afraid to adapt the change in technology. Gradually the momentum of cash transactions through ATM machines increased among youngsters and aged people continued travelling to the bank branches even when the volume was less. ATM card was a unique transformation for banks as most of their cash operations moved to ATM based and high value at bank branches. It increased cost efficiency, less teller operations, reduced over heads and obvious turnaround time.


ATM CARDS CAN BE USED ONLY IN ATM MACHINE

At the next level of transformation ATM cards were issued and linked through VISA/Master international platform and banks started issuing cards to its customer co-branded by VISA or MASTER. By this ATM cards were also converted as debit cards which gave access to use the card at merchant establishments by introducing a new machine called POS (Point of Sale) machines. By this ATM cards were converted as ATM cum Debit cards so that the same card can be used in ATM machines to withdraw physical cash and as debit card at merchant point of sale through POS machines where the cash gets debited and credited directly to the merchant current account linked to the POS machine. This type of transactions involves a unique Personal Identification Number (PIN) for every user.


**DEBIT CARDS CAN BE USED IN ATM AND POS MACHINES**

Simultaneously many ATM frauds were also registered by using skimming machines and phishing methods in the ATM and many cyber-criminal cases were filed. Visa/ Master Plastic ATM cum debit cards are internationally access enabled cards originated from United States. These cards are issued to the customers with an issuance fee and also annual maintenance fee.

To avoid fee and other overhead charges Indian Government has introduced a new card called Rupay card on 26March 2012 by National Payments Corporation of India(NPCI). Rupay is the first domestic Debit and Credit Card payment network of India, with wide acceptance at ATMs, POS devices and e-commerce websites across India. It is a highly secure network that protects against anti-phishing. The name, derived from the words 'Rupee and 'Payment', emphasises that it is India's very own initiative for Debit and Credit Card payments. It is our answer to international payment networks, expressing pride over our nationality. Rupay cards comes with a lesser cost and expanded to 56 banks in the year of 2016. Rupay fulfils RBI's vision of initiating a 'less cash' economy.


To have an increased standard of security, based on R & D and various case studies banks started introducing a new form of debit card with an embedded microchip. This cards mainly controls skimming method of data hacking and also maintains customer data secrecy with high security standards.

**Micro Chip based Card:**

It is a standard-size plastic debit card which contains an embedded microchip as well as a traditional magnetic stripe. The chip encrypts information to increase data security when making transactions at stores, terminals, or automated teller machines.


Further transformation of digitization banks started services like debit card based online transaction using card number and the CVV. It is the acronym for Card Verification Value. It is required to complete transactions using cards, but along with that, it also provides added security against scams. Many type of cards were introduced later based on digital transformation they are Prepaid Cards, Gift Cards, Forex Cards, Credit Cards and so on.

Latest development in the card category is Contact less card where the transaction can be utilized without swiping the card in the POS machines at the merchant establishment and only a touch of card can perform a debit transaction based on wireless platform enabled.



Also banks in India started developing many pre-paid and post-paid cards and issue to the customers of the banks.

Prepaid cards are Food plus cards, Gift Cards and forex cards issued to customers and these cards comes with a validity and are re-loadable. Food plus cards are loaded and issued to customers after ensuring proper kyc and compliance as per banks policy. This food plus card can be used in the prescribed pre-listed hotel, bars and restaurants, cash withdrawal is not allowed in this card. Gift cards are another mode of making gifts to the kin and kith by avoiding cash payments. These gift cards also come with a validity and the same can be loaded and used in any merchant establishments only. Again cash withdrawal is not allowed in this card.


Forex cards are utilized for overseas travellers who travel abroad for tour, education and work. This card also has a validity and loaded in multicurrency optional access. Customers can load this card with the prescribed currency for which the customer tend to travel for a purpose and utilize cash withdrawal and direct debits in the particular country of travel.

Post Paid Cards are predominantly called as credit cards issued by banks to its eligible customers. A pre-approved limit will be set by banks to its eligible customer and issue this card with a validity. Customers are allowed to utilize the pre-approved credit limit set by the banks and repay within a time frame without interest and after the due date with interest. Digitization in ATM cards gradually transformed from an ordinary card to a pre-paid/post-paid card services over a decade of years and still competitive digital products are getting enabled time and again.

Next venture of digitization is QR card or Quick response card, this card carries a unique water mark for each customer and the card comes with an option called scan and pay. Merchants will be enabled with a scanner in their hand held device connected with a biometric device and customers QR card can be scanned and make payment based on OTP or biometric authentication.

This QR card based transactions are highly secured whereas the transaction gets executed with either a biometric authentication or OTP based authentication. It cannot be hacked or mis used by any other source. More than that this type of cards and transaction platform are provided to its customers almost at a zero cost and the maintenance cost of this QR based transactions for banks are also very minimal. The turnaround time for this type of transactions are lesser than that of the other mode. This biometric based digital banking transaction will be a revolution and need of the hour. Most of the banks have started adapting this facility. This is how the cards transformed over a decade due to digitization.

**Transformation of Digitization in ATM Machines:**

Remarkable transformation has happened in ATM teller machines over a decade due to digitization and technological development in Indian banking. Introduction of ATM machines have drastically reduced the human involvement in cash dispensing activity at bank branches. Teller activities for lesser volume of cash has been replaced by introducing Automated Teller Machines. Only larger volume of cash transactions is performed in bank branch teller counters. But originally when ATM Machines were

introduced it was only a cash dispenser with closed architecture and the pre-limits set in the ATM machine for every customer was also less. Only customers of same bank were allowed to use their ATM machines and that was a discomfort to the banking customers as they hardly find their bank owned ATMs across the territory. Later this was liberalized due to the formation of NFS unit (National Financial Switch) and the member banks signed an MOU that all the member banks can have an inter-bank ATM withdrawal access. Hence due to digital penetration the ATM access was converted as an open architecture and the member bank customers were allowed to withdraw cash from any bank ATM with a prescribed limit. Gradually due to development in the network and cabling of ATMs all the ATM Platforms were made to be synchronized under VISA/MASTER platform and there was an undue increase in the ATM counters across the banks in the country. Every bank in India started focussing more in increasing the ATM counters which was used as an USP for customer acquisition and capitalizing the territory as well. All these developments were made by NFS National Financial Switch which has an ATM network of member banks owned by Institute for Development and Research in Banking Technology (IDRBT). Later in the year of December 14, 2009 NPCI (National Payment Corporation of India) took over NFS from IDBRT and started developing the fold of ATMs incrementally. Over a span of years NFS ATM network has grown into many folds and they are the leading multilateral ATM network in the country. As on 31st July' 19, there were 1,140 members that includes 110 Direct, 966 Sub members, 56 RRBs and 8 WLAOs using NFS network connected to more than 2.41 Lac ATMs in the country. This also added a featured ATM card service provisioned to bank customers based on utility. Banks started introducing cards at multiple variant and the same is issued to the customer based on their utilization limits. Limits are predominantly set on cash withdrawal and debit transactions in merchant establishments. Cash withdrawal limits are set between INR 10000 to INR 500000 and debit access in POS machines too. It has established a strong and sustainable operational model with in-house capabilities and it can be compared at par with other major and well-established switch networks. Their operational functions and other services rendered are at par with most of the ATM networks across the globe. Few salient developments made in the ATM network due to advanced digital penetration are. Sub-membership model was introduced which enabled access to smaller, regional banks including RRBs and local co-operative banks to participate in the ATM networks in the country. High standards of application is maintained and network uptime of above 99.50% which has helped the member banks to ensure enhanced customer experience and customer satisfaction. Dispute Management System (DMS) was introduced and it has benefitted members with high operational efficiency and ease of online transaction eco-system management (chargeback, re-presentment, etc.) in the network apart from being compliant with local regulatory requirements. It has also tied up with International card schemes like Discover Financial Service (DFS), Japan Credit Bureau (JCB) and China Union Pay International (CUPI) which allows their cardholders to use ATMs connected to NFS network globally. Fraud Risk Management (FRM) solution is offered as a value added service to monitor transactions on a real time basis and to alert or decline the transaction in the NFS network lively basis.

In addition to the regular banking services, digitization paved a way to enhance ATM machines to offer a value added services as well.

Basic transactions performed in an ATM Machine are:

- Cash Withdrawal,
- Balance Enquiry,
- PIN Change and
- Mini Statement etc

In addition to that many value added services are digitally enabled over a period of time, few services are listed below.

- Mobile Banking Registration,
- Card-to-Card Fund Transfer,
- Cheque Book Request,
- Statement Request,
- Aadhaar Number Seeding,
- Credit Card Payments,
- Insta-money transfer,
- Preferential withdrawal limits,
- Account opening alerts for other bank customers,
- Insta pre-approved loan applying alerts,
- Fixed Deposit Interest rates flash,
- FasTag apply flash,
- Express FD flash,
- Gold Loan / Car Loan / Home Loan flash,
- Trade and forex flash,
- ATM/Mobile Security instructions flash,
- Tax payments facility available flash and
- Mobile recharge and top up are the major value added services enabled over a period of time in ATM machined of banks.

Cash Deposit Machines CDMs are the major transformation of digitization into ATM services. This facility is interoperable and also called as Interoperable Cash Deposit Machines ICDMs. This service enables the cardholders of banks to use Cash Deposit Machines of banks to depositing cash in their own account or third party account. It is beneficial for banks and also for their customers as it will help banks to minimize cash handling cost and at the same time provide convenience to customers by allowing them to use any Cash Deposit Machine to deposit cash into their own account or any third party account. Most of the banks in the country have already deployed more than 30,000 Cash Deposit Machines to cater the financial needs of the customers. Interoperability will further help to optimize cash handling cost and earn higher fee income and increase Return on Investment.

**Key features of this service are:**

- Real time credit to beneficiary account
- Instant verification of notes by cash deposit machine
- Optimize cash handling cost and reduce idle cash in machines
- 24/7 availability of cash deposit facility
- Limit per transaction is restricted to Rs. 50,000/-
- Paperless Transaction

Recent development in this Interoperable Cash Deposit Machine is Cash Re-cycle option enabled. When CDMs were introduced, the specific machine was performing only cash deposit transactions and for dispensing cash another ATM machine has to be installed. In order to reduce the cost and optimize customer transaction both the CDMs and ATMs were integrated into a single machine and same was installed in a name of Cash Recycler Machine. This machine can perform dual role as both cash deposit and cash dispense happens simultaneously which is a major transformation in ATM services.

**Findings:**

- Introduction of ATM and Cards have drastically reduced the work load of bank branches.
- Most of the cash transaction of lesser denomination has got migrated to ATM based transactions
- It increased the ease of customers for emergency transaction, reduced cost to banks and increased the operating profit.
- It has reduced customer crowd in banks for small transactions and increased productivity of the banking personnel, primarily it increased more focus on customer acquisition and service to banks rather spending more time in cash operations.
- Deployment of more ATMs across the country paved a way to capitalize the unbanked and under banked territories.
- Still many rural populations to be capitalized and promote financial inclusion bigtime.
- Introduction of ATMs and cards have made customers to use their account as and when required, also reduced cash and carry mode across the country.
- POS machines play a vital role in digital payments, which is a major transformation in Indian Banking, mainly Card access through merchant outlets increased digital payments predominantly.
- Further advancement in technology though this segment enables customer to transact their bank accounts even on a holiday by accessing through standalone Cash Deposit machines and dispensers.
- Safety and security is well addressed, but more control mechanism has to be profound.
- On the whole, introduction of ATMs and Cards have set a new benchmark in Indian Banking and made banks to reach new milestone.

**Suggestions:**

- Banks have to focus penetrating more into rural unbanked and underbanked by deploying more ATMs and increase issuance of cards to support mission Financial inclusion and Digital payments.
- Mostly people in under developed rural areas are still reluctant to open a bank account or scared to access ATMs and card based digital transaction, banks should focus in more such areas and give basic awareness of using digital products by conducting various financial literacy programs.
- Easily accessible alternate technology to be established and capitalize this unbanked and underbanked territories very particularly.
- Highly secured platform to be established to increase the customer accessibility of ATMs and Cards.
- Biometric scanning, retina scanning based technology to be incorporated in ATM machines, which can allow all type of customers to access their bank account through their finger prints and eye retina scanning.
- Banks to open up more branches and deploy more ATM machines in the non-capitalized territories to increase customer base of rural segment and support mission Digital India of Government of India

**CONCLUSION:**

This transition is mainly from analog to digital, a common example is from a physical branch manual teller to an Automated teller machine. The current shift in consumer attitude and the new competitive

landscape mainly forces banks to tackle the digital requirement as a matter of urgency, unless this is addressed then there might be a risk that banks will be left behind in the market which finds it very difficult to change. It became necessary to accommodate digital mobility within a consistent channel experience as it became apparent that a growing proportion of customers relied solely on portable devices.

Many successful banks have built a separate channel for wide-range of research on the technical investment front and quickly adjusting to it. From physical mode to digitally accessible card-based transactions with greater internet speed and human power. Banks to invest huge in upgrading their technology based on continuous research in customer psychology helps them to successfully compete the other players in the Industry. In this paper it is understood how digitization in ATMs and Cards transformed over a decade.

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# Investigation on the Mechanical, and Third Harmonic Generation Analyses of Non-Linear Optical Single Crystal of 2-Phenyl benzimidazole

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## ABSTRACT

*The slow evaporation solution growth technique is used to grow single crystals of 2-phenylbenzimidazole (2PBMZ). The crystal is belongs to the monoclinic system with space group C2/c, which is revealed through the single crystal XRD. The cut-off wavelength and optical band gap energy of the 2PBMZ crystal were observed at 568 nm and 1.96 eV respectively. The Vickers (Hv) hardness number, yield strength and stiffness constant are calculated, which is found to increase with the applied load. The Z-scan technique with He–Ne laser (632.8 nm) has used to study the third order nonlinear optical property of 2PBMZ crystal.*

***Key words: Crystal growth, Vickers Microhardness, Z-Scan.***

## 1. INTRODUCTION

In recent years, researchers show more interest towards organic materials due to its probable applications in frequency conversion, telecommunication, optical information processing, and high optical disk data storage [1]. The organic materials are more non-linear when compared to inorganic materials due to its bonds and weak Vander Waal's nature, which result in high degree of delocalization [2]. The organic materials show prominent properties due to their fast and large nonlinear response over a broad frequency range, inherent synthetic flexibility, and large optical damage threshold [3]. All these superior properties of the organic non-linear (NLO) materials attract the interest of researchers, rather than inorganic materials. The organic π-conjugated materials with strong optical nonlinearities can be easily refrained by molecular design. Such material shows an effective output in all-optical device applications [4]. The title material is a benzimidazole derivative. The very essential thing for the fabrication of devices is hardness measurement [5]. Muthuraja et al. [6] reported the growth, structural and optical properties of 2PBMZ single crystals using Solution growth method and it was compared with other benzimidazole derivatives. There is no information available on depth analysis of mechanical properties such as Knoop measurement, Stiffness constant, Resistance pressure plot, yield strength and third harmonic generation. In the present investigation, we have reported the mechanical analysis with different kind of analysis, photoconductivity, and third harmonic generation. In addition to that, the powder XRD and UV–Vis–NIR studies of 2PBMZ single crystal were also carried out.

## 2. EXPERIMENTAL PROCEDURE

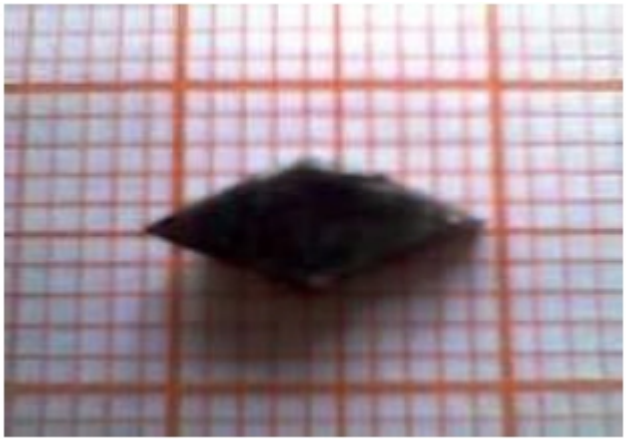

**Fig.1 As grown crystal**

The 2PBMZ with 99% purity was commercially purchased from Sigma Aldrich. The 2PBMZ is highly soluble in N-N-dimethylformamide. The 0.017 mole of 2-phenylbenzimidazole was dissolved in 20ml of solvent at room temperature. The saturated solution was prepared and filtered. The filtered solution is allowed to evaporate and the slow evaporation solution growth technique was use to grow single crystals within a period of 30 days. The grown crystals are Rhombohedra in shape and black in colour. The dimension of the grown crystal is 10x4x2 mm3. Fig. 1 shows the grown 2PBMZ single crystals.

## 3. RESULT AND DISCUSSION

### 3.1 X-ray diffraction analysis

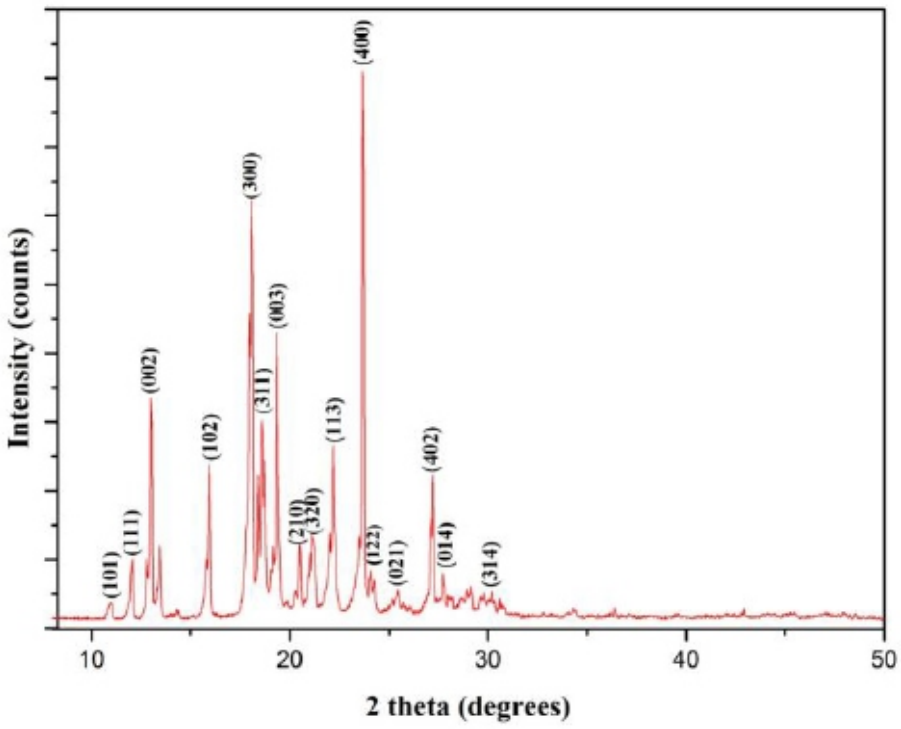


**Fig. 2 Powder XRD spectrum**

At room temperature, the 2PBMZ single crystal was subjected to single crystal X-ray diffraction study and it is found that the grown crystal is belongs to monoclinic system with Centro symmetric space group C2/c. The lattice parameters are a=22.303 Å, b=7.303 Å, c=5.341 Å; α=γ=90O and β=91.58O, and the cell volume is 869.6 Å3. The crystal was finely powdered and subjected to powder X-ray diffraction analysis and the values are recorded in the 2θ ranging from 20 - 70º. The grown 2PBMZ crystal shows the good crystalline nature, which is clearly observed from the diffraction peaks. The powder XRD pattern of 2PBMZ crystal was shown in Fig. 2. The unit cell parameters of 2PBMZ are in good agreement with reported values [7].

### 3.2 Microhardness measurements.

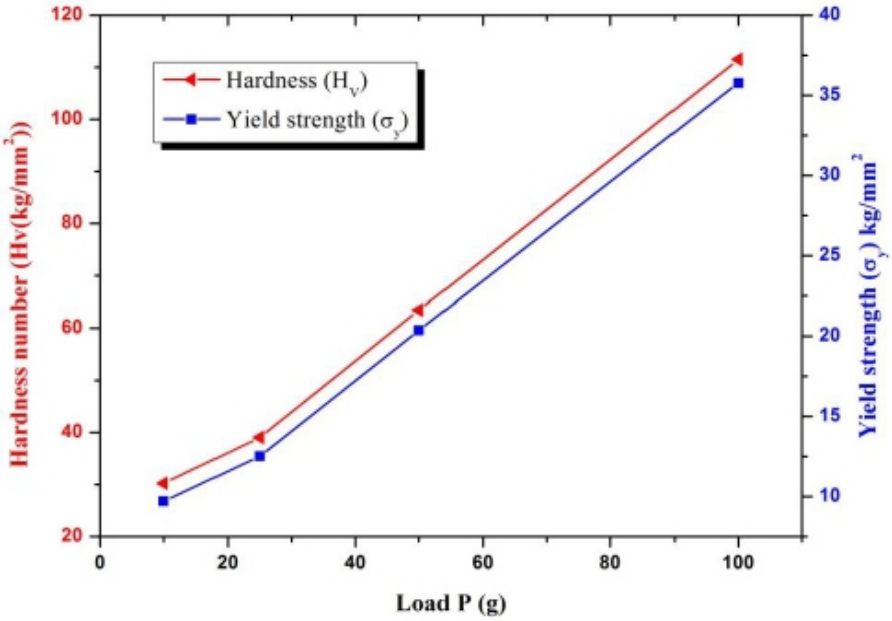


**Fig 3. Hardness and yield strength with applied load,**

The hardness is the most domineering mechanical property of the crystal among several other properties. The hardness of the crystal is used to determine the mechanical stability of the crystal, which is an undeniable parameter [8]. The Mututoyo MH-112 micro hardness tester was used to carry out the hardness measurement. The dimension of the sample used for the hardness measurement is 10x4x2mm3. The Indentation was applied on the polished surface of the crystal with indentation time of 10s. The measurements were carried out for various loads ranging from 10 to 100 gm which shown in Fig 3. The hardness number increases with an increase in applied load, which is due to the reverse indentation size effect [9]. The Vickers Micro hardness number (Hv) of the crystal was calculated using the standard formula

$$Hv = 1.8544\ P/d2\ .$$

Where P is the load applied in kg, d in mm. Hv is the Vickers hardness number in kg/mm2. When the applied load reaches 100 gm, the crack starts to occur on the surface of the crystal, which is due to the release of internal stresses generated locally by indentation [10].

### 3.4 Hays-Kendall's approach

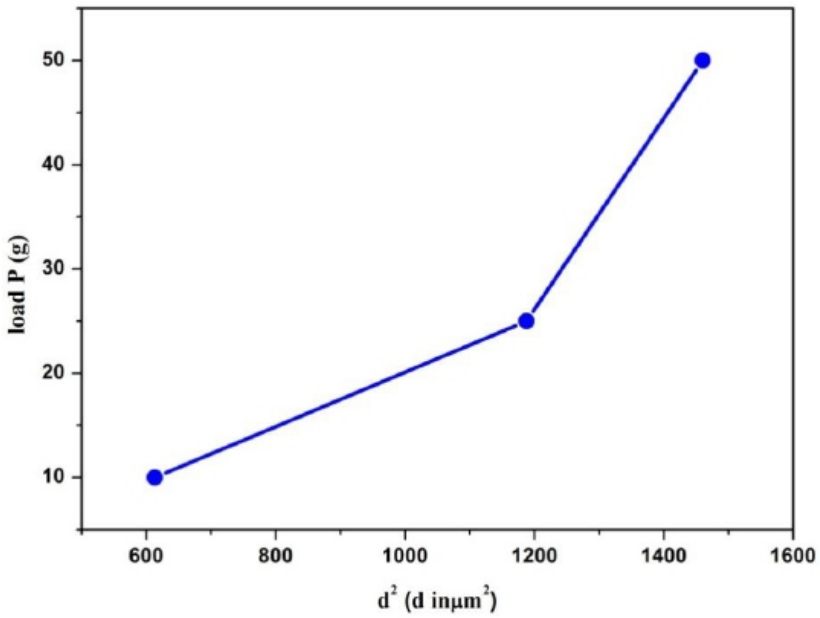


**Fig. 4. Resistance pressure plot.**

According to Hays – Kendall approach [11]. $P = W + A_1d^2$, Where W is the minimum load to initiate plastic deformation and A1 is a load independent constant. Fig. 4 shows the graph plotted between the values of P and $d^2$. The value of W is the intercept along the load axis and A1 is the slope. The corrected hardness $H_0$ for the crystal has been estimated using the following relation $Ho = 1854 \times A_1$. The negative value of constant W indicates that the crystals are exhibiting the strongly behaviour of reverse ISE. The values of Wand $H_o$ were calculated and tabulated (Table 1).

**Table . 1 2-PBMZ crystal Calculated value of W, $A_1$ and $H_o$**

| Hays–Kendall approach | 2-PBMZ Crystal |
|---|---|
| Resistance pressure (W) | -19.42093 (g) |
| Load independent constant (A1) | 0.04394 (g μm-$^2$) |
| Corrected hardness (Ho) | 81.4647(g μm-$^2$) |

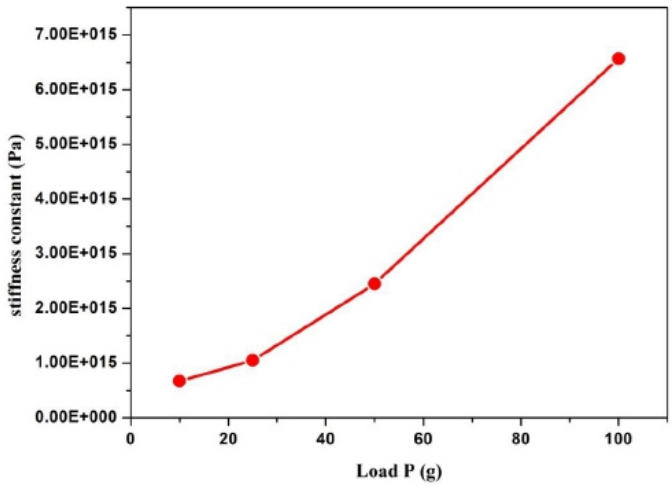


**Fig. 5. Stiffness constant**

The elastic stiffness constant (C11) gives an idea of the tightness of bonding between the neighbouring atoms. The stiffness constant increases with an increase in load which is clearly shown in Fig. 5. The Wooster's empirical relation $C_{11} = Hv^{7/4}$ was used to derive the elastic stiffness constant for different loads. It gives an idea about the tightness of bonding between neigh boring atoms [12]. The hardness value was used to derive the yield strength (σy) by using the following equation [13]. From a Meyer index value n > 2 (2.1), the yield strength $\sigma_y$ was calculated using the expression. Fig. 3 clearly reveals that the yield strength increases with an increase in applied load.

$$\sigma_y = \frac{H_v}{2.9}[1-(n-2)]\left(\frac{12.5(n-2)}{1-(n-2)}\right)^{n-2}$$

The values of yield strength and elastic stiffness constant were calculated with various loads and tabulated in the table 2.

**Table 2: Microhardness, yield strength, and elastic stiffness constant values of 2-PBMZ**

| S.No | Load P (g) | Hv (kg mm$^2$) | Yield Strength σy (kg/mm$^2$) | Elastic stiffness constant $C_{11}$ x $10^{15}$ (Pa) |
|---|---|---|---|---|
| 1 | 10 | 30.26060156 | 9.70484982 | 6.70164 |
| 2 | 20 | 39.04027616 | 12.52057122 | 1.04663 |
| 3 | 50 | 63.4900538 | 20.36183702 | 2.45121 |
| 4 | 100 | 111.5087573 | 35.76187144 | 6.56805 |

### 3.5 Knoop measurement

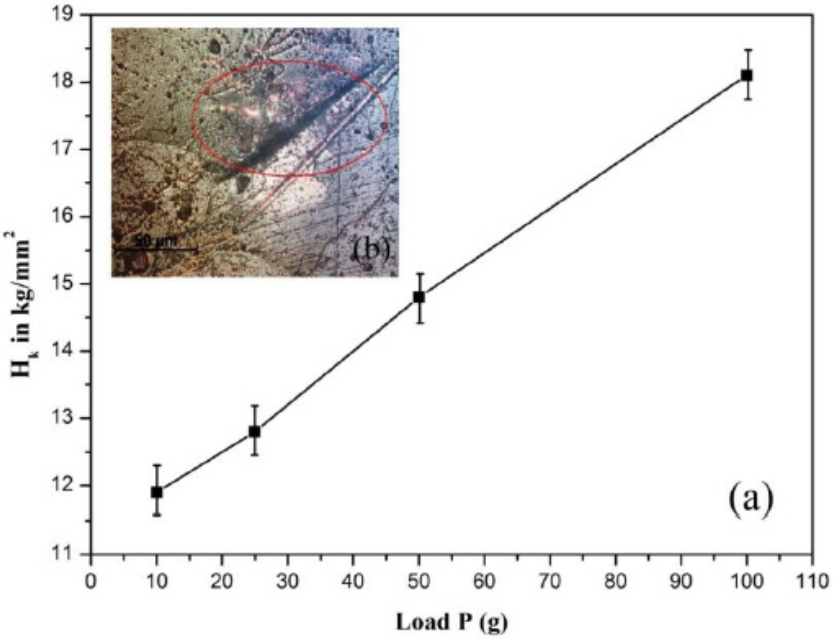


**Fig. 6. (a) Knoop measurement, (b) Knoop indentation**

When the applied load increases up to 100 g, the Knoop microhardness number also increases. This is due to the reverse indentation size effect and which is proved from the Knoop hardness measurement [14]. The Knoop hardness number (Hk) was calculated in consideration with the long diagonal length (d) from the following derivation,

$$H_k = 14.229P/d^2.$$

Fig. 6 (a) shows the graph was plotted for Knoop hardness ($H_k$) versus load (P). The knoop impression obtained from the Knoop hardness seems in a rhombohedral shape which is shown in Fig 6 (b). The Knoop microhardness Young's modulus was derived from the hardness value using the following relation,

$$E = 0.45H_k / (0.1406 - b/a).$$

Where Hk is the hardness value at a particular load, b and a are the shorter and longer Knoop indentation diagonal respectively. The derived Young's Modulus value is 2.895 X $10^{12}$ g/$m^2$.

### 3.6 Photoconductivity

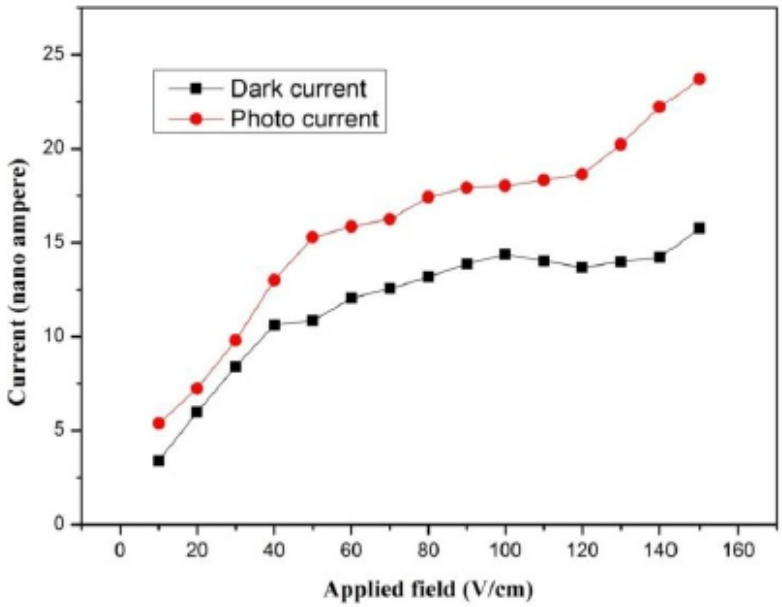


**Fig. 7. Photo conductivity**

The photosensitive materials are most recently used in many latest applications such as military applications, photo detection, communication through fiber optics, radiation measurements and in guided weapons [15, 16]. The photoconductivity was measured using the Keithley 6485 Pico ammeter at room temperature. The voltage power supply and sample was connected with Keithley 6485 Pico-Ammeter in series. The crystal was ignited using the halogen lamp with 100 W applied voltage and the photo current was recorded for the same applied voltage. Along with the electrometer DC supply, the thin copper wire was connected to the opposite faces of the sample crystal. The input voltage was increased from 1 V to 30 V by the steps of 2 V. The applied field was adjusted for both dark and photo currents. The photoconductivity plot depends is shown in Fig. 7. From the graph, it is very clear that both the dark current and photo current increases with the applied field. At the same time, the photo current increases rapidly than the dark current. This condition is termed as positive photo conductivity. Materials with the positive photo conductivity behaviour are used for soliton wave communications [17].

### 3.8 Z-scan Analysis

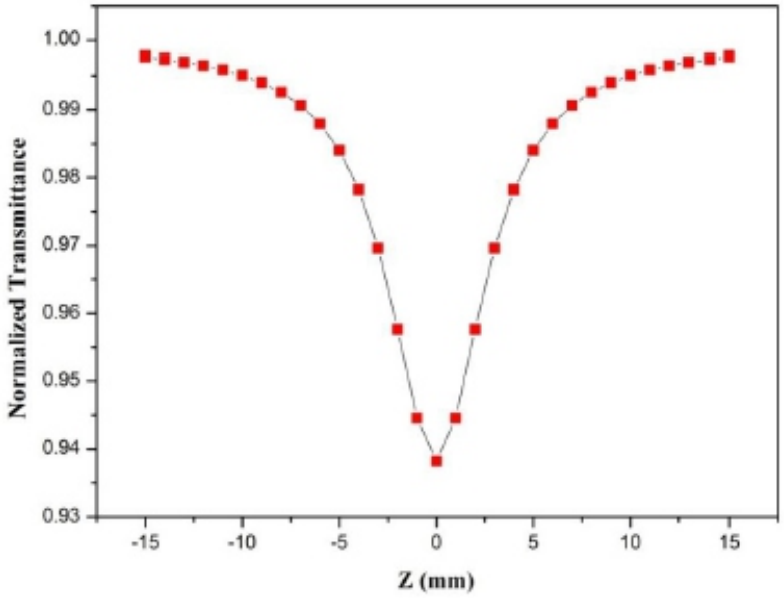


**Fig. 8 open aperture**

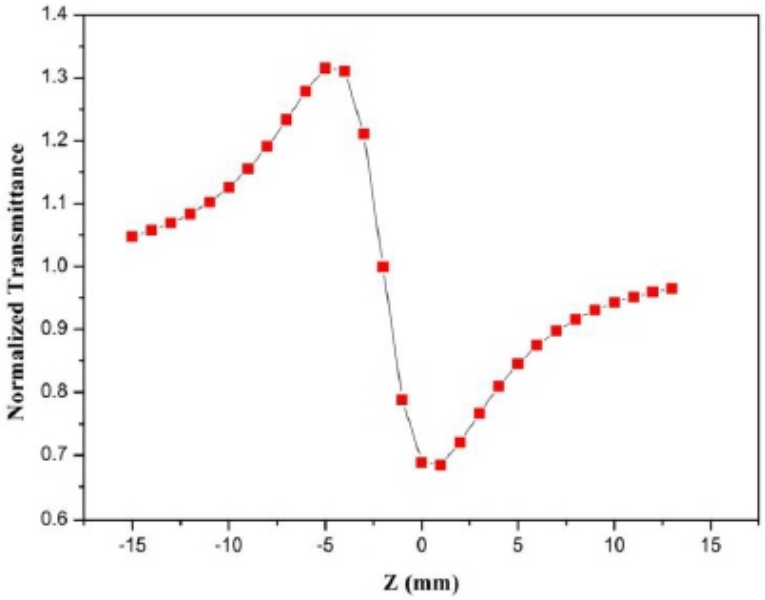


**Fig. 9 Closed apertures**

When compared to other measurement techniques like nonlinear refraction interferometer, ellipse rotation, beam distortion measurements, degenerate four wave mixing and three wave mixing, the Z-scan technique is very easy and efficient technique [18]. Both the non-linear absorption and refraction of crystals can be clearly defined from the Z-scan technique, than the thin films and liquid solutions established by shakebahae et.al. The Z-scan technique is very laid-back to understand, so this method was agree to take by non-linear optics community. It is used to quantity both the non-linear refractive index and non-linear absorption coefficient. The two main basic factors behind the Z-scan technique is self-focusing and self-defocusing [19]. In this current experiment, the third-order NLO properties of the title crystal were measured using the He–Ne laser (5 mW), in which the laser possess the wavelength and beam diameter of 632.8 nm and 0.5 mm respectively. The Gaussian filter was used to convert the input laser beam in to the Gaussian form. The Gaussian beam was allowed to pass through the convex lens

with the focal length of 30 mm, in which the focal length mainly depends on the incident Gaussian beam. The diameter of the Gaussian beam waist ω0 at the focal length was 12.05 mm. The sample was transitioned from +Z to - Z axial direction using stepper motor, and also to regulate the incident intensity falling on the crystal surface. The far field transmittance intensity variation in a closed aperture method was measured using the digital power meter (Field master GS-coherent). On the other hand, the refracted laser beam was entirely placid in the detector in an open aperture method which is shown in fig. 8. The size of the aperture decreased in terms of the diameter of the laser beam at the closed aperture method. Fig. 9 reveals self-defocusing effect at the closed aperture method. The self-defocusing effect upsurges the beam divergence which directly leads to broadening of beam at the focal length. The saturation absorption enriches the peak and surmounts the valley at the focal point of the optical path and it is vice versa in the case of multi-photon absorption [20]. The effective non-linear optical property of the grown crystal makes it an auspicious material for optical limiting applications. The experimental results and details of the 2PBMZ crystal are tabulated in Table 3.

**Table 3. The experimental results and details of the 2PBMZ crystal are tabulated**

| Measurement details of Z-Scan experiment | |
|---|---|
| Laser beam wavelength ($\lambda$) | 632.8 nm |
| Focal length of lens | 30 mm |
| Optical path length | 75 cm |
| Beam radius of the aperture ($w_a$) | 3.5 mm |
| Aperture radius ($r_a$) | 1mm |
| Sample thickness ($L$) | 1.07 mm |
| Beam radius (Wo) | $6.03X\ 10^{-6}$ |
| Effective thickness ($L_{eff}$) | 0.153004978 mm |
| Linear absorption coefficient ($\alpha$) | 6.5296959 |
| Linear transmittance ($S$) | 0.150634 |
| Nonlinear refractive index ($n_2$) | $3.97\ X\ 10^{-11}\ m^2/W$ |
| Nonlinear absorption coefficient ($\beta$) | $2.74\ X\ 10^{-4}\ m/W$ |
| Real part of third order susceptibility [Re($\chi$3)] | $2.65237\ X\ 10^{-5}esu$ |
| Imaginary part of third order susceptibility [Im($\chi$3)] | $9.24315\ X\ 10^{-6}esu$ |
| Third order nonlinear susceptibility ($\chi$3) | $2.8088\ X\ 10^{-5}esu$ |

## 4. CONCLUSION

The slow evaporation technique was used to grow the 2-phenyl benzimidazole (2PBMZ) single crystals successfully. The reverse indentation size effect is observed in the grown single crystals. The elastic stiffness constant ($C_{11}$) and yield strength ($\sigma_v$) of the grown crystal were derived. From the stiffness constant value of the crystal, this is found that the binding forces between the ions are very strong. The Young's modulus value of the crystal was calculated from the diagonal lengths of the Knoop indentation. The nonlinear refractive index and nonlinear susceptibility of 2PBMZ single crystals are calculated from Z-scan measurements.

## ACKNOWLEDGMENT

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# Propagation of Dromions in Microtubulin System Under the Influence of Viscosity

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## ABSTRACT

*Microtubules (MTs) are the very important for cellular organization and information processing. MTs serve as structural components within cells and are involved in many cellular process including mitosis, cytokinesis and vesicular transport. The energy transfer along the protofilaments of microtubules can be understood by the underlying nonlinear excitations which explain their dynamics. We employ symbolic computation to solve the associated dynamical equation and exhibit the dromion-like solution in microtubules.*

***Keywords: Dromions, analytical method, microtubules***

## 1. INTRODUCTION

Living cells are profoundly and actively categorized by the networks of protein polymers termed cytoskeleton [1]. The cytoskeleton shows intense structure. As the cell, change their shape, it overhauls continuously, by dividing the cells which respond to the environment. The cytoskeleton comprises of intermediate filaments, actin filaments (microfilaments), and microtubules. Microtubules and filaments are co-operatively connected and manifest to form a three-dimensional network in the cell [2-5]. The primordial structure of the cytoskeleton manifested by the microtubules which gratify the vital requirements for the stimulation of vibrations and prompting of narcissistic oscillating electric field [6]. Microtubules play a crucial role for the far- reaching cellular organisation and information processing. MTs assist as structural components within cells and are take part in many cellular processes which encompass mitosis, cytokinesis and vesicular transport. MTs are nucleated and sort out by the microtubule organizing centres (MTOCs), such as centrosomes and basal bodies. The MTOCs is typically track down beside the nucleus midst interphase. MTOC which are grown out by microtubules, forming a hub and spoke array, even meanwhile interphase. MTs are numerous which is more than twice the width of an intermediate filament and three times the width of a microfilament.

Altering length from a fraction of micrometre to hundreds of micrometres, MTs are much rigid than either microfilaments or transitional filaments of their tube-like construction. A significance of this tubular design is the dexterity of MTs to trigger pushing forces without buckling, a property that is critical to the gesture of chromosomes and the mitotic spindle in mitosis. The discrimination of the replicated chromosome is brought about by a tangled cytoskeletal machine with many moving parts-the mitotic spindle. It is hammered from MTs and their federated proteins, which both pull the daughter chromosomes toward the poles apart. (MAPs (microtubule associated proteins) are of remarkable pertinent of stability of MT assembly. The presence of MAPs sustains the growth of microtubules. The mitotic spindle is superintendent for the segregation of sister chromatids in the course of cell division.

Chromosomes are sequestered to the spindle with their kinetochores [7] attached to the plus ends of microtubules. Chromosome movement is tentative on kinetochore-microtubule dynamics: only when the chromosomes kinetochore is adhering to the microtubules, a chromosome will proceed with regard to pole. In the course of mitosis, MTs similarly stretch outward from replicated centrosomes to manifest the mitotic spindle, which is sensible for the separation and allocation of chromosomes to daughter cells.

Around 20 years ago, the researcher are very much interested to study the dromion like excitations in different kinds of systems [8-13]. For constructing dromion-like forms, we consider the following nonlinear partial differential equation (nPDE) of motion for microtubulin systems [14]:

$$m\frac{\partial^2 z}{\partial t^2} - kl^2\frac{\partial^2 z}{\partial x^2} - qE - Az + Bz^3 + \gamma\frac{\partial z}{\partial t} = 0, \qquad (1)$$

where, m implies the mass of the dimer, l attest length of the dimer, k controvert harmonic constant between the dimers affiliation to the same protofilament, E tags magnitude of the intrinsic electric field while q represents the charge within the dipole, -viscosity coefficient, A and B describes the positive parameters of double well potential. The organization of the paper is as follows. In sec. II, we come into the soliton solutions originating from the symbolic computation, namely, extended rational sinh-cosh method. This method is convenient to acquire the dromion-like solution. Eventually, we conclude this work in sec. III.

**2. Dromion solutions using extended rational sinh-cosh method**

In the recent years, various analytical methods have been used to solve the nonlinear partial differential equations (PDEs). Hirota's bilenearization method [15], modified extended tanh method [16,17], Jacobi-elliptic function method [14], double exponential function method [15]. We describe the first step of the new extended rational methods for finding exact solutions of partial differential equations (PDEs)

$$F\left[z, \frac{\partial z}{\partial t}, \frac{\partial z}{\partial x}, \frac{\partial^2 z}{\partial x}, \frac{\partial^2 z}{\partial x^2}, \ldots.\right] = 0, \qquad (2)$$

where, z = z(x, t), is an unknown function and F is a polynomial in z and its various partial derivatives. According to extended rational sinh-cosh method [18,19], we assume that the exact solution can be expressed in the following forms

$$z(\xi) = \frac{a_0 sinh(\mu\xi)}{a_2 + a_1 cosh(\mu\xi)}, \quad cosh(\mu\xi) \neq -\frac{a_2}{a_1}, \qquad (3)$$

where, $\alpha_0$, $\alpha_1$ and $\alpha_2$ are parameters to be found in terms of the other parameters. The nonzero constant is the wave number. The derivatives of the predicted solutions are

$$z_\xi(\xi) = \frac{a_0\mu\left[cosh(\mu\xi)a_2 + a_1\right]}{\left[a_2 + a_1 cosh(\mu\xi)\right]^2},$$
$$z_{\xi\xi}(\xi) = \frac{-a_0 sinh(\mu\xi)\mu^2\left[-a_2^2 + a_2 a_1 cosh(\mu\xi) + 2a_1^2\right]}{\left[a_2 + a_1 cosh(\mu\xi)\right]^3}. \qquad (4)$$

We seek its traveling wave solution of the form

$$z(x,t) = z(\xi), \quad \xi = x - ct, \qquad (5)$$

where c is the soliton speed. Substituting Eq. (5) into Eq. (1), we get the ordinary differential equation (ODE),

$$z_{\xi\xi}(\xi) - T_1 z_{\xi}(\xi) - T_2 z(\xi) + T_3 z^3(\xi) - T_4 = 0, \tag{6}$$

where,

$$T_1 = \left[\frac{c\gamma}{mc^2 - kl^2}\right],\ T_2 = \left[\frac{A}{mc^2 - kl^2}\right],\ T_3 = \left[\frac{B}{mc^2 - kl^2}\right] \text{ and } T_4 = \left[\frac{qE}{mc^2 - kl^2}\right].$$

Substituting the Eq. (4) into Eq. (6), we get,

$$\begin{aligned}
&\frac{a_0 sinh(\mu\xi)\mu^2}{(a_2 + a_1 cosh(\mu\xi))} - \frac{3a_0 cosh(\mu\xi)\mu^2}{(a_2 + a_1 cosh(\mu\xi))^2 a_1 sinh(\mu\xi)} + \frac{2a_0 sinh(\mu\xi)^3}{(a_2 + a_1 cosh(\mu\xi))^3 a_1^2 \mu^2} \\
&-T_1\left(\frac{a_0 cosh(\mu\xi)\mu}{(a_2 + a_1 cosh(\mu\xi)}\right) - \frac{a_0 sinh(\mu\xi)^2}{(a_2 + a_1 cosh(\mu\xi))^2 a_1 \mu)} - \frac{T_2 a_0 sinh(\mu\xi)}{(a_2 + a_1 cosh(\mu\xi))} \\
&+\frac{T_3 a_0^3 sinh(\mu\xi)^3}{(a_2 + a_1 cosh(\mu\xi))^3} - T_4 = 0,
\end{aligned} \tag{7}$$

after simplifying the Eq. (7) we get,

$$\begin{aligned}
&a_0 sinh(\mu\xi)\mu^2 a_2^2 - a_0 sinh(\mu\xi)\mu^2 a_2 a_1 cosh(\mu\xi) - 2a_0 sinh(\mu\xi)\mu^2 a_1^2 - T_1 a_0 \mu cosh(\mu\xi) a_2^2 \\
&-T_1 a_0 \mu cosh(\mu\xi)^2 a_2 a_1 - T_1 a_0 \mu a_2 a_1 - T_1 a_0 \mu a_1^2 cosh(\mu\xi) - T_2 a_0 sinh(\mu\xi) a_2^2 \\
&-2T_2 a_0 sinh(\mu\xi) a_2 a_1 cosh(\mu\xi) - T_2 a_0 sinh(\mu\xi) a_1^2 cosh(\mu\xi)^2 + T_3 a_0^3 sinh(\mu\xi) cosh(\mu\xi)^2 \\
&-T_3 a_0^3 sinh(\mu\xi) - T_4 a_2^3 - 3T_4 a_2^2 a_1 cosh(\mu\xi) - 3T_4 a_2 a_1^2 cosh(\mu\xi)^2 - T_4 a_1^3 cosh(\mu\xi)^3 = 0,
\end{aligned} \tag{8}$$

collecting the coefficients of cosh(□□) and sinh(□□), we obtain

$$\begin{aligned}
&a_0\mu^2 a_2^2 - 2a_0\mu^2 a_1^2 - T_2 a_0 a_2^2 - T_3 a_0^3 = 0, \\
&-T_1 a_0 \mu a_2^2 - T_1 a_0 \mu a_1^2 - 3T_4 a_1 a_2^2 = 0, \\
&-a_0\mu^2 a_1 a_2 - 2T_2 a_0 a_1 a_2 = 0, \\
&-T_1 a_0 \mu a_1 a_2 - 3T_4 a_1^2 a_2 = 0, \\
&-T_2 a_0 a_1^2 + T_3 a_0^3 = 0, \\
&-T_4 a_1^3 = 0, \\
&-T_1 a_0 \mu a_1 a_2 - T_4 a_2^3 = 0,
\end{aligned} \tag{9}$$

solving the above system of equations, we obtain $a_1$, □ and $a_2$,

$$a_1 = \sqrt{\frac{T_3}{T_2}}\ a_0,\ \mu = \sqrt{-2T_2},\ a_2 = \sqrt{\frac{\frac{-T_1 T_3\ \sqrt{-2T_2 a_0^3}}{T_2}}{T_1 a_0 \sqrt{-2T_2} + 3T_4 \sqrt{\frac{T_3}{T_2}}\ a_0}}, \tag{10}$$

substituting the above equation into Eq. (5), we obtain the solitary wave solution,

$$z(x,t) = \frac{a_0 sinh(\mu\xi)}{\left(\sqrt{\frac{\frac{-T_1 T_3\ \sqrt{-2T_2 a_0^3}}{T_2}}{T_1 a_0 \sqrt{-2T_2} + 3T_4 \sqrt{\frac{T_3}{T_2}}\ a_0}} + \sqrt{\frac{T_3}{T_2}}\ a_0 cosh(\mu\xi)\right)}. \tag{11}$$

The above equation represents the dromion-like solutions of Eq. (1). We have plotted the Eq. (11), for microtubulin system and obtained the dromion-like profile. We fix the viscosity value = $0.001x10^{-28}$, and by keeping the parameter values m = $10^{26}$kg, E = $10^{5}$V $m^{-1}$, q = $6x10^{-18}$C, l = $8x10^{-8}$ m, c = 2.1 m/s, $\alpha_0$ = 1, A = 1 and B = $10^{2}$, we obtain the dromion-like forms which is shown in the Fig. (1). By increasing the value of = 0:01x$10^{-28}$, we obtain the dromion profile with decreasing amplitude which is depicted in the Fig. (1b). Further, increasing the value of = $0.1x10^{-28}$, $1x10^{-28}$, $5x10^{-28}$ and $10x10^{-28}$, the amplitudes of the dromion-like forms are decreasing by increasing the value of viscosity and traveling along the tubulin dimers which is shown in the Fig. (1 c-f). This amplitude variations are pointed in the darker region and exist in the corresponding contour plots which is depicted in the Fig. (1 a-f).

## 3. CONCLUSIONS

We investigate the microtubule dynamics and look for the governed nonlinear excitations in the form of dromions and the viscosity & amplitude of the dromions are inversely proportional to each other. This dromions will move smoothly from one end of the protofilament to another end of the protofilament. The nonlinear behaviour of microtubule system can be understood by the evolutionary plots which are in the form of dromions.


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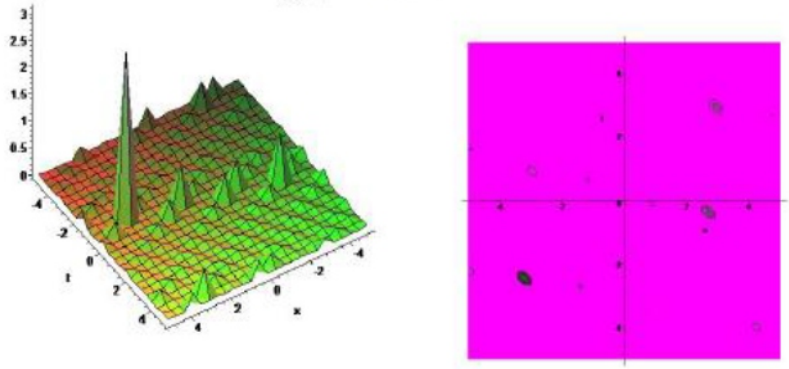
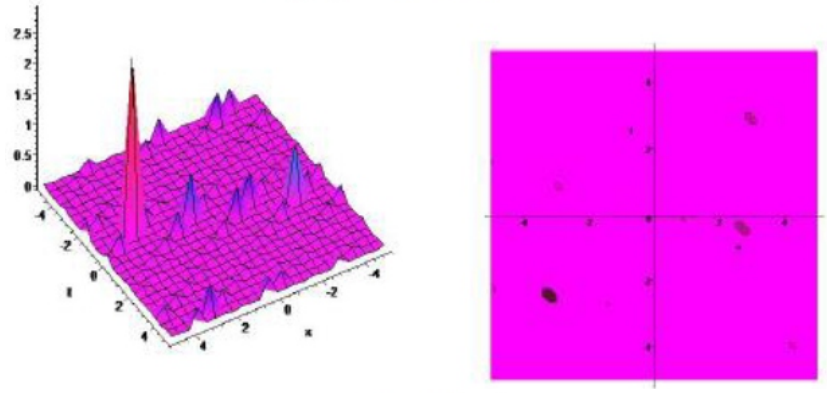
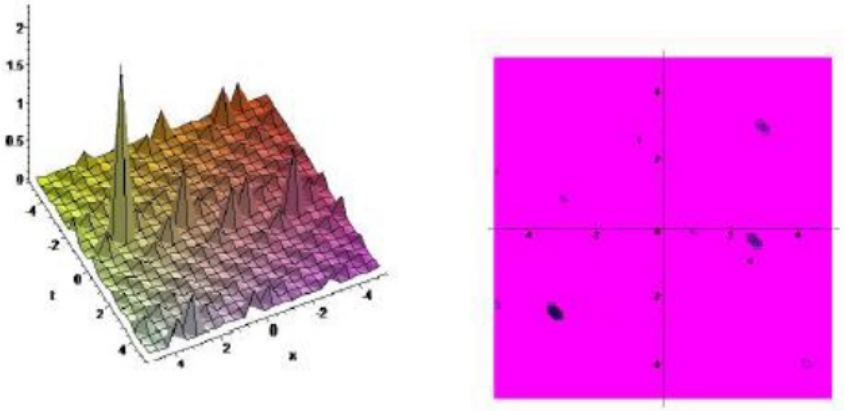
(a) $\gamma = 0.001 \text{ x } 10^{-28}$



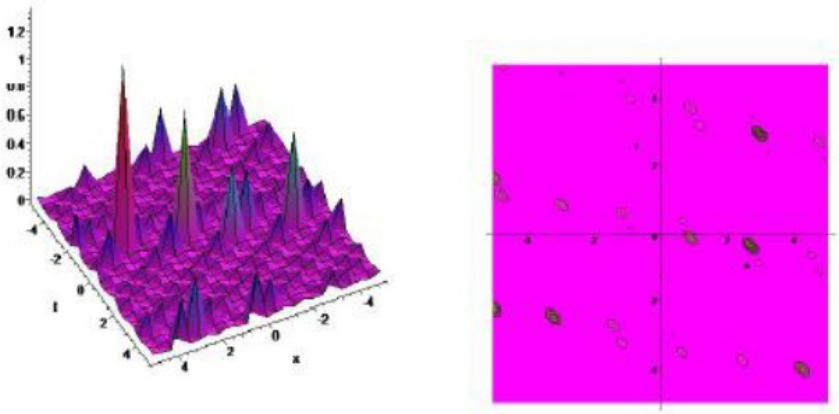
(b) $\gamma = 0.01 \text{ x } 10^{-28}$



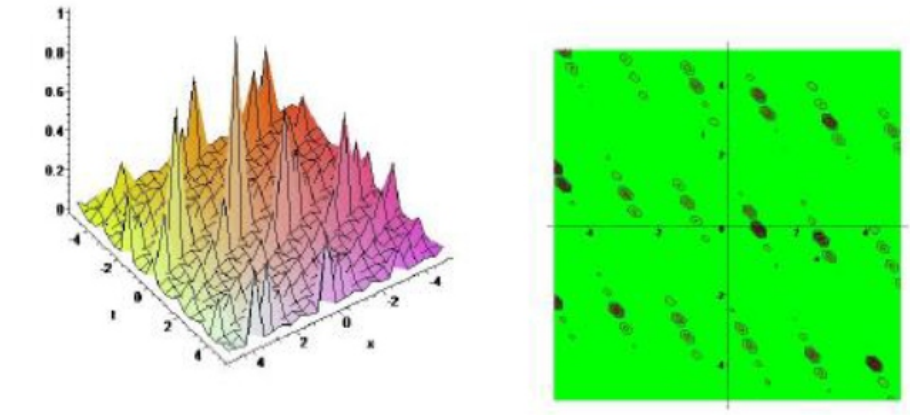
(c) $\gamma = 0.1 \text{ x } 10^{-28}$



(d) $\gamma = 1 \text{ x } 10^{-28}$



(e) $\gamma = 5 \text{ x } 10^{-28}$



(f) $\gamma = 10 \text{ x } 10^{-28}$

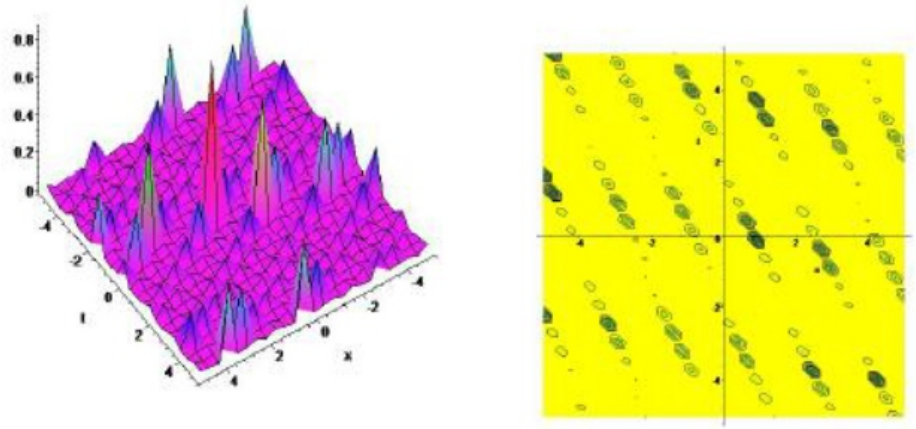


**Figure 1: Profile of dromions along the microtubules for Eq. (11).**

# Nonlinear Wave Propagation Along Microtubulin System using Analytical Method

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## ABSTRACT

*In the present paper, we consider microtubules as lattice arrays of coupled local dipolestates that interact with their immediate neighbours. It is demonstrated that solitary wave likeexcitations arise as a result of the guanosine 5-triphosphate (GTP) hydrolysis and that the springconstant may cause them to propagate by admitting the nonlinear wave along a microtubule usinganalytical method.*

***Keywords: Solitary wave, microtubules, analytical method***

## 1. INTRODUCTION

Microtubules was first observed by Led better and Poster [1], in the cortical cytoplasm of plant cells, which is involved in important cellular process during growth and development [2,3].Microtubules from cortical arrays during the interphase, that are generally transverse to the direction of cell elongation. On completing the cell elongation phase [3, 4], they become oblique or longitudinal. The orientation of microtubule arrays is not always uniform across a cell and they frequently [5] occur with mixed array. Cortical microtubules are involved in directional cellulose deposition, although the details remain to be established [6]. The interphase array of microtubules gives way to a dense preprophase band (PPB) during the cell division [7, 8]. This predicts the plane of future cell division. Then the mitotic spindle is formed by microtubules, which involved in the separation of paired chromosomes and finally between the daughter nuclei a new cell wall is laid, it is the phragmoplast. The regeneration of interphase array in the cell cortex is occurred and it is possible from microtubule-nucleating sites along the plasmalemma or the nuclear envelope[9].

A Microtubules, which forms a long hallow cylinder with its diameter about 25 nm. The interior part of this hallow cylinder (MTS) is filled with ordered water molecules and this implies the existence of electric dipoles and electric fields [10]. The oriented molecules of cytoplasm waterand enzymes [11] are surrounded in the outer surface of MT. Protofilaments with alternating andsubunits are formed by tubulin heterodimers, which are along the microtubules axis and joinedend to end. In vitro, the MTs composed of 12 to 17 protofilaments wen it is self-assembled and 13protofilaments in vivo. The internal bound of these protofilaments are strong and they are connected by weaker lateral bounds to form a sheet which is wrapped up into a tube in the nucleation process [12]. About 13 identical protofilaments in the wall of MT each consist of several subunit swhich are known as tubulin dimers. These dimers associated in a chain like manner resulting in so called protofilaments. Alpha and beta tubulin are three tubulins at least associated with microtubules. Each subunit of tubulin is about 8nm peanut shaped dimer, which comprises alpha, beta tubulin. This consists of single polypeptide chain folded over on itself and approximately 4nm in diameter. Both alpha and beta tubulin monomers have (GTP) Guanosine Triphosphate which is binding sites that playsa critical role in dynamics of microtubule formation. Monomers, the alpha and beta tubulin assemble to form alpha beta-heterodimers each

consisting of single alpha-monomer and a single beta-monomer. The body of microtubule is formed by heterodimers as discussed below in detail. At the end of (MTOCs) Microtubule Organizing Centers, monomers of -tubule are bounded but not within microtubules themselves. We use the following nonlinear (PDE) partial differential equation of motion [13]:

$$m\frac{\partial^2 z}{\partial t^2} - kl^2\frac{\partial^2 z}{\partial x^2} - qE - Az + Bz^3 + \gamma\frac{\partial z}{\partial t} = 0, \qquad (1)$$

where, m denotes the mass of the dimer, l - is the length of the dimer, k - is the harmonic constant between the dimers belonging to the same protofilament, E - is the magnitude of the intrinsic electric field while q represents the charge within the dipole, -viscosity coefficient, A andB represents the positive parameters of double well potential. The organization of the paper is as follows. In sec. II, we get, the soliton solutions by using analytical method, namely, extended rational sin-cos method. It is very useful technique to obtain the periodic solitary solution. Finally,conclude this work in sec. III.

## 2. Solitary wave solutions using extended rational sin-cosmethod

In the recent years, various analytical methods have been used to solve the nonlinear partial differential equations (PDEs). Hirota's bilenearization method [14], modified extended tanhmethod [15,16], Jacobi-elliptic function method [13], double exponential function method [14]. Wedescribe the first step of the new extended rational methods for finding exact solutions of partial differential equations (PDEs)

$$F\left[z, \frac{\partial z}{\partial t}, \frac{\partial z}{\partial x}, \frac{\partial^2 z}{\partial x}, \frac{\partial^2 z}{\partial x^2}, ....\right] = 0, \qquad (2)$$

where, z = z(x,t), is an unknown function and F is a polynomial in z and its various partial derivatives. According to extended rational sin-cos method, [17,18], we assume that the exact solution can be expressed in the following forms

$$z(\xi) = \frac{a_0 sin(\mu\xi)}{a_2 + a_1 cos(\mu\xi)}, \quad cos(\mu\xi) \neq -\frac{a_2}{a_1} \qquad (3)$$

where, $a_0$,$a_1$ and $a_2$ are parameters to be found in terms of the other parameters. The nonzero constant □ is the wave number. The derivatives of the predicted solutions are

$$z_\xi(\xi) = -\frac{a_0\mu\left[sin(\mu\xi)a_2 + a_1\right]}{\left[a_2 + a_1 sin(\mu\xi)\right]^2},$$

$$z_{\xi\xi}(\xi) = \frac{a_0 cos(\mu\xi)\mu^2\left[-a_2^2 + a_2 a_1 sin(\mu\xi) + 2a_1^2\right]}{\left[a_2 + a_1 sin(\mu\xi)\right]^3}, \qquad (4)$$

we seek its traveling wave solution of the form

$$z(x,t) = z(\xi), \quad \xi = x - ct, \qquad (5)$$

where c is the soliton speed. Substituting Eq. (5) into Eq. (1), we get the ordinary differentialequation (ODE),

$$z_{\xi\xi}(\xi) - T_1 z_\xi(\xi) - T_2 z(\xi) + T_3 z^3(\xi) - T_4 = 0, \qquad (6)$$

where,

$$T_1 = \left[\frac{c\gamma}{mc^2 - kl^2}\right],\ T_2 = \left[\frac{A}{mc^2 - kl^2}\right],\ T_3 = \left[\frac{B}{mc^2 - kl^2}\right] \text{ and } T_4 = \left[\frac{qE}{mc^2 - kl^2}\right].$$

Substituting theEq. (4) into Eq. (6), we get,

$$\frac{-a_0 sin(\mu\xi)\mu^2}{(a_2+a_1 cos(\mu\xi))}+\frac{3a_0 cos(\mu\xi)\mu^2}{(a_2+a_1 cos(\mu\xi))^2 a_1 sin(\mu\xi)}+\frac{2a_0 sin(\mu\xi)^3}{(a_2+a_1 cos(\mu\xi))^3 a_1^2\mu^2}$$
$$-\frac{T_1(a_0 cos(\mu\xi)\mu}{(a_2+a_1 cos(\mu\xi))}+\frac{a_0 sin(\mu\xi)^2}{(a_2+a_1 cos(\mu\xi))^2 a_1\mu)}-\frac{T_2 a_0 sin(\mu\xi)}{(a_2+a_1 cos(\mu\xi))}$$
$$+\frac{T_3 a_0^3 sin(\mu\xi)^3}{(a_2+a_1 cos(\mu\xi))^3}-T_4=0, \tag{7}$$

after simplifying the Eq. (7) we get,

$$-a_0 sin(\mu\xi)\mu^2 a_2^2+a_0 sin(\mu\xi)\mu^2 a_2 a_1 cos(\mu\xi)+2a_0 sin(\mu\xi)\mu^2 a_1^2$$
$$-T_1 a_0\mu cos(\mu\xi)^2 a_2 a_1-T_1 a_0\mu a_2 a_1-T_1 a_0\mu a_1^2 cos(\mu\xi)-T_2 a_0 sin(\mu\xi)a_2^2$$
$$-2T_2 a_0 sin(\mu\xi)a_2 a_1 cos(\mu\xi)-T_2 a_0 sin(\mu\xi)a_1^2 cos(\mu\xi)^2+T_3 a_0^3 sin(\mu\xi)$$
$$-T_3 a_0^3 sin(\mu\xi)cos(\mu\xi)^2-T_4 a_2^3-3T_4 a_2^2 a_1 cos(\mu\xi)-3T_4 a_2 a_1^2 cos(\mu\xi)^2$$
$$-T_4 a_1^3 cos(\mu\xi)^3-T_1 a_0\mu cos(\mu\xi)a_2^2=0, \tag{8}$$

collecting the coefficients of cos(□□) and sin(□□), we obtain

Substituting theEq. (4) into Eq. (6), we get,

$$-a_0\mu^2 a_2^2+2a_0\mu^2 a_1^2-T_2 a_0 a_2^2+T_3 a_0^3=0,$$
$$a_0 a_1 a_2\mu^2-2T_2 a_0 a_1 a_2=0,$$
$$-T_1 a_0\mu a_2^2-T_1 a_0\mu a_1^2-3T_4 a_2^2 a_1=0,$$
$$-T_1 a_0\mu a_2 a_1-3T_4 a_1^2 a_2=0,$$
$$-T_4 a_1^3=0,$$
$$-T_2 a_0 a_1^2-T_3 a_0^3=0,$$
$$T_1 a_0 a_2 a_1\mu c-T_4 a_2^3=0, \tag{9}$$

solving the above system of equations, we obtain $a_1$,□ and $a_2$, as follows

$$a_1=\sqrt{\frac{-T_3}{T_2}}\ a_0,\ \ \mu=\sqrt{2T_2},\ \ a_2=\sqrt{\frac{-T_1 a_0\left(\frac{-T_3}{T_2}\ a_0\right)(2T_2)^{\frac{1}{2}}}{T_1 a_0(2T_2)^{\frac{1}{2}}+3T_4\left(\sqrt{\frac{-T_3}{T_2}}\ a_0\right)}}, \tag{10}$$

substituting the above equation into Eq. (5), we obtain the solitary wave solution,

$$z(x,t)=\frac{a_0 sin(\sqrt{2T_2}\ \xi)}{\sqrt{\frac{-T_1 a_0\left(\frac{-T_3}{T_2}\ a_0\right)(2T_2)^{\frac{1}{2}}}{T_1 a_0(2T_2)^{\frac{1}{2}}+3T_4\left(\sqrt{\frac{-T_3}{T_2}}\ a_0\right)}+\left(\sqrt{\frac{-T_3}{T_2}}\ a_0\right)cos(\sqrt{2T_2}\xi)}}. \tag{11}$$

The above equation represents the solitary wave solutions of Eq. (1). We have plotted theEq. (11), for microtubulin system and obtained the periodic solitary wave profile. We obtain theperiodic nonlinear wave profile by choosing the value of velocity c = 0.9 m/s which is shown in theFig. (1a). By increasing the value of c = 1.0 m/s, we get the periodic wave profile with differentdirection which is depicted in the Fig. (1b). Finally, we get the periodic structure with constantamplitude for c = 1.1 m/s which shown in the Fig. (1c).

We fix the spring constant value $k = 0.01x10^{-12}Nm^{-1}$ and by keeping the parameter values $m = 10^{-26}kg$, $E = 10^{5}Vm^{-1}$, $q = 6x10^{-18}$ C,$l = 8x10^{-8}$m,c = 2.1 m/s,$a_0 = 1$,A = 1 and $B = 10^{23}$, we obtain the cusp-like multi-nonperiodic solitary wave forms which is shown in the Fig.(2a). By increasing the value of $k = 0.1x10^{-12}$ $Nm^{-1}$, we obtain the nonperiodic solitary wave profile with constant amplitude which is depicted in the Fig. (2b). Further, increasing the value of spring constant $k = 0.1x10^{-12}$ $Nm^{-1}$, we received nonperiodic solitary waves are generated and traveling on the tubulin dimers with change of direction of propagation which is shown in the Fig. (2c).

## 3. CONCLUSIONS

We investigate the microtubule dynamics and look for the governed nonlinear excitations in the form of solitons. We employ symbolic computation to solve the associated dynamical equation and exhibit the periodic wave property of the solitons in microtubules under the effect of velocity and spring constant. These nonlinear excitations may be utilized as signalling and switching mechanisms.


## ACKNOWLEDGMENTS

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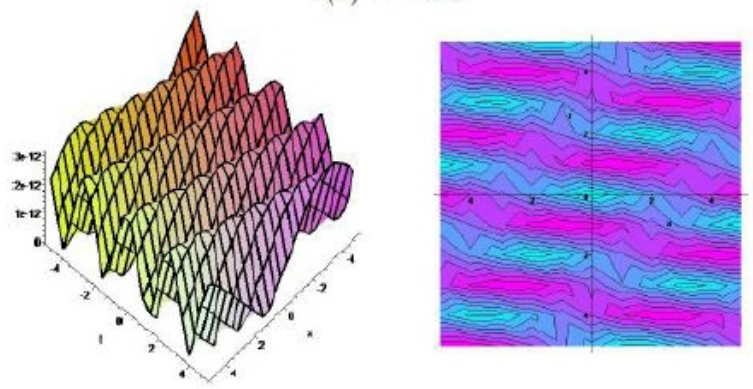
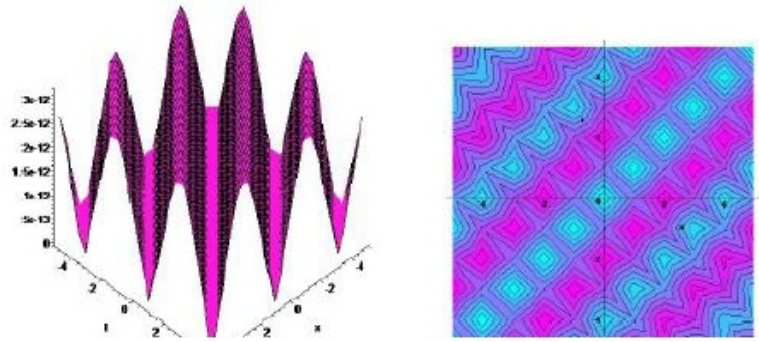
(a) $c = 0.9$



(b) $c = 1.0$



(c) $c = 1.1$

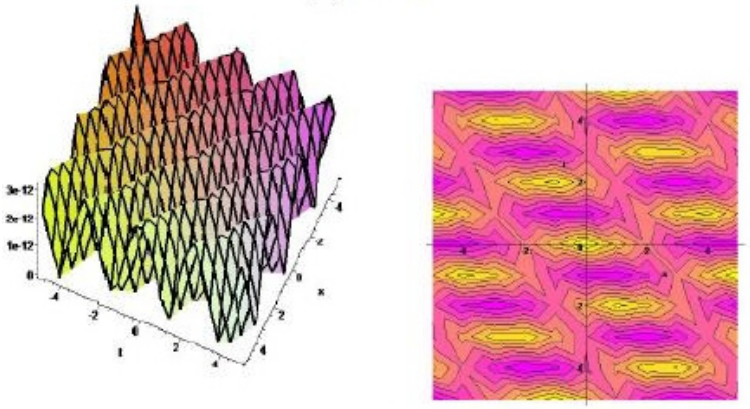
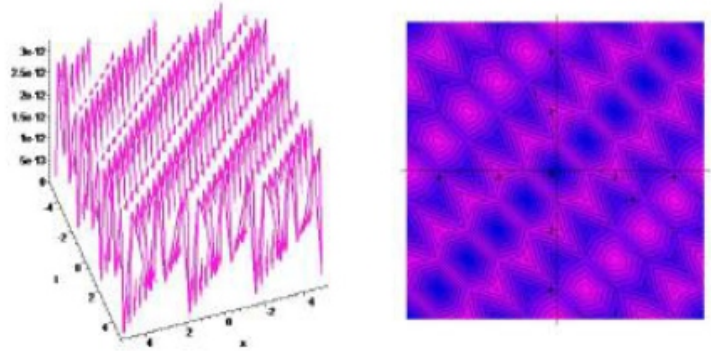
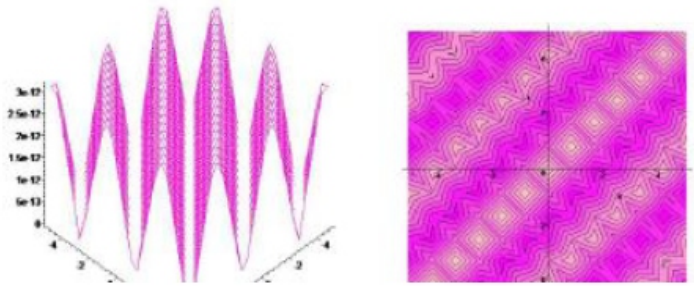


**Figure 1: Solitary wave structure for Eq. (11) by varying the value velocity (c).**

(a) $k = 0.01\text{x}10^{-12}\ Nm^{-1}$



(b) $k = 0.10\text{x}10^{-12}\ Nm^{-1}$



(c) $k = 1.00\text{x}10^{-12}\ Nm^{-1}$

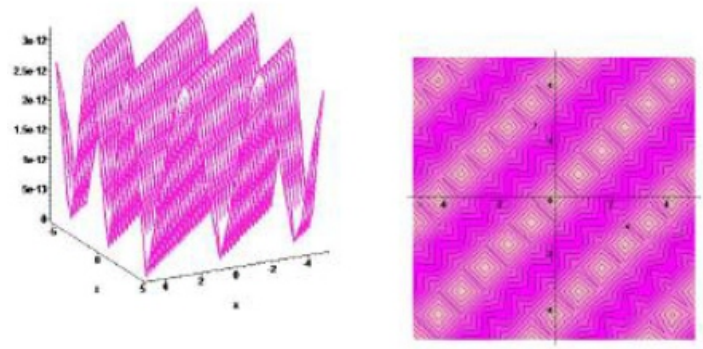


**Figure 2: Solitary wave structure for Eq. (11) by varying the value spring constant (k).**

# Shape Changing Solitons in Optical System using Analytical Method

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## ABSTRACT

*The perturbed Gerdjikov-Ivannov (G-I) equation governs the behavior of solitons in fibre optical system. We derived the solitary wave solutions of the G-I equation by implementingsech-tanh method. This method is very much helpful to construct the many solitary wave solutions such as kink/anti-kink, dark solitonic structures for different kinds of nonlinear systems. We investigated the propagation of dark solitons and shape changing antikink solitons along theoptical fibre.*

***Keywords: Optical soliton, analytical method, Fibre optics***

## 1. INTRODUCTION

Optical solitons are produced by the cancellation of the nonlinear dependence of index of refraction upon intensity and the linear chromatic dispersion [1]. Under ideal conditions, soliton pulses can travel over long distances without any distortion. In experiments, solitons are transmitted over long distances of about 10,000 km at a rate 10Gbps or more in a single-channel. When combined with wavelength-division-multiplexing (WBM), where the N channels are transmitted simultaneously, the transoceanic distances has been achieved when soliton transmitted with N10Gbps bit rates. Generally, higher bit rates per channel are allowed in soliton transmission (ashigh as 40-100Gbps over shorter distances) in comparison with other schemes such as non-return to zero (NRZ) transmission. The performance of the fibre optical systems are considerably improved, although these data rates are quite high, there is an demand for increasingly higher speed communications. This paper is mainly focused on the solitary solutions to the perturbed Gerdjikov-Ivannov (G-I) equation using analytical method in section 2. This equation is one ofthe three forms of derivative nonlinear Schrodingers equation and is studied to govern the dynamics of soliton propagation through optical fibers [2-4]. Finally, the conclusion is given in section 3.Consider the perturbed Gerdjikov-Ivanov (G-I) equation, in its dimensionless form, given as [2]

$$iu_t + au_{xx} + b|u|^4u = i\left[cu^2u_x^* + \alpha u_x + \lambda_1(|u|^2u)_x + \theta(|u|^2)_x u\right], \qquad (1)$$

where, u(x,t) is a complex function represents the wave profile, the independent variable t and xdenotes time in dimensionless form and distance along the fiber.

## 2. SHAPE CHANGING SOLITON SOLUTIONS USING SECH-TANH METHOD

Many new approaches with advantages on the one hand and disadvantages on the other hand have been suggested to solve various nonlinear equations, such as the variational iteration method [5], the homotopy perturbation method [6], the Jacobi-elliptic function method [7], doubleexp-function method [8], the modified extended tanh-function method [9,10] and others. Ouraim is to obtain traveling wave solutions of the form:

$$u(x,t) = u(\xi)\ exp\left[i(px + rt + \phi)\right], \quad \xi = x + vt, \qquad (2)$$

where v is the soliton speed, p is the soliton frequency, r is the soliton wave number and is thephase constant. Substituting Eq. (2) into Eq. (1), we obtain the ODE in the following form,

$$u_{\xi\xi}(\xi) - iA_4 u_{\xi}(\xi) + iA_5 u^2(\xi) u_{\xi}(\xi) - A_1 u(\xi) - A_2 u^3(\xi) + A_3 u^5(\xi) = 0, \qquad (3)$$

where,

$A_1 = \frac{r}{a} + p^2 - \frac{\alpha p}{a}$, $A_2 = \frac{cp - \lambda_1}{a}$, $A_3 = \frac{b}{a}$, $A_4 = \frac{c}{a} + 2p - \frac{\alpha}{a}$ and $A_5 = \frac{c + 3\lambda_1 + 2\theta}{a}$. Separating real and imaginary parts of the ordinary differential equation (ODE)

$$u_{\xi\xi}(\xi) - A_1 u(\xi) - A_2 u^3(\xi) + A_3 u^5(\xi) = 0, \qquad (4)$$

and

$$-A_4 u_{\xi}(\xi) + A_5 u^2(\xi) u_{\xi}(\xi) = 0, \qquad (5)$$

we use the following solutions in series of sech-tanh as [11]

$$u(\xi) = a_0 + \sum_{i=1}^{n} sech^{i-1}\xi (a_i sech\xi + b_i tanh\xi) \qquad (6)$$

where, $a_0, a_1, \ldots . a_n, b_1, \ldots . b_n$ solitary constants. Balancing the highest-order nonlinear term and highest-order linear partial derivative term in Eq. (3), which yields the value of n = 1. The solution of Eq. (3) takes the form

$$u(\xi) = a_0 + a_1 sech(\xi) + b_1 tanh(\xi), \qquad (7)$$

where, $a_0, a_1$ and $b_1$ are parameters to be found in terms of the other parameters. Substituting Eq. (7) into Eqs. (4 & 5), and collecting the powers of sech() tanh(), subsequently solving the system of equations with the help of Maple, we obtain the values of a0,a1 and b1 as follows,

$$a_0 = \sqrt{\frac{-3A_2}{10A_3}}, \quad a_1 = 0, \quad b_1 = \sqrt{-\left(\frac{A_4}{A_5} + \frac{3A_2}{10A_3}\right)}, \qquad (8)$$

substituting the above equation in Eq. (2), we get

$$u(x,t) = \left[\sqrt{\frac{-3A_2}{10A_3}} + \sqrt{-\left(\frac{A_4}{A_5} + \frac{3A_2}{10A_3}\right)} tanh(\xi)\right] exp\Big[i(px + rt + \phi)\Big]. \qquad (9)$$

We have plotted the above equation for optical system and obtain the dark solitonic structure with the parameter values p = 0.1,r = 0.01,v = 0.0008,= 0.2, c = 1, = 0.2, = 0.5, = 0:5and b = 1 which is shown in the Fig. (1). By increasing the value of b = 2 the amplitude of the dark solitonic structure is decreased which is depicted in the Fig. (1 b). Further increasing the value ofb = 3 the amplitude of the dark solitonic structure decreasing in the bottom region which is shown in the Fig. (1 c). Again increasing the value of b = 5 the bottom region of the dark solitonic structure decreased but there is no change in the upper region of dark solitonic structure which is shown in the Fig. (1 d). This change is obtained till the value b = 100 which is shown in the Fig.(1 e-i) for the parameter values p = 0.1,r = 0.01,v = 0.0008, = 0.2, c = 1, = 0.2, = 0.5 and = 0.5. The variations of dark solitonic structure is clearly exhibits in the corresponding contour plots which is shown in the Fig. (1 a-I).

The shape changing anti-kink solitonic structure for the optical systems are obtained by choosing the value of c = 1 with the parameter values p = 0.1,r = 0.01,v = 0.0008, = 0.2,b =0.5, = 0.2, = 0.5 and = 0.5 which is shown in the Fig. (2). This anti-kink solitonic structure changes its shape to dark solitonic

structure for c = 3 which is shown in the Fig. (2 b). Further, we get the dark solitonic structure for increasing in the value c = 5 with the increasing of its amplitude which is shown in the Fig. (2 c). Again, we obtain the dark solitonic structure with increasing the amplitude of its structure for c = 7 which is shown in the Fig. (2 d). The Fig.(2 e-g) exhibits the dark solitonic structure for c = 9, 15, 50 by choosing the parameter valuesp = 0.1,r = 0.01,v = 0.0008, = 0.2,b =0.5, = 0.2, = 0.5 and = 0.5. For c=80 the dark solitonic structure is slightly changes its shape to anti-kink solitonic structure which is shown in the Fig. (2 h). Finally, the figure completely exhibits like a anti-kink solitonic structure for c = 500which is shown in the Fig. (i). This change of structure clearly exhibits in the corresponding contour plots which is depicted in the Fig. (2 a-I).

## 3. CONCLUSIONS

We investigated the solitary wave solutions for the Gerdjikov-Ivannov (G-I) equation for optical systems by using the sech-tanh method. In this paper, we studied the influences of the coefficient of quintic nonlinearity term and the coefficient of perturbative term c which gives the variations in the dark optical solitonic structure and the shape changing property of kink/antikinksolitonic structure.


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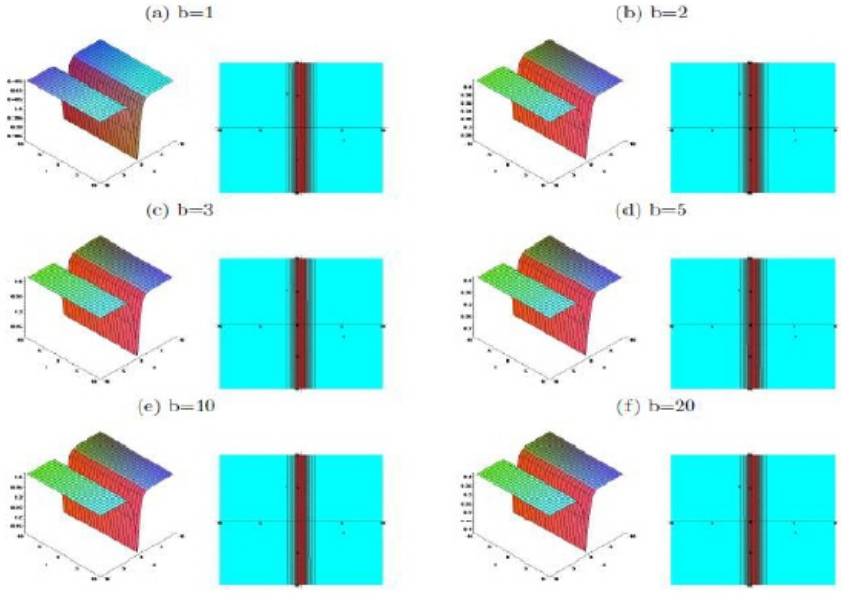


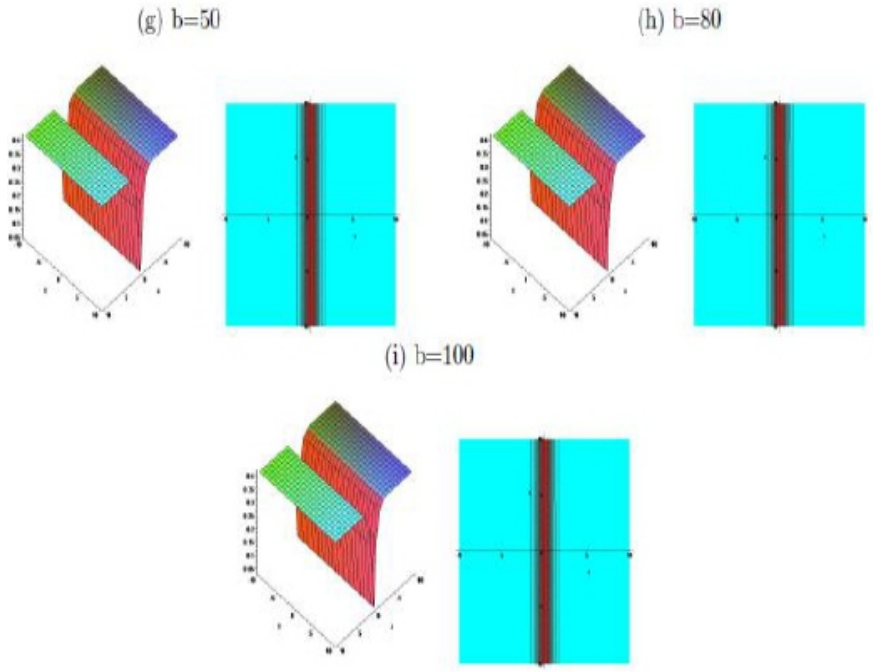
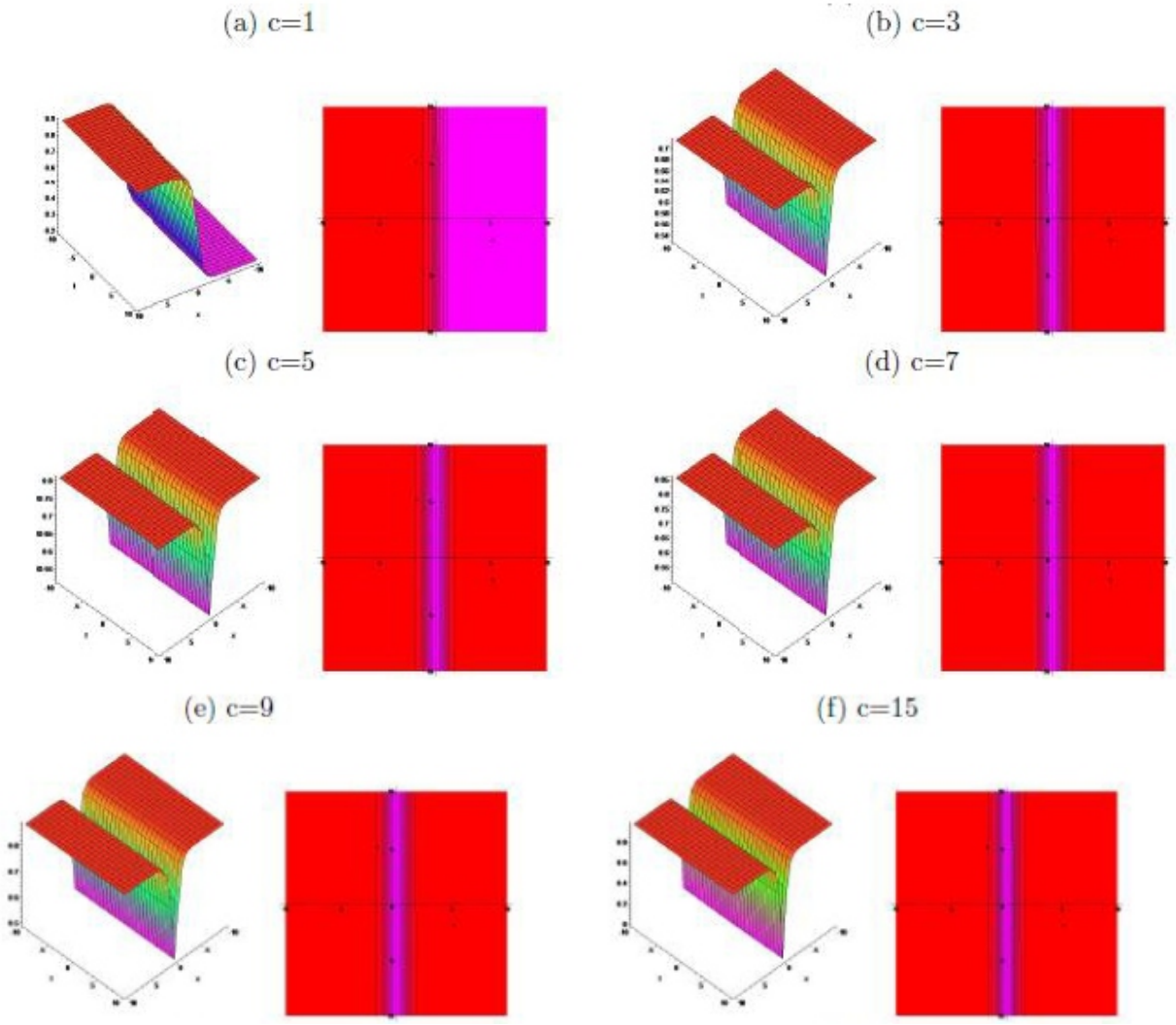



**Figure 1: Profile of dark solitons for Eq. (9).**



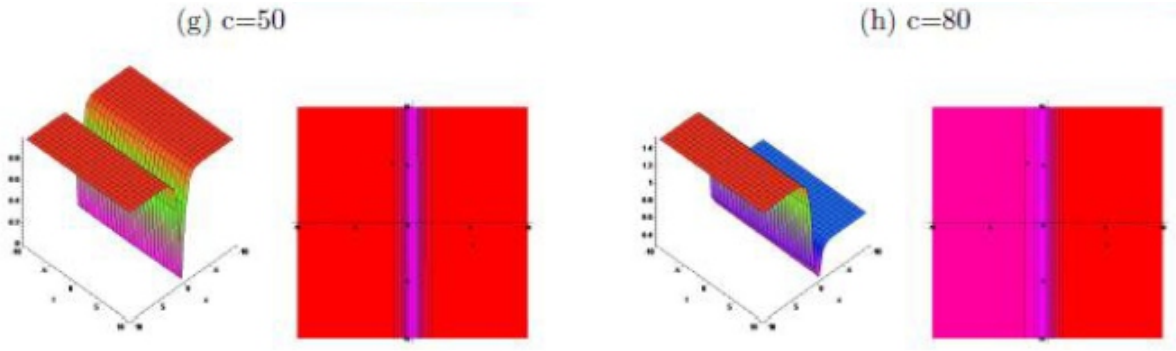



**Figure 2: Shape changing anti-kink soliton through dark soliton for Eq. (9).**

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