Chapter 3 Experiment Setup

3.1 Laser system

Our experiment schematic is shown in Fig. 3.1. We use a laser diode as the pumping source. Note that, in order to control the pump spot size, we used some optics before the objective lens. We will discuss how to find the suitable pumping spot size in the following section. The pumping light passed through the optics to rearrange the pumping distribution, then focused on the gain media by the objective lens. The laser gain medium is a 1mm- thick Nd:YVO_4 crystal. The facet of the pumping side is coated with greater than 99.8% reflection at 1064 nm and greater than 99.5% transmission at the pump wavelength. The other facet is coated an antireflection layer at 1064nm to avoid the effect of intracavity etalon. The gain medium is mounted on a translation stage to tune the pumping spot size. The output coupler with the radius of curvature is 8 cm with 10% transmission at the lasing wavelength 1064 nm, and is mounted on a translation stage so that we can tune the cavity length around the degenerate configuration. In our experiment, we focus our attention on the cavity configuration of $g_1g_2 = 1/4$, and the output coupler has 8cm-curvature, so the cavity length is around 6cm. The laser output is separated into two beams by the beam splitter, one of which is observed the pattern by a CCD camera, another is focused on a photodiode with rise time < 0.3 ns. The signal of the photodiode is sent to the LeCroy 9450A oscilloscope (bandwidth 200MHz) and the HP 8560E RF spectrum (bandwidth 2.9GHz), respectively.

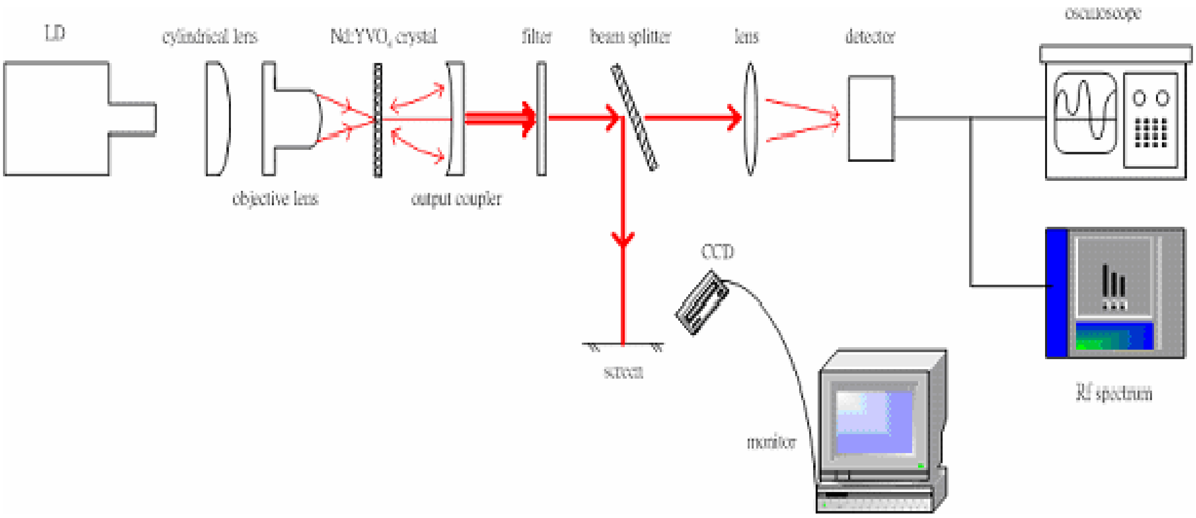


Fig. 3.1 the Nd:YVO_4 laser system setup

3.2 Controlling of the spot size

We used a laser diode as a pumping source, and the diode with a proper optics element to form a 200μm x 200μm beam spot. Fig. 3.2 is a measurement of the spot size by standard knife method. Because of the diffraction effect, the divergent angle of the light from the laser diode is asymmetric. It is obviously that the foci are located at different places on the Z-axis for X and Y- directions respectively. The larger aspect ratio of the pump spot, (i.e. 10:1), the more non-orthogonal transverse modes would be induced (ref. [11]), and that would make the dynamics more complicated. We must make the light distribution as symmetry as possible approach symmetrically to avoid such transverse effect. However, it is impossible to have perfect symmetrically pump spot because of the optical character of laser diode. So, we try our best to make the light distribution symmetric, and will introduce these methods in the following section.

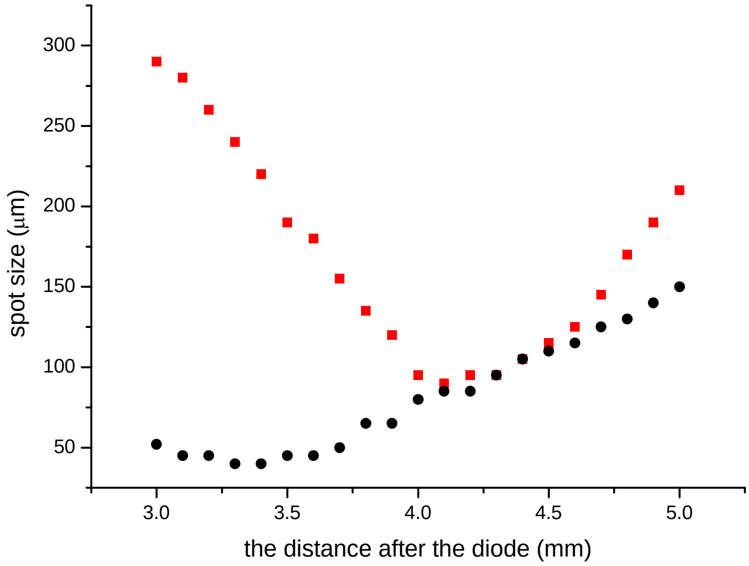
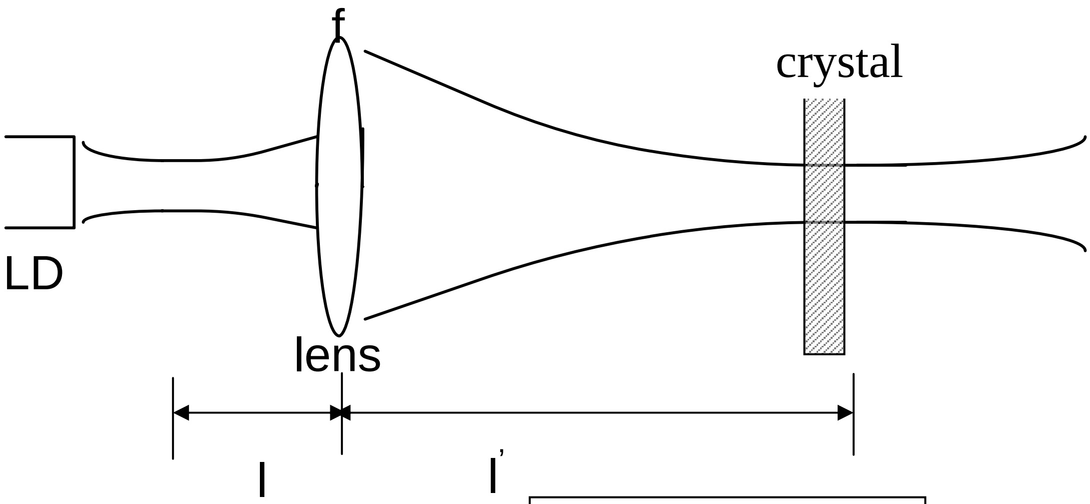


Fig. [3.2] The distribution of the light from the laser diode

3.2.1 Lens imaging

In the beginning, we try to use lens image to shape pumping spot, show as in Fig. 3.3. From Fig. 3.2, we know that the aspect ratio of pump spot is approach to one at 4mm. Using theory of geometric optics, we can use a lens to image and magnify this square spot on the laser crystal. However, the square spot is not a beam waist which is expanding on the X direction, so the distance and magnification derived from geometric optics is not exactly. And the other disadvantage is that, if we want to change the spot size pumped on the crystal, we must change the magnification of the lens image. Then we must change the distance of both object and image, it would induce a lot of experimental error. Because of these two reasons, we give up this method and try another method in which we use prism pair to rearrange the light distribution.



$$\frac{1}{l'} = \frac{1}{l} + \frac{1}{f'}$$

$$m = \frac{l'}{l}$$

Fig. 3.3 The alignment of lens image

3.2.2 Prism pair

A simple and economic way of transforming the elliptical laser beam cross-section emerging from a collimating lens into a circle, is to use a pair of identical wedge prisms, as shown in Fig. 3.4. When the parallel light pass as through the first prism, the light would be expanded because of the astigmatism effect. Then incident to the other prism, the light would be collected to parallel but also enlarged. So we try to use prism pair to expand the light distribution.

However, there are still several disadvantages in this method. First of all, as shown in Fig. 3.4, the light ray would be shifted by the prism pair, and this shift will affect our optical alignment. Second, the magnification effect is induced by the relative angle of the prisms pair. But if the angle is misaligned, the prism pair will cause a lot of loss. So we try the other method to use cylindrical lens.

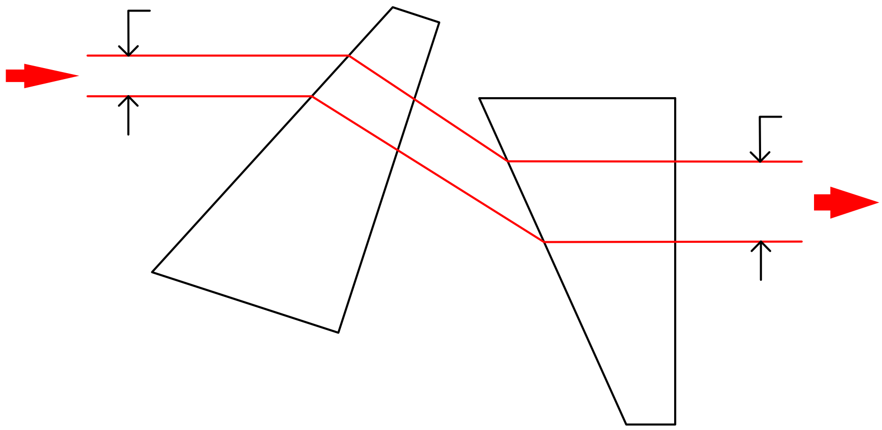


Fig. 3.4 The light expansion of prism pair

D_{in}

3.2.3 cylindrical lens

Finally we use a cylindrical lens after the laser diode to rearrange the light distribution make the symmetric pump. As the Fig. 3.5, we can see the only one axis of light is focused by the cylindrical lens. We use this character of cylindrical lens to focus the long axis of the asymmetric light which is emitted from laser diode and make the light symmetrically. On the other hand, we can tune the focal point of the long axis of the light by tuning the relative distance between the cylindrical lens and laser diode.

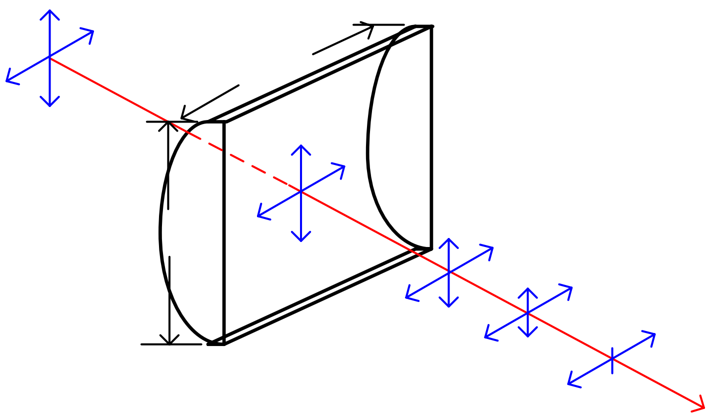
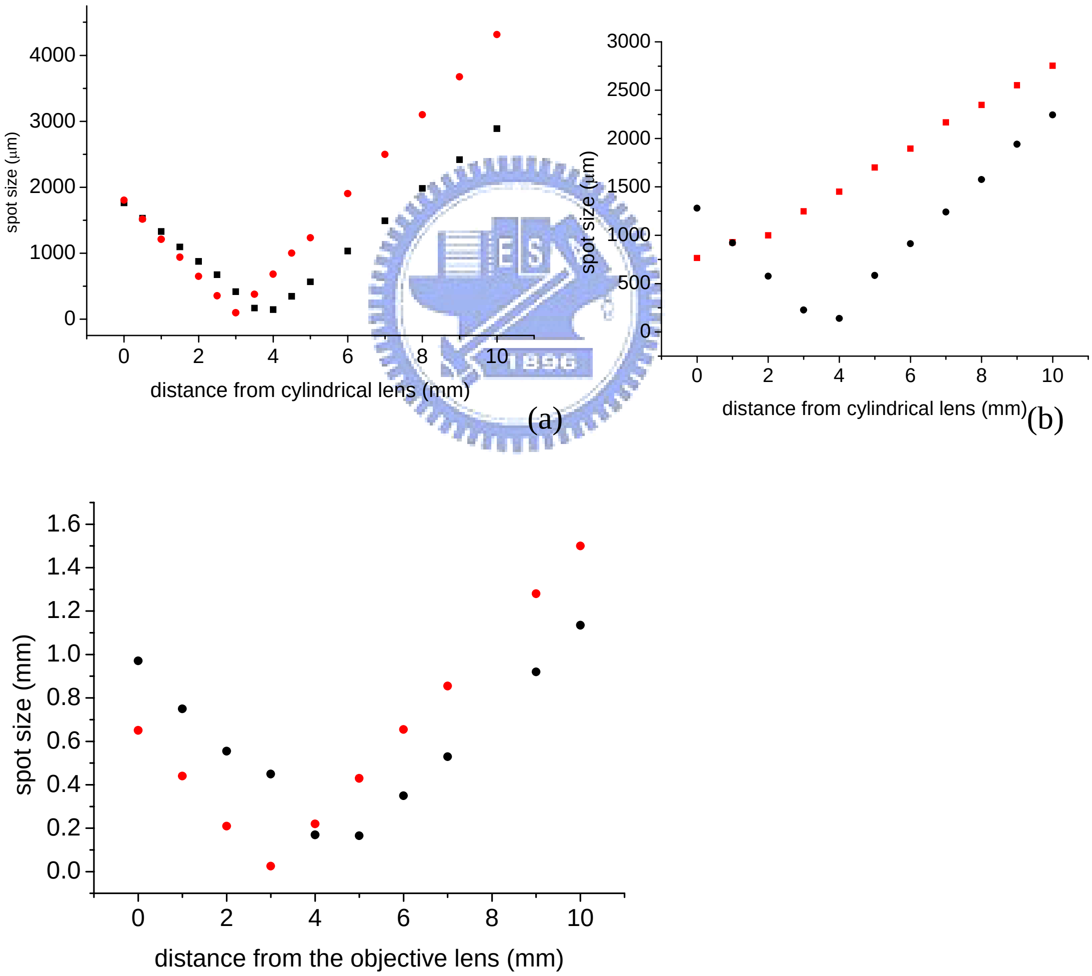


Fig. [3.5] The light rearrange by the cylindrical lens

We can rearrange the spot size of each axis of the pump light and tuning the focal points. We had measured three spot size of different relative distance between laser diode and cylindrical lens, shown as Fig. 3.6. It is measurement of the minimum relative distance, we can see that the divergent angle is nearly equal, and the focal points almost coincide each other. In Contrast, Fig. 3.6 (b) is measurement of the maximum relative distance, the spot size of two axes is significant unequal, and the focal point is far away from each other. Fig. 3.6(c) is the same measurement of a distance between (a) and (b). The spot size in Fig. 3.6(a) is the most symmetric one, but we carried out our experiment in the region of Fig. 3.6(c), and we will discuss the reason in the following section.



(c)

Fig. 3.6 The distribution of the light after rearrange by the cylindrical lens as tuning the distance between laser diode and the cylindrical lens. The distance in (a) is smallest, (b) is largest, and (c) is middle.

3.3 Determine the location of the smallest spot size by the pump saturation

In the previous section, we have found a suitable setup to proceed our experiment, but another question is coming. We use the knife method to measure the distribution of the pumping beam after the cylindrical lens. However, can we know the beam exactly focusing on the crystal? There is a method of pumping saturation can help us to determine it.

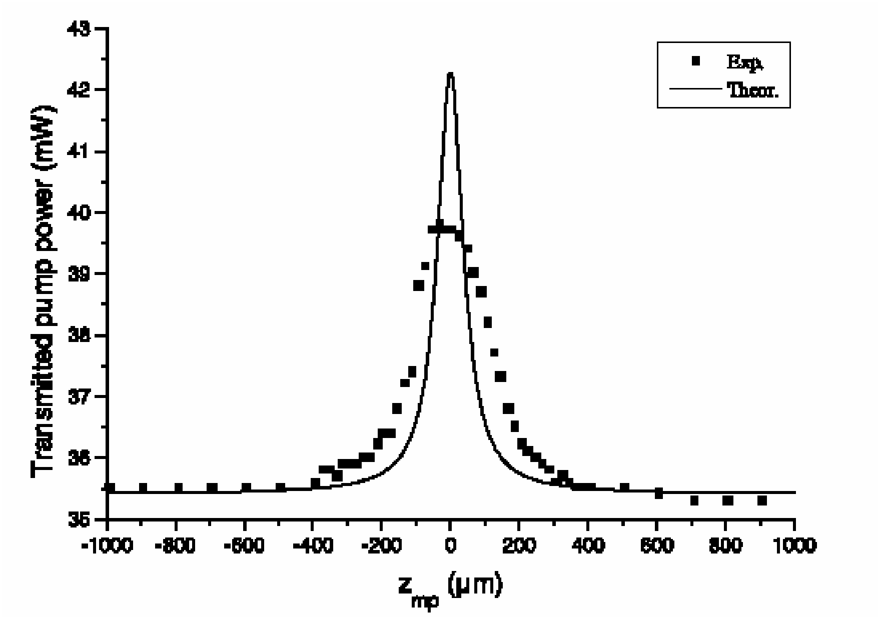


Fig. [3.7] transmitted power versus the focusing position

Pump saturation effects have been observed in a tiny end pumped solid state Nd:YVO_4 laser (ref. [12]). It shows that the transition pump power will arise under the focus of pump beam on the laser crystal, shown as Fig. 3.7. Z_{mp} = 0 means that the crystal put on the position where the pump beam waist is. The larger Z_{mp}, the larger spot size is, and the crystal is farther away from the focal point. The sign presents that we move the distance away from or close to the objective lens. This configuration shows that the transmitted pump power increases significantly at the focal point.

The experiment sketch shows in Fig 3.8. Mounting the crystal on a translation stage, and then tuning the location of the crystal, we can measure the residual pump power after the laser crystal. We also can obtain the similar result to show as Fig. [3.7]. Because the pumping saturation effect, we know that the transmitted pump power is maximum as the pump spot size is minimum. Using the location and the distribution of the pumping beam, then we can control the spot size pumped on the crystal by tuning the position of the crystal.

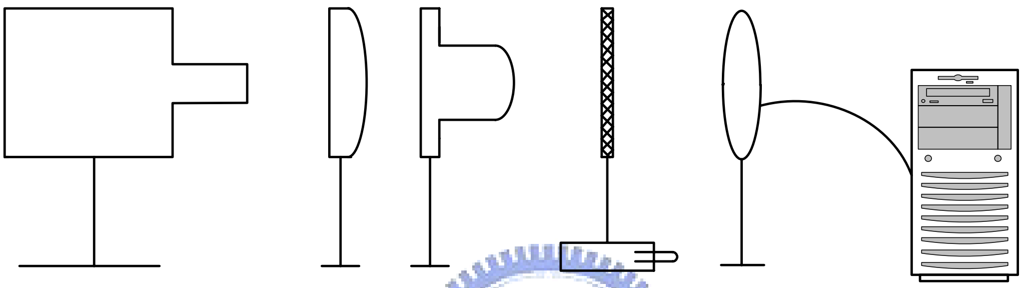


Fig. [3.8] the experiment setup for determining the spot size

3.4 Laser system

The cavity is a plano-concave resonator, for this kind of cavity, the most important work is to determine the optical axis. We use two apertures and a He-Ne laser to align all optics elements. First, set two apertures to the same high, then use two reflective mirrors to line up the ray of the He-Ne laser passing through these two apertures. Then make the laser emitting from the laser diode overlap with the He-Ne laser. Put the element on the axis and tune the angle slightly to make the reflection point back to the aperture that we can be sure that this element is perpendicular and centered on the optical axis. Use this method we can construct our cavity on the optical axis and complete the rough laser cavity alignment.

LD

3.4 Laser system alignment

Turn off the He-Ne laser and turn on the LD, we can see the laser output pattern on CCD. However, because of the slightly miss alignment of the angles of the elements, the pattern may be not the TEM_{00} mode but some high order modes. The following procedure describes the fine tuning of the laser system:

1. Adjust the angle of the output coupler to make the output power maximum.
2. Decrease the cavity length.
3. Adjust the angle of the crystal to make the output power maximum
4. Increase the cavity length.
5. Adjust the angle of the output coupler to make the output power maximum.

Repeat this procedure several times until the output power would not change as we tile the angle of the output coupler and crystal. So as the alignment is finished and we can be sure that our laser output pattern is TEM_{00} mode.