Additional/Home Tasks – From "Lasers" – A. Siegman

1. *Energy storage and Q-switching in a solid-state laser.* Solid-state lasers (and some gas lasers) can be operated in a useful fashion known as "Q-switching," in which laser oscillation is prevented by blocking (or misaligning) one of the cavity end mirrors, and building up a very large population inversion in the laser medium using a long pump pulse. At the end of this pumping pulse, the mirrors are suddenly unblocked, and the laser then oscillates in a short but very intense burst that "dumps" most of the energy available in the inverted atomic population.

   Pink ruby of the type used in ruby lasers contains $\sim 2 \times 10^{19}$ chromium Cr^{3+} ions/cm^3. In a typical Q-switched ruby laser, almost all the ions in the laser rod can be pumped into the upper laser level while the mirrors are blocked, by a flashlamp pump pulse lasting $\sim$1 ms. Since the resulting Q-switched pulse when the mirrors are unblocked typically lasts only $\sim$50 ns, there will be no further pumping or repumping once the Q-switched pulse begins. What will be the maximum possible energy output in such a single-shot Q-switched burst from a cylindrical ruby rod 7.5 cm long by 1 cm diameter? What will be the peak laser power output (approximately)?

2. *Optical intensity in a focused laser-beam spot.* If the laser pulse in the preceding problem is focused onto a circular spot 1 mm in diameter, what will be the peak power density (in W/cm^2) in the spot? What will be the optical E field strength in the spot?

5. *Heating effects due to focused laser beams.* We wish to gain some feeling for the heating effects of focused laser beams, by calculating these effects for some highly idealized (and hence not fully realistic) examples, as follows.

   (a) A 1-Joule, 100-nanosecond pulse from a Q-switched Nd:glass laser is focused onto a metallic surface and totally absorbed in a volume of material 20 microns in diameter by 10 nm (100Å) deep. Neglecting surface losses and heat conduction into the material, what will be the initial rate of rise of the temperature in the absorbing volume?

   (b) A 1-Watt laser beam (perhaps from a 1-Watt cw Nd:YAG laser) is focused by a good-quality lens into the same spot. If both heat conduction and vaporization of the material are ignored (which is clearly *not* realistic), what will be the predicted steady-state temperature of the surface in the focused spot?

   (c) Suppose a 100-Watt cw beam is used, and all the laser power goes into vaporizing material in and near the spot, so that the laser beam tunnels a hole with a constant 50 μm diameter into the medium. What is the drilling rate in meters/second?

   In each of (a) to (c), assume for simplicity a material density of 2 gms/cm^3, a material specific heat of 1 cal/gm-deg K, and in (c) a vaporization temperature of 1,800 K .