Development and Implementation a Programmable Model for Evaluation Pumping Technique

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Abstract

This work represents development and implementation a programmable model for evaluating pumping technique and spectroscopic properties of solid state laser, as well as designing and constructing a suitable software program to simulate this techniques .

A study of a new approach for Diode Pumped Solid State Laser systems (DPSSL), to build the optimum path technology and to manufacture a new solid state laser gain medium. From this model the threshold input power, output power optimum transmission, slop efficiency and available power were predicted.

different systems configuration of diode pumped solid state laser for side pumping, end pump method using different shape type (rod,slab,disk) three main parameters are (energy transfer efficiency (r_{fac}) and output coupler reflectivity (Roc) and spot shape) had been studied.

The spectral distribution was measured with bandwidth 26nm.Optical pumped analysis, which used pump source input pump power 100mW increased to 700 mW step 100mw .

برنامج حساب تقنية الضخ للأوساط الليزرية

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الخلاصة

يمثل هذا العمل تطوير وتوظيف نموذج مبرمج لتقييم تقنية الضخ والخواص الطيفية لليزر الحالة الصلبة مع تصميم وبناء برنامج حاسوبي مناسب لتمثيل البحث. تم دراسة فكرة جديدة لضخ انظمة ليزرات الحالة الصلبة باستخدام (DPSSL) لتصميم وبناء مسلك تكنولوجي متكامل لتصنيع ليزرات حالة صلبة جديدة بواسطة (gain media). من هذا النموذج تم تخمينن دخل حد العتبة والانتقال الأمثل لطاقة الخرج وكفاءة الميل والطاقة المتوفرة.

بعد تلك الحسابات تم استخدام طرق ضخ مختلفة الضخ الجانبي و الضخ الخلفي باستخدام أشكال مختلفة شملت شكل القضيب وشكل الشريحة وشكل القرص و تم دراسة المعلمات الاساسية الثلاثة وهي: كفاءة نقل الطاقة والتي تعرف على اساس انها عامل (r_{fac}) وانعكاسية مزدوج الخرج (Roc) وشكل البقعة (ليزر دايود 810nm) ، كذلك تم قياس التوزيع الطيفي عند عرض حزمة 26 nm وتحليل الضخ البصري الذي يستخدم مصدر ضخ الدخل بطاقة 100mW وتزداد الى 700mW بخطوة مقدارها (100mW) .

1-Introduction:

The laser gain medium can be solid, liquid or gas and the pump source can be an electrical discharge, a flash lamp or another laser. The specific components of a laser depend strongly on the gain medium and whether the laser is operated continuously (cw) or pulsed. The gain medium in a solid state laser is an impurity center in crystal or glass. Laser can be classified according to the type of material used for the gain medium (active amplifying) and the temporal (time) characteristics of the output and the pump source. All solid state laser are optically pumped, which means that excitation of the gain medium is achieved by the absorption of light [1].

The critical component of solid state lasers include the laser gain medium, the mechanisms of pumping,and the cavity configuration. the operational characteristics of the specific laser system are determined by the properties of these individual component and how they are integrated into the overall system design[2].

2-Type of Pumping.

2.1:Fist :Flash Lamps Pumping:

Flash lamps are still being used to pump solid state laser gain medium and dye lasers. This is due to the fact that flash lamps are fairly inexpensive and are capable of delivering a large amount of optical power in a short time. This feature makes them useful in pulsed laser systems, such as Q-switched lasers. As the processing techniques for the production of laser diodes become more and more refined[3].

2.2:Second: Diode Laser Pumping:

The most efficient laser pump will produce maximum emission at wavelengths which excite Fluorescence in the laser material and produce minimal emission in all spectral regions outside of the useful absorption bands .The key to having efficient absorption of pump radiation is having a strong absorption transition at the wavelength of the pump radiation. If the pump source is a broad-band spectral emitter, then the absorption band of the ion should be broad in order to absorb the maximum number of pump photons. If narrow-line pump sources are used (such as a laser), then the absorption band of the ion can be narrow but must be exactly matched in frequency with pump emission[4].

3-Advantage of Diode Pump.

Diode pump solid state lasers offer a number of key advantages over laser diode and these help to determine their marketability and applications [5]:

1- Beam quality. 2-Line width. 3-Output Stability. 4-Peak Power.
5- Spectral Regions. 6-Efficiency.

4-Method of DPSSL:

The pumping methods could be categorized into two kinds, end pump and side pump.

The Axially (or end) pumped laser is excited through the end faces optically or by fiber coupled diodes. For axial pumping, the beam needs to be concentrated on a small and circular spot. By matching of light distribution to the desired mode volume and due to almost complete absorption of the pumped light, a high efficiency with a good beam quality can be reached[4][6].

In the **transversal** (or side) pumping, the pumped volume is extended and thus the attainable total power can be increased considerably, is plausible to arrange the modules, the laser diode array, including the cooler without optics directly around a laser rod, in this case the flow tube with the laser rod acts as a cylinder lens[4][6].

5-Software construction.

In this section a path technology to the program has been constructed that made of input data to final software design of optical pumped solid state laser. The computational performance of software design is divided into four sections, these parameters and other were put in the software make a design path to manufacture the different solid state laser gain media in different active ions and hosts in optimum concentration in specific applications which we required in low cost and short time.

This software is like a laboratory to design and construct solid state laser system before starting to manufactured unit. Software is designed in a suitable software program in visual C++ language written by using reference [7][8] to simulate the project and an interactive process. Figure (1) describes some option to select pump data named (window select option).

1- input physical constant data .

Pi constant ratio.
h blank constant (6.63e-34J.s)
e charge of electron
n_{ov} overlap efficiency
c speed of light in vacuum
L_c length of cavity

2-solid state laser active ion designed.

1- Nd^{3+} 2-Pr^{3+}

3- select host material designed.

1- FAP 2- MBBA 3- Glass

4- select direction pumping type designed.

1-end pump 2- side pump

5-select pumping source designed.

1-laser diode 2- flash lamp

6- select operation pumping source designed.

1-pulse 2-Cw

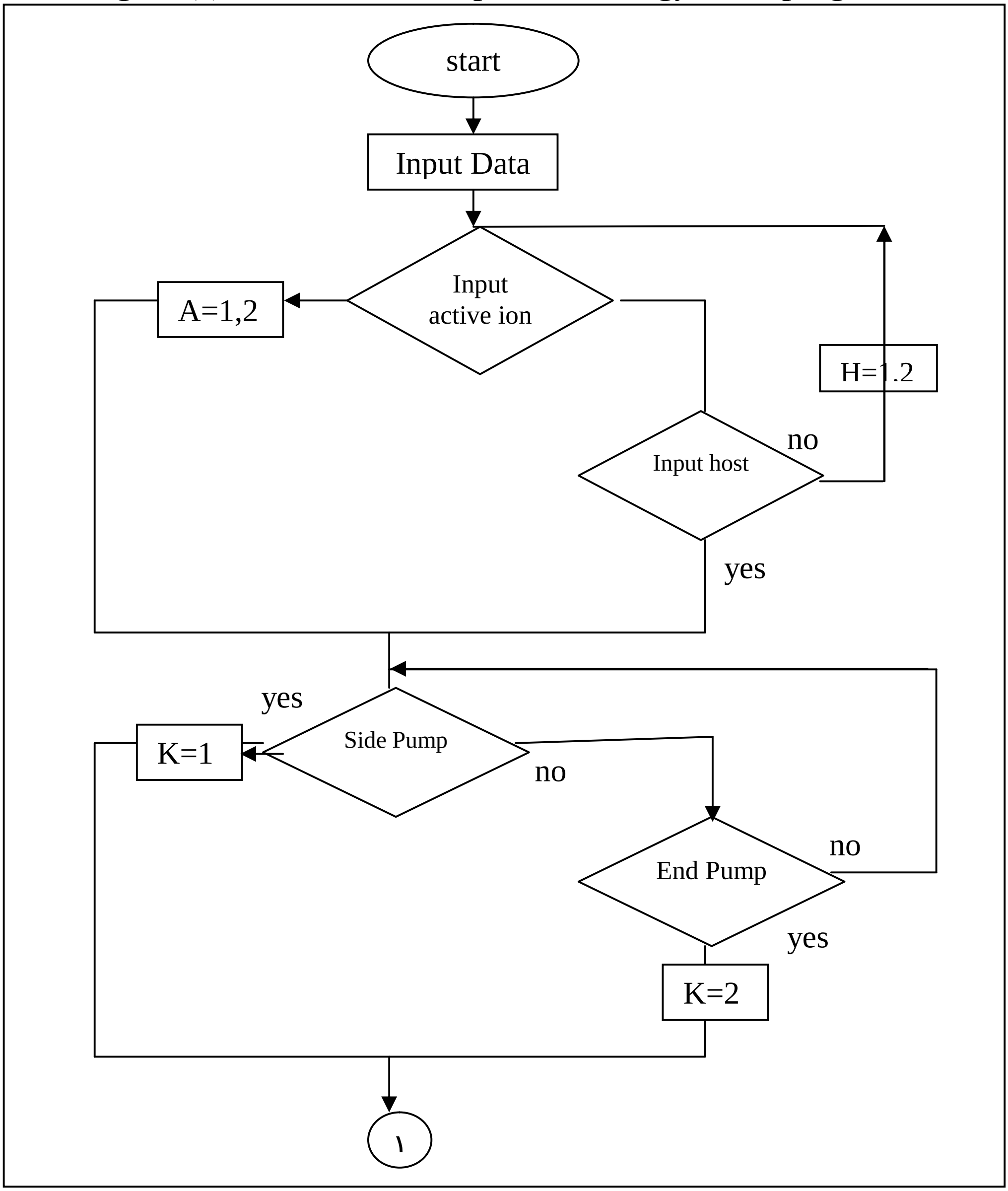
7- choose the sample shape type desiged.

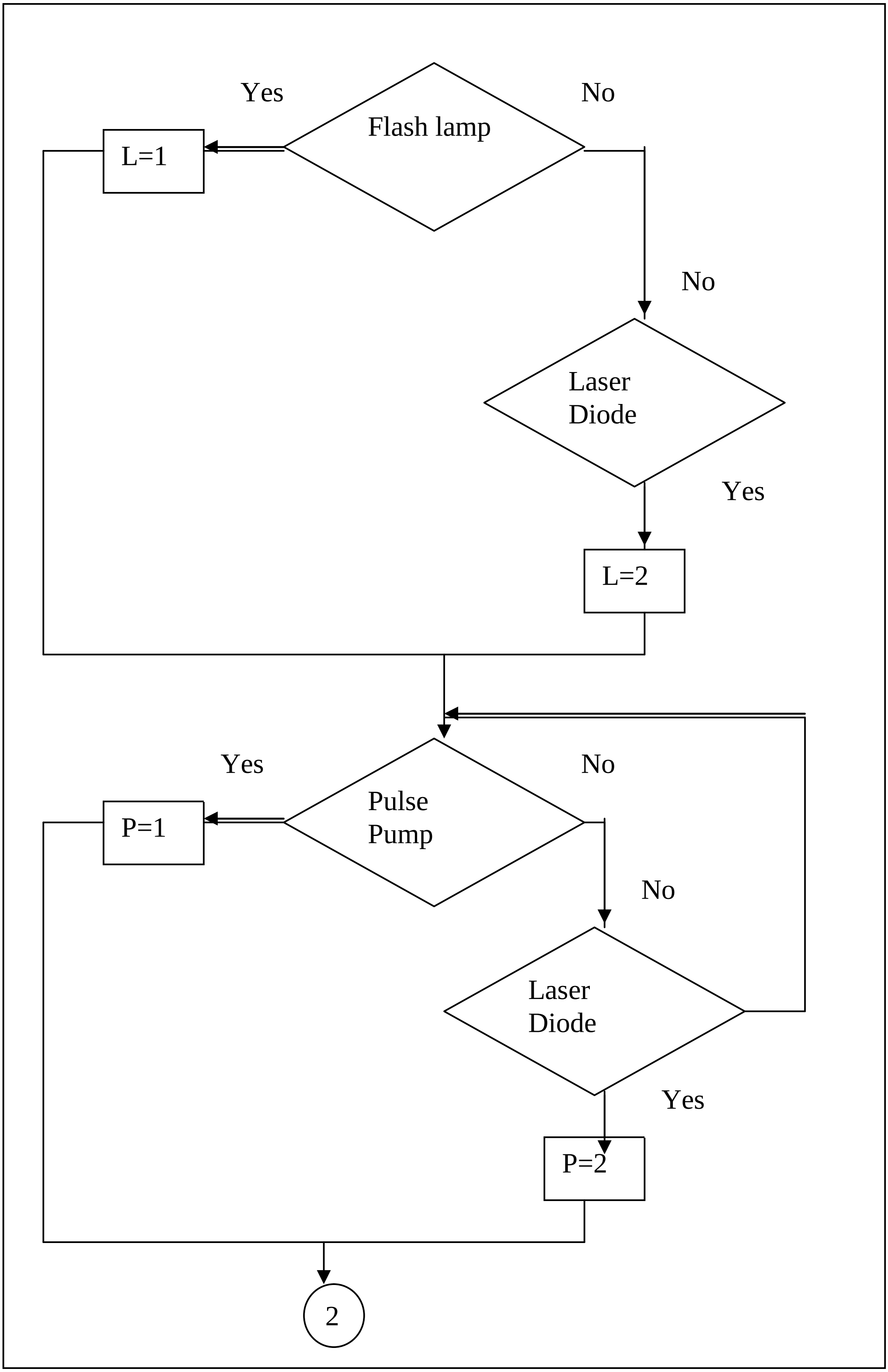
1-rod 2-disk 3-slab

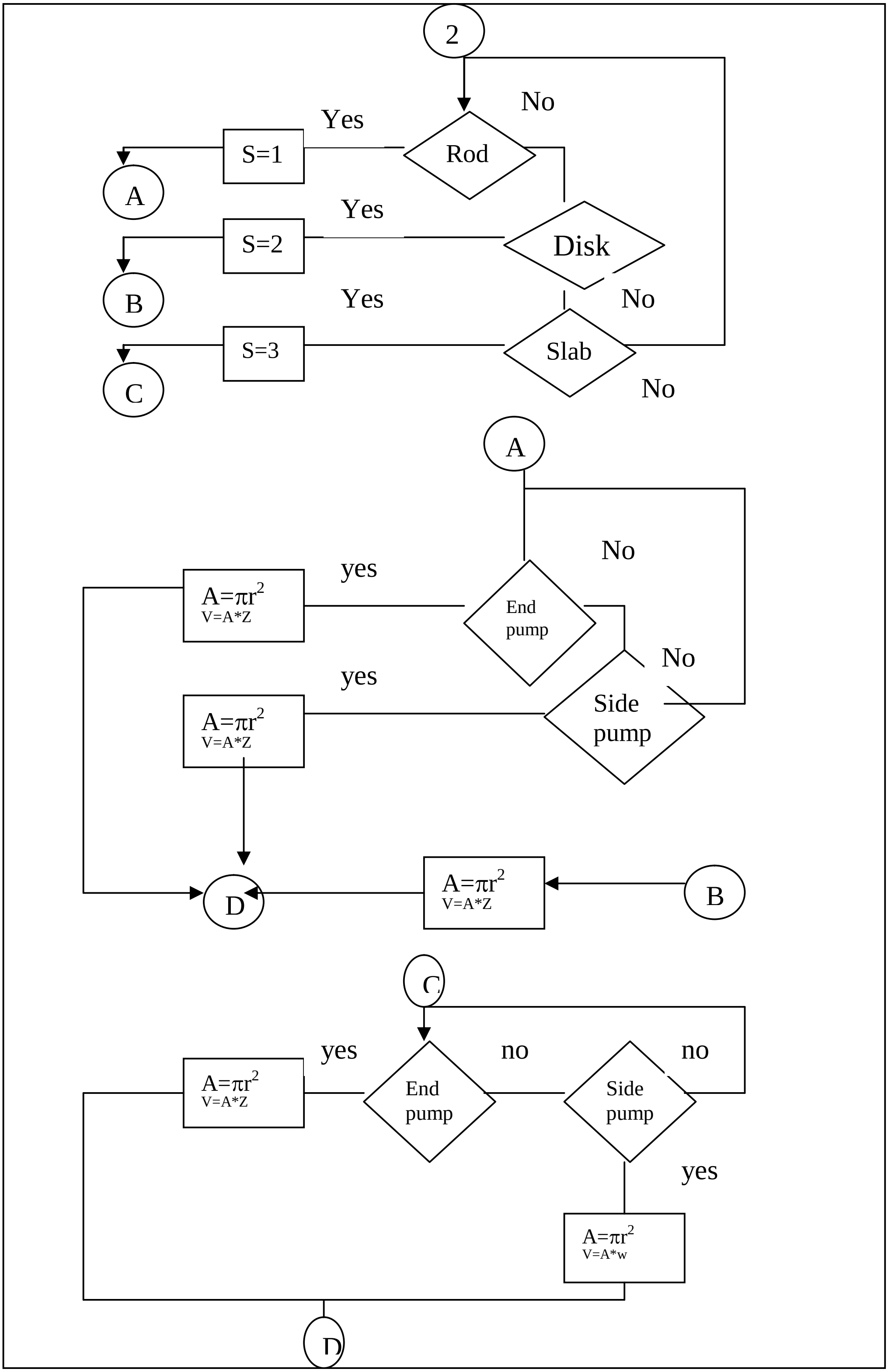
8- entered the information .

(thickness ,width, length ,radius, mass, doping)

Figure (1): the flowchart of path technology to the program.




Yes
Flash lamp
No
L=1
No
Laser Diode
Yes
L=2
Yes
Pulse Pump
No
P=1
No
Laser Diode
Yes
P=2
2


2
No
Yes
S=1
Rod
A
Yes
S=2
Disk
B
Yes
No
S=3
Slab
C
No
A
No
yes
A=πr2
V=A*Z
End
pump
No
yes
A=πr2
V=A*Z
Side
pump
A=πr2
V=A*Z
B
D
C
yes
no
no
A=πr2
V=A*Z
End
pump
Side
pump
yes
A=πr2
V=A*w
D

5-Mathematical Model.

This section is related to new idea which computes fundamental characteristic of laser mode from selection of the optimum designed cavity length, resonator configurations optimum output coupler transmission minimum losses, optimum input pump power to generate high output power at low threshold power and high efficiency .

By using (absorption and fluorescence) spectrum measurement to compute the absorption cross-section as a function to the average wavelength within main absorption band and absorption coefficient ,quantum efficiency, radiative life time ,The following steps illustrate the evaluation parameter for model optical pump solid state laser.

The firs step: Evaluate the data ($\eta,, \sigma_{st}, \tau_{rad}$) from the equations(1,2.3) given in reference [3] and [4].

$$\tau_{rad} = \left(A_{sep}\right)^{-1} in\mu_s$$ where τ_{rad} =radiative life time ---------------(1)

A_{sep} =spontaneous radiative transition probability

$$\sigma_{st} = ((\lambda_p^4)/(8\pi cn^2 \Delta\lambda_{eff}))A_{ab}$$ where σ_{st} =cross section -----------(2)

λ_{eff} =effective fluorescence bandwidth

λ_p^4 =peak fluorescence wavelength emission band.

$$\eta_q = \frac{\tau_m}{\tau}$$ where η_q =quantum efficiency-------------(3)

τ_m =time measured.

The second step :Input the parameter $\lambda_p, \rho_p, \omega_p$

ω_p Where waist size of the pump beam

ρ_p Where active ion doping density

λ_p Where peak fluorescence wavelength of emission band.

Select value R_1 (reflectivity output coupler) and R_2 (reflectivity rear mirror)
Select transmission T_1(transmittance mirror 1) and T_2(transmittance mirror 2)

The third step :Calculate absorption efficiency from equation(4)[6].

$$\eta_a = 1 - \exp(\alpha_\lambda z)$$ -----------------(4)

α_λ = Absorption Coefficient.

The forth step :Calculate η_{ov} (overlap efficiency)from the following Equation(5)[9].

$$\eta_{ov} = \eta_B = \frac{2\omega_p^2}{\omega_1^2 + \omega_p^2} \quad \text{for } \omega \succ \omega_p$$ -----------------(5)

$$\eta_B = 1 \quad \text{for } \omega \le \omega_p$$

ω = waist size.

The fifth step :Calculate (quantum efficiency) η_q from equation (6) [9].

$$\eta_s = \frac{h\upsilon_l}{h\upsilon_p} = \frac{\lambda_p}{\lambda i}$$ ---------------(6)

h =blanks constant.

υ =Transition frequency.

The sixth step :Calculate (saturation intensity) Isat from equation(7)[9][10].

$$Pp = \frac{P_p}{I_{sat}}$$ -----------------(7)

Pp =pump beam power**.**

The seventh step :Calculate (threshold pump) FL from equation(8)[11].

$$P_{th} = \frac{I_{sat}(Los + T)}{2\eta_\varsigma \alpha_\lambda C}$$ -----------------(8)

Los=all losses.

C= speed of light in vacuum.

The eight step Calculate (slop efficiency) Fp from equation(9)[11].

$$\eta_s = \eta_B \eta_q \eta_a \frac{T_1}{Los + T}$$ -----------------(9)

η_a =Absorption efficiency.

η_q =quantum efficiency.

η_B=overlap efficiency.

The ninth step Calculate (all losses) LOS from equation(10)[11].

$$LOS = 16\pi^2 N_f \exp(14\pi N_f) \qquad \text{-----------------(10)}$$

N_f =fresnel number.

The tenth step Calculate (pump intensity) Ip from equation(11)[12][13].

$$I_{p(x,y,z)} = \frac{P_p}{A_p(z)} f_p(x,y,z)\exp(-\alpha_\lambda z) \qquad \text{------------(11)}$$

A_p =pump power area at plan z-direction

f_p = oscillator strength.

The eleventh step Calculate (pump beam power) Pp from equation (12)[12][13].

$$P_p = I_p(x,y,z)A_p(z) \qquad \text{----------------(12)}$$

The twelfth step Calculate (circulation intensity) I_{circ} from equation (13)[13][14].

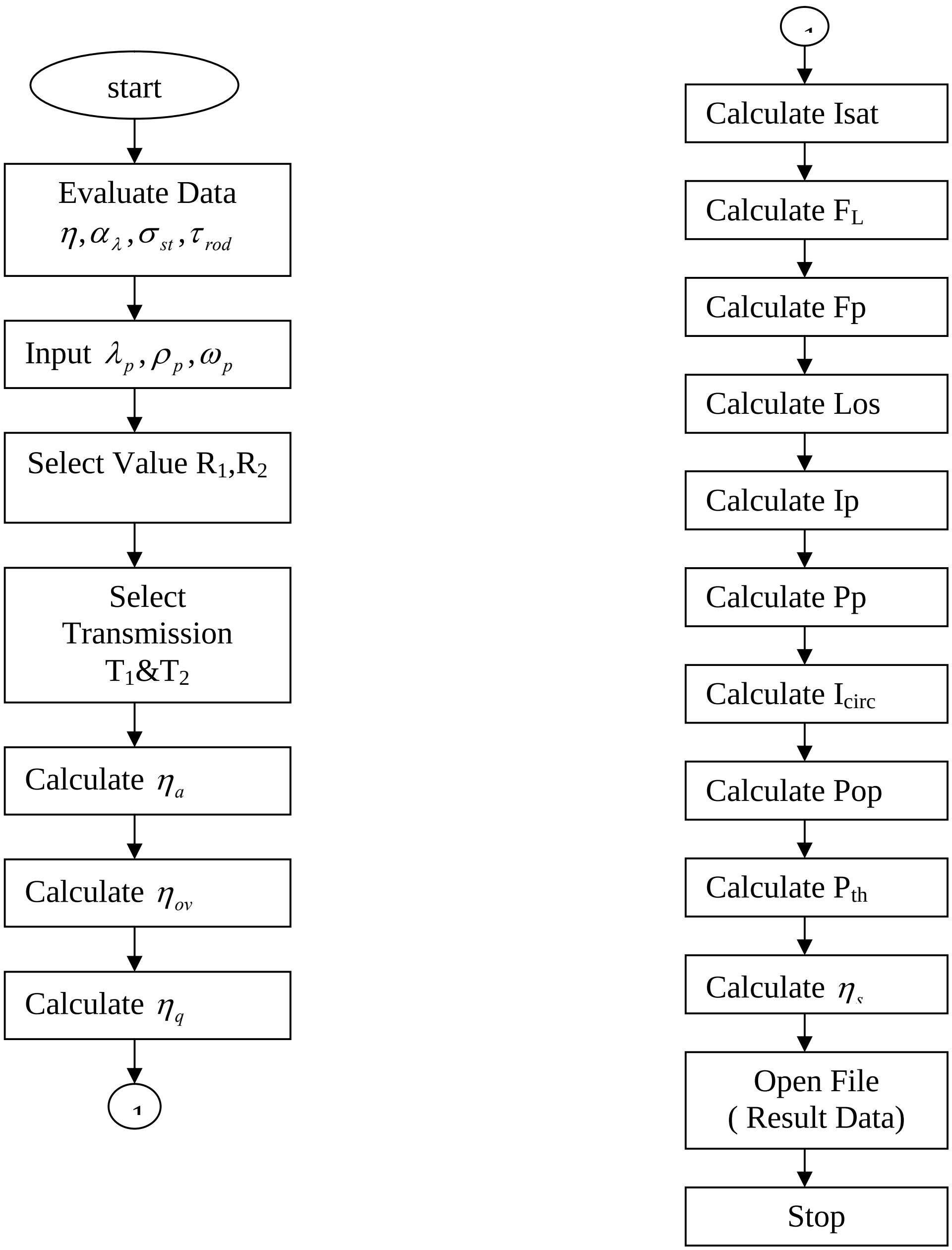
$$I_{circ}(x,y,z) = \frac{P_{circ}}{A_L} f_L(x,y,z) \qquad \text{---------------(13)}$$

P_{circ} =circulation power.

A_L =mode area at plan Z direction.

The thirteenth step Calculate (output power) Pop from equation (14)[13][14].

$$P_{circ} = \frac{I_{sat}\langle A_L\rangle}{2D}\left[\frac{2\eta_q\alpha_\lambda P_p C}{T + L_{os}}\right] - 1 \qquad \text{---------------(14)}$$



Figure(4):The flowchart that present the step of the mathematical model

Experimental work .

The following figure (2,4) present the absorption spectrum for two samples with output power as a function of input pump power with increase from 100 mW to 700mW step 100mW with fixed area pump factor rfac

(85%) **,** the pump direction from end pump to side pump respectively in figure (3,5).

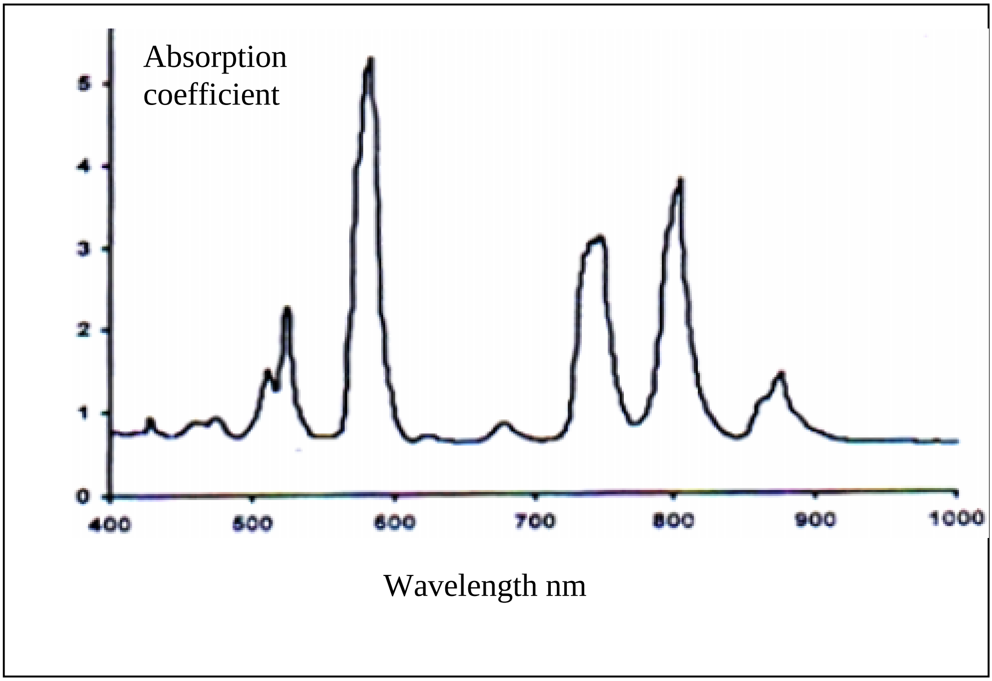


Figure (2):Absorption spectrum for sample one at rate doping 3%

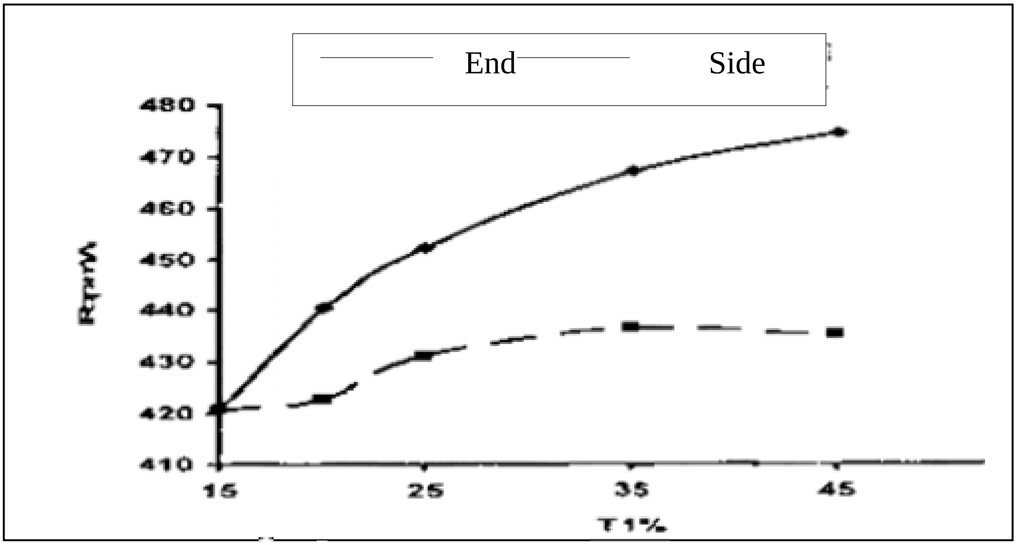


Figure (3):output power as a function of coupling transmission sample one

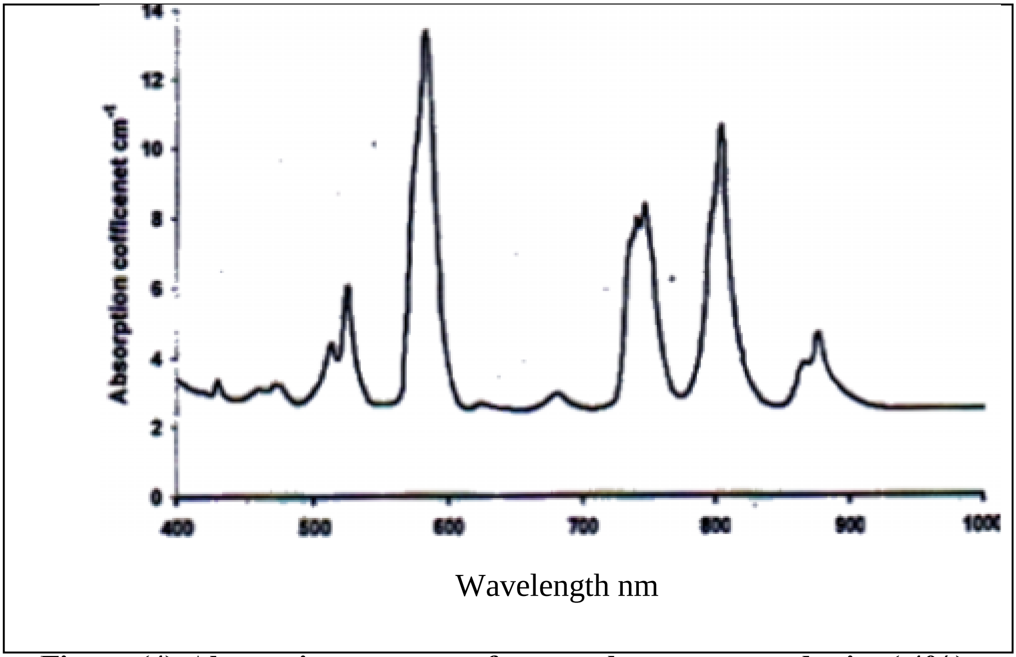


Figure (4):Absorption spectrum for sample tow at rate doping(4%)

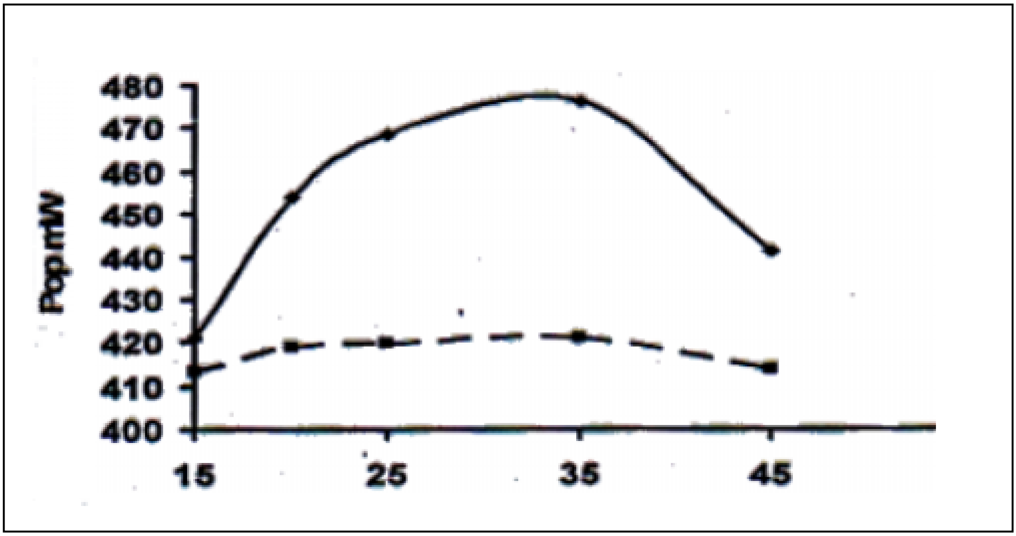


Figure (5):output power as a function of coupling transmission sample tow

Conclusion

To examine the technological path and compared with the literature tow samples of Nd^{3+} doped MBBA [14] [15] are used.

1- found the same values to calculate the absorption measurement and new approach used to compute very important parameter which is intensity parameter , from the result of these part ,can fined the effect of doping ratio which means increase in absorption coefficient ,and computes fluorescence line strength for the sample which is increases with increase in doping ratio.

2- The diode pumped solid state laser details in the work exhibits features that render it a potentially useful tool for several applicatio n.Our result demonstrate that high output energies and high efficient at the doping concentration 4% in sample 2.

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