HW 1

1) Problem 1.1

a) Laser beam is coherent – all photons are in phase, Also they propagate in same direction and have the same freq.

b) To test out the coherency of a laser beam, we can use intereferometer that rely on this unique property of a laser. For laser, we will see dark and bright fringings.

2) $E(ev) = E(J)/q$ $\quad q = 1.6\times10^{-19}$ (C)

Prob. 1.5 $\lambda(\mu m) = \frac{1.24}{E(eV)}$

$\nu = c_0/\lambda$

a)

	E(ev)	E(J)	λ(nm)	ν(Hz)	1/λ (cm⁻¹)
XeCl	4.025	6.45×10^{-19}	308.07	9.73×10^{14}	32460.2
Coumarin-2	2.755	4.414×10^{-19}	450.09	6.66×10^{14}	22217.8
Argon-ion	2.410	3.8614×10^{-19}	514.5	5.827×10^{14}	19436.4
Ti:Sapphire	1.631	2.614×10^{-19}	760.12	3.944×10^{14}	13155.8
Nd:YAG	1.165	1.867×10^{-19}	1064.0	2.8176×10^{14}	9398.5

c)

	E(eV)	E(J)	λ(nm)	ν(Hz)	1/λ (cm⁻¹)
Coumarin-102	2.53	4.054×10^{-19}	490.12	6.12×10^{14}	20403.2
Coumarin-7	2.60	4.169×10^{-19}	476.54	6.29×10^{14}	20984.6
Rhodamine 110	2.175	3.485×10^{-19}	570.0	5.26×10^{14}	17543.6
Cresyl violet	1.82	2.922×10^{-19}	679.95	4.409×10^{14}	14707
Nile blue-A	1.6986	2.72×10^{-19}	730.0	4.11×10^{14}	13698.6

d)

	E(eV)	E(J)	λ(nm)	ν(Hz)	1/λ (cm⁻¹)
AlGaAs	1.589	2.55×10^{-19}	780.4	3.84×10^{14}	12814.0
Nd:YLF	1.177	1.886×10^{-19}	1053.4	2.85×10^{14}	9493.1
Nd:glass (LHG-8)	1.176	1.885×10^{-19}	1054	2.84×10^{14}	9487.6
Nd:glass (LG-670)	1.169	1.873×10^{-19}	1060.8	2.826×10^{14}	9426.8
Er:YAG	0.422	6.758×10^{-20}	2940.0	1.02×10^{14}	3401.36

3) Prob. 1.7 $\frac{N_2}{N_1} = \exp\left(\frac{-(E_2-E_1)}{k_B T}\right)$ $k_B = 1.38065 \times 10^{-23}$ J/K

or $k_B = 8.617385 \times 10^{-5}$ eV/K

N_2/N_1	$E_2 - E_1$	T (K)
0.01	6328 Å	4937.8
0.01	11 GHz	0.1146
0.01	6 eV	15119.2
0.1	6328 Å	9875.6
0.1	11 GHz	0.2292
0.1	6 eV	30238.4

Prob. 18

a) $E_{pulse} = 0.4$ J/pulse, $\nu_{rep} = 30$ Hz, $t_{pulse} = 20$ ns, radius = 0.5 mm

$P_{ave} = E_{pulse} \nu_{rep} = 0.4 \times 30 = 12$ (W)//

$P_{peak} = 0.4 / 20 \times 10^{-9} = 20$ (MW)//

Fluence = E_{pulse} / area = $0.4 / \pi (0.5 \times 10^{-3})^2$

$= 5.093 \times 10^5$ (J/m^2) $= 50.93$ (J/cm^2)//

Peak intensity = P_{peak} / area = $20 \times 10^6 / \pi (0.5 \times 10^{-3})^2$

$= 2.546 \times 10^{13}$ (W/m^2)

$= 2.546$ (GW/cm^2)//

4) Problem 1.10

b) $\Delta\nu_{FSR} = \frac{c_0}{2nL}$, $\frac{\Delta\nu}{\nu} = \left|\frac{\Delta\lambda}{\lambda}\right|$, $n = 1$, $\Delta\lambda = |\Delta\nu| \lambda^2 / c_0$

	λ (nm)	L (cm)	$\Delta\nu_{FSR}$ (Hz)	$\Delta\lambda_{FSR}$ (Å)
Blue	465.8	65.5	2.2885×10^8	1.6563×10^{-3}
Blue	472.7	71.1	2.1082×10^8	1.5713×10^{-3}
Blue-green	476.5	89.1	1.6823×10^8	1.2741×10^{-3}
Blue-green	488.0	73.9	2.0284×10^8	1.6113×10^{-3}
Blue-green	496.5	78.7	1.9047×10^8	1.5662×10^{-3}

Green	501.7	88.4	1.6957×10^{8}	1.4237×10^{-3}
Emerald Green	514.5	93.5	1.6032×10^{8}	1.4156×10^{-3}

c)

	λ (nm)	L (cm)	$\Delta\nu_{FSR}$ (Hz)	$\Delta\lambda_{FSR}$ (Å)
Ruby	694.3	68.2	2.1979×10^{8}	3.5341×10^{-3}
Ti : Sapphire	760	75.2	1.9933×10^{8}	3.8404×10^{-3}
Cr : LiSAF	840	87.4	1.7151×10^{8}	4.0367×10^{-3}
Nd : YLF	1053.0	59.4	2.5235×10^{8}	9.3334×10^{-3}
Nd : Glass (LHG-5)	1053.0	63.8	2.3495×10^{8}	8.6898×10^{-3}
Nd : Glass (ED-2)	1062.3	79.1	1.8950×10^{8}	7.1332×10^{-3}
Nd : YAG	1064.0	85.9	1.7450×10^{8}	6.5896×10^{-3}

5) $E_n = \frac{13.595}{n^2}$ (eV)

a) From $n=3$ to $n=1$

$E(eV) = E_3 - E_1 = 13.595\left(-\frac{1}{9}+1\right) = 12.084$ (eV)

$\lambda(\mu m) = \frac{1.24}{E(eV)} = \frac{1.24}{12.084} = 0.1026\ (\mu m)$

b) From $n=5$ to $n=4$

$E(eV) = E_5 - E_4 = 13.595\left(\frac{-1}{25}+\frac{1}{16}\right) = 0.3059$ (eV)

$\lambda(\mu m) = \frac{1.24}{E(eV)} = 4.0538\ (\mu m)$

Extra-Credit:

a) $E_{pulse} = 0.4\,J/pulse$, $\nu_{rep} = 30\,Hz$, $t_{pulse} = 20\,ns$ (FWHM),

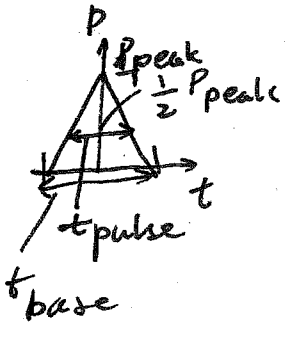
$r_{radius} = 0.5\,mm$

Notice that only pulse width is affected by the pulse shape.

$P_{ave} = E_{pulse}\,\nu_{rep} = 0.4 \times 30 = 12\,(W)$ // (same)

$t_{base} = 2\,t_{pulse} = 40\,ns$

$P_{peak} = 0.4/t_{base/2} = 0.4/t_{pulse} = 20\,(MW)$ // (same)



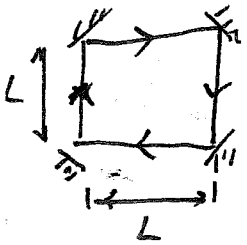
$(E_{pulse} = \frac{1}{2} P_{peak} t_{base}$ for triangular pulse.)

$Fluence = E_{pulse}/area = 0.4/\pi(0.5\times10^{-3})^2$

$= 50.93\,(J/cm^2)$ (same)

Peak intensity $= 2.546\,(GW/cm^2)$ (same)

Prob. 1.10



$\Delta\nu_{FSR} = \frac{c_0}{4nL}$ (round trip distance is 4L instead of 2L)

Therefore $\Delta\nu_{FSR} = \frac{1}{2}(\Delta\nu_{FSR})_{old}$ in 1.10 $\frac{1}{4}$

$\Delta\lambda_{FSR} = \frac{1}{2}(\Delta\lambda_{FSR})_{old}$ in 1.20.

i.e. Table (c) becomes

	$\Delta\nu_{FSR}$ (Hz)	$\Delta\lambda_{FSR}$ (Å)
Ruby	1.099×10^{8}	1.7671×10^{-3}
Ti:Sapphire	0.9967×10^{8}	1.9202×10^{-3}
Cr:LiSAF	0.8576×10^{8}	2.0183×10^{-3}
Nd:YLF	1.2618×10^{8}	4.6667×10^{-3}
Nd:glass (LHG-5)	1.1748×10^{8}	4.3449×10^{-3}
Nd:glass (ED-2)	0.9475×10^{8}	3.5666×10^{-3}
Nd:YAG	0.8725×10^{8}	3.2948×10^{-3}