CW Nd:YAG LASER SYSTEMS

Introduction

Several solid-state laser systems may be operated continuously, but the most common of these is the CW Nd:YAG laser system, operating at 1.06 microns. This lecture discusses the basic components, general characteristics, and subsystems of these lasers. As the removal of waste heat energy is of the greatest importance in the solid-state laser systems, and in particular in CW systems, much of this lecture will deal with energy flow in the laser and with cooling considerations.

This lecture explains the efficiency of a CW Nd:YAG laser by analyzing the power flow and conversion through each component of the system. The purpose of this exercise is to illustrate where power losses can occur, which elements of the laser will become excessively hot during operation, and what methods are useful to cool these components.

Components of a CW Nd:YAG Laser

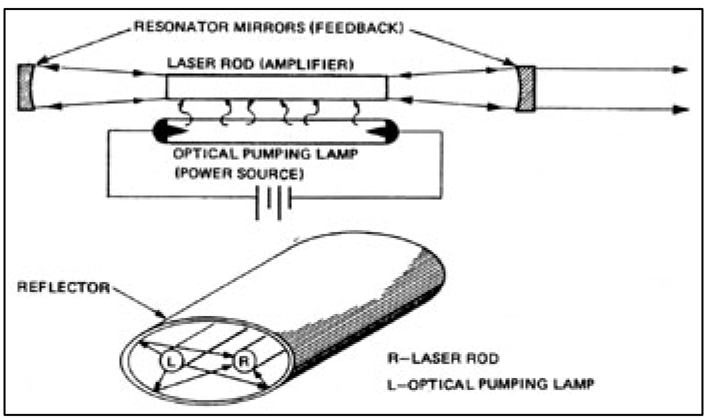

Fig. 1 Basic design of CW Nd:YAG lasers.

Laser Rod

Optical Pumping System

Optical Cavity

Cooling System

The cooling system is one of the most critical subsystems in the laser. Smaller lasers may use open-loop cooling systems with tap water flowing across the rod. In such cases, the water should be filtered to remove any contamination or impurities. Larger systems use closed-loop cooling with water or a water-glycol solution. The coolant is usually refrigerated, but water-to-water or water-to-air heat exchanger may also be employed.

Energy Losses in Nd:YAG Lasers

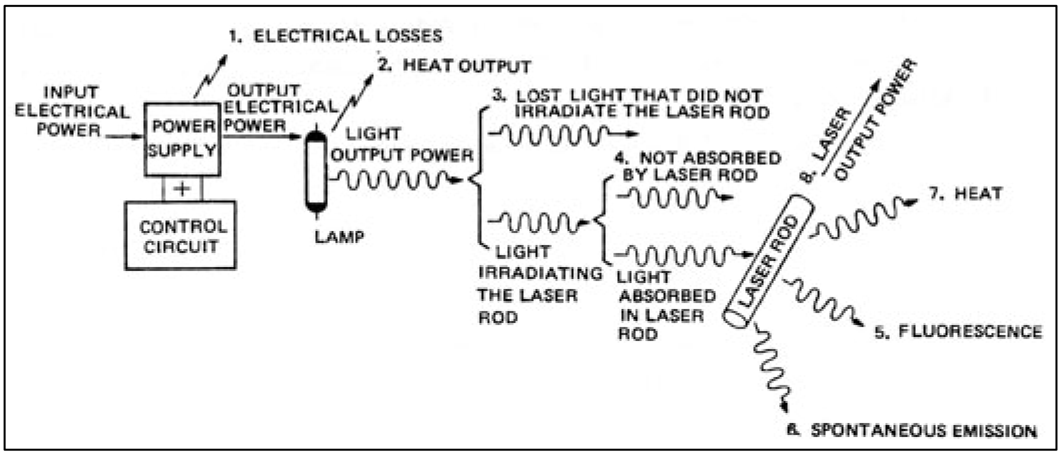

Fig. 2 CW solid-state laser efficiency diagram.

Cooling System Calculations

The cooling system of the laser must remove most of the waste heat from the entire system. Only a small fraction of the input energy appears in the laser output. Other relatively small amounts of energy escape as fluorescence passing through the rod ends and as radiative or convective heating of the laser environment. The cooling system must be capable of removing waste heat continuously at the maximum input power level.

Example A: Cooling System Design for Nd:YAG Laser.	
Given:	A CW Nd:YAG laser with 1000 watts of electrical power input to a tungsten lamp requires a cooling system which will limit the

	temperature rise in the rod coolant to 3 centigrade degrees.
Find:	Water flow rate and total temperature rise in cooling water.
Solution:	*Step 1*: Estimate the amount of power absorbed by the rod. a. Power supply losses can be measured. (For this problem, assume that the power supply is 80% efficient). b. Percentage of lamp output (incident on the rod) absorbed by the laser can be estimated by comparing the output spectra with the absorption spectra of the rod. (For this problem, assume that 30% of the output is absorbed). c. Assume that the pump lamp reflector is 90% efficient. Total power absorbed in laser rod = (1000 watts) × (0.8) ×(0.30) × (0.9) = 216 watts *Step 2***:** Estimate laser rod heat power to be removed (H_{LR}). a. Total power absorbed = 216 watts b. Output laser power = 7 watts $H_{LR} = 216 - 7 = 209$ watts *Step 3*: Convert units of heat power from watts to calories/second. $H_{LR} = 209$ watts 1 watt = $\frac{\text{joule}}{\text{sec}}$ $H_{LR} = 209$ joules/sec 1 calorie = 4.18 joules

	$H_{LR} = \frac{209}{4.18} = 50$ cal/sec *Step 4:* Determine flow rate. We know that 1 calorie will raise 1 gram of water (or approximately 1 cm^3) 1 degree centigrade. To limit temperature rise in the coolant water to 3 centigrade degrees, dissipating a heat rate of 50 calories/second, the heat exchanger must have a flow rate of $\frac{50}{3}$ cm3 /sec = 16.7 cm3 /sec = 1000 cm^3 /min or 0.26 gal/min. *Step 5*: Determine total temperature rise in coolant water. After the water has cooled the laser rod, it must cool the lamp and cavity. Total heat to be dissipated in coolant (H_{TOT}): $H_{TOT} = P_{in}$ – power supply losses – laser output $H_{TOT} = 1000 - 200 - 7 = 793$ watts $H_{TOT} = 793 \frac{\text{joules}}{\text{sec}} = 189.7$ cal/sec Flow rate = 16.7 cm3 /sec Temperature rise = $\frac{H_{TOT}}{\text{Flow Rate}} = \frac{189.7 \text{ cal / sec}}{16.7 \text{ cm}^3 \text{ / sec}}$ = 11.4 cal/cm3 – 11.4 C? Temperature rise in coolant = 11.4 centigrade degrees

The absolute equilibrium input temperature of the coolant water will be determined by characteristics of the cooling system and the ambient conditions.

A typical coolant temperature might be 40C^o. Using this value and those calculated in Example A, a coolant flow diagram can be drawn as shown in Figure 7.

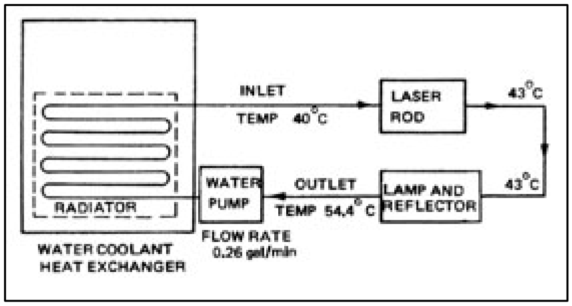

Fig. 3 Typical CW laser coolant flow diagram (parameter values obtained from Example A).