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TITLE: STRESS AND STRAIN OF SLAB TYPE AMPLIFIERS

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SUMMARY We measured the stress and strain of slab amplifiers, improved sealing materials and installation methods, as well as finding a type of sealing method which does not produce stress.

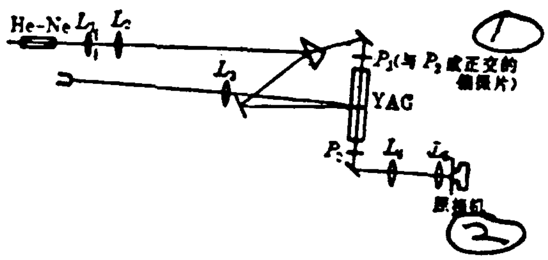
KEY TERMS Slab Amplifier, Stress, Strain

I. INTRODUCTION

The test production of high repetition rate, high power slab configuration solid state laser devices is, at the present time, both inside China and abroad, a topic which interests scientists[1]. In order to make slab amplifiers capable of supporting high powers and high energies simultaneously, and, in order to reduce double refraction, and improve the luminosity of laser output, the important thing is that there must be research on the status of the stresses and strains produced by laser amplifiers. Besides this, in order to raise slab amplifier anti-explosive capabilities[2], besides factors associated with laser materials themselves, it is also necessary to find a type of installation method which does not produce stress[3]. In order to do this, we designed four types of installation systems, improving the seal materials as well as the installation methods and obtaining relatively good results.

II. EXPERIMENTAL EQUIPMENT AND EXPERIMENTAL RESULTS

Stress and strain measuring equipment was as shown in Fig.1. A He-Ne laser, through a beam amplifying device, produced a beam with a diameter of 35mm from uniform polarized light. This light beam goes through a pair of axially intersecting polarization slabs. In conjunction with this, to the rear of the polarization slabs, there is formed a dark field. When laser materials are projected into the interval between the two polarization slabs, if the material receives forces in a non-uniform way, then, at that time, they will produce opposite characteristics in various directions. Then, light rays will produce, in two mutually perpendicular directions, different speeds of propagation. As a result of this, light path deviations are produced. Because of this, behind the polarization slabs, one gets the appearance of luminous striations or streaks. This is capable of being expressed as[4]:



(1)

Fig.1 Light Path Diagram for Measurements of Stress and Strain (1) P_1 (polarization slab orthogonal to P_2) (2) Camera

$$\sigma_y - \sigma_x = \frac{n\lambda}{B \cdot d}$$

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σ_x and σ_y are stresses in two directions. n is the streak series. λ is the measuring laser wavelength. B was selected as the constant for the laser material. d is the thickness of the material in the direction ϕ .

In order to measure stresses and strains, we make use of the Shanghai Optical Instrument Institute's Model III silicate glass slabs as laser material. In the equipment shown in Fig.2, stress research was carried out. Fig.3 is the original stress diagram associated with the laser material. The two angle side stresses are given rise to when the neodymium glass side surfaces are ground off. In order to reduce stress, one opts for the use of a special black colored material with plenty of elasticity to carry out the sealing on the side surfaces of the neodymium glass. The sealing method is as shown in Fig.4. When the tightly blocking laser material cover plate and the tightly connected fluoresent lamps are screwed into the two ends of the laser material, the stresses which are produced are, respectively, as shown in Fig.5(a) and (b).

In order to set up methods to eliminate stresses, the second equipment or system we designed does not use screw tight solid seals. Instead, it makes use of four plastic slabs. Two pieces are utilized at each end of the slab amplifiers. Between the two pieces, one places a silica gel rich in elasticity to carry out the sealing. The sealing method is as shown in Fig.6. However, due to the fact that the two corners of the glass slabs have been sealed dead, the silica gel, after it dries, produces shrinkage. As a result of this, at the corners, there are produced extra stresses.

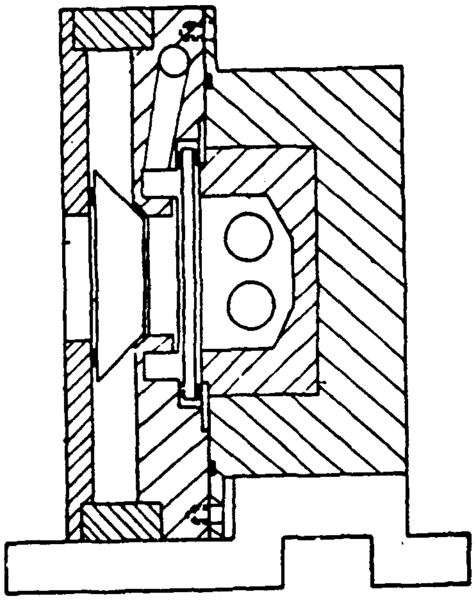

Fig.2 Nd:YAG Activated Reflection Type Slab Amplifier

Fig.3

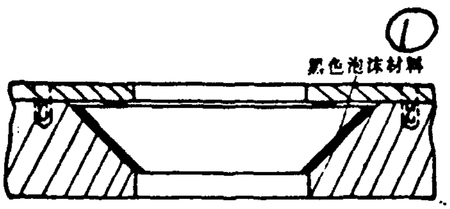

Fig.4 Schematic Diagram of Sealing Method (1) Black Colored Foam Material

Fig.5 (a) Installation Stress Diagram for the First System (Added Face Plate) (b) Installation Stress Diagram for the First System (After Screws Are Twisted Tight)

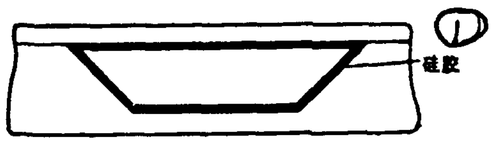

Fig.6 Schematic Diagram of Sealing Method (1) Silica Gel

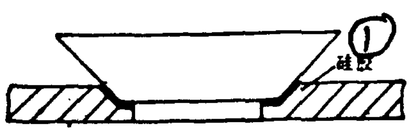

Fig.7 Schematic Diagram of Sealing Method (1) Silica Gel

The third equipment system designed was set up as a way to make the two corners of the glass slabs free. On the bottom sections of the two sides of the slabs as well as on the bottom portions of the edges, use was made of silica gel to carry out sealing, as shown in

Fig.7. However, due to the fact that silica gel contracts, it still creates the appearance of stresses on the two sides of the glass material and on the bottom portions.

The fourth type of equipment system designed used a type of gel that does not contract. Moreover, only the bottom portions of the two sides are glued with the gel, as shown in Fig.8(a) and (b). The U.S. Corning Company produces a 186 elastic gel or glue which satisfies this requirement. Measurements clearly indicate that, after installation, the glass slabs do not produce extra or extraneous stresses. Stresses are only

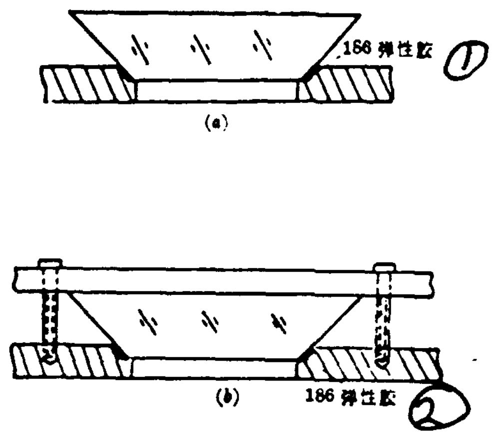

Fig.8 Schematic Diagram of Sealing Method (1) 186 Elastic Gel or Glue

produced after they are put through water cooling, and not until then. After face plates were added to the front of glass slabs, stresses were not produced (Fig.9(a)). After going through water, the stresses produced, when compared with stresses without the addition of the face plate, are, on the contrary, reduced (see Fig.9(b)). This is due to
the fact that face plate pressure creates a certain balancing or 689
equilibrium effect on water pressure. When light pump input is 2645W at 5 Hz, the corresponding stresses are as shown in Fig.9(c). In experiments, there was no appearance of any breakage in the glass.

Finally, installation and stress measurements were carried out on YAG slabs with the same sort of dimensions. Due to the fact that YAG material is much harder as compared to glass, for this reason, the stresses are altered and are much smaller than those of glass. After installation, there were no stresses produced. Even if they went through cooling water, there were still no extra stresses produced. See Fig.10(a) and (b).

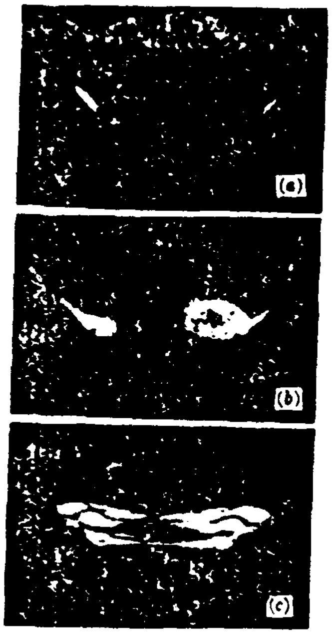

Fig.9 (a) Stress Diagram After Installation of the Fourth System With the Addition of Face Plate (b) Stress Diagram (Face Plate Added) After the Equipment Went Through Water (c) Stress Diagram for Light Pump Input of 2645W at 5Hz

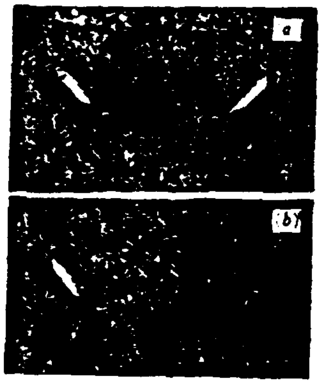

Fig.10 (a) Stress Diagram After YAG Installation (b) YAG Stress Diagram After Going Through Cooling Water

III. ANALYSIS OF EXPERIMENTAL RESULTS

From among experimental measurements, it is possible to see that there is an extremely large relationship between the stresses produced by materials and all the factors of the nature of the material, its form, processing requirements, the placement of the material's mechanical design, the method of its installation, and the nature of the sealing material. We primarily improved the installation method, made use of sealing material which does not shrink, and stresses were not produced after installation.

Theoretically speaking, the power limit on the energy which is capable of being supported per unit volume input for slab materials is estimated to be[5]:

$$P_{max} = \frac{12 R_s}{x t^2} \qquad (2)$$

In this equation, $R_{s(illegible)}$ is the thermal shock parameter. x is the ratio of light that is transformed into heat. Generally, it is selected to be 5-7%. t is the thickness of the slab material.

On the basis of the formula above, we estimated the light pump limit powers for unit volume inputs which are capable of being supported by the Model IV neodymium glass slabs utilized at the U.S. University of Maryland, YAG slabs, as well as the neodymium glass slabs made use of by other U.S. units, and the actual input powers in experiments (see Table 1).

表 1

(1) 单位	(2) 材料	(3) 尺寸 (cm³)	(4) 理论极限值 (W/cm³)	(5) 实验输入值 (W/cm³)
(6) 马里兰大学	(9) III型 Nd 玻璃	1.3×2.8×10	130	73
(6) 马里兰大学	YAG	1.3×2.8×10	780	158
(7) [6]光谱物理公司	(10) Nd 玻璃	0.44×15×16.7	220	45
(8) [7]斯坦福大学	(10) Nd 玻璃	0.63×5.6×35	440	[illegible]4.5

Table 1 (1) Unit (2) Material (3) Dimensions (4) Theoretical Limit Values (5) Actual Input Values (6) University of Maryland (7) Spectrum Physics Company (8) Stanford University (9) Model III Nd Glass (10) Glass

From this, it is possible to see that, under installation conditions without stress, with a light pump input power of 2645W into our slab formed glass (that is, $73W/cm^3$) no phenomena of bursting into pieces of any sort was produced, and this is quite a good experimental result. If one uses the same type of methods installing YAG, the light pump powers will far, far exceed $158W/cm^3$, but it will not produce breakage. The reason for this is that its theoretical limit values are very much greater than those for Nd glass. As a result of this, it is guaranteed that YAG reflecting lens type laser amplifiers have the possibility of obtaining high energy and high repetition rate outputs.

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