

1. (8 pts) The mass of a copper atom is 1.0552×10^{-25} kg (there are two stable isotopes of copper, and this is the isotopically averaged mass). The density of solid copper is 8.933 grams/cm³. (a) Assuming that each copper atom contributes one electron to the “gas” of conduction electrons inside the metal, what is the Fermi energy for solid copper (in eV)? (b) What is kT in eV for room temperature ($T = 300$ K)? This explains why quantum mechanics is vital to understand what electrons do in solids. You can’t understand conductors, semiconductors, optical absorption, etc. without quantum mechanics. (c) What is the average kinetic energy per conduction electron (in eV) in a piece of copper at room temperature (300 K)?
2. (6 pts) Justin Peatross, a professor here in our department, has a laser can produce pulses centered at 800 nm with an energy of 100 mJ and which last about 25 femtoseconds. (a) What is the average power output of the laser during the pulse? (b) If he focuses the laser to a round spot which is 10 μ m in diameter, what is the light intensity in the laser focus? For reference, the intensity of light at the surface of the sun is about 6×10^7 W/m². (c) How many photons are there in a pulse?
3. (6 pts) (a) The gain medium that Justin uses, Ti:Al₂O₃ (titanium doped sapphire, or Ti:sapphire), has a gain bandwidth of about 250 nm, extending from 700 nm to 950 nm. Estimate the duration of the shortest pulse possible from a Ti:sapphire laser. (b) How much bandwidth would my gain medium need to have to make a pulse of light centered at 800 nm which consisted of a single cycle (i.e. the electric field goes from zero, up to a maximum value, down to a minimum, and then back to zero again only once)?
4. (5 pts) What advantage is there of using a 4-state rather than a 3-state laser scheme?
5. (5 pts) Why are mirrors important to make a laser work?

Extra problems I recommend you work (not to be turned in)

- I have two lasers. They have identical high reflectors, but different output couplers. One lets only 1% of the light through, reflecting 99%. The other lets 10% through, reflecting 90%. If my goal is to get as much power out of my laser as possible, under what conditions would I choose the 99% reflector, and under what conditions would I choose the 90% reflector?
- In many types of lasers we “pump” the gain medium by shining light from another laser onto it. (a) Explain why the “pump” laser usually has to have a shorter wavelength than the laser it is pumping. (b) Explain why the laser beam we generate will have less power than the “pump” laser beam, even if we have perfect mirrors, no spontaneous emission, etc.
- Consider how the length of the laser cavity will affect the minimum “pump power” that you need to reach threshold. Does the threshold go up or down as you increase the length of the cavity?