CHAPTER 3

System Description

3.1. *General Laser Theory*

LASER is the acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. The laser is a device consisting of an active medium and a pumping source enclosed in an optical cavity. The pumping source 'pumps' the active medium from its ground energy state to excited states. If 'population inversion' between two excited states takes place (where the higher energy state is more populated), stimulated emission of radiation (photons) can occur. This emission is resonated (reflected back and forth) within the optical resonator and amplified. A portion of this amplified electromagnetic energy is then emitted as a laser beam.

The main properties of the beam are:

- **Monochromaticity -** the radiation is within a very narrow wavelength range on the spectrum.
- **High degree of collimation -** unidirectional beam with very small divergence.
- **Coherence -** all photons emitted are in phase, both in space and time.

The high degree of collimation and coherence enable the focusing of the beam to small spot sizes, although when connected to the delivery fiber, the beam diverges at a wide angle.

The active (lasing) medium of a laser can be either gas, liquid or solid. Most gas lasers consist of atoms, molecules, or mixtures of both. Solid-state lasers consist of atoms or ions "doped" in some solid matrix. Liquid lasers consist of higher molecular weight molecules dissolved in liquids.

Under specific pumping conditions, all these materials can undergo the unnatural phenomenon of 'population inversion' that results in stimulated emission of radiation at a wavelength characteristic of the active medium.

3.2. Diode Laser Theory

The diode laser is a semiconductor laser array emitting in the near infrared range at a wavelength of 810-850nm.

The active medium in a diode laser is a semiconductor P-N junction made in a GaAlAs crystal.

When the junction is forward biased, electrons and 'holes' are injected across the junction to create a 'population inversion' in a narrow zone called the **active region**.

Light emission takes place at the junction, where electrons and 'holes' recombine to emit photons. If the current injected into the junction becomes strong enough, the inverted population can produce an optical gain large enough to overcome power losses in the crystal, thereby achieving the laser effect.

In the case of diode lasers, it is not necessary to use external mirrors to provide positive feedback. The reflectance at the cleaved crystal/air interface is sufficiently high to reflect a large portion of the radiation produced at the P-N junction.