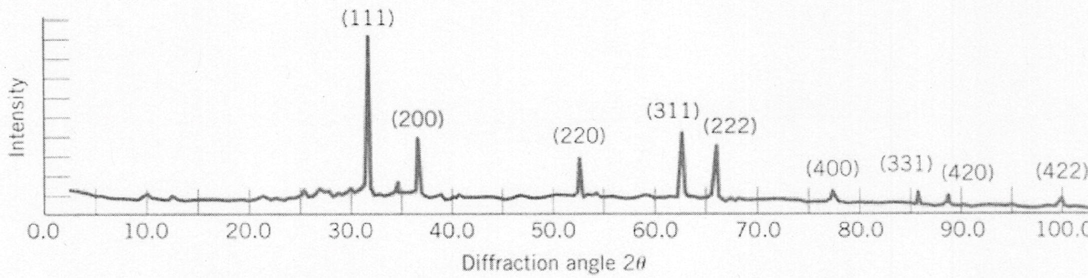
4. The figure below shows an x-ray diffraction pattern for lead taken using a diffractometer and monochromatic x-ray radiation having a wavelength of 0.1542 nm; each diffraction peak on the pattern has been indexed.

   a. Determine the structure of lead (simple cubic, BCC, FCC)
   b. Compute the interplanar spacing for each set of planes indexed.
   c. Determine the lattice parameter and atomic radius of lead for each of the peaks, and compare to the accepted atomic radius of 0.175 nm.



a) The peaks have h, k, l all even or all odd, so it must be FCC.

b)
c) $\lambda = 2d\sin\theta$, $d = \frac{\lambda}{2\sin\theta}$

$d = \frac{a}{\sqrt{h^2+k^2+l^2}}$, $a = d\sqrt{h^2+k^2+l^2}$

for FCC: $a = 2\sqrt{2}R$

$R = \frac{a}{2\sqrt{2}}$

Peak	2θ	d (nm)	a (nm)	R (nm)
(111)	~~34.8~~ 31.3	0.2858	0.4950	0.1750
(200)	36.6	0.2455	0.4910	0.1736
(220)	52.6	0.1740	0.4921	0.1739
(311)	62.5	0.1486	0.4929	0.1743
(222)	65.5	0.1425	0.4936	0.1745

The calculated R are very close to the accepted value.

3.1 a) $P = 1\ kW = 10^3\ W$ $\quad P = \frac{E_{total}}{t}$

$f = 700\ kHz$

$t = 1\ s$

the energy of one photon:

$$E_{ph} = hf = (6.62\times10^{-34}\ Js)(700\times10^3/s) =$$
$$= 4.638\times10^{-28}\ J/photon$$

$$E_{total} = N_{ph}E_{ph} = P.t$$

$$N_{ph} = \frac{P.t}{E_{ph}} = \frac{(10^3\ W)(1s)}{(4.638\times10^{-28}\ J/photon)} = 2.16\times10^{30}\ photons$$

b) $I = 1\ kW/m^2$

$\lambda = 800\ nm$

$A = 1m^2$

$t = 1s$

$$I = \frac{P}{A} = \frac{E_{total}/t}{A}$$

$$E_{ph} = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\ Js)(3\times10^8\ m/s)}{800\times10^{-9}\ m} = 2.485\times10^{-19}\ J$$

$$E_{total} = N_{ph}E_{ph} = I\cdot A\cdot t$$

$$N_{ph} = \frac{I.A.t}{E_{ph}} = \frac{(1\times10^3\ W/m^2)(1m^2)(1s)}{2.485\times10^{-19}\ J} = 4.02\times10^{21}\ photons$$

for the magnitude of the electric field,

$$I_{average} = \frac{1}{2}c\varepsilon_0 E^2$$

$$E = \sqrt{\frac{2I_{ave}}{c\varepsilon_0}} = \sqrt{\frac{2\times10^3\ W/m^2}{(3\times10^8\ m/s)(8.85\times10^{-12}\ F/m)}} = 868\ V/m$$

c) $N_{electrons} = N_{photons}$

then current density (current/area): $J = N_{ph}\cdot e = (4.02\times10^{21})(1.602\times10^{-19}\ C)$ (electrons/s.m^2)

$$= 644\ A/m^2$$

3.2 a) $P = \frac{E}{t}$, $t = 1s$, $N_{green} = 100$

$P_{red} = P_{green} = P_{blue}$ then $N_{red} E_{red} = N_{blue} E_{blue} = N_{green} E_{green}$

$$N_{red} = \frac{N_{green} E_{green}}{E_{red}} = N_{green} \cdot \frac{hc}{\lambda_{green}} \cdot \frac{\lambda_{red}}{hc} = \frac{\lambda_{red}}{\lambda_{green}} N_{green} = \frac{660nm}{563nm} \times 100 = 117 \text{ photons}$$

$$N_{blue} = \frac{\lambda_{blue}}{\lambda_{green}} N_{green} = \frac{450nm}{563nm} \times 100 = 80 \text{ photons}$$

b) $P = 0.1\ W$

photon flux $\Phi = N/t$ (number of photons per second)

$$P = \frac{N_{ph} E_{ph}}{t} = \Phi \cdot E_{ph} \Rightarrow \Phi = \frac{P}{E_{ph}} = \frac{P\lambda}{hc}$$

$$\Phi_{red} = \frac{(0.1\ W)(700 \times 10^{-9} m)}{(6.63 \times 10^{-34} Js)(3 \times 10^{8} m/s)} = 3.52 \times 10^{17} \text{ photons/s}$$

$\Phi_{green} = 2.75 \times 10^{17}$ photons/s

$\Phi_{blue} = 2.20 \times 10^{17}$ photons/s

c) $$\frac{P_{yellow}}{P_{blue}} = 1.74 = \frac{N_{yellow} E_{yellow}}{t} \cdot \frac{t}{N_{blue} E_{blue}} = \frac{N_{yellow}}{\lambda_{yellow}} \cdot \frac{\lambda_{blue}}{N_{blue}} \Rightarrow$$

$$\frac{N_{blue}}{N_{yellow}} = \frac{\lambda_{blue}}{\lambda_{yellow}} \cdot \frac{1}{1.74} = 0.46$$

$\Phi_{blue} = \frac{P_b \lambda_b}{hc}$, $P_{total} = P_y + P_b = 100mW$

$$\frac{P_y}{P_b} + 1 = \frac{100\ mW}{P_b} \Rightarrow P_b = \frac{100mW}{(1 + 1.74)} = 36.5mW$$

$\Phi_{blue} = 8.26 \times 10^{16}$ photons/s

$\Phi_{yellow} = 1.8 \times 10^{17}$ photons/s