Distribution of profiles in relation to solitonic width for graphene nanolayer in high power regime

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1. Abstract

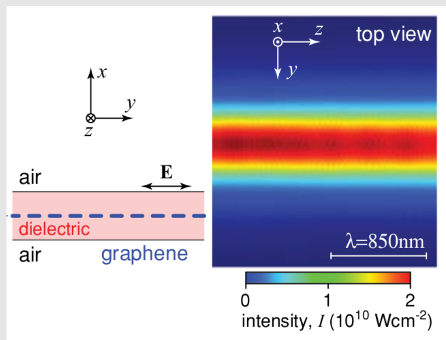
The propagation of bright solitons in a high power regime in a graphene sheet is studied, where the alteration of the fraction of flowing energy within the sheet causes the variation in the propagating solitonic peaks, which when compared in relative unit allows confirm that the latter only depend on the length of the soliton. Finally the relation is proposed $\kappa = \rho_i/\rho_j$ showing the magnitude between solitons i j close or approaching to 2 μm and an application to characterize width of films with non-linear susceptibility.

2. Introduction

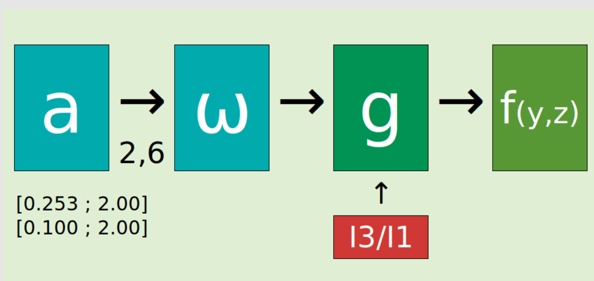
The soliton is a type of solitary wave that can propagate in a non-linear medium, it does not disperse so it preserves its identity during propagation. It was described for the first time in 1834 by JS Russell [1], as an example of a soliton that does not need a material medium to propagate is the gravitational soliton, better known as gravitational wave [2]. Matematically, a soliton is a solution to a wave equation with a non-linear term, such as the Korteweg-deVries equation (KdV) [3]. Solitons are also present in the Yang Mills magnetic monopole theory, these solutions are stable and must be observed in nature as material objects [4]. By imposing conditions of interest, such as a null potential in the Nonlinear Schrodinger Equation (NLSE) [5], solutions can be obtained in a bright soliton-type Kerr medium. This can be described as a high propagation over the background of uniform density. In this work a study is carried out on the bright soliton because it allows modeling the propagation of electromagnetic waves in a graphene sheet.

3. Methodology

The complete non-linear time-dependent Schrodinger equation is broken down by making a separation of variables to obtain the bright soliton among its first analytical solutions. This solution represents a self-focusing concentration in a space of zero density in a non-linear medium, in [6] the computational propagation of solitons in graphene is studied



developing an analysis on the propagation of solitons in graphene films on $SiO2$ and Au in a high power regime ($I > 10^9 W/cm^2$). In this work, it is proposed as a contribution to make an outline about the behavior of solitonic profiles, taking different values of the fraction of electromagnetic energy that flows within graphene and evaluating the effects.



The process to follow to obtain solitonic functions is described:

1. We scale the values for the soliton width a between 0,1 and 2μm with a jump of 0,01μm, obtaining a base array of 190 elements.
2. With the proportionality factor 2.64 we obtain the measurements of the lateral beam ω.
3. Each coupling value is computed g for each part of the energy fraction of I_3/I_1.
4. Obtaining solitonic functions.

For the fraction of flowing energy $I_{3/1} = I_3/I_1$ we use:

$$\frac{I_3}{I_1} = \frac{\int_{-dgr/2}^{dgr/2} dx|A(x)|^4}{\int_{-\infty}^{\infty} |A(x)|^2} \tag{1}$$

where $A(x)$ is a component of the vector potential $A(r)$ and d_{gr} is the thickness of the 0.3 nm sheet. The family of functions $f(y,z)$ is of the form

$$f(y,z) = \frac{1}{\omega}\sqrt{\frac{2}{g}} sech(\frac{y}{\omega}) e^{iz/2\beta\omega^2} \tag{2}$$

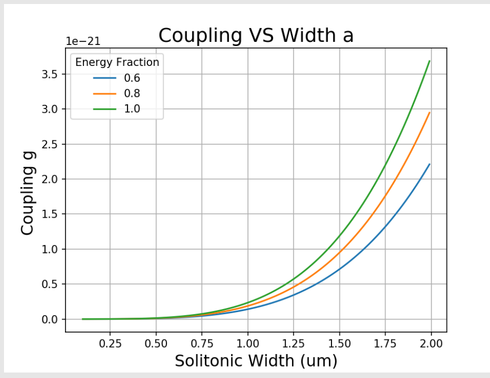
of hyperbolic secant profile, being of our interest $\rho = |f(y,z)|^2$, which describes the density profile of the propagating soliton in graphene.

$$\rho_i = |f_i(y,z)|^2 \tag{3}$$

Finally, we normalize each density.

4. Results

4.1. Coupling

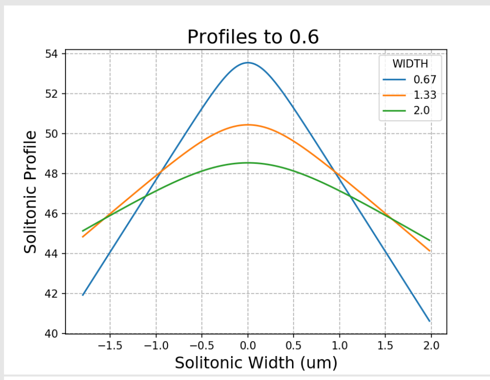


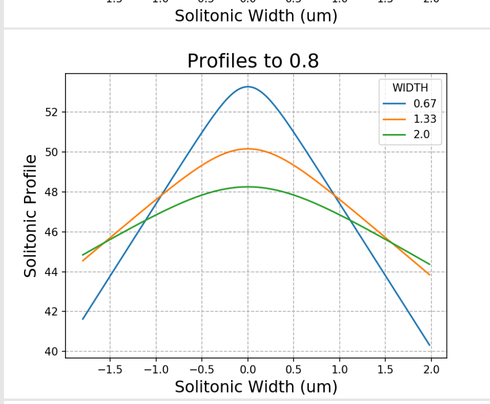
The first result shows the shape of the dependence between the soliton width and the coupling g for three chosen values of the fraction of flowing energy within the graphene sheet. The values used to obtain the results were 0.6, 0.8, and 1.0. These for the purpose of illustrating an answer.

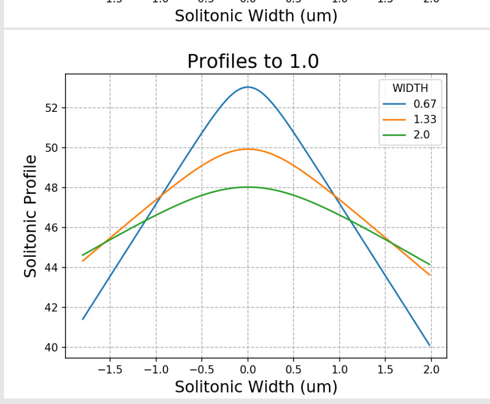
$$g = \frac{3}{4}\frac{\omega^4 \chi_{gr}^{(3)}}{c^2}\frac{I_3}{I_1} \tag{4}$$

$\chi_{gr}^{(3)}$ is the third-order nonlinear susceptibility of graphene $2,095{,}10^{-15} m^2/V^2$

4.2. Soliton profile

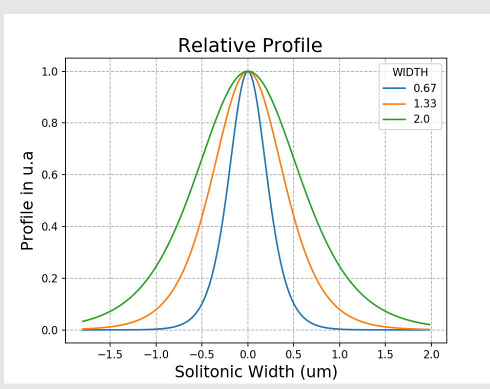






To obtain the solitonic peaks, the results of the coupling were used for soliton widths of 0.66, 1.33, and 2.0 μm, for a better visualization of the behavior, it was plotted on a logarithmic scale.

4.3. Relative soliton profile



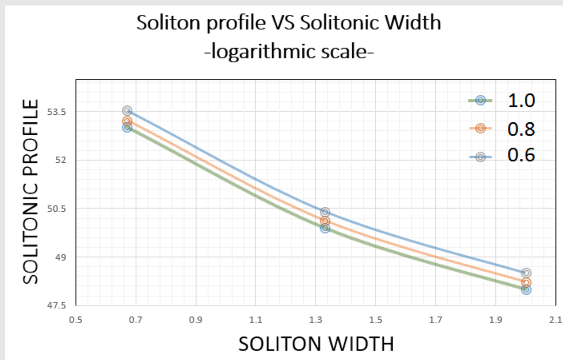
The relative soliton profiles were obtained by performing the quotient between the soliton profiles for each $\frac{2}{g\omega^2}$ proper to each soliton length and energy fraction, obtaining similar graphs for 0.6, 0.8, and 1.0.

5. Discussions

The behavior of propagating solitons in graphene in a high power regime studied in [6] is reported as a function of soliton width a, coupling g and the fraction of flowing energy within the graphene film. In the first result, the coupling depends proportionally on a^4. This helps to mathematically imagine the behavior of the soliton profiles since they depend inversely on the coupling and the lateral beam measurement. The resulting solitonic profiles are summarized in the following table in relation to their maximum peaks distributed by the soliton width,

Soliton peak $I_{3/1}$ Vs Width (in log)

Width(um)	a=1.0	a=0.8	a=0.6
0.67	53.03	53.23	53.53
1.33	49.90	50.13	50.41
2.00	48.00	48.23	48.51



with the peaks of the soliton profiles, and the respective couplings, we can predict the electric field **E** strengths required to generate specific solitons in a longitudinal or sublongitudinal regime with respect to the input pulsed beam, The one used was 850 $nm(0.85\mu m)$, this limit is between 0.66 and 1.33 μm in the attached graph. In the set of the last result, the normal profiles are illustrated in terms of amplitude, they do not depend on the width of the soliton or the contribution of the fraction of energy in the sheet. They are obtained from $sech^2(y/\omega)$, when doing an analysis regarding the 0.6, 0.8, and 1.0 fractions they, turn out to be identical, seen from the form of the argument, it only depends on the quotient of the position by the measure of the lateral beam y/ω, leaving aside arguments of percentage of flowing energy or of specific solitonic widths that only affect the amplitude of the wave. It can be concluded that the solitonic profiles in graphene acquire greater amplitude as the energy fraction decreases due to the broadening of I_3.

It is proposed that, if we want to explore an evolution from a soliton i to a soliton j, we can start by relating its quotient $\frac{|f_i(y,z)|^2}{|f_j(y,z)|^2}$, where if the jumps are small to each other or are close to greater than 2 μm, they are related by κ. This helps to reduce the number of variables for the construction of a soliton neighborhood.

$$\kappa = \frac{\rho_i}{\rho_j} = \left(\frac{a_j}{a_i}\right)^6 \frac{I_{3/1}^j}{I_{3/1}^i} \tag{5}$$

One application of the results would be to use measurements of the experimental soliton propagation of a material with non-linear susceptibility in high power regime at a constant wavelength (for example a laser at 850 nm). Hence the denominator of $I_{3/1}$ to a potential fixed vector becomes a constant

$$\varepsilon = \frac{I_3}{I_1} = \frac{\int_{-dgr/2}^{dgr/2} dx|A(x)|^4}{\int_{-\infty}^{\infty} |A(x)|^2} = \frac{\Phi|_{-d_{gr}/2}^{+d_{gr}/2}}{constant} \tag{6}$$

being Φ the integral of I_3 evaluated for thickness d_{gr} of the material, one could find for each experimental measure the corresponding value of d_{gr} of the sheet taking advantage of the logarithmic scale separation seen previously in order to be able to characterize the thickness of the material.

6. Bibliographic references.

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