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طراحی و بهینه سازی لیزر Nd:YAG کلیدزنی Q شده هوا خنک توسط نرم افزار LASCAD

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چکیده – در این مقاله سعی شده است، بیشترین بازده ممکن از طراحی یک لیزر *Nd:YAG* کلیدزنی *Q* شده هوا خنک با دمش دیودی از پهلو به‌دست آید. در این طراحی بر روی بیشینه و بهینه کردن عوامل بازده انتقالی و بازده همپوشانی پرتو با ماده فعال لیزر کار شده است. فاصله بهینه لیزر دیودها از مرکز میله لیزر را برای جذب حداکثری توسط نرم‌افزار لیزری *LASCAD* برابر با 4/85 میلی‌متر یافتیم. با بررسی طول‌های مختلف مشدد و در نقاط مختلف نمودار پایداری، بهترین بازده شیب در حالت کلیدزنی *Q* با ایجاد یک بازده همپوشانی بالا در مد خروجی TEM_{oo} برابر با 10/8٪ بدست آمد.

کلید واژه- بازده انتقالی، بازده شیب، بازده همپوشانی، طراحی مشدد، نرم‌افزار LASCAD

Design and optimization of an air-cooled Q-switched Nd:YAG Laser by LASCAD software

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Abstract- In this paper we have endeavoured the design of a side pumped air-cooled Q-switched Nd:YAG Laser with uttermost efficiency. In this design has been tried to achieve a maximum and optimum transfer and overlap efficiencies. The diode lasers optimum distance from laser rod center for a maximum absorption has been found 4.85 mm with LASCAD laser software. With scrutiny of different resonator lengths and in the different stability diagram points, the best slope efficiency in the Q-switched mode by producing high overlap efficiency and in the TEM_{oo} mode is reported equal to 10.8%.

Keywords: transfer efficiency, slope efficiency, overlaps efficiency, resonator design, LASCAD software

1 Introduction

Roughly, main concepts related to the optical resonators and propagation of Gaussian beams have been formulated. Also key points in design of these passive resonators are introduced. But in active resonators, taking active medium into account, makes the problem very complicated, because there are some phenomena such as thermal lensing and induced birefringence which are impressive on the behaviour of the resonator[1-3]. Fortunately, availability of comprehensive softwares in laser field, provides a strong tool which yields ease of design and prevents needs to solve complex differential equations[4]. In this study, an air cooled Nd:YAG laser has been designed and then we found its optimum operational point, using LASCAD software. The laser should provide output pulse energy of 50 mJ at a 20-Hz repetition rate and near-diffraction-limited beam. The Nd:YAG rod was considered to be 80mm long with a diameter of 3.5 mm which was pumped by 808nm diode lasers with total energy equal 450mJ. In simulations temperature of lateral surface of the rod, was assumed to be 300 K.

2 Design procedure

First step of design procedure is finding a zero point for geometrical parameters of resonator as well as physical parameters of lasing media. This step could not be done with LASCAD software and we did it with using common equations in laser literatures which give a good approximation of laser behaviour. In figure 1, typical parameters of an active resonator have been shown. Resonator length, gain medium length, rear mirror and output mirror curvatures are L, lg, R1 and R2 respectively. h1 and h2 are distances of principal planes of thermal lens from end faces of the rod and ΔL is separation of them. W1, W2 and W3 are size of laser spots on the rear mirror, output mirror and gain medium, respectively. It should be noted that the place of principal planes of thermally induced lens is independent of pump power [5].

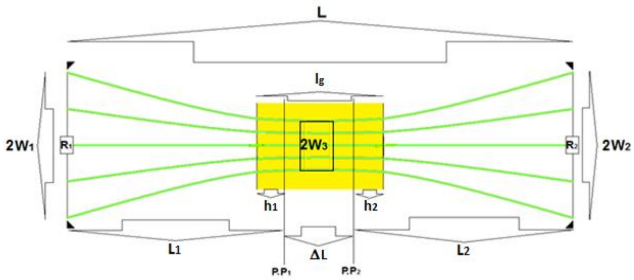

Figure 1: Schematic of a typical active resonator

Common method for analyzing a laser resonator and investigation of its stability is based on considering an equivalent passive resonator instead of the active resonator in which the thermally induced lens is replaced by a simple thin lens. After finding equivalent resonator, we used ABCD transformation matrix for ray tracing in new passive resonator. Also to investigate how the Gaussian beam propagates inside the resonator, we used resonator conjugated parameter q(z), which is a function of curvature of wavefront [6]. Because of abbreviating the article and also emphasize on results obtained from the LASCAD software, we do not write about long procedure of the mentioned step and its relevant equations. Interested reader can refer to the references in the text. In the next sections we consider result of optimizations which are obtained by LASCAD software.

3 Optimization of pump radiation transfer efficiency

According to the obtained results from DMA code (Dynamic Multimode Analysis) of LASCAD software[4], the most transfer efficiency of pump radiation into the laser rod with 3.5 mm diameter was obtained when the distance of laser diodes to rod surface is 4.85 mm. Figure 2 shows ray tracing of pump radiation through the laser rod.

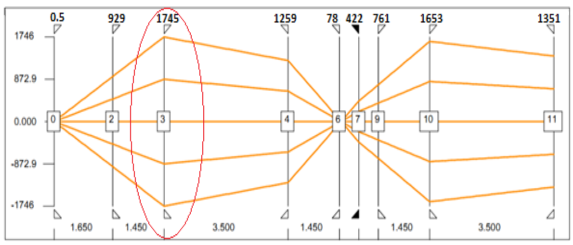

Figure 2 : Ray tracing of pump radiation when absorption is maximum.

Surface number zero, indicates emitter surface of diode lasers. Surfaces number 3 and 4 are lateral surfaces of Nd:YAG rod with a distance of 3.5mm.

Surface number 7 shows the reflector from which the portion of pump radiation that is not absorbed by crystal in the first pass again would reflect back into the laser rod. Values that are written below figure 2, show distances between surfaces in millimeter. Also values that are written over each surface, show pump spot size on that surface in micrometer. It can be seen that distances are adjusted so that spot size on the crystal lateral surface become smaller than crystal radius and therefore without using optics in front of laser diodes all the pump radiation is concentrated into the laser crystal.

4 Resonator design

In this section using LASCAD software, we optimized a plane-concave resonator to reach a design with both important features of compactness and stability. As it has been shown in figure 3, we investigated different length for resonator.

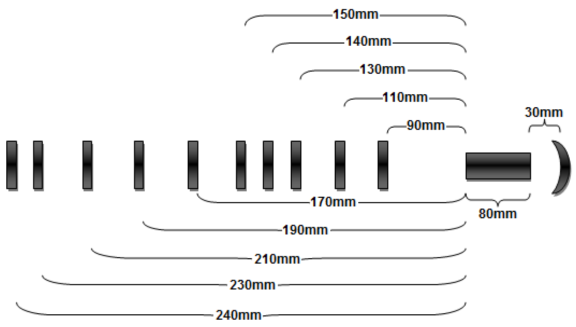

Figure 3 : Investigated plano-concave resonators with different length

In all of the considered resonators which are shown in figure 3, we assumed that distance between laser crystal from output mirror to be 30 mm. reaching the most overlap efficiency and the lowest order mode, is the reason of this near distance between output mirror and laser crystal [7]. Assuming average power of 2 Watt in the free running output, the best length for resonator obtained 340 mm with $g^*_1 g^*_2=0.923$ in the stability diagram. Also the spot size of laser beam on the active medium found to be 0.620 mm. in the Q-Switch mode a pulse with energy equal 45mJ and duration of 6.1ns was obtained.

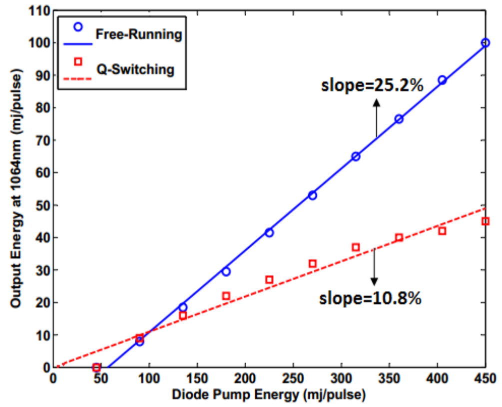

Figure 4 : Slope efficiency in free running and Q-Switched mode for optimized resonator length of 340 mm.

As it can be seen in figure 4, Optical to optical Slope efficiency in the free running was 25.2% and in Q-Switch mode it was 10.8%.
Simulations showed a diffraction limited beam in TEM00 mode (figure 5).

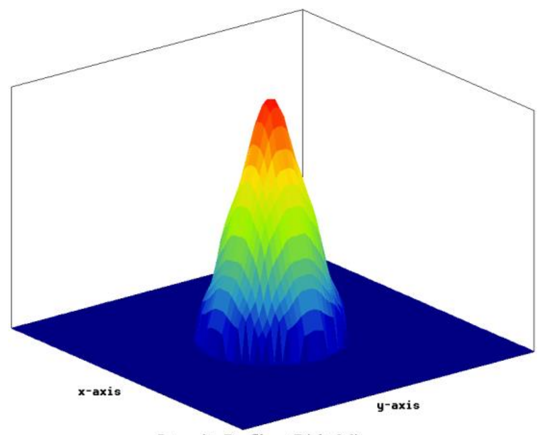

Figure 5: TEM_{00} Q-Switched output pulse from optimized simulated resonator

The pulse shape in figure 6, indicates a pulse width equal to 6.1 ns that is proper duration for us.

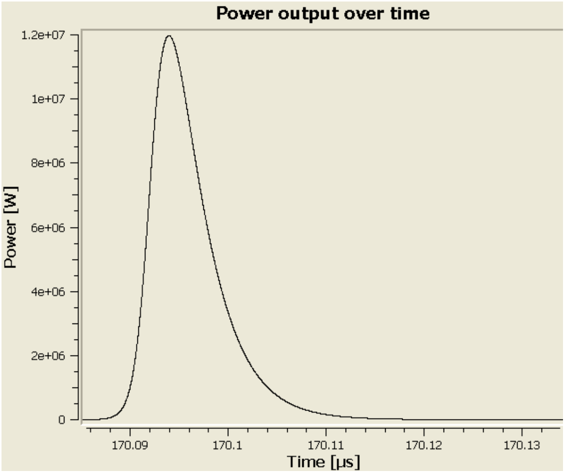

Figure 6 : time profile of laser output pulse

According to characteristics of pump cavity and assumption of cooling the laser rod using air, the needed air flow rate was determined to be 2812 cm^3/s [8].

5 conclusion

Since for different distances of laser diode from laser rod, the transmitted energy through the active medium will change, the exact design of this space leads to more energy absorption and at last a better output efficiency. Using ray tracing by LASCAD software code we found its optimum value to be 4.85 mm. The simplest way to reach desired output energy was making high overlap efficiency and simultaneously providing a stable resonator. In order to satisfy these requirements, we had to increase the length of resonator and using a curved mirror as the output coupler. The best efficiency that we obtained is 10.8% for a 340mm laser resonator that is a high value in these kinds of systems. The beam profile was Gaussian with a pure TEM_{00} transverse mode.

References

[1] A.E. Siegman, *Laser Beams and Resonators: The 1960s*, p. 1380-1388, **IEEE J. of selected topics in quantum electronics,** 2000**.**

[2] A.E. Siegman, *Laser Beams and Resonators: Beyond the 1960s*, p. 1389-1399, **IEEE J. of selected topics in quantum electronics,** 2000**.**

[3] V. Magni, *Resonators for solid-state lasers with large-volume fundamental mode and high alignment stability*, p. 107-117, **Appl. Opt** 1986.

[4] K. Altmann, LAS-CAD Software, Laser Cavity Analysis and Design**,** The Unique Combination of Simulation Tools, http://www.lascad.com, Munich, 2014.

[5] H.P. Kortz, R. Ifflander and H. Weber, *Stability and beam divergence of multimode lasers with internal variable lenses*, p. 4124-4134, **Appl. Opt** 1981.

[6] A.D. McAulay, *Military Laser Technology for Defense*, Wiley, New Jersey, 2011.

[7] N. Hodgson and H. Weber, *Laser Resonators and Beam Propagation*, 2nd Edition, Springer, New York, 2005.

[8] A. Hosseini, A. Maleki and M. Kavosh Tehrani, *Determination of the Optimum Heat Transfer Coefficient and Coolant Flow Rate in a Nd:YAG Laser Rod with Air Cooling*, The Annual Phys. Conf of Iran, Zahedan, 2014.