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# Solid State Pump Lasers with High Power and High Repetition Rate

Masaki Oba, Masaaki Kato and Takashi Arisawa
*Department of Chemistry and Fuel Research*
*Japan Atomic Energy Research Institute*
*Tokai-mura, Ibaraki-ken, 319-11, Japan*
Tel.0292-82-6085, Fax.0292-82-5572

## Abstract

We built a laser diode pumped solid state green laser (LDPSSGL) rated at high repetition rate. Two laser heads are placed in one cavity with a rotator in between to design to avoid thermal lensing and thermal birefringence effect. Although average green laser power higher than 10 W was obtained at 1 kHz repetition rate with pulse width of 20~30 nsec,the beam quality was so much deteriorated that energy efficiency was as low as 2 %. Learning from this experience that high power oscillator causes a lot of thermal distortion not only in the laser rod but also in the Q-switch device,we proceeded to built a oscillator/amplifier system. A low power oscillator has a slab type crystal in the cavity. As a result spatial distribution of laser power was extremely improved.

As we expect that the high repetition rate solid state laser should be CW operated Q-switch type laser from the view point of lifetime of diode lasers, a conventional arc lamp pumped CW Q-switch green YAG laser of which the repetition rate is changeable from 1 kHz to 5 kHz and the pulse width is 250~570 nsec was also tested to obtain pumping characteristics of a dye laser as a function of power, pulse width etc., and dye laser pulse width of 100~130 nsec were obtained.

**key words:** laser diode, solid state laser, slab, CW Q-switch, tunable laser

## 1.Introduction

Tunable lasers in the visible wavelength region, such as Ti:sapphire or a dye laser are generally pumped by green lasers. Some of them have been developed for carrying out the experiments on chemical reaction in the reprocessing of nuclear fuels or uranium enrichment process. For the implementation of these applications high power, high repetition rate, high energy efficiency, reliability and compactness are indispensable. Green YAG lasers excited by laser diodes are greatly promising to be used as a pump laser for tunable laser system. High power laser diode makes possible to built compact all solid state lasers with high power and high repetition rate. In atomic vapor laser isotope separation (AVLIS) process, CVLs are used for pumping dye lasers, because of their high power and high repetition rate. But energy efficiency is as low as 1 % and they occupy much space. LD pumped solid state laser can be compact and more than 3 % of energy efficiency is expected.

We built two types of quasi CW LD pumped Nd:YAG lasers operated at the repetition rate 1 kHz to study their characteristics. First of all we built a rod type oscillator with two heads and at the second step we built zig-zag slab type laser at low power region.

CW pumped Q-switch green laser is attractive because of longer lifetime of laser diodes. But their pulse width generated by AO Q-switch is normally longer than EO Q-switch laser. As we are interested in the dye laser pumped by such long pulse, we measured the characteristics of dye laser pumped by a conventional CW Q-switch YAG green laser.

## 2.LD Pumped Double Rod YAG Laser

Fig.1 shows the schematics of the laser in which 96 bars of LDs were used, and were set on the 8 faces around the YAG rods.LDs were operated with 250 μsec pulse width at 1 kHz repetition rate. A 90° rotator was set between rods to avoid thermal birefringence effect. Green (532 nm) output was obtained by KTP crystal in the external cavity. About 50 W output power was obtained at 1064 nm (fig.2). Energy conversion efficiency was 2.5 % at the 50 W output power and slope efficiency was 12.5 %. But its green output power converted by KTP was lower than 13 W. This inefficient performance was probably caused by bad beam quality. Fig.3 shows beam profile at 1064 nm. Two peaks appeared at high power region. We considered that the cause was attributed to thermal distortion not only in a YAG rod but also in a Q-switch crystal.

## 3.Zig-zag YAG Slab Laser

We built a zig-zag YAG slab laser at low power region to improve the beam quality of the laser above developed. Laser beam travels in the YAG crystal in zig-zag, and to compensate the thermal distortion in a crystal. Fig.4 shows the schematics of zig-zag slab YAG laser. 48 bars of LDs were set on the YAG slab. LDs were operated at 1 kHz repetition rate and 150 μsec pulse width. Fig.5 shows the output power vs. input power. Maximum output power at 1064 nm was 12 W. 2.4 % of energy conversion efficiency and 7.9 % of slope efficiency was obtained.Beam profile was considerably improved as shown in fig.6. Green output power converted by KTP was measured,and the green conversion efficiency was about 45 % which is better than the previous rod type laser. We also measured the beam pointing stability using a CCD camera. Fig.7 shows the peak position of the beam profile. Along the axis vertical to the brewster's face, pointing stability was 0.2 mrad, and that along the horizontal axis was 0.06 mrad. We considered that this effect was caused by thermal stress induced by the irradiation of LDs.

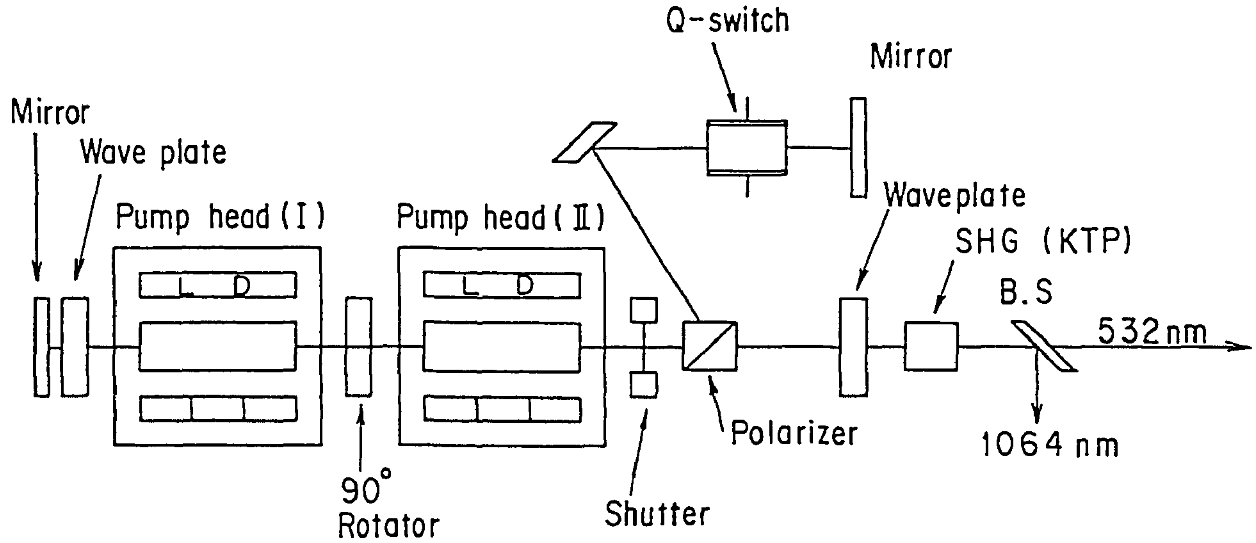
## 4.Dye Laser Pumped by CW Q-switch YAG Green Laser

From the view point of long lifetime and higher repetition rate, CW Q-switch laser is very attractive compared with quasi CW LDs. But the pulse width in the CW Q-switch system is longer because AO Q-switch is used. So we studied the characteristics of dye laser pumped by a long pulse laser. We used conventional CW Q-switch YAG green laser of which repetition rate is changeable up to 5 kHz and pulse width is 260~570 nsec. Dye laser with a most simple structure composed of two mirrors and dye cell was used. R6G was used as a dye. Fig.8 shows the dye laser output power vs. pump power. Dye laser power pumped by 260 nsec pulse was higher than that pumped by 570nsec under the same power. Fig.9 shows the dye laser pulse width vs. pump pulse width. Dye laser pulse width was not longer than 150 nsec and did not change much, even pump laser pulse width was longer than 500 nsec. We considered that the dye laser pulse width was not extended, since the dye molecule is trapped in the triplet state.

**5.Summary**

We built two types of solid state laser pumped by laser diode. First one was a double rod type laser with 50 W average power at the fundamental wavelength. But its beam quality was not good because of the thermal birefringence effect. Second one was a zig-zag slab YAG laser. Thermal effects were compensated, but beam pointing stability was not good.

Characteristics of the dye laser pumped by CW Q-switch YAG green laser was measured as a function of pulse width. Dye laser pulse width was about 100–130 nsec.




L D side pumped YAG laser head schematic

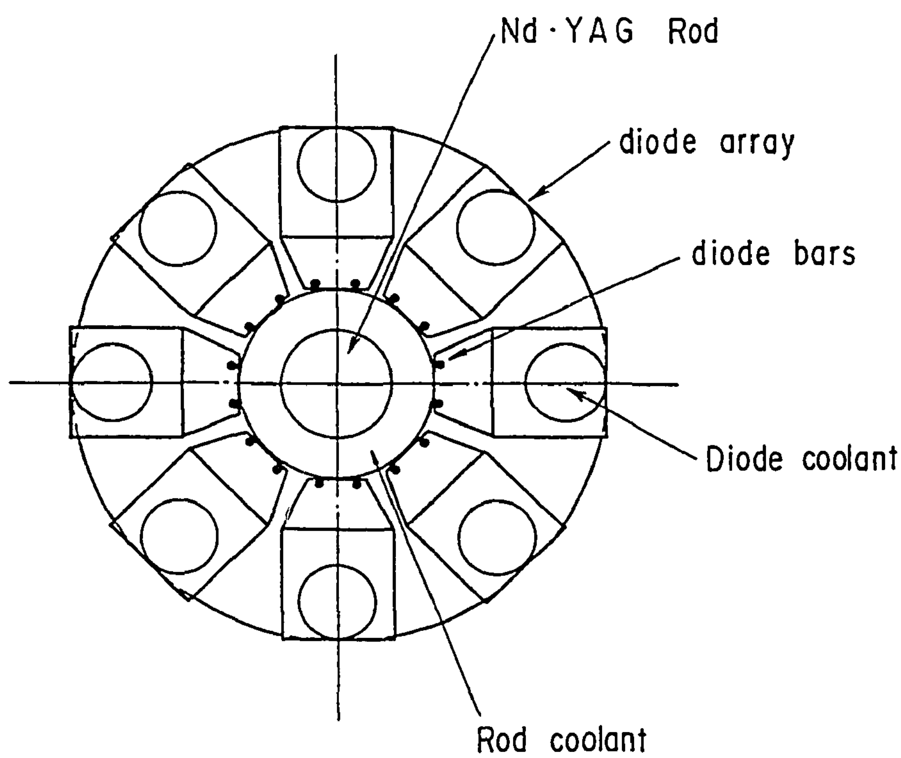



fig. 1 Pump head schematic

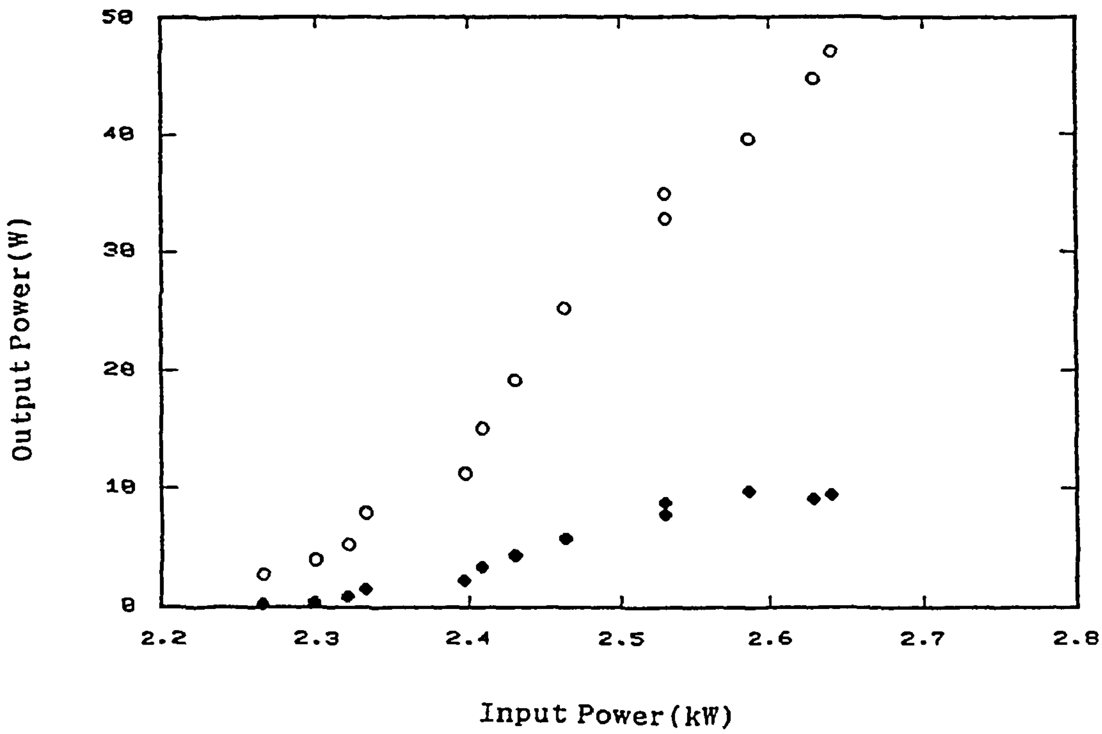



fig. 2 1064nm Output Power vs. Input Power

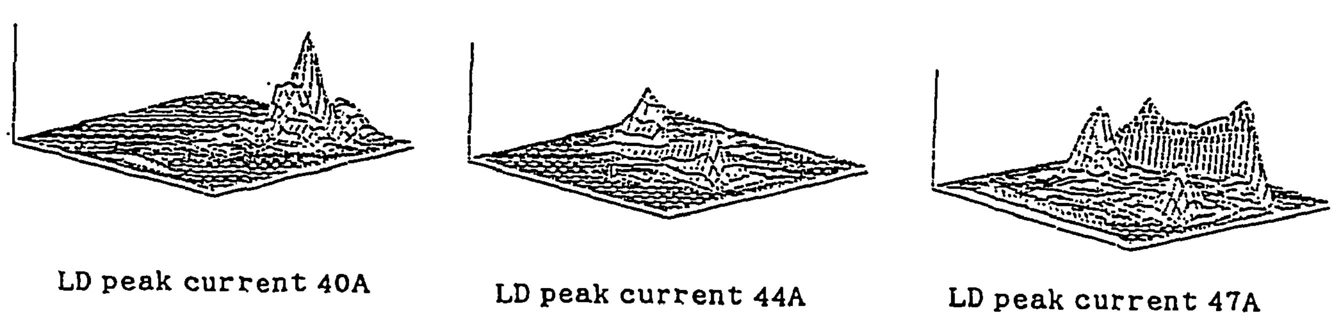
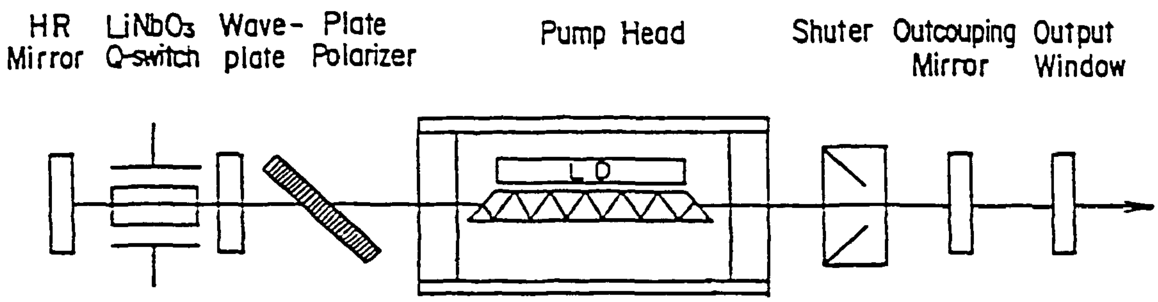
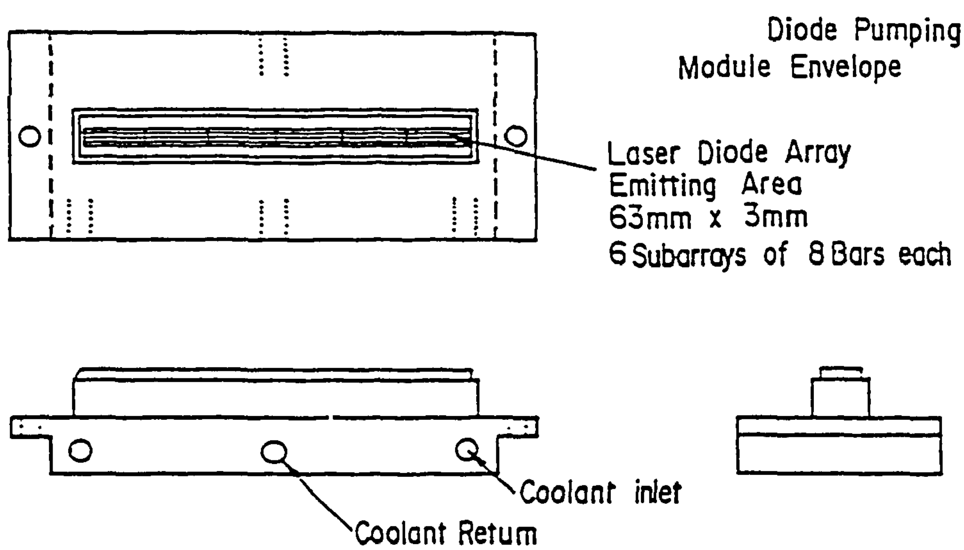



fig. 3 Beam Profile of 1064nm




Laser Head Optical Schematic




Diode Pumping Module Machanical Envelppe

fig. 4 LD Pumped Zig-Zag Slab YAG Laser

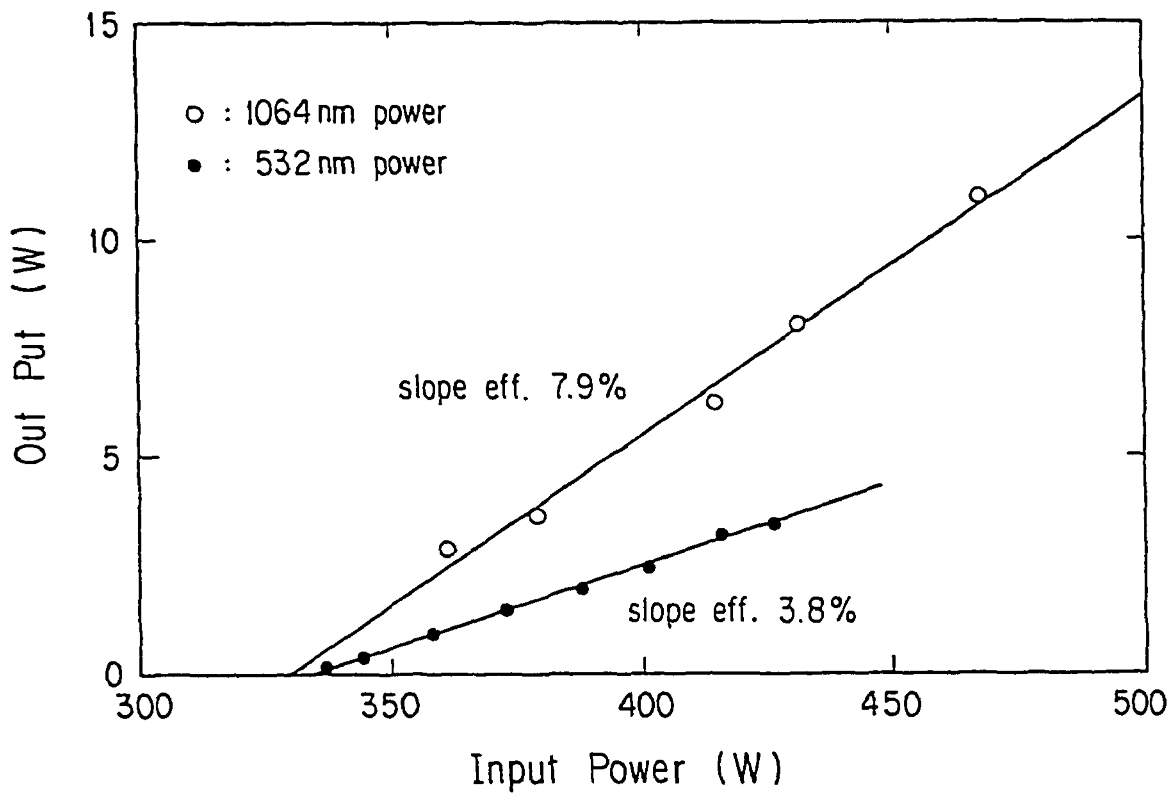



fig. 5 Zig-Zag Slub YAG Out Put Power

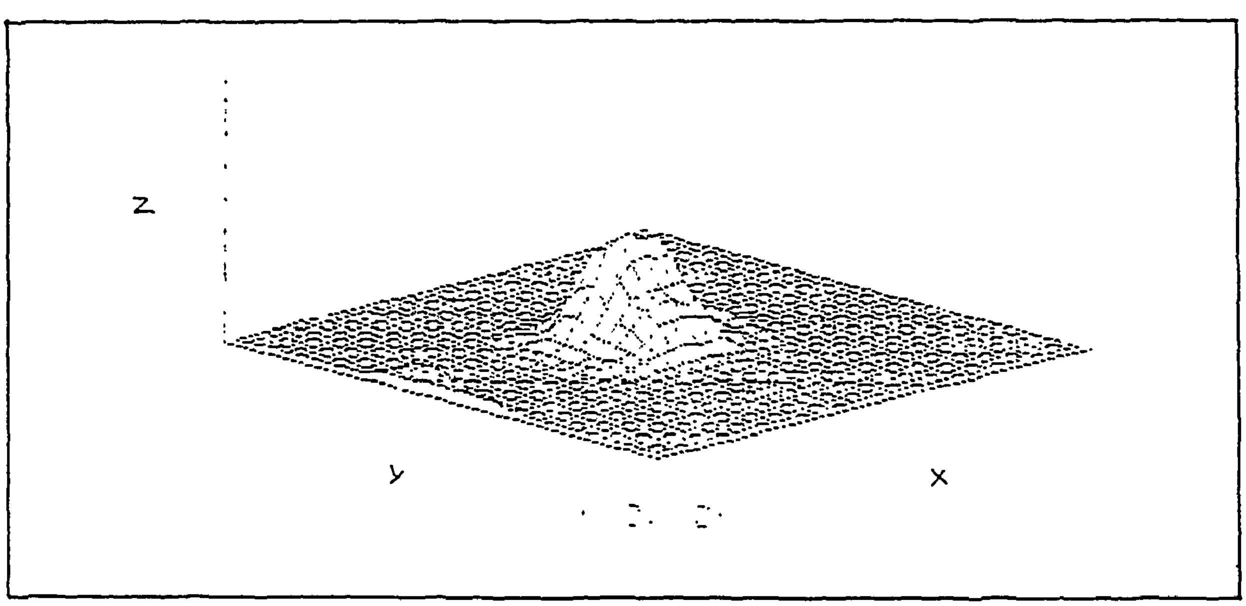



fig. 6 Beam Profile of 1064nm

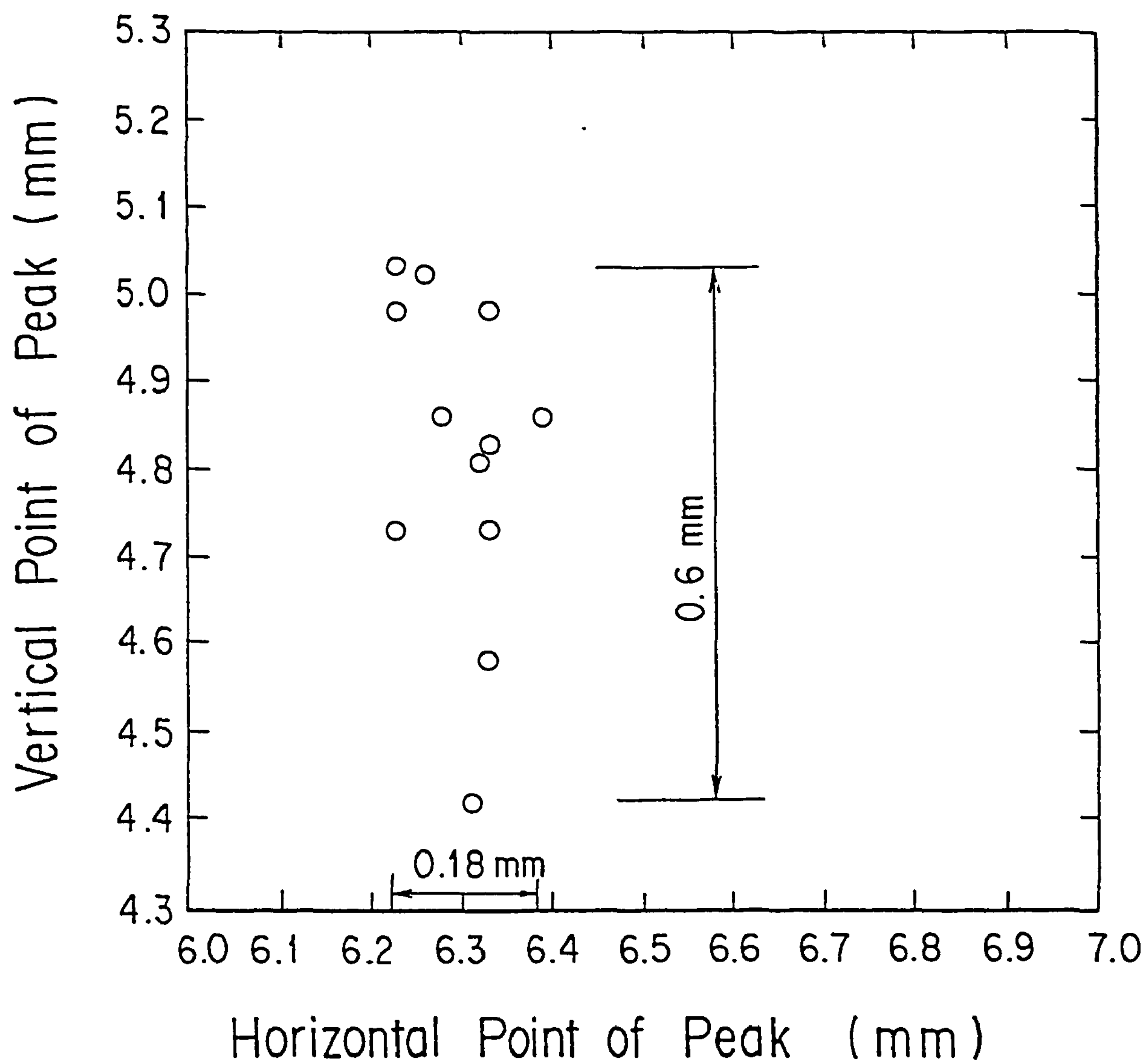



fig. 7 Zig-Zag YAG Slab Pointing Stability

3m from out put mirror

Beam diameter : 3.9 mm

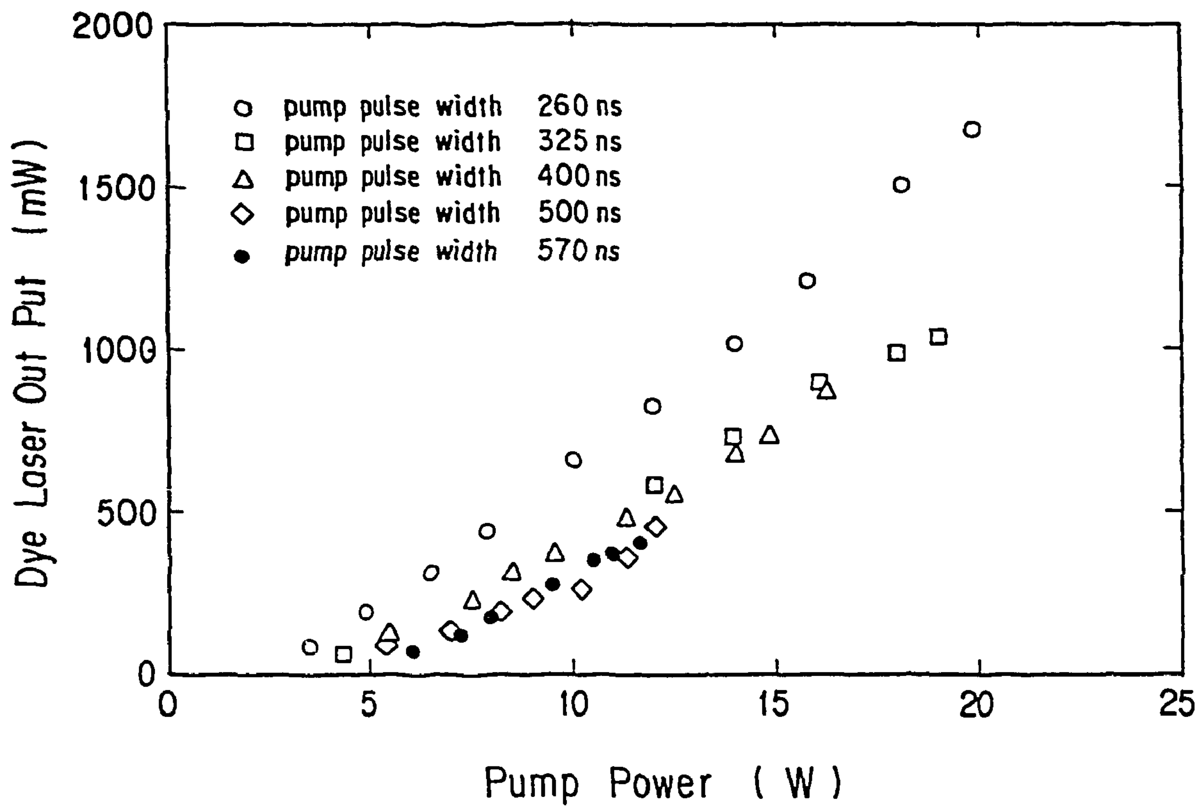



fig. 8 Dye Laser Out Put vs. Pump Laser Power

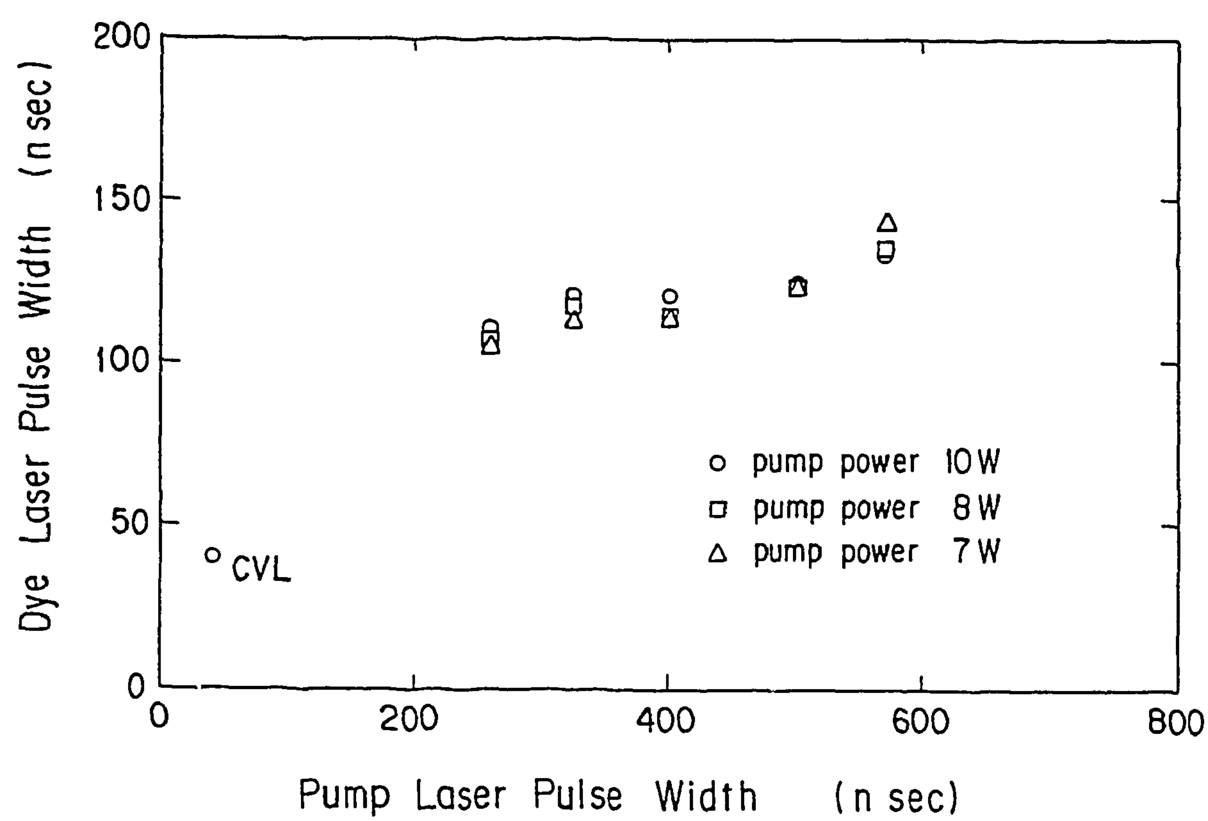



fig. 9 Properties of Dye Laser Pulse Width