# OPTICAL PUMPING WITH LASER DIODE

## 1. INTRODUCTION

In recent years, a pronounced trend toward laser diode pumping of solid state lasers has gained considerable interest. The availability of cheap and reliable laser diodes tuned to the absorption band of laser crystals brought many changes to the way solid-state lasers are being designed. This is particularly true for end-pumped lasers. In many regards end-pumping resembles coupling to multimode fibers. In both cases the goal is to fill a fiber/laser core with an illuminating beam within a certain acceptance cone (a numerical aperture). Once the beam enters the optical fiber, the fiber cladding confines the light inside the fiber and prevents the beam from spreading. In laser crystals, the doped area is not limited by an effective cladding and the pump beam that enters the doped area within its cross-section might subsequently stray outside. This can be avoided either by collimating the pump beam and/or by adjusting the divergence and cross-section of the illuminating beam to fit inside a doped region on its passage along the lasing medium. Fortunately, the high refractive index of most lasing media helps lessen the beam divergence. Here are three possible approaches to the design of end-pumping optical systems using only cylindrical lenses:

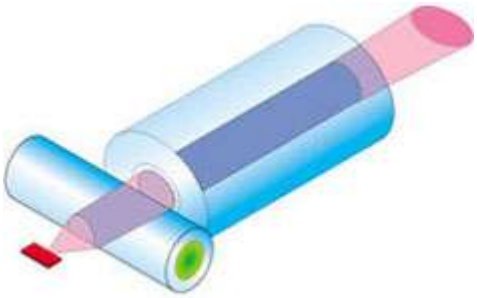

**Figure 1**. Single cylindrical lens pumping

## 2. SINGLE CYLINDRICAL LENS

A lens with a small diameter between 60 mm and 150 mm collimates the fast axis of the laser diode and leaves the slow axis divergence unchanged. This is a simple and compact approach that requires tight tolerancing due to a very short focal length of the lens. For example, the 60 mm diameter lens has a focal length of 41 mm and a working distance of 11 mm. For the laser diode with fast axis divergence of 60°, the beam width in the fast axis direction after collimation is only 41 mm. The laser crystal is so close to the laser diode that the slow axis beam grows only slightly larger than the length of the laser strip.

## 3. TWO CYLINDRICAL LENSES (for multimode fibers only)

The first lens collimates the fast axis of the laser diode while the second lens projects the image of the laser diode strip onto the fiber end. The second lens simply makes the slow axis beam to converge so that its waist is centered at the fiber-end. If the laser diode window is too long, this lens could be used to demagnify its size to fit inside the fiber's modal diameter. This should be used with caution since the beam divergence or numerical aperture will increase accordingly.

## 4. THREE CYLINDRICAL LENS (for singlemode and multimode fibers)

If the beam after the fast axis collimation is larger than the diameter of the fiber, the third cylindrical lens is added to refocus the beam to smaller size. Longer focal length of this lens reduces the beam divergence and helps match the numerical aperture of the fiber. The second lens is used to image the length of the diode strip, with necessary demagnification, on the fiber end. In this approach the system can be scaled to any size and thanks to extraordinary quality of our gradient cylindrical lenses it can be used for singlemode or multimode coupling. Larger lens diameters increase the system size but relax the positioning tolerances.

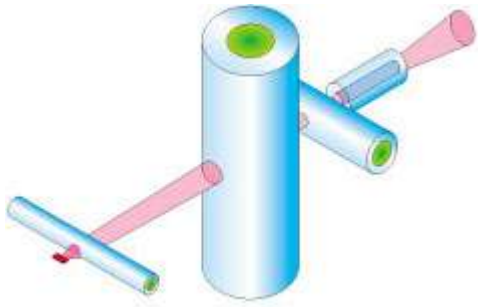

**Figure 2**. Three cylindrical lens pumping