1. a) For the n = 3 to n = 2 transition in hydrogen, the emitted photon energy is given by

$$E_{photon} = \Delta E_{atom} = E_{n=3} - E_{n=2}$$
$$= 13.6\ \text{eV}[1/2^2 - 1/3^2] = 1.89\ \text{eV}$$

In joules this is equal to $E_{photon} = 3.02 \times 10^{-19}$ J. Then λ is given by

$$\lambda = hc/E_{photon} = 658.1\ \text{nm}$$

[Knowing that 632.8 nm is red (the He-Ne) means that 658 nm is a somewhat deeper red]

b. The intensity is

$$I = E_{photon}\ (N/t)\ (\text{efficiency})/\ \text{Area},$$

where (N/t) is the number of photons/sec. Therefore

$$I = (3.02 \times 10^{-19}\ \text{J/photon})(10^{12}\ \text{photons/s}) / (10^{-3}\ \text{m})^2$$

or $I = 3.0 \times 10^{-1}\ \text{W/m}^2 = 0.3\ \text{W/m}^2$;

but we only collect half of these and so the net I = 0.15 W/m^2.

c. In 1 minute the energy delivered by the CW beam is

$$E = \text{Power x time} = (3.02 \times 10^{-19}\ \text{J/photon})(10^{12}\ \text{photons/s})(60\ \text{s})$$
$$E = 1.8 \times 10^{-5}\ \text{J}$$

For a 1 nsec pulse to deliver this same energy the average pulse power needs to be

$$P = \text{Energy/time} = 1.8 \times 10^{-5}\ \text{J}/1 \times 10^{-9}\ \text{s} = 18{,}000\ \text{W} = 1.8 \times 10^4\ \text{W}$$