PHGN 480: Laser Physics due 14 Oct 2010
Homework 4

1) *Gain saturation.* In a high-power amplifier, the beam passes through the gain medium once, and the beam size is adjusted to maximize the energy extracted from the amplifier.
   a. The saturated gain of a square pulse passing through an amplifier is given by the Frantz-Nodvick equation (1963):
   $$G = \frac{F_{sat}}{F_{in}} \log\left[1 + \left(\exp\left(\frac{F_{in}}{F_{sat}}\right) - 1\right)\exp\left(\frac{F_{stor}}{F_{sat}}\right)\right]$$
   Here, F_{sat} is the saturation fluence, F_{in} is the input fluence, and F_{stor} is the stored fluence (total extractable energy density times the length of the gain medium.) Show that in the limit of $F_{in}/F_{sat} \ll 1$, the single-pass gain reduces to the expected small-signal gain (independent of F_{in}).
   b. Calculate an expression for the ratio of the extracted energy to the stored energy. Plot this ratio versus input fluence, making curves for a few values of the small-signal gain. Explain the trend you see, and determine a good estimate for the value of F_{in}/F_{sat} that allows for extraction of 50% of the stored energy.
   c. The Frantz-Nodvick equation assumes that electrons leave the lower lasing level in a time much shorter than the pulse duration. How would you expect your answer to change if the opposite were true?

   Comment: This ratio for input fluence/saturation fluence is the major determinant of how amplifiers are designed for different gain media. At one end, the saturation fluence for dyes is on the order of a few mJ/cm2, and at the other end, ytterbium amplifiers (e.g. Yb:KGW, Yb:glass) have a saturation fluence of around 10J/cm2. With low saturation fluence, the amplifier is easy to saturate, but there is a limited amount of energy that can be stored. With high saturation fluence, there is high energy storage, but it is difficult to extract the energy without damaging the laser rod.

2) Svelto 6.2
3) Svelto 6.8
4) Svelto 6.9
5) Svelto 7.5
6) Svelto 7.14