Performance Enhancement of the Solid Saturable Absorber for Laser Passive-Switching at 1.353 µm

تحسين انجاز الماص القابل للاشباع الصلب لعمليه مفاتيح عامل النوعيه السلبي لليزر 1.353 مايكرومتر

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ABSTRACT

In order to approach the ideal conditions to optimized the performance of the 10mm CaF_2 crystal which is containing(5%) standard mixing of uranium ions as proposal saturable absorber element model for Q-switching laser operation in the spectral wave length around 1.353 µm, the main aspects of this investigation are accomplished by means of the analytical treatments and direct calculations of derived equations as well as several programmed plotted graphs are obtained and applied to evaluated the most important active influences parametric and its effect on this type passively Q-switching laser operation such as, the output pulse peak power, the pulse energy, the depth modulation as well as the absorption cross-section and the nonlinear reflectivity .

The comparing of the interpolated results for this work with the different wave length ranges and by another materials types are strongly agreed with the earlier researchers calculations . Slightly different with some researcher measurements were owing to experiment errors as well as, which were because of the close estimations and the high precise treatments of this work . The errors percentage were only 4-5.8%, which are seem insignificant its influences on the essential goals for this work

The results are very satisfied to applied this proposal model as optimum controlling element for the passively Q-switching laser operation at 1.353 µm ●

الخلاصـــــــة //

البحث لايجاد افضل الشروط اللازمه لتحقيق الانجاز الامثل لبلورة فلوريد الكالسيوم المطعم بنسبة قدرها 5% من عنصر اليورانيوم وبطول قدره 10 ملي متر , كماده اساسيه تعمل كمفاتيح عامل النوعيه السلبي لليزر طول موجته 1.353 مايكرو متر .

كانت النتائج المعتمده على المعالجات التحليليه والقيم المحسوبه ووفقا لمعادلات رياضيه اشتقت لافتراضات تطابق الانجاز المثالي لمثل هده العمليه مع تطبيق الخصائص البصريه الخطيه واللاخطيه المثاليه للنمودج المقترح واعتمدت كمدخلات لبرامج فرعيه بلغه الفورتران ولاكثر العوامل(البارمترات) المؤثره على انجازها لعملية مفاتيح عامل النوعيه السلبيه لليزر.

وكانت النتائج مشجعه لتحقيق مثل غايه البحث الرئيسية كما وانها كانت مطابقه عند معايرتها مع اطوال موجيه لمديات مختلفه و لمواد صلبه متقاربه من خواصها البصريه لنتائج دراسات نظريه لباحثين اخرين واختلاف بسيط لايعتبر مؤثرا في مثل اهداف هدا البحث مع قياسات عمليه سابفه .

1. INTRODUCTION

One of the most useful and the famous way among several ways of achieving high power pulses with short duration is Q-switching technique.

The possibility of Q-switching laser was first proposed by Hellwarth in 1961[1]. In practice, Q-switching can be achieved by deflecting the beam at the high reflecting mirror mechanically (Collins and Kisliuk, 1962)[2] or by acousto-optic (Koechner, 1976) [3] or electro-optic (Hellwarth and McClung, 1962)[4] devices or by using an opaque satiable absorber (Soffer, 1964)[5] , which bleaches and become transparent when the fluorescent light output reaches a given level.

The first three methods of Q-switching are active types, where the switching of the laser light occurs externally, which are difficult to implement, complex for installation, alignment and operation.

Besides of these active methods laser also can be easily **switching passively** as, mentioned in the fourth method. This technique potentially offers an advantage of low cost, reliability and emission of pulses with a relatively narrow line width (Koechner, 1976) [3]. It is also simple in fabrication and operation since it requires no high voltages or fast electro-optic devices[5,6].

Crystal of calcium fluoride CaF2 containing uranium ions have been used to passively Q-switch at 1.54 μm (Er:Yb):glass laser[7-9], a recent studies reported appreciable excited state absorption (ESA) at 1.573 μm assuming divalent uranium(U+2) as the absorber and details of the complex absorption spectra depend on the methods and materials used to dope and grow these crystal materials were chemical activity studied[10-12].

Interpretation the optical spectra has been problematic ever since Conway [13], published an analyses of the absorption spectrum in 1959.

Hargreaves [14,15] characterized CaF2:U crystals by their wavelength of green, red and yellow and proposed that the numerous absorption lines and bands were due to transitions between crystal-field split state of divalent, trivalent, and tetravalent uranium ions in the green, red and yellow crystals, respectively, located in different charge-compensated site. That the green CaF2 crystal would be the only known sample of U+2 occurring in the solid state made the verisimilitude of this particular assignment doubtful.

Subsequently, based on chemical analyses and spectroscopic arguments, Mc.Laughin et al. [16], proposed instead that the green CaF2:U crystals contained mostly U+4 ; their conclusions that the red crystals contained a mixture of U+3 and U+4 and the yellow crystals contained the uranyl complex UO+2 in different charge-compensated site, are substantially consistent with the investigation of Hargreaves [14, 15].

To elucidate the details of the spectra, Hargreaves provided Gruber and his colleagues [17, 18] with samples of green and red CaF2:U crystals for site-selective spectroscopy measurements. A comparative study between the transmittance and the site-selective laser excitation and fluorescence spectra of both crystals led these investigators to the identification of different charge-compensated site for U+4 in the green crystal and different site for both U+4 and U+3 in the red crystal. Depending on whether Hargreaves had used UO2 or UF4 as the doping in growing crystals, Gruber et al. [17] found differences in the spectra that were traced to uranium ions in different sites. Two sites of U+4 that were identified in the green crystals. These two sites was also identified from electron spin resonance studies on CaF_2:U+4 reported earlier [19].

Recent interest in improving the optical properties of the green crystals for use as a saturable absorber in laser transmitters has led to re-examination of the methods used for growing crystals and the absorption spectrum from high purity different crystal types have reported [12].

In this work fluoride calcium , CaF_2 crystal is very suitable chosen element for this passively switching laser operation around 1.353 μm owing to its higher transparency, lower refractive index limiting the nonlinear effect and lower photon-energy to reducing the no radiative relaxation between the energy level caused by the lower photon frequency as well as high withstand thermal .

The aim of this work is accomplished to approach the ideal conditions to optimize the performance of this CaF_2 model, which is assumed to be has thickness equal to 10 mm and containing standard 5% uranium as the application element of the passively Q-switching at the sharply 1.353μm wave length laser●

2. Principle of the Passively Q-switching operation

Passive Q-switching received its name from the action of generated radiation itself as mentioned earlier by Smith and Soroken in 1964 and 1966 [6,23]. Passive Q-switches can be used with pulse pumped systems only in the range of infra and far infrared wavelengths because a CW pumped laser never produces sufficient fluorescence to bleach either the dye (Kuhn, 1998)[20], or the solid satiable absorber such as, crystal of calcium fluoride which is the basic substance for our model construction in this investigation.

In this type Q-switching operation, the absorbing molecules of the material are transferred to excited state, and the material become transparent and the switching is opened. The essential of this passively Q-switching method is the bleaching process inside the material either dye or solid, therefore in the following section this processing is deeply described.

The saturable absorbers which are using as element for passive Q switching or mode locking of lasers depend on the physical idea that the relationship of the light absorbers with a degree of absorption which is decreases at high optical intensities.

The saturable absorber is an optical component with a certain optical loss, which is reduced at high optical intensities. This can occur, in a medium with absorbing doping ions, when a strong optical intensity leads to depletion of the ground state of these ions. Similar effects can occur in semiconductors, where excitation of electrons from the valence band into the conduction band reduces the absorption for photon energies just above the band gap energy.

2.1 Bleaching processing mechanism

Passive Q-switching consists of a saturable absorber placed inside the optical cavity, between the active material of the laser and the high reflection mirror as shown in figure 1.

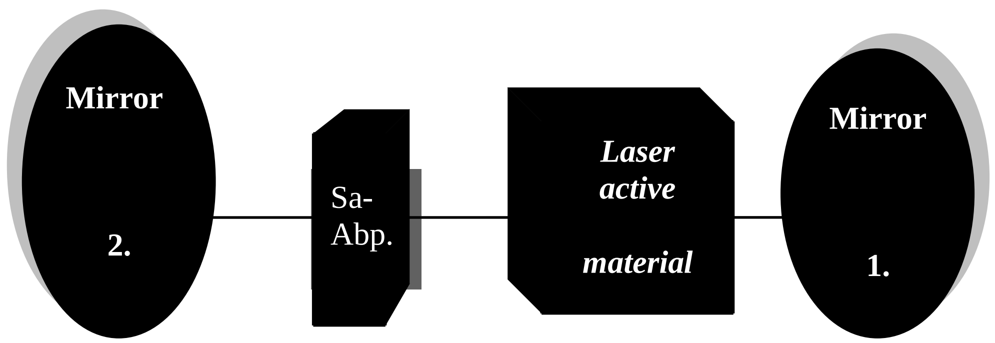

Figure 1, The saturable Absorber configuration for passively Q-switching

The saturable absorber either dye or solid material, whose absorption is decreasing with increasing light intensity as shown in figure 2.

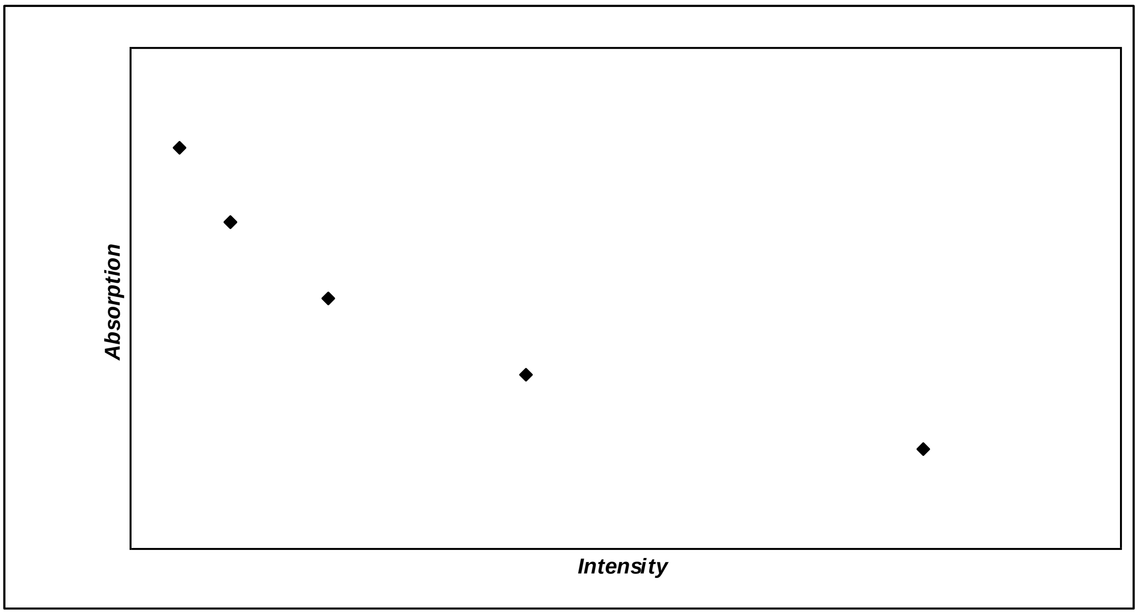

Figure 2, The absorption as a function of incident light intensity [21]

The solid material absorber are strongly absorb the light of the active material frequency, and this absorption prevents net amplification until a much large proportion of satiable absorber molecules have been pumped the excited state. The pumping energy input increases until amplification in the active material overcomes the loss due to absorption in the cell, and the laser begins to emit coherent light weekly. A very small amount of this weak laser light bleaches the saturable absorber either the solution or black of the solid, which then becomes almost perfectly transparent to the active material light. At this instant, there is suddenly a large net amplification and a narrow pulse that containing at the stored energy in the lasing medium, develops rapidly.

Usually, this Q-switching pulse energy is lower compared to the normal operation laser, owing to the losses and the absorption of the photon along the instant of the Q-switching process. However, the peak of this Q-switched laser pulse power is much higher short duration (less than nanoseconds range) . So, the output peak power Q-Switching laser pulse is computed in this work according to the Zehang relationship[3]:

Peak Power = Pulse Energy / Pulse Duration ………(1)

In passive Q-switching, this saturable absorber is used to introduce a variable loss in order build up the light in the cavity until bleaches, in this case the cavity opening suddenly to emitted very short pulse so called Q-switching pulse. After emitted this giant laser pulse, the molecules returning quickly to its absorbing and beginning build up of the next narrow pulse and so on [3].

Passive Q-switching are used the organic dyes as saturable absorber, but this dyes cell is highly absorption and low intensity, as well as this dye Q-switches suffer from poor chemical stability and inadequate thermal properties. To overcome this problem a few semiconductors such as, fused silica and CaF_2 crystals have chosen for this type Q- switching operation. However, the other benefits of saturable absorber are only one optical component and no complex electronics.

2.2 Material description and its properties

Calcium fluoride which is indicated as, CaF_2 and an insoluble ionic compound of calcium and fluorine, it occurs naturally as the mineral fluorite (fluorspar) and it the source of the most fluorine. This insoluble solid adopts a cubic structure where in calcium is coordinated to eight fluoride anions and each F^- ions is sounded by four Ca+2 ions[21]. Although the pure material is colorless, the mineral is often deeply colored due to the presence of F-centers.

Naturally occurring CaF2 is the principle source of the hydrogen fluoride, commodity chemical used to produce a wide range of material. Fluoride is liberated from the mineral sulfuric acid:

$$\mathbf{CaF(S)+H2SO4(L)\rightarrow CaSO4(S)+2HF(G)}$$

The resulting HF is converted into fluorine, fluorocarbons and divers fluoride materials.

Calcium fluoride is appearance white crystalline solid as single crystals and virtually insoluble water. The most physical and chemical properties are listed below in table 1.

Table 1, Specification and properties of 10mm thickness CaF2 for optical crystals [22]

Transparence range µm	*Crystal structure*	**Lattice constant**	*Density g/cm3*	*Mohs hardness*	*Refractive indexes*	*Solubility in g/100g water at 18 C*	*Clear aperture*	**Diameter tolerance mm**	*Thickness Tolerance mm*	*Flatness 0.633 µm*	*Optical loss at 4µm*
0.15-9.00	*cubic*	5.462	*3.18*	*4*	*1.6921-1.3161*	*0.0016*	*90 ٪ of Demeter*	*± o.1*	*± 2*	*λ/4*	5.6٪

The commonly application of Calcium fluoride is used as optical crystal and window material for both infrared and ultraviolet, owing to it is low loss optical windows, prisms, lenses, achromatic lenses and parallel planes can be fabricated from theses materials as well as its good transparent from 0.15 µm to 9µm and extremely exhibit weak birefringence[3]. Furthermore these materials are fairly inert chemically so that these windows are not attacked. Nevertheless, at wavelengths as low as 0.157 µm, which are interesting to semiconductor manufacturers, the birefringence of the calcium fluoride (CaF_2) exceeds tolerable limits[21]. This problem with birefringence can be mitigated through optimized growth process. It is practically important as, an ultraviolet materials for integrated circuit lithography. Calcium fluoride are used in some components in some application laser lenses to reduce the dispersion of the light in wide wavelength range, its from the ultraviolet to far infra red region, these types crystals are widely applied to the entire optical wavelength range form ultraviolet (0.11 µm) to far infrared(40µm).

Uranium-doped calcium fluoride was the second type of the solid state laser invented by Peter Sorokin, and later achieved at 2.5 µm shortly after Miamian's ruby laser [23].

The most important parameters of this type satiable absorber, which are studied in this work are listed in the following:

-**The modulation depth,** i.e. the maximum possible change of optical loss

- **The insatiable loss,** i.e. the part of the loss which can be not saturated.

-**The recovery time,** i.e., the decay time of the excitation after an exciting pulse, its energy per unit area by 1/e ≈ 37% .

-**The saturation energy,** i.e. the saturation influence times the mode area.

- **The saturation intensity,** i.e. the optical intensity (power per unit area) it take in a steady state to reduce the absorption to one half its unbleached value.

- **The saturation power,** i.e. the saturation intensity times the area mode.

3. Analytical treatments on influents the parameters of the passively Q-switching operation

This study is supplemented by the following analytically treatments on the bleachable absorber operation and its influences on the output of this passively Q-Switching.

In order to understanding this non-linear optical effect by means of the general and basic interaction transients between, the light and material, we can consider bleachable absorber to represent able by a simple two-level with population densities N_2 and N_1 for energy level E_2 and E_1. When a beam of light interacts with a material, three fundamental phenomena will occur, namely, the process of spontaneous and stimulated emission as well as the process of absorption as description earlier by Smith and Sorokin [6].

For the level E_1, the population density changing due to the absorption is given by:

$$(d N_1 / d t) = - \sigma_{12} F \quad \ldots\ldots\ldots\ldots (2)$$

$$W_{12} N_1 = \sigma_{12} F \quad \ldots\ldots\ldots\ldots (3)$$

Where, F , σ_{12} , W_{12} are, the photon flux of the incident light, the absorption cross-section and the absorption probability respectively.

The absorption process populates level 2 can be here expressed by:

$$(d N_2 / d t) = - W_{21} N_2 \quad \ldots\ldots\ldots\ldots (4)$$

The processes of the spontaneous and stimulated emissions are depopulated level 2 by the following rate equations:

$$(d N_2 / d t) = - A_{21} N_2 \quad \ldots\ldots\ldots\ldots (5)$$

$$(d N_2 / d t) = - \sigma_{21} F \quad \ldots\ldots\ldots\ldots (6)$$

Also,

$$\sigma F = W N_2 \quad \ldots\ldots\ldots\ldots (7)$$

Here, σ_{21} is represented the stimulated emission cross section **.**

With the relation case of this our aim work model, the stationary case became where is:

$$d N_2 = 0 \quad \ldots\ldots\ldots\ldots (8)$$

Then the suitable solution for this condition is become as the following expression:

$$N_2 / N_1 = (W_{12} / W_{12} + A_{21}) \quad \ldots\ldots\ldots\ldots (9)$$

If we assuming the laser is pumped with high values pumping rate as, it is one of the assuming parametric conditions which have been applied on this our investigation model, in this case the absorption probability became extremely higher then the spontaneous emission:

$$W_{12} \ggg A_{21} \quad \ldots\ldots\ldots\ldots (10)$$

Therefore, the equation 9 became as:

$$N_2 / N_1 \approx 1 \quad \ldots\ldots\ldots\ldots (11)$$

The physical meaning of this equation (11), is that the number of the absorbed photon becomes the same as the emitted ones. According to this condition the material is transparent and the pulse of the laser can be suddenly emitted with the output energy can be given by the following general expression for passive Q-switched [20,5].

$$E= (h\nu A/2\gamma\sigma)\rho \ln(1/R) \quad \text{……….. (12)}$$

Where, hv, A,σ, γ, and R are the laser photon energy, the effective laser beam area, the spectroscopic cross section of the laser transition, the inversion reduction factor and the reflectivity of output mirror respectively and the parameter ρ can be expressed by the following equation:

$$\rho= \ln(n_i /n_f) \quad \text{…………… (13)}$$

Where, n_i and n_f are the population inversion density at the onset of the Q-switching operation and the final population inversion density after the passage of the Q-switched pulse. Also the parameter ρ can be related to others parameters as shown in the following expression:

$$[1-1/\rho\{1-\exp(-\rho)\}] = \varphi\, [1-(1/\alpha\rho)\{1-\exp(-\rho\alpha)\}] \quad \text{…………. (14)}$$

Where,

$$\varphi= (1-\delta)[\ln(1/T_o)/\ln G_o] \quad \text{............ (15)}$$

and α , δ , T_0 and G_0 are the ration of saturation energy , the inverse of the optical modulation depth, transmission and the gain respectively.

If the transmission of this CaF_2 for only one way passing i.e only one half tripe and by assuming the effective beam area in the gain laser equal to the effective area of the satiable absorber, therefore the ratio of the laser saturation energy to the absorber saturation energy can be calculated by:

$$\alpha = \sigma_{gs} / \gamma\sigma_{es} \quad \text{………… (16)}$$

Where, σ_{gs} and σ_{es} are the absorption cross-section of the ground and excited state, respectively.

The peak power (P) of the general passively Q-switched laser can be calculated by means of the following equation:

$$P= (h\nu A \ln G_o / \gamma\sigma\tau_r\, \rho) \ln(1/R)[(1-1/\alpha)] \quad \text{………….. (17)}$$

In order to approach the rough approximation for 1.353 μm range modulation with this CaF_2 type, the values of $G_o \approx 2$, and by dividing the equation (19) in to equation (14) , the laser pulse width (τ_p) is yielding by the following expression:

$$\tau_p \approx (13.328\, \tau r\, \rho)/(1-1/\alpha) \quad \text{…………… (18)}$$

But for more precise estimated with the fully saturated absorber condition can evaluate by the following equation:

$$(\tau_p)_{ful} =1.56\, L/ \Delta\Theta \quad \text{……….. (19)}$$

Where, L, ΔΘ are optical length and the maximum modulation depth respectively.

4. The model construction and its influences on the characteristics of the operation of the passively Q-switching

According to these above analytically treatments, the optimization values of the absorption cross section of this type material, the output pulse energy, the peak power and the pulse width of the laser were programmed by Fortran-V.90 , computed as shown in table 2 and also by the programmed plotting, as shown in figures 3-4.

The input data of the theoretical computations were constructed by means of applying the above derivation equations(12,17,18) and using the following assumptions:

-The roundtrip losses was assumed to be equal zero(i.e negligibly) , owing to be very small compared to the high roundtrip gain

-The laser beam area was assumed to be constant and equal to ≈ 1.5ωω where ω≈ 60-120 μm with the pumped power in the range 3-15 Watt.

-Satiable absorber cross-section for the ground and for excited states were used the values of Burshtien measuring[10], which are equal to 7×10 18- and 2×10 -18 cm"

-The cross-section and the inversion reduction factor of according to this our model conditions and by well compared to reference[11] were assumed to be approximately equal to 6×10-19 cm2 and 0.45 respectively.

Table 2, Evaluated parameters of an operation Q-switching with the satiable absorber of 10mm-5% U+4 CaF2 crystal at 1.353 μm with repetition rate of 350 Hz

Pumping power Watt	***Pulse Energy μJ***	***Pulse Width nsec***	***Peak Power KW***	***Peak Intensity mW/cm^2***
1	12.1	800	12.5	64
3	15.4	1400	11.2	22.6
5	19	2500	39.7	34
7	22.5	1600	120	145
9	26.7	410	135.5	159
13	30.4	1200	195	210
15	31.5	1550	210.8	225

The sensitivity of the both of these parametric, the peak power and the peak intensity of this passively model Q-switching are proportional with the pumping powers and seem to be goes with the same ratio as shown very clear in Figure 3.

The point of the optimal performance of this model also, shown in figure 4, where the minimum width of the producing pulse is coincident with maximum pulse energy;

Both of these above two results are indicated that our treatments and evaluations were agreement with the basic principals and optimal performance conditions of the general Q-switching laser operation**.**

Therefore, the following parts of this investigation is worthy to further extend to construct and apply the optimization conditions for the passively Q-switching at 1,353 wavelength by means of this proposed type CaF_2.

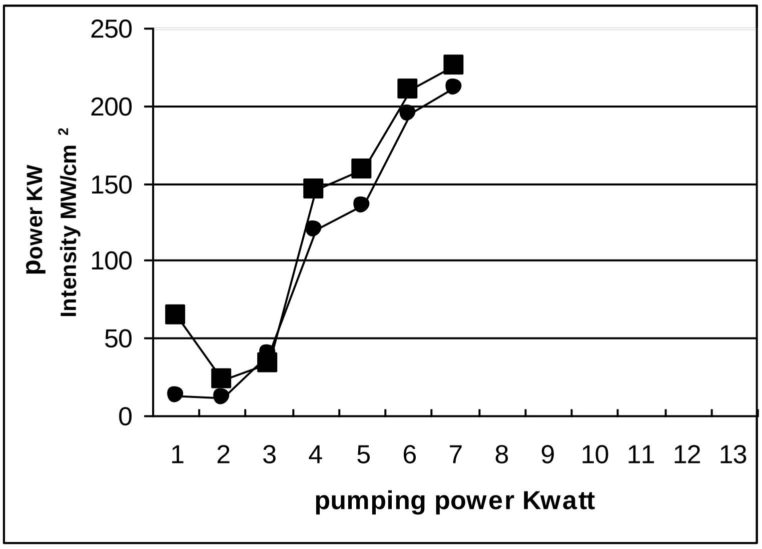

Figure 4, Dependences of the peak power and peak intensity of the CaF2 passively Q-switching 1.353 μm wavelength

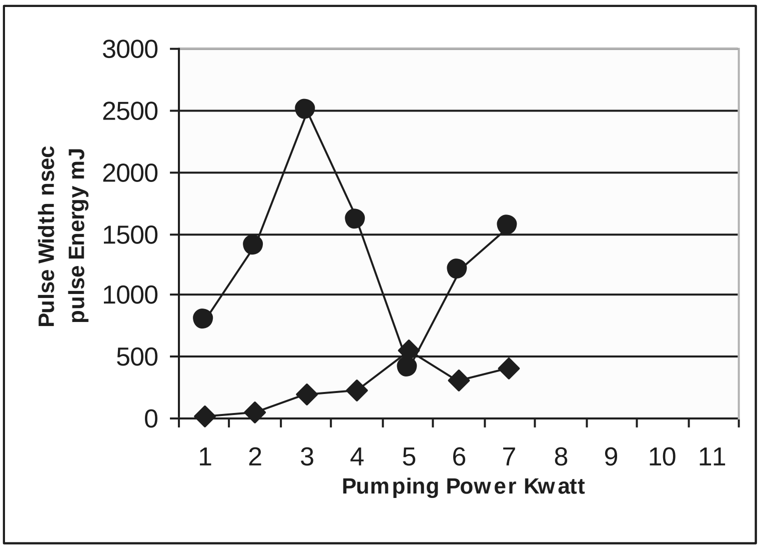

Figure 5, Dependence of the Q-switching pulse Width and pulse Energy on the Pumping power with Passively CaF2 application

4.1 Calculation of saturable absorber coefficients

In the case as the aim of this investigation, the quantity of the saturable absorption coefficients are defined with respect of the two most important parametric, the absorption recovery time (τ_A) and the laser pulse power (p), which is well evaluated from figures 3-4, . Both of these two parametric can be related together and estimated by the following equation:

$$dP / dt = - [\{(q-q_o) / \tau_A \} + \{(q \times p) / E_{sat}\}] \text{ ………….. } (20)$$

Where, qo is the corresponding quality of the satiable absorptions coefficients in the equilibrium with no interaction power, i.e $P \approx 0$.

E_{sat} is denoted as the absorber saturation energy which is represented as the production of the absorber saturation ifluence and the effective laser mode area on the satiable absorber ..

The above equation can be solved for the time elapsed during pulse as:

$$E_{sat} = F_{sat} * A_{eff} \text{ ……………. } (21)$$

Where, F_{sat} is the influences of the saturation absorption i.e the full absorption effect, which is used to evaluated the corresponds of the pulse influence and very important to study with regard to one of the main goals for this investigation.

A_{eff} here is the effective absorption which can be bleaching the satiable absorption equal to **1/e** of the maximum amount of the absorption (with the interaction of the pumping power which is denoted as, **q**).

In such CaF_2 crystal material, the absorber recovery time can be designed within a wide range, therefore we can assume that the absorber time to recovery the pulse of the laser (τ_A), must be shorter than the cavity round-trip time. According to this our estimated which is also valid for all semiconductor material, it is possible to neglect the relaxation term in the above equation during the time of the pumping laser pulse to pass the CaF_2-absorber crystal material and the absorber is fully recovered before the next pulse reach the absorber crystal again.

The loss in the pulse energy for only one trip (L_{Ep}), , which is caused by the crystal material absorption is, also be an important parameter for the field of such investigation and can be evaluated by the following expression :

$$L_{Ep} = (q_o / E_p)\ (F_{sat} \times A_{eff})\ [\ 1- \exp\{ E_p / (F_{sat} \times A_{eff}) \}] \ldots (22)$$

Where, Ep is the energy of the pulse.

From the above relations, it is can be assumed the following expression to evaluated the nonlinear reflectivity with the regard pulse energy, (R_{Ep})), which is also important parameter for this Q-switching laser operation:

$$R_{Ep} = 1-[\ \Delta R\ \{(F_{sat} \times A_{eff}) / Ep \}] \ldots\ldots\ldots\ldots\ldots\ldots (23)$$

According to the definition of the pulse energy, which is the pulse energy per unit of the effective area, the nonlinear reflectivity expression can be rewrite with the regard of the pulse energy influence (F_{Ep}) , as in the following equation:

$$R_{Ep} = 1- [\ \Delta R(F_{sat} / F_{Ep})\ ] \ldots\ldots\ldots\ldots\ldots (24)$$

4.2 Evaluating of the optimal parameters with the CaF_2-model

By means of these previous derivation equations the calculations, estimations and well theoretical treatments have applied on 10 mm CaF_2 –satiable absorber crystal , The require parametric values are evaluated as listed in table (4) below , which have been used as the input data for developing the earlier our programmer application and used for the plotted as shown in the figures 5-6.

Table 4, Nonlinear parameters evaluations for CaF_2 model

Parameters title	*Saturation influence*	*Modulation depth*	*Recovery time*
Value	***46.9***	***17.45***	***15.4***
Unit	***m J / cm2***	*%*	***PSc***

Dependence of the reflectivity of a this satiable absorber on the saturation parameter are evaluated from the above derivation equations, and plotted as shown in figure (5) below, from this figure, we can well seen that the nonlinear reflectivity is begun as worth value from ≈ 81% to full maximum value ≈ 99.5 % with saturation parametric approximately equal to 12.5%.

The above estimated results are applied to calculate the non-satiable losses as well as the modulation depth (maximum change in reflectivity) which are 0.5% and 18.5% respectively.

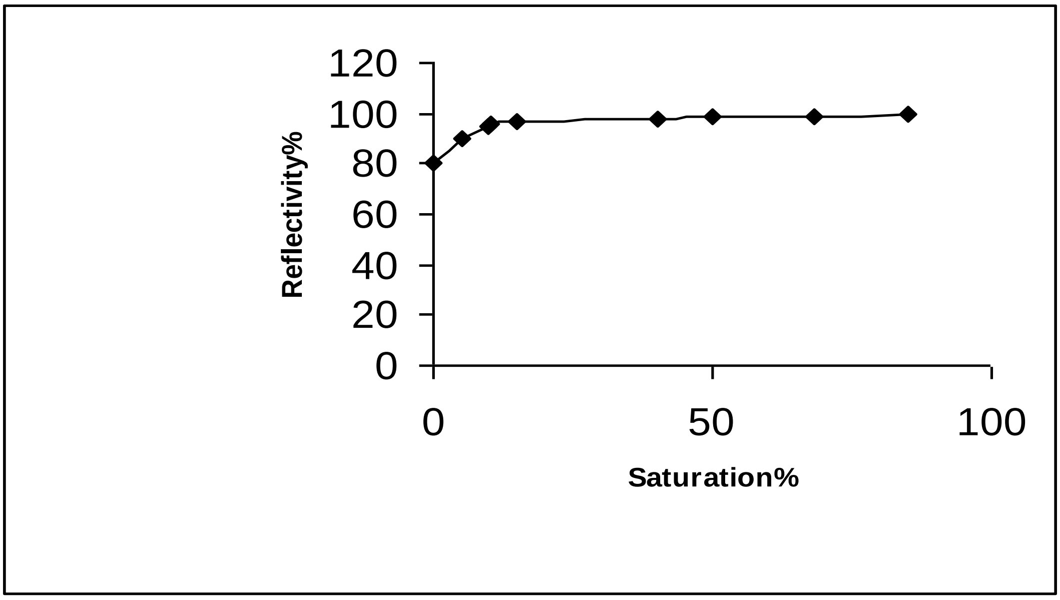

Figure 5, Nonlinear Reflectivity against the saturation absorption

The dependence of the absorption cross section of this 10 mm CaF_2 with the x-axis crystal on the tuning infrared wavelength range also were plotted as shown in figure (6) below.

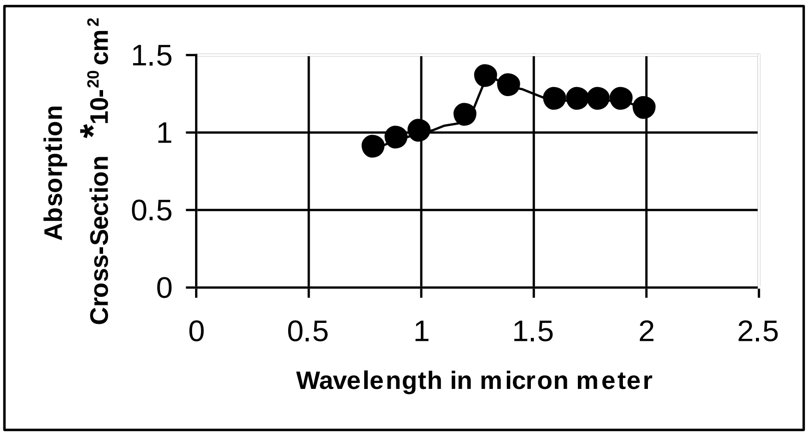

Figure 6, Dependence of the absorption cross section of the CaF_2 crystal on the wavelength

5. Results and Discussion

From this above figure, it is very clear to evaluated the absorption cross-section of this CaF_2 material with polarization along x-axis, its maximum value equal to $1.4*10^{-20}$ cm^2 with the wavelength equal to 1.353 μm. These result are précised with the values, which are obtained by the derivation equations as shown in table (4) as well as, it is strongly agreement of the interpolation of these work results with those were earlier calculated and experimentally measured by several different researchers groups [24-27], with the sharp wave length equal to 1.353μm.

Owing to applied the wide range wavelength as well as, the over estimated with some negligible treatments during the different steps of this work, the errors percentages are approximated only (± 8-10%), which is seem to slightly and satisfied for purposes of the main goals of this work.

In order to have an effective passive Q-switching performance the population reduction factor of the 1.353 μm laser which is regarded as, a four-level system must be equal a value of one. Owing to the calculations and estimated treatments, the 10mm thickness was very suitable chooser.

The (10 mm- U^{+4} – CaF_2) is proved to be an effective satiable absorber Q switch for the wide range tunable cover all the infrared and far infrared, but the optimum performance is obtained around 1.353 μm wavelength.

The peak power and the energy of the out put laser pulse are increasing with the wider absorption cross-section and longer optical path, owing to high influence absorption of the satiable absorber in the range of this wavelength, the optimal thickness of this CaF_2 type material for this goal is estimated as ≈ 8.5 mm to 12 mm .

The maximum out put energy pulses and the minimum recovery time is the optimum condition to produce (giant) Q-switching laser pulse, i.e dramatic highest peak power pulses with this our proposal model is shown according to the dependence of theses above parameters around the 1.353 μm.

To approach the optimal passive Q-switching performance, i.e., a shorter pulse can be obtained, the thicker satiable absorber was used i.e elongated the optical path of the light, in order to increase the activity of this satiable absorber sample by effective of the absorption influence.

Finally, it is worth to recommend that, the fast satiable absorption, i.e the recovery time less than the output pulse duration is necessary for passively Q-switching while, the most other giant pulses techniques such as mode locking laser operation and cavity damping types can be achieved only with a slow saturable absorption as well as to approach the optimum higher output energy pulses, it must be looking for the best conditions to yielding the decreasing in the initial transmission percentage for less than 50% .

The dependence of satiable absorber performance on its effective temperatures to combined the nonlinear optics application as, frequency doublers, with the linear optics application as, Q-switching operation at 1.353 μm will be the extended goals for this topic

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